TECHNICAL PAPER
CAA-TP-84-11
ADF860017

PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL (SHORT TITLE: PARCOM PARTIAL SUBSTITUTION)

N. DTIC

NOVEMBER 1984

PREPARED BY
FORCE SYSTEMS DIRECTORATE
US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814-2797

DISCLAIMER

The findings of this report are not to be construed as an official Department of the Army position, policy, or decision unless so designated by other official documentation. Comments or suggestions should be addressed to:

Director
US Army Concepts Analysis Agency
ATTN: CSCA-FS
8120 Woodmont Avenue
Bethesda, MD 20814-2797

CAA-TP-84-11

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CAA-TP-84-11	2. GOVT ACCESSION NO. ADF860017	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Partial Substitution and Other Modifications to the PARCOM Model (Short title: PARCOM Partial Substitution)		5. TYPE OF REPORT & PERIOD COVERED Final Report May 84 - Oct 84
		6. PERFORMING ORG. REPORT NUMBER CAA-TP-84-11
7. AUTHOR(s) Mr. Walter J. Bauman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Concepts Analysis Agency 8120 Woodmont Avenue Bethesda, Maryland 20814-2797		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE November 1984
		13. NUMBER OF PAGES 91
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release. Distribution is unlimited.

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

18. SUPPLEMENTARY NOTES

The work reported was performed for:
Office of the Deputy Chief of Staff for Logistics
Department of the Army

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

Aircraft, spares, spare parts, PARCOM, logistics, stockage requirements, logistics management, inventory management, helicopters, readiness.

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

The basic PARCOM methodology developed in the Aircraft Spares Study was expanded to include a partial-substitution parts replacement policy and distribution of stock over time. As with basic PARCOM, extended PARCOM relates aviation spare parts requirements and fleet capability to flying hour and availability objectives, part replacement (substitution) policies, and stockage deployment schedule, all subject to optional cost constraints. Partial substitution was defined in terms of a oartition of part types into

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Block 20 - ABSTRACT continued

a full-sub set, within which all installed serviceable parts on NMCS aircraft are substitutable for unavailable spares, and a no-sub set, within which no installed parts are substitutable for spares. The extended PARCOM was applied in several illustrative example cases, showing plausible results as substitution policy was varied.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TECHNICAL PAPER
CAA-TP-84-11

PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL (SHORT TITLE: PARCOM PARTIAL SUBSTITUTION)

NOVEMBER 1984

PREPARED BY
FORCE SYSTEMS DIRECTORATE

US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814-2797

CAA	**PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL (PARCOM PARTIAL SUBSTITUTION)**	**STUDY SUMMARY CAA-TP-84-11**

THE REASON FOR PERFORMING THE STUDY was that the two models recommended by the Aircraft Spares Study, Overview and PARCOM, could treat a full-substitution or a no-substitution part replacement policy but lacked the ability to represent a more realistic partial-substitution replacement policy. Of the two models, PARCOM was judged to be the better candidate for incorporation of a partial-substitution capability.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The basic PARCOM (Parts Requirements and Cost Model), developed for the Aircraft Spares Study, was extended to include the effects of partial-substitution replacement policies and deployment of initial stocks over time.

(2) The resulting extended model relates spare requirements to a flying hour/aircraft availability objective, parts replacement policy, and stockage deployment schedule--all subject to optional cost constraints. Example applications illustrated the plausibility of the model logic.

(3) The extended PARCOM significantly expands the range of application and results of the basic PARCOM methodology. As such, its implementation, in place of basic PARCOM, is warranted.

THE MAIN ASSUMPTION was that partial substitution can be usefully defined in terms of a partition of part types into a full-substitution part set and a no-substitution set.

THE PRINCIPAL LIMITATION was that definitions of partial substitution other than the assumed definition might not be addressable by the extended PARCOM.

THE SCOPE OF THE STUDY addressed the relationship of spare requirements and fleet capabililty for a notional Army aviation program to a flying hour/availability objective, part replacement (substitution) policy, and stockage deployment schedule--all subject to optional cost constraints. The study applied the subject model to an example, using four part types over 5 days, and to an all-up case, treating an AH-1S scenario involving 334 part types over 120 days.

THE STUDY OBJECTIVES were:

(1) To evaluate the potential for extending the capability of the basic PARCOM, developed in the Aircraft Spares Study, to include partial substitution and other desirable features lacking in the basic PARCOM.

(2) To make the above extensions and to report on and illustrate the application of the extended PARCOM and methodology.

THE BASIC APPROACH was:

(1) To assess the limitations of the basic PARCOM.

(2) To select features and capabilities, to include partial substitution, for incorporation into an extended PARCOM.

(3) To develop an extended PARCOM incorporating the selected capabilities.

(4) To report on the nature of the extended PARCOM methodology and model through exposition and illustrative example applications.

THE STUDY SPONSOR was the Deputy Chief of Staff for Logistics, Headquarters, Department of the Army.

THE STUDY EFFORT was conducted by Mr. Walter J. Bauman, Force Systems Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be directed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FS, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

Tear-out copies of this synopsis are at back cover.

CONTENTS

CHAPTER		Page
1	MODEL DEVELOPMENT	1-1
	Background	1-1
	Basic PARCOM Problem Specification	1-1
	Summary of Requirements Output for Basic PARCOM	1-2
	Limitations of Basic PARCOM	1-3
	PARCOM Extension	1-5
	Future Output	1-6
2	REQUIREMENTS DETERMINATION WITH PARTIAL SUBSTITUTION	2-1
	Concept Formulation	2-1
	Example Test	2-2
	Application to Full-Scale Data Base	2-12
	Workaround - An Approach that Failed	2-14
3	CAPABILITY ASSESSMENT WITH PARTIAL SUBSTITUTION	3-1
	Background	3-1
	Chapter Organization	3-1
	Assessment with Full Substitution	3-1
	Assessment with No Substitution	3-2
	Assessment with Partial Substitution	3-4
	Assessment of Current Inventory with Partial Substitution	3-6
4	DISTRIBUTING PARTS OVER TIME	4-1
	Background	4-1
	Logic	4-1
	Impact	4-2
	Example Results	4-2
5	CONSTRAINED COST REQUIREMENTS	5-1
	Background	5-1
	Constrained Cost No-Substitution Requirement in Basic PARCOM	5-1
	Approach in Extended PARCOM	5-1
	Constrained Cost with Full Substitution	5-2
	Constrained Cost Algorithm 1	5-2
	Constrained Cost Algorithm 2	5-3
	Solution Selection	5-3
	Sample Results	5-3

CHAPTER		Page
6	**OBSERVATIONS**	6-1
	Partial-substitution Requirements	6-1
	Partial-substitution Capability Assessment	6-1
	Parts Distributed Over Time	6-1
	Partial Substitution with Constrained Cost	6-1

APPENDIX

A	Extended PARCOM - Input Summary	
B	Extended PARCOM - Program Source Code	
C	References	

GLOSSARY Glossary-1

STUDY SUMMARY (tear-out copies)

FIGURES

FIGURE		
3-1	Capability Assessment of Current Inventory - MAX FLY Example Case	3-9

TABLES

TABLE		
2-1	Example Problem - Parts Data	2-2
2-2	Example Problem - Scenario Data	2-3
2-3	Calculation of Allowable NMCS Aircraft	2-3
2-4	Unconstrained Cost Residual Requirement with Full Substitution - Part 1 (initial inventory = 250) ..	2-4
2-5	Unconstrained Cost Residual Requirement with Full Substitution - Part 2 (initial inventory = 10) ...	2-4
2-6	Unconstrained Cost Residual Requirement with Full Substitution - Part 3 (initial inventory = 260) ..	2-5
2-7	Unconstrained Cost Residual Requirement with Full Substitution - Part 4 (initial inventory = 30) ...	2-5

TABLE		Page
2-8	Unconstrained Cost Residual Requirement with No Substitution - Part 1 (initial inventory = 250) ..	2-6
2-9	Unconstrained Cost Residual Requirement with No Substitution - Part 2 (initial inventory = 10) ...	2-7
2-10	Unconstrained Cost Residual Requirement with No Substitution - Part 3 (initial inventory = 260) ..	2-7
2-11	Unconstrained Cost Residual Requirement with No Substitution - Part 4 (initial inventory = 30) ...	2-8
2-12	Summary of Unconstrained Cost Residual Requirements	2-8
2-13	Unconstrained Cost Residual Requirements Calculations for Day 5 with Partial Substitution - Example 1 ..	2-10
2-14	Part Unit Cost Data for Example 2	2-11
2-15	Unconstrained Cost Residual Requirements Calculations for Day 5 with Partial Substitution - Example 2 ..	2-12
2-16	Add-on Requirements Costs by Policy - MAX FLY Example	2-13
3-1	Capability Assessment for Unconstrained Cost Residual Requirement with Full Substitution	3-2
3-2	Capability Assessment for Unconstrained Cost Residual Requirement with Full Substitution (continued)	3-2
3-3	Capability Assessment for Unconstrained Cost Residual Requirement with No Substitution	3-3
3-4	Capability Assessment for Unconstrained Cost Residual Requirement with No Substitution (continued)	3-3
3-5	Capabililty Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 1	3-4
3-6	Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 1 (continued)	3-5
3-7	Capabililty Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 2	3-5
3-8	Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 2 (continued)	3-6
3-9	Capability Assessment of Current Inventory with Partial Substitution	3-7
3-10	Capability Assessment of Current Inventory with Partial Substitution (continued)	3-8
3-11	Capability Assessment of Current Inventory with Partial Substitution (continued)	3-8

TABLE		Page
4-1	Example - Part 1 Stock Distribution Over Time	4-3
4-2	Unconstrained Cost Residual Requirement with Full Substitution - Part 1 (initial stock distributed over time)	4-3
5-1	Add-on Requirements Costs - Unconstrained Budget with Partial Substitution - MAX FLY Example	5-4
5-2	Comparison of Constrained Cost Algorithms - Add-on Requirements - Partial Substitution - MAX FLY Example	5-4
5-3	Add-on Requirements Cost - Constrained Budget with Partial Substitution - MAX FLY Example	5-4
A-1	Data Elements for Each Part Type in the Parts Data Base	A-1
A-2	Data Elements for the Scenario Data Base	A-1

PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL
(Short title: PARCOM Partial Substitution)

CHAPTER 1

MODEL DEVELOPMENT

1-1. BACKGROUND

a. **Model Origin.** The US Army Concepts Analysis Agency (CAA) developed the Parts Requirements and Cost Model (PARCOM) to generate cost effective mixes of aircraft spare parts and to assess aircraft fleet performance under specified wartime scenario conditions. Development occurred during the course of the Aircraft Spare Stockage Methodology (Aircraft Spares) Study[1] conducted by CAA. That study, and PARCOM development, were in response to interest shown by the Deputy Chief of Staff for Logistics (DCSLOG) in developing a methodology (or methodologies) relating aircraft spare parts stockage levels to combat readiness and flying hour capability. The calculation of spare parts requirements, and of the effects of budgeting changes, had been a slow and cumbersome peacetime oriented exercise. The principal criterion for spares stockage had been the achievement of acceptable stockout, or fill rate, levels. To more realistically predict wartime spare parts requirements, and to better justify budget requests for spare parts procurement, the Army needed a more responsive methodology based on wartime flying hour expectations and system readiness/availability requirements. PARCOM was developed to meet that need.

b. **Current Study Purpose.** Results reported in Aircraft Spares were sufficiently encouraging to warrant a follow-on study, designated the Overview/PARCOM Turnkey Project (OPTP). Included in the objectives of OPTP were the following actions pertaining to PARCOM:

(1) Document the PARCOM, as developed in the Aircraft Spares Study, and deliver it to the US Army Aviation Systems Command (USAVSCOM).

(2) Evaluate and report on the potential for extending the capability of PARCOM to include partial-substitution parts replacement policies and any other features deemed desirable, but lacking in the model (PARCOM) developed for Aircraft Spares.

This technical paper is a report on the model extension. The extended model reported herein is denoted as extended PARCOM; the original model, as developed in the Aircraft Spares Study, is denoted herein as basic PARCOM.

1-2. BASIC PARCOM PROBLEM SPECIFICATION. The basic PARCOM was designed to generate cost-effective mixes of add-on spare parts needed to permit an aircraft fleet of specified type to achieve specified flying program and availability goals under various cost constraints, part replacement policies, and aircraft availability objectives. These are described below in summary fashion. Additional detail may be found in the PARCOM User's Guide.[2]

a. Cost Constraints. The two cost constraint modes are:

(1) Unconstrained Funds - where unlimited funds for procurement of additional required parts are assumed available.

(2) Constrained Funds - where a cost (funding) limit for add-on spares is set. If unable to meet the flying hour and, possibly, availability objectives with the limited funds, the model generates a "best" solution mix with the funds available, i.e., it seeks to maximize program flying hours achievable within the funding constraint.

b. Basic Part Replacement Policies. The two basic part replacement policies are:

(1) Full Substitution - where a failed part on an aircraft may be replaced by either a spare (if available) or by a serviceable part installed on a not-mission-capable (NMC) aircraft (if a spare is not available).

(2) No Substitution - where a failed part on an aircraft may only be replaced by a spare part.

c. Flying Hour Objective. A flying hour objective is a requirement for the aircraft fleet to achieve a specified number of flying hours on each day of the scenario. An input flying hour program designates the daily goal. A basic PARCOM objective is to generate a parts mix which will achieve the specified flying program at least cost.

d. Aircraft Availability Objective. An aircraft availability objective is a requirement for a specific minimum aircraft availability on each day (different days may have different minimum required availabilities). In this context, aircraft availability = 1 - NMCS, where NMCS = the fraction of surviving aircraft in not-mission-capable-supply status. An aircraft is in an NMCS status if it is nonoperational because spare parts are needed but are not available to restore it to serviceability. Specification of availability objectives is in addition to the flying hour objective. Specification of a zero availability objective is equivalent to no availability objective at all.

1-3. SUMMARY OF REQUIREMENTS OUTPUT FOR BASIC PARCOM. The following are the types of print output produced by basic PARCOM for requirements problems. Details may be found in the PARCOM User's Guide.

a. Unconstrained Cost Cases

(1) Total Requirement. Total least-cost parts mix and costs required to achieve the case objectives (flying program and availability) given a zero initial inventory.

(2) Residual Requirement. The least-cost add-on parts mix (to an input initial inventory) and costs required to achieve the case objectives.

(3) **Cumulative Cost by Day.** For each day N (N=1, 2, ..., through end of war), the total and the add-on costs of the full parts requirements to meet the case objectives through day N only, i.e., it is the cost of the requirement for a truncated scenario of N days. Parts mix is not shown.

(4) **Cumulative Requirement by Day.** For selected items, for each day N, the cumulative total parts requirement needed (in the full parts scenario) to meet the case objectives through N days. A zero initial inventory is assumed in this output.

(5) **Daily Aircraft Available.** For each day of the full scenario, the fraction of surviving aircraft which are not NMCS, assuming that the starting spare inventory is set equal to the sum of the computed parts requirement and the initial inventory.

(6) **Daily Flying Hours per Aircraft per Day.** For each day of the scenario, the average achieved flying hours per available aircraft per day assuming the computed solution parts mix is stocked.

b. **Constrained Costs**

(1) **Total Requirement.** Total best requirements mix, with zero initial inventory, and with a no-substitution policy, that can be bought with a funding limit equal to the sum of the values of the current spares inventory and the input cost limit. The objective of a best mix is to maximize flying hour productivity with the constrained funds.

(2) **Residual Requirement.** Add-on (to input initial inventory) requirements mix, with a no-substitution policy, that can be bought with a funding limit equal to the input cost limit.

(3) **Daily Aircraft Available.** For each day of the full scenario, the fraction of surviving aircraft which are not NMCS, assuming that the starting spare inventory is set equal to the sum of the computed parts requirement and the initial inventory.

(4) **Daily Flying Hour Fraction.** For each day of the full scenario, the fraction of the fleet flying program which can be achieved assuming that the starting spare inventory is set equal to the sum of the computed parts requirement and the initial inventory.

(5) **Daily Flying Hours per Aircraft per Day.** For each day of the scenario, the average achieved flying hours per aircraft per day, assuming the computed solution parts mix is stocked.

1-4. LIMITATIONS OF BASIC PARCOM. The following limitations of the basic PARCOM were noted as a suitable base for future model extension and/or redesign.

a. **No Partial-substitution Requirements.** A partial-substitution parts replacement policy can be conceptualized as one in which some (but not necessarily all) part types installed in NMCS aircraft are substitutable for spares, i.e., such a part type installed in an NMCS aircraft can, if serviceable, be applied to replace a failed part (of the same type) in another NMCS aircraft if a spare is unavailable. The basic PARCOM does not consider partial substitution. The basic PARCOM requirement algorithms process only a full-substitution replacement policy (all parts substitutable) or a no-substitution replacement policy (no parts substitutable) depending on the case treated.

(1) Unconstrained Cost. The basic PARCOM calculates unconstrained cost requirements with both full substitution and no substitution. However, using a common scenario, PARCOM-generated solution requirement costs under a no-substitution policy are much larger (for nontrivial cases) than solution costs under full substitution. It may be useful, therefore, to examine the effects of partial-substitution policies with corresponding intermediate solution costs.

(2) Constrained Cost. While the standard unconstrained cost requirements solution of the basic PARCOM can treat both full substitution and no substitution, the constrained cost algorithm of that model treats only a no-substitution replacement policy. Extension to processing of partial substitution would enhance model capability.

b. No Partial-substitution Fleet Capability Assessment. The basic PARCOM assesses fleet flying capability (resulting aircraft availability and fraction flying program achieved) based on a solution inventory being stocked or on a current (input-specified) parts inventory. Capability assessments based on unconstrained cost solutions treat both full substitution and no substitution, but assessments based on constrained cost solutions or on a current inventory treat only a no-substitution policy. Application of full substitution and no substitution produce upper and lower bounds, respectively, on assessments of fleet flying hour capability with a fixed spare inventory. Modeling of partial substitution will enable a cause-and-effect analysis of flying hour capabilities between those bounds.

c. No Parts Distributed Over Time. The basic PARCOM, in both assessment and requirement calculations, assumes that all initial spare assets are "front-loaded," i.e., that all initial spares are available at retail on Day 1 of the scenario. Since a spare has no effect unless it is needed, this is equivalent to assuming that all initial assets will reach retail before they are required (as replacements). An efficient stockage and transportation system will achieve this. However, some scenarios will not be optimally matched to the time-phased parts deployments reflected in the authorized stockage list (ASL)/prescribed load list (PLL) of deploying units and the depot-retail pipeline lag for stocks initially at depots. The basic PARCOM, therefore, may yield overly optimistic results. Greater credibility and conformance to real-life constraints can be achieved by enabling PARCOM to process time-phased parts deployments.

1-5. PARCOM EXTENSION

a. Need. The objective of the Aircraft Spares Study was only to develop and demonstrate a feasible methodology. The follow-on study effort, OPTP, was to document the basic PARCOM and to deliver it (as well as Overview) to the US Army Aviation Systems Command (USAVSCOM). The selected models included the basic PARCOM; however, OPTP also proposed to study means of extending the basic PARCOM to include partial substitution and other capabilities found feasible and useful. The final OPTP report was to include an evaluation of the feasibility of implementing these model extensions. This technical paper presents that evaluation.

b. Aspects Selected for Extension. The basic PARCOM limitations noted in paragraph 1-4 were chosen as the basis for extending PARCOM capability, i.e., the extended PARCOM was designed to have the capability to analyze:

(1) Effects of using partial-substitution part replacement policies in requirements calculations.

(2) Effects of using partial-substitution part replacement policies in fleet capability assessment.

(3) Effects of using input-specified parts deployments over time.

(4) Effects of cost constraints on requirements solutions using partial substitution.

In the above context, partial substitution includes full substitution (full sub) and no substitution (no sub) as special cases.

c. Methodology. The approach to PARCOM extension included:

(1) Selection of the capabilities to be added. These are noted above.

(2) Construction of a concept for partial substitution amenable to processing in an extended PARCOM.

(3) Revision or replacement of program code in basic PARCOM to enable demonstration of concept feasibility for the extensions.

(4) Checking, via selected manual examples, or all-up tests, of concept feasibility for the extensions.

(5) Provision of an undocumented copy of the FORTRAN program source code for the extended PARCOM.

1-6. FUTURE OUTPUT. The products of the OPTP do not include delivery and documentation of a complete extended PARCOM (only the basic PARCOM is delivered and documented). However, a follow-on effort of limited scope will provide:

a. Publication of revisions to the (basic) PARCOM User's Guide and Functional Description.

b. Documentation of the program source code for the extended PARCOM.

CHAPTER 2

REQUIREMENTS DETERMINATION WITH PARTIAL SUBSTITUTION

2-1. CONCEPT FORMULATION

a. Definition. In the extended PARCOM, a partial-substitution parts replacement policy is defined by partitioning all part types into a full-sub set and a no-sub set. A part type is in only one set and remains in that set throughout the scenario. These sets are defined as follows:

(1) All parts in the full-sub set operate with a full-substitution replacement policy relative to aircraft which are NMCS due to lack of a part from that set. That is, a failed full-sub part on an aircraft may be replaced either by a spare (if available) or by a serviceable part installed on an NMCS aircraft which is awaiting a full-sub part, if a spare is not available. However, no failed full-sub part can be replaced by any part installed on an NMCS aircraft awaiting a no sub-part.

(2) Parts in the no-sub set operate with a no-substitution replacement policy. That is, a failed no-sub part on an aircraft may only be replaced by a spare part. An NMCS aircraft lacking a no-sub part may neither receive a serviceable part from another NMCS aircraft, nor may it provide a serviceable part to (fill a "hole" in) any other NMCS aircraft.

b. Implications. The full-substitution and no-substitution policies of the basic PARCOM are special cases of partial substitution in which all parts are either in the full-sub set or in the no-sub set. The analytic usefulness of the above definition arises from the consequence that any NMCS aircraft will either be awaiting exactly one no-sub part or at least one full-sub part but will never be awaiting a mixture of full-sub and no-sub parts.

c. Selection of Full-sub Parts. Before requirements processing begins in the extended PARCOM, a full-sub and a no-sub part set, applicable over all scenario days, must be defined. One option allows the user to specify those part types which comprise the full-sub set. By default, all nonspecified parts are presumed to be in the no-sub set. However, the model has another option, allowing the user to specify three screening limits--L1, L2, and L3. With these limits the model selects a part type for the full-sub set if at least one of the following apply:

- The (input) depot repair cycle time for the part exceeds L1 days and the not repairable this station (NRTS) fraction exceeds zero.
- The (input) NRTS fraction for the part exceeds L2.
- The (input) retail repair time for the part exceeds L3.

The model, under this option, examines all part types and assigns those that satisfy the screening limits to the full-sub set. All other part types are assigned to the no-sub set. The above screening criteria were chosen because it appeared plausible that full substitution would be most likely practiced on parts which took a long time to cycle back through the repair pipelines; however, other criteria could also be selected.

2-2. EXAMPLE TEST. The application of the partial-substitution concept is demonstrated below via illustrative examples. For review and comparison purposes, the effects of standard (basic PARCOM) full-substitution and no-substitution policies are also shown, followed by a summary of partial-substitution logic and effect calculations.

a. Problem Framework

(1) A data base containing four part types was applied in a 5-day scenario. Table 2-1 shows input parts data for the example. QPA denotes the quantity per application, i.e., the number of installed parts per operational aircraft. OST denotes the one-way, order and ship time between depot and retail. Overall repair cycle equals the sum of the depot repair time and 2xOST for depot repairable items and equals the retail repair time for retail repairable items. Essentially, it is the (pipeline) time between removal of a failed part and its return to the retail pool of serviceable spares. Table 2-2 shows scenario input data for the example problem. The two columns on the right define the flying hour and availability objectives for the problem. The cumulative aircraft deployments and losses are also input. Cumulative aircraft surviving is calculated from them.

Table 2-1. Example Problem - Parts Data

	PART 1	PART 2	PART 3	PART 4
• PARTS CHARACTERISTICS				
- FAILURE RATES (PER FLY HR)	.08	.02	.06	.02
- QPA	1	1	1	1
- UNIT COST ($)	400	50	40	30
- INIT (INITIAL STOCK)	250	10	260	30
• PARTS REPAIR CYCLE DATA				
- OST (DAYS)	1	0	1	0
- RETAIL REPAIR TIME (DAYS)	0	3	0	2
- DEPOT REPAIR TIME (DAYS)	1	0	2	0
- RETAIL CONDEMN %	0	0	0	0
- DEPOT CONDEMN %	0	0	0	0
- NRTS %	100	0	100	0
(OVERALL REPAIR CYCLE)	(3 DAYS)	(3 DAYS)	(4 DAYS)	(2 DAYS)

Table 2-2. Example Problem - Scenario Data

DAY	CUM ACFT DEPL	CUM ACFT LOST	CUM ACFT SURV	FLYING HR PGM (FHP)	MIN ACFT AVAIL
1	150	0	150	500	.10
2	200	0	200	1,000	.09
3	200	0	200	1,000	.09
4	200	0	200	1,500	.09
5	200	0	200	1,500	.09

MAX FLY HRS/ACFT/DAY = 10

(2) Given the problem input data, Table 2-3 shows necessary preprocessing used in all algorithm calculations. The allowable NMCS aircraft for a day is the maximum number of surviving aircraft which can be NMCS on that day while still allowing fleet accomplishment of the case objective (flying hour and availability) for that day. FHP denotes the specified flying hour program for each day.

Table 2-3. Calculation of Allowable NMCS Aircraft

DAY	#1 MIN ACFT RQR BY FLYING HR PROGRAM FHP/MFHAD*	#2 MIN ACFT RQR BY AVAILABILITY CONSTRAINT SURV AC X MIN AVAIL	#3 OVERALL MIN ACFT REQUIRED MAX (#1, #2)	ALLOWABLE NMCS ACFT SURV AC -#3
1	500/10=50	150x.10=15	50	150-50=100
2	100	18	100	100
3	100	18	100	100
4	150	18	150	50
5	150	18	150	50

* MAXIMUM FLYING HOURS PER AIRCRAFT PER DAY

b. Unconstrained Cost Requirements Under Full Substitution. Tables 2-4 through 2-7 illustrate the basic PARCOM logic for example data under a full-substitution policy. Formulas used in calculations are shown in the table headings. The allowable stockout for a part on a day is just the maximum number of backorders (unfilled demands) for the part which will still allow accomplishment of the case objectives on that day. The day requirement is the minimum add-on stock required to achieve the objectives on a given day. The largest of all the day requirements for a part (circled in the table) is the overall (minimum) requirement for the part. All stock is assumed front-loaded, i.e., available at retail when needed.

Table 2-4. Unconstrained Cost Residual Requirement with Full Substitution - Part 1 (initial inventory = 250)

DAY	#1 CUMULATIVE FAILURES (FAIL RT X FHP X QPA)	#2 CUM RET REPAIRS	#3 CUMULATIVE NET DEMAND MAX [#1-(#2+INIT)] OR (0)	#4 ALLOWABLE STOCKOUTS NMCS AC X QPA	DAY RQMTS MAX (#3-#4) OR (0)
1	.08x500=40	0	40-0-250 OR [0]	100 x 1 = 100	0-100 OR [0]
2	40+.08x1000=120	0	0	100	0
3	200	0	0	100	0
4	320	40	320-290=30	50	0
5	440	120	70	50	(20)

PART 1 OVERALL RQMT = LARGEST DAY RQMT = 20

Table 2-5. Unconstrained Cost Residual Requirement with Full Substitution - Part 2 (initial inventory = 10)

DAY	#1 CUMULATIVE FAILURES (FAIL RT X FHP X QPA)	#2 CUM RET REPAIRS	#3 CUMULATIVE NET DEMAND MAX [#1-(#2+INIT)] OR (0)	#4 ALLOWABLE STOCKOUTS NMCS AC X QPA	DAY RQMT MAX(#3-#4) OR (0)
1	.02x500=10	0	10-0-10 OR [0]	100x1=100	0-100 OR [0]
2	10+.02x1000=30	0	20	100	0
3	50	0	40	100	0
4	80	10	80-10-10=60	50	60-50=10
5	110	30	70	50	70-50=(20)

PART 2 OVERALL RQMT = LARGEST DAY RQMT = 20

Table 2-6. Unconstrained Cost Residual Requirement with Full Substitution - Part 3 (initial inventory = 260)

DAY	#1 CUMULATIVE FAILURES (FAIL RT X FHP X QPA)	#2 CUM RET REPAIRS	#3 CUMULATIVE NET DEMAND MAX [#1-(#2+INIT)] OR (0)	#4 ALLOWABLE STOCKOUTS NMCS AC X QPA	DAY RQMT MAX(#3-#4) OR (0)
1	30	0	0	100	0
2	90	0	0	100	0
3	150	0	0	100	0
4	240	0	0	50	0
5	330	30	40	50	(0)

PART 3 OVERALL RQMT = 0

Table 2-7. Unconstrained Cost Residual Requirement with Full Substitution - Part 4 (initial inventory = 30)

DAY	#1 CUMULATIVE FAILURES (FAIL RT X FHP X QPA)	#2 CUM RET REPAIRS	#3 CUMULATIVE NET DEMAND MAX [#1-(#2+INIT)] OR (0)	#4 ALLOWABLE STOCKOUTS NMCS AC X QPA	DAY RQMT MAX(#3-#4) OR (0)
1	10	0	0	100	0
2	30	0	0	100	0
3	50	10	10	100	0
4	80	30	20	50	0
5	110	50	30	50	(0)

PART 4 OVERALL RQMT = 0

c. Unconstrained Cost Requirements Under No Substitution. Tables 2-8 through 2-11 illustrate the basic PARCOM logic for the example under a no-substitution policy. In this case, requirements must be calculated in order of decreasing part unit cost (i.e., most expensive parts first). For a no-substitution policy, the total allowed stockout consists of the summed stockouts over all parts treated. However, since requirements are calculated (purchased) sequentially, each successive calculation uses an "unallocated allowable stockout" equal to the original (Table 2-3) allowable stockout reduced by the sum total of allocated stockouts reflected in purchases of parts already processed. As before, the overall part requirement (circled) is calculated as the largest of the day requirements.

d. Summary of Full-sub and No-sub Results. Table 2-12 summarizes the results thus far. The full-sub requirement cost is the cheapest over all part replacement policies while the no-sub cost is the most expensive. All partial-sub requirements costs must be between these values. This will be illustrated subsequently.

Table 2-8. Unconstrained Cost Residual Requirement with No Substitution - Part 1 (initial inventory = 250)

CALCULATE FOR MOST EXPENSIVE PART (PART 1)

DAY	#1 CUM NET DEMAND PART 1 (INIT=250) (FROM 'FULL SUB')	#2 UNALLOCATED ALLOWABLE STOCKOUT (=ALLOWED NMCS AC)	DAY RQMT MAX(#1 - #2) OR (0)
1	0	100	0 - 100 OR [0]
2	0	100	0
3	0	100	0
4	30	50	0
5	70	50	(20)

PART 1 RQMT = LARGEST DAY RQMT = 20

Table 2-9. Unconstrained Cost Residual Requirement with No Substitution - Part 2 (initial inventory = 10)

- CALCULATE RQMT FOR NEXT MOST EXPENSIVE PART (PART 2)
- ASSUME PREVIOUS (PART 1) RQMT "BOUGHT" SO THAT NEW PART 1 INIT = OLD INIT (250) + RQMT (20) = 270

DAY	#3 CUM NET DEMAND PART 1 (INIT=270) #1-20 OR (0)	#4 CUM NET DEMAND PART 2 (INIT=10) (FROM 'FULL SUB')	#5 UNALLOCATED ALLOWABLE STOCKOUT #2-#3 OR (0)	DAY RQMT MAX(#4 - #5) OR (0)
1	0	0	100-0=100	0
2	0	20	100-0=100	0
3	0	40	100-0=100	0
4	30-20=10	60	50-10=40	60-40=20
5	70-20=50	70	50-50=0	70-0=70 (circled)

PART 2 RQMT = LARGEST DAY RQMT = 70

Table 2-10. Unconstrained Cost Residual Requirement with No Substitution - Part 3 (initial inventory = 260)

- CALCULATE RQMT FOR NEXT MOST EXPENSIVE PART (PART 3)
- ASSUME PREVIOUS (PARTS 1 & 2) RQMTS "BOUGHT" SO THAT NEW PART 1 INIT = 270, NEW PART 2 INIT = 80

DAY	#3 CUM NET DEMAND PART 1 (INIT=270) #1-20 OR (0)	#6 CUM NET DEMAND PART 2 (INIT=80) #4-70 OR (0)	#7 CUM NET DEMAND PART 3 (INIT=260) (FROM 'FULL SUB')	#8 UNALLOCATED ALLOWABLE STOCKOUT #2-#3-#6 OR (0)	DAY RQMT MAX(#7 - #8) OR (0)
1	0	0	0	100	0
2	0	0	0	100	0
3	0	0	0	100	0
4	10	0	0	40	0
5	50	0	40	0	40 (circled)

PART 3 RQMT = LARGEST DAY RQMT = 40

Table 2-11. Unconstrained Cost Residual Requirement with No Substitution - Part 4 (initial inventory = 30)

- CALCULATE RQMT FOR NEXT MOST EXPENSIVE PART (PART 4)
- ASSUME PREVIOUS (PARTS 1, 2 & 3) RQMTS "BOUGHT" SO THAT NEW PART 1 INIT = 270, PART 2 INIT = 80, PART 3 INIT = 300

DAY	#3 CUM NET DEMAND PART 1 (INIT=270) #1-20 OR (0)	#6 CUM NET DEMAND PART 2 (INIT=80) #4-70 OR (0)	#9 CUM NET DEMAND PART 3* (INIT=300) #7-40 OR (0)	#10 CUM NET DEMAND PART 4 (INIT=30) (FROM FULL SUB)	#11 UNALLOCATED ALLOWABLE STOCKOUT #2-#3-#6-#9 OR (0)	DAY RQMT MAX(#10 - #11) OR (0)
1	0	0	0	0	100	0
2	0	0	0	0	100	0
3	0	0	0	10	100	0
4	10	0	0	20	40	0
5	50	0	0	30	0	30

PART 4 RQMT = LARGEST DAY RQMT = 30

Table 2-12. Summary of Unconstrained Cost Residual Requirements

	'FULL SUB' ADD-ON RQMT	'NO SUB' ADD-ON RQMT
PART 1	20	20
PART 2	20	70
PART 3	0	40
PART 4	0	30
TOTAL COST	9,000	14,000

* FROM CUM NET DEMAND COLUMN OF TABLES 2-4 THRU 2-7

e. Partial-substitution Algorithm Logic. The order of partial-substitution algorithm operations is described below. They will be illustrated in succeeding paragraphs.

(1) Partition all part types into a full-sub set and a no-sub set as defined in paragraph 2-1a.

(2) Calculate the allowable NMCS aircraft for each day.

(3) For each day:

(a) Generate all possible nonnegative integer combinations (AF, AN) (for full-sub and no-sub, respectively) such that AF + AN = allowable NMCS aircraft for that day.

(b) For each integer combination (AF, AN), compute a basic PARCOM full-sub solution <u>over only the **full-sub** part</u> set for the scenario through that day, assuming AF allowed NMCS aircraft (awaiting full-sub parts) for that day. Also compute a basic PARCOM no-sub solution <u>over only the **no-sub** part set</u> for the scenario through that day, assuming AN allowed NMCS aircraft (awaiting no-sub parts) for that day. Calculate the total solution cost for the combination (AF, AN) as the sum of the costs for the full-sub and no-sub solutions described above.

(c) Select the solution for the combination (AF, AN) yielding the <u>minimum</u> total solution cost. This solution consists of the requirements for each part on that day and is called the day requirement. The combination (AF, AN) used in the selected solution then becomes the allowed stockouts used during cumulative (from Day 1) calculations on all succeeding scenario days.

(4) After all days are processed, select the largest (over all scenario days) of the computed day requirements for each part as the overall requirement. The logic for computing a basic PARCOM solution is described in the PARCOM Functional Description.[3] The above algorithm tends toward a least cost solution mix (assuming unconstrained funds) for the partial-substitution replacement policy defined by the full-sub/no-sub partition of the part data base.

f. Unconstrained Cost Requirements Under Partial Substitution - Example Conditions

(1) Simplifying Assumptions. The full set of algorithmic calculations was too complex to represent, so for this example only, the following simplifying assumptions were made:

(a) To simplify computation, the combinations (AF, AN) chosen were multiples of 10.

(b) Since, in this example, Day 5 drives (has the largest day requirements for) the solution, the only calculations shown are for Day 5.

(2) **Definition of Policy.** Part 1 and Part 2 (from Table 2-1) were selected for the full-sub part set and Part 3 and Part 4 for the no-sub part set.

(3) **Calculations for Example 1.** Table 2-13 shows the algorithm calculations for partial-sub for Day 5. Note that:

(a) The calculation of daily allowable NMCS aircraft used in full sub and no sub also applies here.

(b) For AF = 0 on day 5, the full-sub solution for the full-sub part set is just the largest daily cumulative net demand for each full-sub part. From Table 2-4, this is 70 for Part 1. From Table 2-5, this is 70 for Part 2. These are also the requirements for these parts under an "NMCS = 0" policy in basic PARCOM.

(c) For AF greater than 0, to obtain a full-sub solution based on AF allowed NMCS aircraft for the full-sub parts set, AF x QPA = AF (since QPA = 1 in this example) units are subtracted from each part requirement in the "AF = 0" solution. This is done because each reduction of stock by QPA units creates QPA backorders which, in turn, correspond to one NMCS aircraft.

Table 2-13. Unconstrained Cost Residual Requirements Calculations for Day 5 with Partial Substitution - Example 1

ALLOWABLE NMCS ACFT = 50

A_F = ALLOWABLE NMCS ACFT FROM 'FULL SUB' SET

A_N = ALLOWABLE NMCS ACFT FROM 'NO SUB' SET

COMBINED SOLUTION #	A_F	'FULL SUB' SOLUTION PT 1/PT 2 ($400/$50)	COST	A_N	'NO SUB' SOLUTION PT 3/PT 4 ($40/$30)	COST	COMBINED SOLUTION COST
1	0	70/70	$31,500	50	0/20	$600	$32,100
2	10	60/60	27,000	40	0/30	900	27,900
3	20	50/50	22,500	30	10/30	1,300	23,800
4	30	40/40	18,000	20	20/30	1,700	19,700
5	40	30/30	13,500	10	30/30	2,100	15,600
6	50	20/20	9,000	0	40/30	2,500	11,500

	PT 1	PT 2	PT 3	PT 4
MIN COST SOL =	20	20	40	30

(ASSUMING DAY 5 HAS THE MAX RQMT)

(d) For AN = 0 on Day 5, the no-sub solution for the no-sub part set is just the largest daily cumulative net demand for each no-sub part. From Tables 2-6 and 2-7, these are 40 for Part 3 and Part 4. These are also the requirements for these parts under an "NMCS = 0" policy in basic PARCOM.

(e) For AN greater than 0, to obtain a no-sub solution based on AN allowed NMCS aircraft for the no-sub part set, AN units are subtracted from the stock requirement for the most expensive item(s) in the "AN = 0" solution. Each reduction of stock by one unit creates a backorder and corresponds to one NMCS aircraft.

(f) The minimum combined (total) solution cost ($11,500) is marked in Table 2-13. The combined parts requirement for the associated (AF, AN) combination is the day requirement for Day 5. If (as assumed in this example) Day 5 has the largest day requirement, then that day requirement is also the overall minimum cost solution for our partial-substitution Example 1. From Table 2-12, the resulting solution cost ($11,500) is between the full-sub solution cost ($9,000) and the no-sub solution cost ($14,000).

(4) Calculations for Example 2. The conditions of the previous example are altered slightly in order to illustrate another case. Example 2 is identical to the previous example except for the part unit costs. Table 2-14 shows the new (Example 2) part costs alongside their old (Example 1) values. The following observations apply:

Table 2-14. Part Unit Cost Data for Example 2

PREVIOUS EXAMPLE #1 WITH NEW PART COSTS AS FOLLOWS:

	PART 1	PART 2	PART 3	PART 4
NEW COST	$ 40	$ 50	$ 400	$ 30
OLD COST	$ 400	$ 50	$ 40	$ 30

(a) Table 2-15 shows the partial-sub solution calculations for Example 2. Note that the Example 1 full-sub and no-sub solutions for (AF, AN) combinations also apply to Example 2. This is true because:

1. Alteration of part unit cost data never changes a full-sub solution.

2. The no-sub solution with new part costs does not change if the cost ordering of no-sub parts is unchanged with the new cost data (since the most expensive items remain the same then). In the given examples, Part 3 is always more expensive than Part 4.

(b) As in Table 2-13, the minimum combined (total) solution cost ($6,300) is marked in Table 2-15. As before, the combined solution associated with that minimum cost is the day requirement for Day 5 and, by our assumptions, is also the overall minimum cost solution for Example 2. Note that, all else being equal, the relative unit costs of parts drives the partial-sub solution.

Table 2-15. Unconstrained Cost Residual Requirements Calculations for Day 5 with Partial Substitution - Example 2

ALLOWABLE NMCS ACFT = 50

A_F = ALLOWABLE NMCS ACFT FROM 'FULL SUB' SET

A_N = ALLOWABLE NMCS ACFT FROM 'NO SUB' SET

COMBINED SOLUTION #	A_F	'FULL SUB' SOLUTION PT 1/PT 2 ($40/$50)	COST	A_N	'NO SUB' SOLUTION PT 3/PT 4 ($400/$30)	COST	COMBINED SOLUTION COST
1	0	70/70	$6,300	50	0/20	$600	$6,900
2	10	60/60	5,400	40	0/30	900	[6,300]
3	20	50/50	4,500	30	10/30	4,900	9,400
4	30	40/40	3,600	20	20/30	8,900	12,500
5	40	30/30	2,700	10	30/30	12,900	15,600
6	50	20/20	1,800	0	40/30	16,900	18,700

	PT 1	PT 2	PT 3	PT 4
MIN COST SOL =	60	60	0	30

(ASSUMING DAY 5 HAS THE MAX RQMT)

2-3. APPLICATION TO FULL-SCALE DATA BASE

a. Background. The previous section treats relatively simple stylized examples of little practical interest. In this section, requirement results are presented for extended PARCOM applied to the AH-1S helicopter parts data base and scenario used in the CAA study reports for the Aircraft Spare Stockage Methodology Study and the MAX FLY Study.[4] The extended PARCOM case will be denoted as the MAX FLY example. The associated parts data base has 334 different part types tagged as essential to aircraft operation. That data base was applied in a 120-day European scenario.

b. Partial Substitution Policy. A partial-substitution policy in extended PARCOM is defined in terms of the part types (in the parts data base) which comprise the full-sub parts set (see para 2-1). The full-sub parts of the MAX FLY example were defined as all those part types with either a not repairable this station (NRTS) rate exceeding 50 percent or with a retail repair time (as specified in the data base) of at least 30 days. The resulting full-sub part set employed by extended PARCOM contains 102 part types. All other part types are in the no-sub parts set. Again, a full-substitution policy is just a special case of partial substitution in which all part types are in the full-sub set. A no-substitution policy is a special case in which no part type is in the full-sub set.

c. Comparative Results. Table 2-16 summarizes the comparative residual (add-on to current inventory) requirement results, by replacement policy, for the MAX FLY data base and scenario. The partial-substitution policy represented therein is the one defined above. The relatively small difference between the partial-substitution and full-substitution requirement costs is primarily due to the dominance of the requirement costs for a single part type, the stability control amplifier, in all three policy cases. The full-substitution cost and the no-substitution cost are lower and upper bounds, respectively, on all partial-substitution policies. The partial-substitution policy applied here is just one of many potential policies. If new partial-substitution policies are defined by transferring some no-sub part types to the full-sub part set, then the associated requirements costs will decrease and will approach the full-substitution policy cost. Conversely, if policies are defined by transferring some full-sub part types into the no-sub set, then the associated requirements costs will increase and approach the no-substitution policy cost. The size of the change in requirements cost associated with an altered full-sub part set (and hence a different partial-substitution policy) depends on which parts are added to and/or removed from the base full-sub set. Further sensitivity studies, not performed here, would be needed to explore the comparative and marginal effects of variation in the partial-substitution policy employed.

Table 2-16. Add-on Requirements Costs by Policy - MAX FLY Example

Policy	Add-on cost, $M	Number of part types w/add-on	Largest part rqmt (% of total)
Full substitution	20	6	99
Partial substitution	21	60	94
No substitution	43	99	72

2-4. WORKAROUND - AN APPROACH THAT FAILED

a. Background. At the start of OPTP, when it was first determined that partial substitution should be investigated, the prospects for successfully designing appropriate partial-substitution logic for PARCOM and the ease of integrating it into the model were unknown. In view of those uncertainties, it seemed desirable to seek some simple way of working around the limitations of the version of the model in use at that time by developing some kind of input or run modifications that would permit PARCOM to effectively represent partial substitution without changes having to be made in the program code. An approach that seemed feasible at the time is described below.

b. Approach. First, an unconstrained cost residual requirements case is run with a full-sub parts replacement policy. Next, the same case is run with a no-sub policy. Relative to all possible part replacement policies, the former generates the smallest number of required parts and part types and the latter the largest. In order to represent a partial-sub case, one assumes that some parts from the no-sub requirements list are substitutable and would not be required in a partial-sub run if they are so designated. The appropriate substitutable parts are those showing up as required in the full-sub run. For the partial-sub run, then, two sets of parts are established. One set consists of those part types designated as required in a full-sub run, plus those additional part types designated as substitutable (which are associated with the "holes" in the NMCS aircraft generated in the full-sub run). The second set consists of the remaining nonsubstitutable part types. The workaround solution to a partial-sub requirements run is just the original full-sub solution, plus the no-sub, NMCS = 0 solution for the set consisting of the remaining, nonsubstitutable parts. NMCS = 0 is appropriate for this set, since all the allowable NMCS aircraft are assumed "locked up" supplying parts to the full-sub set.

c. Results. The above approach was tested with the example cases of the previous section. For Example 1, the extended PARCOM and workaround solutions are the same--the set of required parts costing $11,500 in each case. For Example 2, however, the workaround solution is three times as expensive as the PARCOM direct modeling solution--$18,700 versus $6,300--thus proving that the workaround approach does not always provide the right answer. The difference is due to the assignment, in Example 2, of greatest cost to Part 3, one of the nonsubstitutable set. It appears that whenever one of the parts from this set is the highest cost part, the workaround solution may not be optimum, depending also on failure rates and other factors. The workaround approach to partial substitution was therefore discontinued, especially since appropriate partial substitution logic for PARCOM had, meanwhile, been accomplished.

CHAPTER 3

CAPABILITY ASSESSMENT WITH PARTIAL SUBSTITUTION

3-1. BACKGROUND. After each unconstrained cost solution mix is computed, PARCOM generates a record of daily and average fleet operational capability achievable by stocking each computed requirement. In particular, these records include achieved daily and average aircraft availability, achieved program flying hours, and achieved flying hours per available aircraft per day. In computing these outputs, the new initial inventory is assumed to be the sum of the computed requirement and the original initial inventory.

3-2. CHAPTER ORGANIZATION. Subsequent paragraphs first illustrate the basic PARCOM capability assessment under full substitution and under no substitution for the unconstrained cost requirements of the example case defined in the previous chapter (Tables 2-1 and 2-2). The extension to partial substitution is then shown for its example cases (defined in Chapter 2). Lastly, assessment of current inventory is portrayed.

3-3. ASSESSMENT WITH FULL SUBSTITUTION. Tables 3-1 and 3-2 show the basic PARCOM capability assessment calculations, under full substitution, of the expected effects of stocking the requirements computed in Tables 2-4 through 2-7, Chapter 2. Cumulative net demand for each part type is based on initial inventories being set to include the computed requirements. NMCS aircraft for each day are set equal to the largest of the "cumulative net demand/QPA" entries for the day. "Surviving aircraft" are from the "cum acft surv" column of Table 2-2. Aircraft availability is 1 minus the quotient of NMCS aircraft and surviving aircraft. Flying hours per (available) aircraft per day are calculated by dividing the program flying hours for each day (see Table 2-2) by the number of available aircraft on that day. Average availability is constructed by weighting daily availabilities by the daily surviving aircraft. Average flying hours per (available) aircraft per day is weighted by the available aircraft on each day.

Table 3-1. Capability Assessment for Unconstrained Cost Residual Requirement with Full Substitution

RESIDUAL RQMT (20,20,0,0) IS ADDED TO ORIGINAL INIT (250,10,260,30)

DAY	#1 CUM NET DEMAND/QPA PART 1 (INIT=270)	#2 CUM NET DEMAND/QPA PART 2 (INIT=30)	#3 CUM NET DEMAND/QPA PART 3 (INIT=260)	#4 CUM NET DEMAND/QPA PART 4 (INIT=30)	#5 NMCS ACFT
	(ORIG*-20)/QPA (OR 0)	(ORIG*-20)/QPA (OR 0)	(ORIG*-0)/QPA (OR 0)	(ORIG*-0)/QPA (OR 0)	MAX (#1,#2,#3,#4)
1	0	0	0	0	0
2	0	0	0	0	0
3	0	20	0	10	20
4	10	40	0	20	40
5	50	50	40	30	50

* ORIGINAL CUM NET DEMAND BASED ON ORIGINAL INIT

Table 3-2. Capability Assessment for Unconstrained Cost Residual Requirement with Full Substitution (continued)

DAY	#5 NMCS ACFT	#6 SURVIVING ACFT	#7 ACFT AVAILABILITY	FLYING HOURS /ACFT/DAY
		DATA	1. - #5/#6	FHP/(#6 x #7)
1	0	150	1.00	3.3
2	0	200	1.00	5.0
3	20	200	.90	5.6
4	40	200	.80	9.4
5	50	200	.75	10.0

AVG AVAIL = .88

AVG FH/ACFT/DAY = 6.5

3-4. ASSESSMENT WITH NO SUBSTITUTION. Tables 3-3 and 3-4 show the basic PARCOM capability assessment calculations, under no substitution, of the expected effects of stocking the requirements computed in Tables 2-8 through 2-11. Cumulative net demand for each part type is based on initial inventories being set to the computed requirements. Under a no-substitution policy, NMCS aircraft for each day are equal to the sum of the cumulative net demand entries for that day. Surviving aircraft are from Table 2-2. Other calculations are analogous to those for the full-substitution case.

Table 3-3. Capability Assessment for Unconstrained Cost Residual Requirement with No Substitution

RESIDUAL RQMT (20,70,40,30) IS ADDED TO ORIGINAL INIT (250,10,260,30)

DAY	#1 CUM NET DEMAND PART 1 (INIT=270) (ORIG*-20) (OR 0)	#2 CUM NET DEMAND PART 2 (INIT=80) (ORIG*-70) (OR 0)	#3 CUM NET DEMAND PART 3 (INIT=300) (ORIG*-40) (OR 0)	#4 CUM NET DEMAND PART 4 (INIT=60) (ORIG*-30) (OR 0)	#5 NMCS ACFT SUM OF #1 - #4
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	10	0	0	0	10
5	50	0	0	0	50

* ORIGINAL CUM NET DEMAND BASED ON ORIGINAL INIT

Table 3-4. Capability Assessment for Unconstrained Cost Residual Requirement with No Substitution (continued)

DAY	#5 NMCS ACFT	#6 SURVIVING ACFT DATA	#7 ACFT AVAILABILITY 1. - #5/#6	FLYING HOURS /ACFT/DAY FHP/(#6 x #7)
1	0	150	1.00	3.3
2	0	200	1.00	5.0
3	0	200	1.00	5.0
4	10	200	.95	7.9
5	50	200	.75	10.0

AVG AVAIL = .94

AVG FH/ACFT/DAY = 6.2

3-5. ASSESSMENT WITH PARTIAL SUBSTITUTION

a. **Example 1.** Tables 3-5 and 3-6 show the extended PARCOM capability assessment calculations, under the partial-substitution policy of Chapter 2 (Part 1 and Part 2 are the full-sub set), of the effects of stocking the Example 1 requirements computed in Table 2-13. Each day consists of a full-sub assessment phase and a no-sub assessment phase. Each full-sub phase is equivalent to a basic PARCOM full-sub assessment of NMCS aircraft with only the full-sub part set considered. The resulting NMCS aircraft for the day are computed as in Table 3-1. The no-sub phase is equivalent to a basic PARCOM no-sub assessment of NMCS aircraft with only the no-sub part set considered. Resulting NMCS aircraft for the day are computed as in Table 3-3. Under our definition of partial substitution, each NMCS aircraft is "down" due to either at least one needed full-sub part or for a single needed no-sub part, but not to a needed combination of the two types. Therefore, the order of performing the phases is irrelevant. On each day, after the two NMCS aircraft calculation phases are completed, the sum of the two results yields the total NMCS aircraft for the day. Other calculations on Table 3-6 are exactly analogous to those applied by basic PARCOM in Tables 3-2 and 3-4.

Table 3-5. Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 1

RESIDUAL RQMT (20,20,40,30) IS ADDED TO ORIGINAL INIT (250,10,260,30)

DAY	PHASE*	#1 CUM NET DEMAND/QPA PART 1 (INIT=270)	#2 CUM NET DEMAND/QPA PART 2 (INIT=30)	#3 CUM NET DEMAND PART 3 (INIT=300)	#4 CUM NET DEMAND PART 4 (INIT=60)	#5 NMCS ACFT
		(ORIG**-20)/QPA (OR 0)	(ORIG**-20)/QPA (OR 0)	(ORIG**-40) (OR 0)	(ORIG**-30) (OR 0)	MAX (#1,#2) (FS PHASE) #3+ #4 (NS PHASE)
1	FS	0	0	--	--	0
	NS	--	--	0	0	0
2	FS	0	0	--	--	0
	NS	--	--	0	0	0
3	FS	0	20	--	--	20
	NS	--	--	0	0	0
4	FS	10	40	--	--	40
	NS	--	--	0	0	0
5	FS	50	50	--	--	50
	NS	--	--	0	0	0

* FS = 'FULL SUB' PHASE (PROCESSES 'FULL SUB' PART SET (PARTS 1 & 2))
NS = 'NO SUB' PHASE (PROCESSES 'NO SUB' PART SET (PARTS 3 & 4))

** ORIGINAL CUM NET DEMAND BASED ON ORIGINAL INIT

Table 3-6. Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 1 (continued)

DAY	#6 TOTAL NMCS ACFT #5(FS) + #5 (NS)	#7 SURVIVING ACFT DATA	#8 ACFT AVAILABILITY 1. - #6/#7	FLYING HOURS /ACFT/DAY FHP/(#7 x #8)
1	0	150	1.00	3.3
2	0	200	1.00	5.0
3	20	200	.90	5.6
4	40	200	.80	9.4
5	50	200	.75	10.0

AVG AVAIL = .88

AVG FH/ACFT/DAY = 6.5

b. **Example 2.** Tables 3-7 and 3-8 show the extended PARCOM capability assessment calculations, under the partial-substitution policy of Chapter 2, of the effects of stocking the Example 2 requirements computed in Table 2-15. Calculations are exactly analogous to those of Tables 3-5 and 3-6.

Table 3-7. Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 2

RESIDUAL RQMT (60,60,0,30) IS ADDED TO ORIGINAL INIT (250,10,260,30)

DAY	PHASE*	#1 CUM NET DEMAND/QPA PART 1 (INIT=310) (ORIG**-60)/QPA (OR 0)	#2 CUM NET DEMAND/QPA PART 2 (INIT=70) (ORIG**-60)/QPA (OR 0)	#3 CUM NET DEMAND PART 3 (INIT=260) (ORIG**-0) (OR 0)	#4 CUM NET DEMAND PART 4 (INIT=60) (ORIG**-30) (OR 0)	#5 NMCS ACFT MAX (#1,#2) (FS PHASE) #3+ #4 (NS PHASE)
1	FS	0	0	--	--	0
	NS	--	--	0	0	0
2	FS	0	0	--	--	0
	NS	--	--	0	0	0
3	FS	0	0	--	--	0
	NS	--	--	0	0	0
4	FS	0	0	--	--	0
	NS	--	--	0	0	0
5	FS	70-60=10	0	--	--	10
	NS	--	--	40	0	40

* FS = 'FULL SUB' PHASE (PROCESSES 'FULL SUB' PART SET (PARTS 1 & 2))
NS = 'NO SUB' PHASE (PROCESSES 'NO SUB' PART SET (PARTS 3 & 4))

** ORIGINAL CUM NET DEMAND BASED ON ORIGINAL INIT

Table 3-8. Capability Assessment for Unconstrained Cost Residual Requirement with Partial Substitution - Example 2 (continued)

DAY	#6 TOTAL NMCS ACFT #5(FS) + #6 (NS)	#7 SURVIVING ACFT DATA	#8 ACFT AVAILABILITY 1. - #6/#7	FLYING HOURS /ACFT/DAY FHP/(#7 x #8)
1	0	150	1.00	3.3
2	0	200	1.00	5.0
3	0	200	1.00	5.0
4	0	200	1.00	7.5
5	10+40=50	200	.75	10.0

AVG AVAIL = .95

AVG FH/ACFT/DAY = 6.1

3-6. ASSESSMENT OF CURRENT INVENTORY WITH PARTIAL SUBSTITUTION

a. Logic. By current inventory is meant any user-specified inventory. This is in contrast to the "required inventory" as assessed above. The basic logic of assessment of current inventory in extended PARCOM is the same as in basic PARCOM. With unconstrained costs, net demand was based on the entire planned flying hour program being flown. For a current inventory mix, some unknown (at first) number of hours will be flown. That number must initially be estimated and an iterative approach applied to determine NMCS aircraft, availability, and achievable program flying hours. For each day, therefore, a starting estimate of flying hours flown is made. The starting (first day's) estimate is the program flying hours. Then, net demand, as based on the estimated flying hours, is computed, followed by implied NMCS aircraft (generated by the estimated flying hours), achievable flying hours, and flying hours per available aircraft. The achievable flying hours are compared with the estimated flying hours flown. If, based on input thresholds, they are close enough, the iterations stop. If not, the calculations are repeated based on a new starting estimate of flying hours equal to the average of the estimated and the achieved flying hours. After iterations for a day are completed, the available aircraft for the day and their flying hour potential are calculated based on the last calculation of NMCS aircraft and on the maximum flying hour potential per aircraft per day (an input). Processing for the next day uses a starting estimate of flying hours based on the achieved flying hours of the previous day.

b. Example. Tables 3-9 through 3-11 show the extended PARCOM current inventory capability assessment calculations, through 4 days, for the example of Tables 2-1 and 2-2. For example purposes, iterations are limited to two. Calculation of daily NMCS aircraft is done in two phases, as before, but cumulative net demand is based on the current inventory and on the estimated flying hours for the iteration. The NMCS aircraft for the last iteration of each day become the basis of final daily calculations. In column 7 calculations, surviving aircraft are from Table 2-2, while NMCS aircraft are from column 6. In column 8, achieved flying hours are capped at the daily program flying hour objective. Column 9 shows the calculation of closeness thresholds for estimated versus achieved flying hours. As in basic PARCOM, the model user sets the limits on iterations and closeness thresholds.

Table 3-9. Capability Assessment of Current Inventory with Partial Substitution

INVENTORY = (250,10,260,30) ITERATION LIMIT = 2

DAY	ITER-ATION	PHASE*	EST FLY HRS**	#1 CUM NET DEMAND*** PART 1 (INIT=250)	#2 CUM NET DEMAND*** PART 2 (INIT=10)	#3 CUM NET DEMAND*** PART 3 (INIT=260)	#4 CUM NET DEMAND*** PART 4 (INIT=30)	#5 NMCS ACFT MAX (#1,#2) OR (#3 + #4)
1	1	FS	500	0	0	--	--	0
	1	NS	500	--	--	0	0	0
2	1	FS	1000	0	20	--	--	20
	1	NS	1000	--	--	0	0	0
3	1	FS	1000	0	40	--	--	40
	1	NS	1000	--	--	0	10	10
4	1	FS	1500	30	60	--	--	60
	1	NS	1500	--	--	0	20	20
	2	FS	1350	18	57	--	--	57
	2	NS	1350	--	--	0	17	17

* FS = 'FULL SUB' PHASE; NS = 'NO SUB' PHASE
** = FHP ON ITERATION 1; = (EFH + AFH)/2 ON ITERATION 2
*** CALCULATED AS CUM FAILURES - CUM RETURNS - INIT INVENTORY

Table 3-10. Capability Assessment of Current Inventory with Partial Substitution (continued)

DAY	ITER-ATION	#6 TOTAL NMCS ACFT #5(FS) + #5 (NS)	#7 AVAIL ACFT SURV-NMCS	#8 ACHIEVED FLYING HRS MIN(#7 X MFHAD*) OR (FHP)	#9 (EFH - AFH)/ (AVG DAY FHP)
1	1	0	150	500	0
2	1	20	180	1000	0
3	1	50	150	1000	0
4	1	80	120	1200	.27
	2	74	126	1260	.08

* MAXIMUM FLYING HOURS PER ACFT PER DAY

Table 3-11. Capability Assessment of Current Inventory with Partial Substitution (continued)

DAY	#10 SURVIVING ACFT DATA	ACFT AVAIL #7/#10	FRAC FLYING PGM ACHIEVED #8/FHP
1	150	1.00	1.00
2	200	.90	1.00
3	200	.75	1.00
4*	200	.63	.84

* LAST ITERATION'S VALUES

c. **Full-scale Data Base Application.** Figure 3-1 shows comparative (by policy) capability assessement of current inventory, in terms of fraction of daily flying program achieved, for the MAX FLY example case of paragraph 2-3. While the partial-substitution policy has almost one-third of the data base parts in the full-sub set, there is only a small difference between program flying hour achievement under partial substitution and under no substitution. Part of the reason is that the mix of parts comprising the full-sub set under the chosen partial-substitution policy is probably not the best one in terms of maximizing fleet capability. Apparently, the criteria defining the chosen partial-substitution, full-substitution set (NRTS $>$ .50 or retail repair time $\geq$ 30) do not correlate closely with performance. That policy does have a plausible aspect in that parts which are repaired at depot and/or which have a long repair cycle time appear to be more likely candidates for substitution. However, items with high failure rates may be more appropriate as members of the full-sub set. Preliminary testing indicates that this may be so. In any case, Figure 3-1 suggests that use of partial substitution may not always be justified by the returns in terms of improved flying hour productivity.

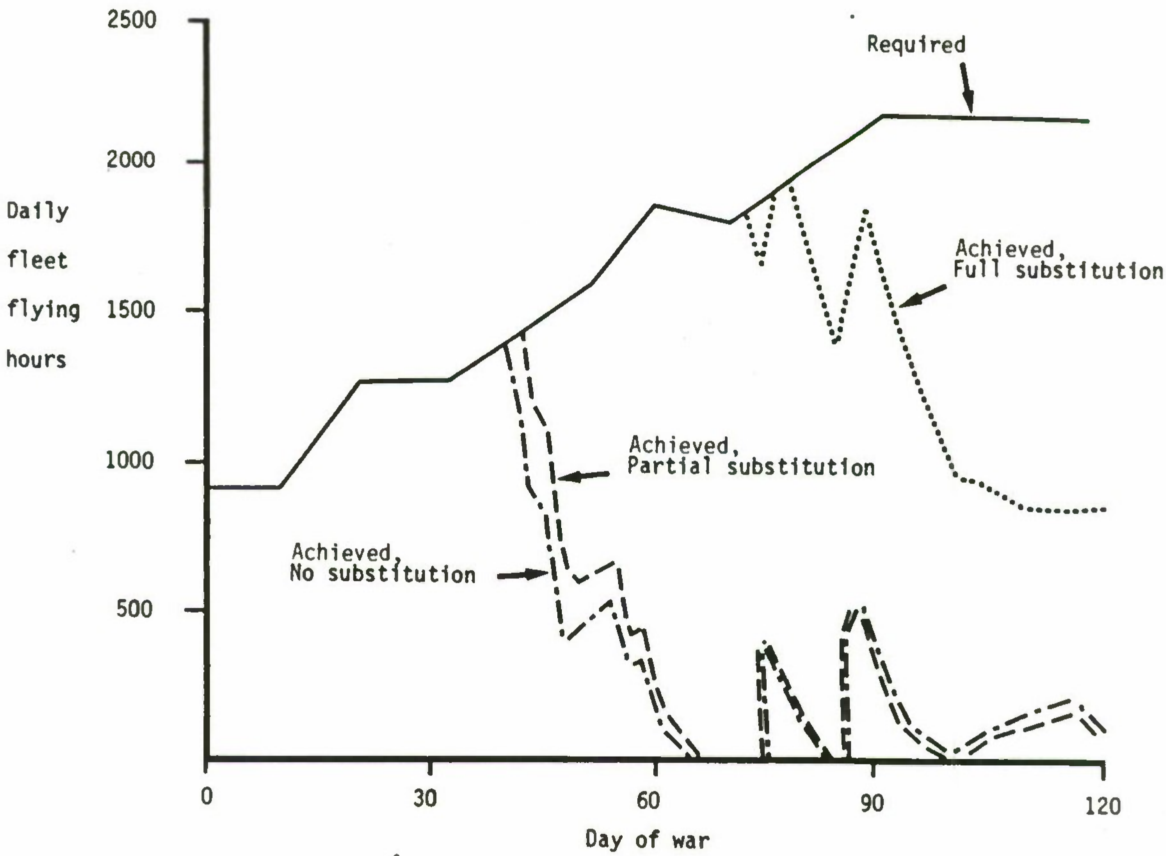

Figure 3-1. Capability Assessment of Current Inventory - MAX FLY Example Case

CHAPTER 4

DISTRIBUTING PARTS OVER TIME

4-1. BACKGROUND. The basic PARCOM Model assumes that all spare assets are front-loaded, i.e., that they are all available at retail on Day 1 of the scenario. The Overview Model (evaluated in the Aircraft Spare Stockage Methodology Study) allows the user to specify a phasing-in of parts (into theater) over time. Such phasing-in is more representative of reality since it reflects movement of unit ASL/PLLs and transit of depot stocks. The extended PARCOM was reconfigured to allow initial stock to be received in theater according to a specified planning schedule. The planning schedule is assumed operative; disruptions in the schedule, due to attrition of resupply lines and facilities, is not simulated.

4-2. LOGIC. Extended PARCOM distributes parts over intervals of 5 days rather than over individual days, as in Overview. All parts due to be received during a given 5-day interval are distributed uniformly throughout that interval. An exception is Day 1 of the scenario. All parts due in (or in place) on Day 1 are treated as received at the beginning of Day 1. The categories of parts treated are as follows:

a. **Depot Serviceables.** These consist of serviceable parts located at depot at the start of the scenario. For each part, the initial stock of depot serviceables is entered in the part data base input. The scenario input specifies a depot lag, L, and a depot distribution time, D, applicable to all parts, such that, for each part, the initial stock of depot serviceables is distributed (received at retail) uniformly between Day (L + 1) and Day (L + D).

b. **Depot Unserviceables.** These consist of unserviceable parts located at depot at the start of the scenario. They are at various stages of the depot repair process and, after repair, are to be shipped to retail. Since a part may be at any stage of its repair cycle, distribution of uncondemned depot unserviceables for each part is assumed uniform over an interval equal to the depot repair time (DRT) for the part, with the first receipt (at retail) after a lag equal to the order/ship time (OST) for the part. For each part, the initial stock of depot unserviceables, the depot condemnation rate (DC), the OST, and the depot repair time are input in the part data base. Letting A = number of depot unserviceables, the extended PARCOM distributes (1-DC) x A parts at retail between Day (OST + 1) and Day (OST + DRT).

c. **War Reserve Serviceables.** These consist of serviceable parts in the war reserve located at retail. For each part, the amount of the serviceable war reserve is input in the parts data base. The entire stock is treated as available at retail from the scenario start (Day 1).

d. War Reserve Unserviceables. These consist of unserviceable war reserve parts located at retail at the start of the scenario. Some of these will be condemned. Others will be sent to depot for repairs. Others are in various stages of repair at retail. The distribution of these parts is as follows:

(1) Items repairable at retail - for each part, let NRTS = the NRTS fraction, BR = the retail repair time, BC = retail condemnation rate, and A = number of war reserve unserviceables. Then extended PARCOM distributes at the theater (1-NRTS) x A x (1-BC) parts repaired at retail between Day 1 and Day BR. All of these factors are input in the parts data base.

(2) Items not repairable at retail - for each part, let NRTS = the NRTS fraction, DR = the depot repair time, DC = depot condemnation rate, OST = the order/ship time, and A = number of war reserve unserviceables. Then extended PARCOM returns to the theater (NRTS) x A x (1-DC) parts repaired at depot between Day (2 x OST + 1) and Day (2 x OST + DR).

e. ASL/PLL Deployments. For each part, the extended PARCOM parts data base inputs on Day 1 the total in-place ASL/PLL parts. In addition, total ASL/PLL parts deployed after Day 1 are input for successive 5-day intervals of the scenario.

4-3. IMPACT. The distribution of parts over time, as opposed to front loading of stocks, has no effect on PARCOM results if all initial assets reach retail before they are required (as replacements). An ideally efficient stockage and transportation system will achieve this. Parts distribution over time may effect an increase in requirements, relative to front loading, if initial assets are sufficiently delayed so that they do not arrive in retail before all retail stocks are drawn down. In effect, such delayed assets may have their usefulness negated because they are in the wrong place at the wrong time. Similarly, the effect of such delays on capability assessment of current inventory may be a decrease in the period over which the flying program can be continuously sustained.

4-4. EXAMPLE RESULTS. A comparative example is presented of the effects of part maldistribution in the full-substitution demonstration example of Chapter 2, which assumed front loaded parts. The parts data of Table 2-1 are used, except that Part 1 initial stock is distributed over time as specified in Table 4-1. Since just Part 1 data is altered, only the full-substitution requirement for that part is recalculated by revising Table 2-4 in accordance with the parts distribution. Table 4-2 shows the revised calculations. The basic change is in column number 3, in which INIT (front loaded initial stock) of Table 2-4 is replaced by STK (cumulative stock distributed) from Table 4-1. The net result is that cumulative net demand through Day 4 is larger under parts distribution. The overall requirement is larger (70, versus 20 for the front loaded case) because the parts deployment is badly timed. On Days 2 through 4, net demands exist while initial assets are unable to fill them, due to distribution delay.

Table 4-1. Example - Part 1 Stock Distribution Over Time

- ALL INITIAL STOCKS UNCHANGED EXCEPT
  - PART 1 DISTRIBUTION

DAY	CUM STOCK DISTRIBUTED
1	40
2	80
3	120
4	160
5	250

Table 4-2. Unconstrained Cost Residual Requirement with Full Substitution - Part 1 (initial stock distributed over time)

PART 1 CALCULATIONS

DAY	#1 CUMULATIVE FAILURES	#2 CUM RET REPAIRS	#3 CUMULATIVE NET DEMAND MAX [#1-(#2+STK*)] OR (0)	#4 ALLOWABLE STOCKOUTS	DAY RQMTS MAX (#3-#4) OR (0)
1	40	0	40-0-40 = 0	100	0
2	120	0	120-0-80 = 40	100	0
3	200	0	200-0-120 = 80	100	0
4	320	40	320-40-160 = 120	50	70
5	440	120	440-120-250 = 70	50	20

PART 1 OVERALL RQMT = LARGEST DAY RQMT = 70

* CUMULATIVE STOCK DISTRIBUTED FROM TABLE 4-1

CHAPTER 5

CONSTRAINED COST REQUIREMENTS

5-1. BACKGROUND. While the unconstrained cost solution is the one that best meets the flying program, a full requirements buy may not be affordable if funds are limited. With constrained costs, a user wishes to apply limited funds to buy a cost effective slice of the full requirements. The basic PARCOM only treated the constrained-cost case for a no substitution policy. Neither full substitution nor partial substitution were addressed. The extended PARCOM incorporates a method for deriving cost effective constrained cost requirements under partial substitution. For a no-substitution policy, the extended PARCOM constrained cost algorithm yields the same solution as the basic PARCOM constrained cost algorithm.

5-2. CONSTRAINED COST NO-SUBSTITUTION REQUIREMENT IN BASIC PARCOM. This algorithm is covered in the PARCOM Functional Description. To summarize, after the unconstrained cost, no-substitution requirements are computed, they become the basis for the constrained cost no-substitution solution. A cost limit on spares is input along with the other scenario and objective data. A constrained cost, no-substitution parts mix can be constructed by the simulated purchase, in order of increasing part unit cost, of the part requirements of the unconstrained cost solution until the money is exhausted. That would entail the procurement of the largest number of total parts from the unconstrained cost solution. However, another characteristic of such a constrained cost parts mix is that it is the mix which has the fewest unbought (hence, unstocked) items from the unconstrained cost solution. The PARCOM algorithm arrives at its solution by calculating unbought items. Initially, it spends the full cost of the unconstrained cost requirements mix, assuming it to be the constrained cost solution. Subsequently PARCOM selects the fewest number of items to remove from that solution until the remaining parts mix is priced at the input cost limit. Because the programed algorithm solves by unbuying items rather than buying them, parts are processed in decreasing order of part unit cost. Under a policy of no substitution each unbought item (regardless of part type) creates an NMCS aircraft. Therefore, our constrained cost, no-substitution solution mix minimizes the instances of NMCS created by the constrained funds. The solution tends, heuristically, toward the achievement of maximum cumulative flying hours.

5-3. APPROACH IN EXTENDED PARCOM. First, a method for treating full substitution was devised. The basic PARCOM constrained cost algorithm for no substitution was retained and combined with the full-substitution algorithm to yield a composite algorithm applicable to all partial substitution cases. However, since this algorithm is not known to be the best in all cases, its solution is compared, in terms of resulting program flying hour productivity, with a solution derived by another algorithm. The solution yielding the most program flying hours is selected. Herein, we denote these two algorithms as constrained cost algorithm one, and constrained cost algorithm two respectively. Since both are based on the approach for a full-substitution case, that case will be discussed first, followed by its adaptation to the two constrained cost algorithms.

5-4. CONSTRAINED COST WITH FULL SUBSTITUTION. For this case, the constrained cost solution is equivalent to using maximum consecutive days of flying hour program achievement as an objective. This algorithm is described in the PARCOM Functional Description. The nature of full substitution is such that the solution yielding the maximum consecutive days of flying program sustainability for fixed funds will also be the solution yielding maximum total program flying hour productivity. As was shown in the Aircraft Spare Stockage Methodology Study Report, this was not the case with a no-substitution policy. The algorithm for obtaining such a maximum sustainability solution also is described in the basic PARCOM Functional Description. Solution generation in extended PARCOM is automatic for full substitution.

5-5. CONSTRAINED COST ALGORITHM 1. After the unconstrained cost partial-substitution requirements are computed, they become the basis for a constrained cost solution as follows:

a. The no-substitution constrained cost algorithm described in paragraph 5-2 is applied to yield the portion of the unconstrained cost requirement for the no-sub part set which yields the most cost-effective mix of no-sub parts priced at (or below) the input cost limit. If the input cost limit is less than or equal to the cost of the unconstrained cost no-sub requirement, then the algorithm solution for the no-sub set is the overall solution and the algorithm terminates. However, if the input cost limit exceeds the unconstrained cost no-sub requirement, then that entire requirement is assumed bought and the input cost limit is adjusted by subtracting the cost of the entire no-sub requirement from it. The second phase of the algorithm (below) is then applied with this adjusted cost limit.

b. During the second phase of the algorithm, a version of the full-substitution constrained cost algorithm described in paragraph 5-4 is applied to the full-sub part set using the adjusted cost limit as follows:

(1) During the solution of the unconstrained cost case, the model stores, for each day, the cumulative total cost of all the full-sub parts in the partial-substitution unconstrained cost requirement for the scenario truncated at that day. The model determines D, the last (latest) day for which the associated cumulative requirement cost of the full-sub set is less than or equal to the adjusted cost limit.

(2) Next, the model generates an unconstrained cost partial-substitution solution for the scenario truncated at that day. The full-sub parts required in that solution, when combined with the no-sub requirement which was bought in the first phase, comprise the overall algorithm solution. There is no guarantee that the above solution is optimum, but it does combine the two algorithms discussed earlier.

5-6. CONSTRAINED COST ALGORITHM 2. This algorithm is a version of the maximum sustainability solution described in paragraph 5-4. It will generate a solution yielding the maximum consecutive days of program flying hour achievement. However, the resulting solution may not yield maximum total program flying hours achievable. The algorithm is:

a. During solution of the unconstrained cost case, the model stores, for each day, the cumulative total cost of all parts in the partial-substitution unconstrained cost requirement for the scenario truncated at that day. The model then determines D, the latest day for which the associated cumulative total requirement cost is less than or equal to the cost limit.

b. Next, the model generates an unconstrained cost partial-substitution solution for the scenario truncated at that day. The resulting solution mix is the overall algorithm solution.

5-7. SOLUTION SELECTION. The preferred solution mix, of those generated by the two algorithms, is the one which yields the maximum program flying hour productivity in the scenario. The model therefore does two separate current inventory capability assessments of the current inventories based on the two constrained cost algorithm solutions being bought and stocked. The add-on solution requirement is assumed to be added to the war reserve. The final constrained cost solution is the one (of the two generated) for which the associated capability assessment yields the larger value for average fraction total flying hour program achieved.

5-8. SAMPLE RESULTS. To illustrate the algorithm described above, the extended PARCOM was applied, in a constrained cost mode, to the partial-substitution MAX FLY example of paragraph 2-3. Table 5-1 summarizes requirement costs with an unconstrained budget. Total cost is the sum of the cost of full-sub parts and of no-sub parts. Three cost limits, as shown in Tables 5-2 and 5-3 were applied. Table 5-2 shows the comparative results, in terms of flying hour productivity, of the two constrained cost algorithms described previously. Notice that the solution selection, using the preferred algorithm, is based on algorithm 2 in one case and algorithm 1 in two cases. Table 5-3 shows the composition of costs of the constrained cost requirement. In this case, the no-sub parts seem to be preferred by the extended PARCOM algorithm. For the example cost limit ($.2M) which is less than the total cost of no-sub parts in the unconstrained cost requirement ($1.1M in Table 5-1), only no-sub parts are bought. For the example cost limits ($2M, $3M) which exceed the total cost of no-sub parts with unconstrained budget, all of the no-sub parts in the unconstrained budget requirement are bought. Algorithm 1 always prefers no-sub part purchases. However, algorithm 2 may buy a mix of both.

Table 5-1. Add-on Requirements Costs - Unconstrained Budget with Partial Substitution - MAX FLY Example

Total cost ($M)	Cost ($M) by part set	
	Full sub	No sub
21.0	19.9	1.1

Table 5-2. Comparison of Constrained Cost Algorithms - Add-on Requirements - Partial Substitution - MAX FLY Example

Cost limit ($M)	Fraction flying program achieved		Preferred algorithm
	Algorithm 1	Algorithm 2	
0.2	.49	.54	2
2.0	.81	.58	1
3.0	.83	.62	1

Table 5-3. Add-on Requirements Costs - Constrained Budget with Partial Substitution - MAX FLY Example

Cost limit ($M)	Solution cost ($M) by part set	
	Full-sub parts	No-sub parts
0.2	0.0	0.2
2.0	0.9	1.1
3.0	1.9	1.1

CHAPTER 6

OBSERVATIONS

6-1. PARTIAL-SUBSTITUTION REQUIREMENTS. Extended PARCOM is restricted to partial substitution policies in which all part types are partitioned by the model user into a full-sub set, within which all parts are substitutable, and a no-sub set, within which no parts are substitutable. However, considerable flexibility is allowed by such policies. Iterative, automated application of basic PARCOM logic enables calculation of least-cost requirements solutions under partial substitution and a no-sub set within which no parts are substitutable. Example application showed extended PARCOM to give plausible results with partial substitution costs between (low) costs under full substitution and (high) costs under no substitution.

6-2. PARTIAL-SUBSTITUTION CAPABILITY ASSESSMENT. Extended PARCOM can evaluate fleet capability (availability, fraction flying program achieved) for an input-specified initial spares inventory or for a spares inventory reflecting a PARCOM requirements solution being stocked. Example applications showed plausible results with fleet capability under partial substitution between (low) capability under no substitution and (high) capability under full substitution.

6-3. PARTS DISTRIBUTED OVER TIME. Extended PARCOM allows initial spare stocks to be deployed to retail in 5-day intervals, according to user input. Example applications showed plausible results with spare requirements increasing if initial stocks are withheld so long that they are unavailable when needed at retail.

6-4. PARTIAL SUBSTITUTION WITH CONSTRAINED COST. A constrained cost solution algorithm for the full substitution case was developed. This was combined with the basic PARCOM solution algorithm for the no-substitution case to yield a composite algorithm for treating constrained cost under partial substitution in extended PARCOM. However, since the algorithm does not always give the best solution (i.e., the one yielding maximum achievable program flying hours with the constrained funds), a second algorithm was also devised. Extended PARCOM applies both algorithms and chooses the solution mix from the one yielding higher flying productivity. Example results appeared plausible.

APPENDIX A

EXTENDED PARCOM - INPUT SUMMARY

A-1. PARTS DATA BASE INPUT. The major portion, in terms of quantity of records, of the extended PARCOM input data is the parts data base. The elements shown in Table A-1 must be input for each part type used.

Table A-1. Data Elements for Each Part Type in the Parts Data Base

1. National stock number (NSN)
2. Unit cost
3. Retail repair time
4. Depot repair time
5. Order and ship time
6. Failure rate
7. Retail NRTS rate
8. Retail condemnation percentage
9. Depot condemnation percentage
10. Item essentiality code
11. Quantity per application
12. Number of initial depot serviceables
13. Number of initial depot unserviceables
14. Number of initial war reserve (retail) serviceables
15. Number of initial war reserve (retail) unserviceables
16. Total parts in retail ASL/PLLs on Day-1
17. Distribution schedule of parts deployed after Day-1 (by 5-day interval)

A-2. CHANGES IN PARTS DATA BASE INPUT. Extended PARCOM shares elements (1) through (11) of Table A-1 with basic PARCOM. However, while basic PARCOM at Day 1 emplaces in the theater all the available for each part, stock, extended PARCOM allows for distribution of that stock over time, through the inclusion of the additional data elements (12) through (17).

A-3. SCENARIO DATA BASE INPUT. In addition to the parts data base, extended PARCOM inputs the scenario data listed in Table A-2.

A-4. CHANGES IN SCENARIO DATA BASE INPUT. Relative to the parts data base used in basic PARCOM, the extended PARCOM includes essentially all basic PARCOM scenario input, but adds the following data/capabilities:

a. Depot distribution and lag times. All basic PARCOM parts were front loaded.

b. Partial-substitution policy specification.

c. Options to specify the list order of part requirements. Basic PARCOM listed requirements only in order of decreasing part unit cost.

d. Options to do only a capability assessment of current inventory under several different partial-substitution policies. Basic PARCOM did a current inventory capability assessment only for a no-substitution policy.

Table A-2. Data Elements for the Scenario Data Base

Scenario Specification Data

- Case identifier
- Length of war
- Flying program
- Aircraft deployment schedule
- Aircraft losses

Scenario Constraint Data

- Cost limit (for constrained cost)
- Aircraft availability constraints (minimum daily availability)
- Maximum flying hours per aircraft per day

Additional Parts Data

- Order ship time offset
- Maximum essentiality code for part to be processed
- Lag time before initial depot serviceables are sent to retail
- Duration of time required to distribute initial depot serviceables to retail

Part Replacement Policy Specification Data for Requirement Calculations

- (1st Option) Number of parts in full-sub parts set and the part numbers of the parts designated as full-sub
- (2nd Option) Screening limits on depot cycle time, NRTS rate, retail repair time, and failure rate. A part type with parameters exceeding any screening limit is selected for the full-sub set.

Part Replacement Policy Specification for Current Inventory Capability Assessment

- Number of parts in each full-sub parts set and the part numbers of parts designated full sub

Print/Calculate Options

- Options to print various input/output lists
- Options to omit requirements calculations and only do capability assessment of current inventory
- Option to select the order in which part requirements are listed in output--either by decreasing part unit cost or by decreasing amount of requirement

Tuning Parameters

- Desired closeness of "flying hours flown" convergence during capability assessment
- Maximum number of iterations used to calculate "flying hours flown" during capability assessment
- Increment step size used during partial-substitution requirements calculations

Miscellaneous

- Designation of (up to 100) part types for which cumulative requirements through each scenario day will be listed

APPENDIX B

EXTENDED PARCOM - PROGRAM SOURCE CODE

MAIN PROGRAM	pages B-3 thru B-11
SUBROUTINE CCCAP	pages B-13 thru B-14
SUBROUTINE CCLIST	page B-15
SUBROUTINE NCRNC	page B-17
SUBROUTINE UCCAP	pages B-19 thru B-20
SUBROUTINE UCRQRS	pages B-21 thru B-23
FUNCTION MAXC	page B-25
FUNCTION SR	page B-27
SUBROUTINE DIST	page B-29

(NOT USED)

MAIN PROGRAM

```fortran
C NAME: PARCOM-X          TYPE: MAIN PROGRAM
C
C WRITTEN BY: WALTER BAUMAN/AUTOVON -295-1662
C         AT: US ARMY CAA/8120 WOODMONT AVE,BETHESDA,MD 20814
C
C PURPOSE: THE PARCOM-X (PARTS REQUIREMENTS AND COST MODEL-EXTENDED) IS USED
C TO GENERATE COST EFFECTIVE MIXES OF SPARE PARTS REQUIRED TO ACHIEVE A
C FLYING PROGRAM/AVAILABILITY OBJECTIVE UNDER A USER-SPECIFIED
C      -PART REPLACEMENT POLICY (EITHER  FULL,PARTIAL OR NO SUBSTITUTION)
C      -(PURCHASE) COST CONSTRAINT
C
C IN ADDITION,THE PROGRAM ALLOWS THE CAPABILITY ASSESSMENT OF AN AIRCRAFT
C FLEET BASED ON A USER-SPECIFIED SPARES INVENTORY APPLIED UNDER A
C VARIETY OF USER-SPECIFIED PARTS REPLACEMENT POLICIES
C
C ARGUMENTS: NOT  APPLICABLE
C
C CALLED BY: NOT  APPLICABLE
C
C CALLS
C      -SUBROUTINE MAXC: ORDERS PART TYPES IN DECREASING ORDER OF UNIT COST
C      -SUBROUTINE CCCAP: PERFORMS A FLEET CAPABILITY ASSESSMENT BASED ON
C                         A SPARES STOCK EQUAL TO THE CONSTRAINED COST SOLUTION
C                         AND/OR CURRENT INVENTORY
C      -SUBROUTINE CLIST: PRINTS SELECTED CONSTRAINED COST SOLUTIONS
C      -SUBROUTINE DIST: DISTRIBUTES PARTS TO THEATER OVER 5-DAY INTERVALS
C      -SUBROUTINE UCROPS: COMPUTES A COST-EFFECTIVE REQUIREMENTS MIX BASED
C                          ON THE UNCONSTRAINED COST SOLUTION BEING STOCKED
C      -SUBROUTINE UCCAP: COMPUTES FLEET CAPABILITY ASSESSMENT BASED
C                         ON THE UNCONSTRAINED COST SOLUTION BEING STOCKED
C
C FILES USED : INPUT - UNIT 10 (PARTS DATA)
C                    - UNIT 11 (SCENARIO DATA)
C             OUTPUT - UNIT 6 (PRINT)
C
      DIMENSION
     +     ALR(120),      AM(61),        BC(300),        DAY10(300),
     +     DC(300),       DSER(300),     DUNSER(300),    FR(300),
     +     IDAY(61),      NAC(61),       NFH(61),        OST(300),
     +     PT(24),        WRES(300),     WRESU(300),     XRNCS(300),
     +     ZLOSS(61),     ZNRT(300)
      COMMON
     +     AC(120),       ACL,           ADESC(300),     ALLOWI(120),
     +     ALLOWB(120),   AMSN(300),     ASURV(120),     AVAVG(6),
     +     AVM(120),      BCY(300),      BF(300),        CASE,
     +     CDMCA(300),    CF(300),       CL,             CMINT,
     +     CNCS(300),     COST(300),     CRNCS(300),     DCOSTI(300),
     +     DCOSTF(120),   DCY(300),      DF(300),        DMD(300),
     +     DOD(300),      FHA(120),      FHM,            FHPAPD(3,120),
     +     FHR(120),      ICOST,         IOCC(2),        IFHC(120),
     +     IFS(300),      IMSEL,         INS(300),       INT,
     +     IPT(100),      IRC(300),      IRO(300),       ISHORT,
     +     NP,            NP1,           NP2,            NW,
     +     PTDEP(300,24), OPR(300),      RNC(120),       RNCS(300),
     +     SM(120,100),   SRMAY1(300),   STK(300),       SUMB(120),
     +     TRNCS(300),    TSTK(300),     TSUMB
      CHARACTER*16
     +     ADESC,         ADSC,          AMSN,           CASE,
     +     CLASS(300),    Z1
      ISHORT=0
      IFCC=1
      DO 100 I=1,2
  100 IOCC(I)=0
      DO 200 I=1,61
         IDAY(I)=0
         AVM(I)=0.
         NAC(I)=0
         NFH(I)=0
         ZLOSS(I)=0
  200 AM(I)=0.
      DO 300 I=1,300
         IFS(I)=0
  300 INS(I)=0
      ZZ=0.
      KNTC=1
      READ (11,9000) ADDOST,CONVF,IESS,DLAG,DDIS
      NP=0
      NP1=0
      READ (11,9100) NFS
      IF (NFS.LT.0) READ (11,9200) ZDCY,ZNRTL,BREPL,FRLIM
      IF (NFS.LE.0) GO TO 400
```

```
      READ (11,9100) (IFS(J),J=1,NFS)
      WRITE (6,9100) (IFS(J),J=1,NFS)
  400 READ (11,9300) CASE
      READ (10,9400)
      I=0
  500 READ (10,9500,END=1300) Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,IES,INIT
      READ (10,9600,END=1300) DSRV,DUNS,WRS,WRU,DAY1
      READ (10,9700,END=1300) ICPA
      READ (10,9800,END=1300) ADSC
      READ (10,9900,END=1300) (PT(K),K=1,24)
      READ (10,9400,END=1300)
      IF (IES.GT.IESS) GO TO 700
      ZT=Z3+ACDOST
      ZXD=2.*ZT+Z7
      Z2C=Z2/100.
      Z4F=Z4/1000000.
      Z5N=Z5/100.
      Z10Q=ICPA
      Z8B=Z8/100.
      Z9D=Z9/100.
      IF (MOD(NP+I,50).NE.0) GO TO 600
      WRITE (6,10000) CASE
      WRITE (6,10100)
      WRITE (6,10200)
      WRITE (6,10300)
  600 IF (Z4.GE..0000001) GO TO 800
  700 WRITE (6,10400) Z1,ADSC,Z2C,Z3,Z4F,Z5N,Z6,ZXD,Z7,Z8B,Z9D,Z10Q,IES
      I=I+1
      GO TO 500
  800 NP=NP+1
      STK(NP)=WRS+DAY1
      BCY(NP)=Z6
      DCY(NP)=0.
      IF (Z5N.GT.0.) DCY(NP)=ZXD
      ZNRT(NP)=Z5N
      CLASS(NP)='  NO SUB'
      IF (NFS.GE.0) GO TO 900
      CLASS(NP)='FULL SUB'
      IF (BCY(NP).LE.BREPL.AND.DCY(NP).LE.ZDCY.AND.Z4F.LE.FRLIM.AND.ZNRT
     +(NP).LE.ZNRTL) CLASS(NP)='  NO SUB'
      GO TO 1100
  900 IF (NFS.EQ.0) GO TO 1100
      DO 1000 L=1,NFS
        IF (IFS(L).NE.NP) GO TO 1000
        CLASS(NP)='FULL SUB'
        GO TO 1100
 1000 CONTINUE
 1100 WRITE (6,10500) NP,Z1,ADSC,Z2C,Z3,Z4F,Z5N,Z6,ZXD,Z7,Z8B,Z9D,Z10Q,I
     +ES,CLASS(NP),STK(NP)
      OST(NP)=ZT
      AMSN(NP)=Z1
      COST(NP)=Z2C
      FR(NP)=Z4F
      BC(NP)=Z8B
      DC(NP)=Z9D
      QPA(NP)=Z10Q
      ADESC(NP)=ADSC
      DSER(NP)=DSRV
      DUNSER(NP)=DUNS
      WRES(NP)=WRS
      WRESU(NP)=WRU
      DAY1D(NP)=DAY1
      DO 1200 L=1,24
 1200 PTDEP(NP,L)=PT(L)
      IF (NFS.GE.0.OR.CLASS(NP).EQ.'  NO SUB') GO TO 500
      NP1=NP1+1
      IFS(NP1)=NP
      GO TO 500
 1300 II=NP+I
      IF (NFS.GE.0) NP1=NFS
      WRITE (6,10600) II,NP
      READ (11,10700) CLNCR,CLNCT,LIMIT
      READ (11,10800) FHM,NW,ISEL,IORD,IOPT1,IOPT2,IOPT3,IOPT4,IOPT5,IPR
     +T,IPRT1,INT
      IF (NP1.EQ.0.OR.IPRT1.LE.0) GO TO 1500
      DO 1400 I=1,NP1
        II=IFS(I)
        IF (MOD(I-1,50).NE.0) GO TO 1400
        WRITE (6,10000) CASE
        WRITE (6,10900) KNTC
        WRITE (6,10200)
        WRITE (6,10300)
```

```
 1400 WRITE (6,11000) II,AMSN(II),ADESC(II),COST(II),FR(II),ZNRT(II),BCY
     +(II),OCY(II),BC(II),DC(II),STK(II)
 1500 NP2=0
      DO 1800 K=1,NP
         IF (NP1.EQ.0) GO TO 1700
         DO 1600 I=1,NP1
            IF (IFS(I).EQ.K) GO TO 1800
 1600    CONTINUE
 1700    NP2=NP2+1
         INS(NP2)=K
 1800 CONTINUE
      IF (NP2.EQ.0.OR.IPRT1.LE.0) GO TO 2000
      DO 1900 I=1,NP2
         II=INS(I)
         IF (MOD(I-1,50).NE.0) GO TO 1900
         WRITE (6,10000) CASE
         WRITE (6,11100) KNTC
         WRITE (6,10200)
         WRITE (6,10300)
 1900 WRITE (6,11200) II,AMSN(II),ADESC(II),COST(II),FR(II),ZNRT(II),BCY
     +(II),OCY(II),BC(II),DC(II),STK(II)
 2000 READ (11,9100) NACDEP
      READ (11,9100) (IDAY(I),I=1,NACDEP)
      READ (11,9100) (NAC(I),I=1,NACDEP)
      DO 2200 I=1,NACDEP
         K1=IDAY(I)
         K2=IDAY(I+1)-1
         IF (I.EQ.NACDEP) K2=NW
         DO 2100 J=K1,K2
 2100    AC(J)=NAC(I)
 2200 CONTINUE
      READ (11,9100) NFHDAY
      READ (11,9100) (IDAY(I),I=1,NFHDAY)
      READ (11,9100) (NFH(I),I=1,NFHDAY)
      DO 2400 I=1,NFHDAY
         K1=IDAY(I)
         K2=IDAY(I+1)-1
         IF (I.EQ.NFHDAY) K2=NW
         DO 2300 J=K1,K2
            FHA(J)=NFH(I)
 2300    FHR(J)=NFH(I)
 2400 CONTINUE
      READ (11,9100) NLDAY
      READ (11,9100) (IDAY(I),I=1,NLDAY)
      READ (11,11300) (ZLOSS(I),I=1,NLDAY)
      DO 2600 I=1,NLDAY
         K1=IDAY(I)
         K2=IDAY(I+1)-1
         IF (I.EQ.NLDAY) K2=NW
         DO 2500 J=K1,K2
 2500    ALR(J)=ZLOSS(I)
 2600 CONTINUE
      READ (11,9100) NMDAY
      READ (11,9100) (IDAY(I),I=1,NMDAY)
      READ (11,11400) (AM(I),I=1,NMDAY)
      DO 2800 I=1,NMDAY
         K1=IDAY(I)
         K2=IDAY(I+1)-1
         IF (I.EQ.NMDAY) K2=NW
         DO 2700 J=K1,K2
 2700    AVM(J)=AM(I)
 2800 CONTINUE
      READ (11,9100) IMSEL
      READ (11,9100) (IPT(K),K=1,IMSEL)
      IF (IPRT1.LE.0) GO TO 3300
      ZCOST=0.
      DO 3000 K=1,NP
         SUM=0.
         DO 2900 I=1,24
 2900    SUM=SUM+PTOEP(K,I)
         SUMT=SUM+DSER(K)+DUMSER(K)*(1.-DC(K))+WRES(K)+DAY10(K)+(1.-ZNRT(
     +   K))*WRESU(K)*(1.-BC(K))+ZNRT(K)*WRESU(K)*(1.-DC(K))
         ZCOST=ZCOST+SUMT*COST(K)
         IF (MOD(K-1,51).NE.0) GO TO 3000
         WRITE (6,10000) CASE
         WRITE (6,11500)
         WRITE (6,10100)
         WRITE (6,11600)
         WRITE (6,10300)
 3000 WRITE (6,11700) K,K,AMSN(K),ADESC(K),COST(K),CLASS(K),DSEP(K),DUNS
     +ER(K),WRES(K),WRESU(K),DAY10(K),SUM,SUMT
      DO 3200 K=1,NP
```

```
      IF (MOD((K-1)*3,60).NE.0) GO TO 3100
      WRITE (6,10000) CASE
      WRITE (6,11800)
      WRITE (6,11900)
      WRITE (6,12000)
      WRITE (6,10300)
3100  WRITE (6,12100) K,AMSN(K),ADESC(K)
3200 WRITE (6,12200) (PTDEP(K,L),L=1,24)
3300 DO 3500 K=1,NP
      IFDAY=DLAG+1
      ILDAY=DLAG+DDIS
      DAMT=DSER(K)/DDIS
      CALL DIST (IFDAY,ILDAY,DAMT,K)
      IFDAY=OST(K)+1.
      DREP=DCY(K)-2.*OST(K)
      IF (DREP.LT.1.) DREP=1.000
      ILDAY=OST(K)+DREP
      DAMT=((1.-DC(K))*DUNSER(K))/DREP
      CALL DIST (IFDAY,ILDAY,DAMT,K)
      AMT=(1.-ZNRT(K))*WRESU(K)*(1.-BC(K))
      IFDAY=1
      IF (BCY(K).LT.1.) BCY(K)=1.
      ILDAY=BCY(K)
      DAMT=AMT/BCY(K)
      CALL DIST (IFDAY,ILDAY,DAMT,K)
      AMT=ZNRT(K)*WRESU(K)*(1.-DC(K))
      IFDAY=1.+2.*OST(K)
      ILDAY=2.*OST(K)+DREP
      DAMT=AMT/DREP
      CALL DIST (IFDAY,ILDAY,DAMT,K)
      IF (IPRT1.LE.0) GO TO 3500
      IF (MOD((K-1)*3,60).NE.0) GO TO 3400
      WRITE (6,10000) CASE
      WRITE (6,12300)
      WRITE (6,11900)
      WRITE (6,12000)
      WRITE (6,10300)
3400  IF (DCY(K).GE..0001.OR.DAMT.LE..001) WRITE (6,12100) K,AMSN(K),A
     * DESC(K)
      IF (DCY(K).LT..0001.AND.DAMT.GT.001) WRITE (6,12400) K,AMSN(K),A
     * DESC(K)
      WRITE (6,12200) (PTDEP(K,L),L=1,24)
3500 CONTINUE
     IF (IPRT.LE.0) GO TO 3800
     DO 3700 J=1,NW
      IF (MOD(J-1,51).NE.0) GO TO 3600
      WRITE (6,10000) CASE
      WRITE (6,12500)
      WRITE (6,12600) ADDOST,CONVF,LIMIT,IESS
      WRITE (6,12700) FHM,CLNCR,CLNCT
      WRITE (6,12800) ZCOST
      WRITE (6,12900)
      WRITE (6,13000)
3600  CALR=CALR+ALR(J)
3700 WRITE (6,13100) J,AC(J),FHR(J),AVM(J),ALR(J),CALR
3800 WRITE (6,10000) CASE
     WRITE (6,13200)
     IF (ISEL.EQ.0) WRITE (6,13300) ISEL
     IF (ISEL.EQ.1) WRITE (6,13400) ISEL
     IF (ISEL.EQ.2) WRITE (6,13500) ISEL
     IF (NFS.LT.0) WRITE (6,13600) NFS,ZOCY,ZNRTL,BREPL,FRLIM
     IF (NFS.GE.0) WRITE (6,13700) NFS
     IF (IORD.LE.0) WRITE (6,13800) IORD
     IF (IORD.GT.0) WRITE (6,13900) IORD
     IF (IOPT1.LE.0) WRITE (6,14000) IOPT1
     IF (IOPT1.GT.0) WRITE (6,14100) IOPT1
     IF (IOPT2.LE.0) WRITE (6,14200) IOPT2
     IF (IOPT2.GT.0) WRITE (6,14300) IOPT2
     IF (IOPT3.LE.0) WRITE (6,14400) IOPT3
     IF (IOPT3.GT.0) WRITE (6,14500) IOPT3
     IF (IOPT4.LE.0) WRITE (6,14600) IOPT4
     IF (IOPT4.GT.0) WRITE (6,14700) IOPT4
     IF (IOPT5.LE.0) WRITE (6,14800) IOPT5
     IF (IOPT5.GT.0) WRITE (6,14900) IOPT5
     IF (IPRT.LE.0) WRITE (6,15000) IPRT
     IF (IPRT.GT.0) WRITE (6,15100) IPRT
     IF (IPRT1.LE.0) WRITE (6,15200) IPRT1
     IF (IPRT1.GT.0) WRITE (6,15300) IPRT1
     WRITE (6,15400) INT,INT
     DO 3900 I=1,NW
3900 DCOSTF(I)=0.
     DO 4000 I=1,NP
```

```
4000 DOO(I)=COST(I)
     KNT=0
     NDUMMY=NP
     DO 4300 K=1,NP
        CALL MAXC (NDUMMY,NOUT)
        IRC(K)=NOUT
        II=IRC(K)
        IF (NP1.LE.0) GO TO 4200
        DO 4100 L=1,NP1
           IF (IFS(L).EQ.II) GO TO 4300
4100    CONTINUE
4200    KNT=KNT+1
        INS(KNT)=II
4300 DOO(II)=-1.
     IF (IPRT1.LE.0) GO TO 4600
     DO 4500 K=1,NP
        II=IRC(K)
        SUM=0.
        DO 4400 I=1,24
4400    SUM=SUM+PTDEP(II,I)
        SUMT=SUM+OSER(II)+DUNSEP(II)*(1.-DC(II))+WRES(II)+DAY10(II)+(1.-
     +  ZNRT(II))*WRESU(II)*(1.-BC(II))+ZNRT(II)*WRESU(II)*(1.-DC(II))
        IF (MOD(K-1,5)).NE.0) GO TO 4500
        WRITE (6,10000) CASE
        WRITE (6,15500)
        WRITE (6,11500)
        WRITE (6,11600)
        WRITE (6,10300)
4500 WRITE (6,11700) K,II,AMSN(II),ADESC(II),COST(II),CLASS(II),OSER(II
     +),DUNSEP(II),WRES(II),WRESU(II),DAY10(II),SUM,SUMT
4600 CALR=0.
     WRITE (6,15600)
     DO 4700 I=1,NW
        CALR=CALR+ALR(I)
        ASURV(I)=AC(I)-CALR
        XX=AMAX1(0.,ASURV(I)*(1.-AVM(I)))
        YY=AMAX1(0.,ASURV(I)-FHP(I)/FHM)
        ALLOWB(I)=AMIN1(XX,YY)
        IF (ALLOWB(I).EQ.YY) IFHC(I)=0
        IF (ALLOWB(I).EQ.XX) IFHC(I)=1
4700 CONTINUE
     TTFH=0.000001
     DO 4800 I=1,NW
4800 TTFH=TTFH+FHR(I)
     DO 4900 J=1,NP
        CF(J)=FR(J)*QPA(J)
        BF(J)=(1.-BC(J))*(1.-ZNRT(J))*CF(J)
        DF(J)=(1.-DC(J))*(ZNRT(J))*CF(J)
4900 CONTINUE
     IF (IOPT1.LE.0) GO TO 7600
     IND1=1
     IND2=2
     IF (ISEL.EQ.2) GO TO 5000
     IND1=1+ISEL
     IND2=1+ISEL
5000 DO 7500 IND=IND1,IND2
        ACL=0.
        CL=CLNCT
        ICOST=0
        IF (IND.EQ.2) CL=CLNCR
        CALL UCROPS (IND,IOPT4,IOPT5,IORD)
        CALL UCCAP (IND)
        IF (CL.LE.0.) GO TO 7500
        IW=NW
        UCNS =0.
        FRAC1=0.
        IF (NP2.EQ.0) GO TO 6600
        DO 5100 J=1,NP2
           II=INS(J)
5100    UCNS=UCNS+COST(II)*PNCS(II)
        WRITE (6,10000) CASE
        WRITE (6,15700)
        DO 5200 J=1,NP
5200    TRNCS(J)=RNCS(J)
        CL1=CL
        CNC=CMINT-CL
        IF (CNC.GT.0.) GO TO 5300
        IF (IND.EQ.1) WRITE (6,15800)
        IF (IND.EQ.2) WRITE (6,15900)
        GO TO 7500
5300    IF (CNC.GT.DCOST1(NW)) GO TO 5400
        CL1=UCNS
```

```
                 CL2=CL-CL1
                 GO TO 5900
      5400       IF (NP1.EQ.0) GO TO 5600
                 DO 5500 J=1,NP1
                   II=IFS(J)
      5500       TRNCS(II)=0.
      5600       CL2=0.
                 CL1=CL-CL2
                 CNC=UCNS-CL1
                 DO 5800 J=1,NP2
                   II=INS(J)
                   C=TRNCS(II)*COST(II)
                   IF (C.LT.CNC) GO TO 5700
                   TRNCS(II)=TRNCS(II)-CNC/COST(II)
                   IW=NW
                   GO TO 6200
      5700         TRNCS(II)=0.
                   CNC=CNC-C
      5800       CONTINUE
                 GO TO 6100
      5900       IFCC=1
                 DO 6000 I=1,NW
                   IF (DCOST1(I).GT.CL2) GO TO 6000
                   IFCC=I
                   BCL=DCOST1(I)
      6000       CONTINUE
                 WRITE (6,16000)
      6100       IF (CL2.GE.DCOST1(NW)) WRITE (6,16100)
                 IF (CL2.LT.DCOST1(NW)) WRITE (6,16200) CL2,BCL,IFCC
                 IW=NW
                 NW=IFCC
                 CALL UCROPS (IND,IOPT4,IOPT5,IORD)
      6200       WRITE (6,16300) CL,CL1
                 IF (CL2.LE..0001) WRITE (6,16400)
                 NW=IW
                 DO 6300 I=1,NP2
                   II=INS(I)
      6300       RNCS(II)=TRNCS(II)
                 DO 6400 I=1,NP
      6400       TRNCS(I)=RNCS(I)
                 TOT=0.
                 DO 6500 I=1,NP
                   TOT=TOT+COST(I)*RNCS(I)
      6500       RNCS(I)=RNCS(I)+STK(I)*(IND-1)
                 IP=0
                 CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
                 FRAC1=FNC
                 WRITE (6,16500) FRAC1
      6600       IF (ICCC(IND).LE.1.OR.ICCC(IND).GE.NW) GO TO 7500
                 NW=ICCC(IND)
                 DO 6700 I=1,NW
      6700       FHA(I)=FHR(I)
                 CALL UCROPS (IND,IOPT4,IOPT5,IORD)
                 DO 6800 J=1,NP
                   XRNCS(J)=RNCS(J)
                   NW=IW
                   IP=0
      6800       RNCS(J)=RNCS(J)+STK(J)*(IND-1)
                 CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
                 FRAC2=FNC
                 WRITE (6,16600) FRAC2
                 IF (FRAC1.LE.FRAC2) GO TO 7100
                 DO 6900 J=1,NP
      6900       RNCS(J)=TRNCS(J)
                 IG=1
                 ACL=TOT
                 CALL CCLIST (IG,IORD,IND)
                 DO 7000 J=1,NP
      7000       RNCS(J)=TRNCS(J)+STK(J)*(IND-1)
                 IP=1
                 CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
                 GO TO 7400
      7100       IG=2
                 DO 7200 J=1,NP
      7200       RNCS(J)=XRNCS(J)
                 CALL CCLIST (IG,IORD,IND)
                 DO 7300 J=1,NP
      7300       RNCS(J)=XRNCS(J)+STK(J)*(IND-1)
                 IP=1
                 CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
      7400       NW=IW
      7500    ICOST=0
```

```
 7600 DO 7700 K=1,NP
 7700 RNCS(K)=STK(K)
      IP=1
      IND=2
      CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
      KNTC=2
 7800 DO 7900 K=1,NP
         RNCS(K)=STK(K)
         INS(K)=0
 7900 IFS(K)=0
      READ (11,9100,END=16700) NPTFS,NPTNS
      IF ((NPTFS+NPTNS).LE.0) GO TO 16700
      IF (NPTFS.LE.0) GO TO 8200
      NP1=NPTFS
      READ (11,9100) (IFS(I),I=1,NPTFS)
      NP2=0
      DO 8100 K=1,NP
         DO 8000 I=1,NP1
            IF (IFS(I).EQ.K) GO TO 8100
 8000    CONTINUE
         NP2=NP2+1
         INS(NP2)=K
 8100 CONTINUE
      GO TO 8500
 8200 NP2=NPTNS
      READ (11,9100) (INS(I),I=1,NPTNS)
      NP1=0
      DO 8400 K=1,NP
         DO 8300 I=1,NP2
            IF (INS(I).EQ.K) GO TO 8400
 8300    CONTINUE
         NP1=NP1+1
         IFS(NP1)=K
 8400 CONTINUE
 8500 IF (IOPT2.LE.0) GO TO 8700
      DO 8600 I=1,NP1
         II=IFS(I)
         IF (MOD(I-1,50).NE.0) GO TO 8600
         WRITE (6,10000) CASE
         WRITE (6,10900) KNTC
         WRITE (6,10200)
         WRITE (6,10300)
 8600 WRITE (6,11000) II,AMSN(II),ADESC(II),COST(II),FR(II),ZNRT(II),BCY
     +(II),DCY(II),BC(II),DC(II),STK(II)
 8700 IF (IOPT3.LE.0) GO TO 8900
      DO 8800 I=1,NP2
         II=INS(I)
         IF (MOD(I-1,50).NE.0) GO TO 8800
         WRITE (6,10000) CASE
         WRITE (6,11100) KNTC
         WRITE (6,10200)
         WRITE (6,10300)
 8800 WRITE (6,11200) II,AMSN(II),ADESC(II),COST(II),FR(II),ZNRT(II),BCY
     +(II),DCY(II),BC(II),DC(II),STK(II)
      IND=2
 8900 CALL CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
      KNTC=KNTC+1
      GO TO 7800
 9000 FORMAT (2F5.2,I5,2F5.0)
 9100 FORMAT (16I5)
 9200 FORMAT (F5.0,F5.3,F5.0,F10.6)
 9300 FORMAT (1X,A16)
 9400 FORMAT (//)
 9500 FORMAT (2X,A15,F9.0,5X,F3.0,F5.0,5F3.0,I1,10X,I5)
 9600 FORMAT (/,5F6.0,/)
 9700 FORMAT (I2)
 9800 FORMAT (A16)
 9900 FORMAT (10F10.0)
10000 FORMAT (1H1,30X,'CASE= ',A16)
10100 FORMAT (//,' ITEMS RANK ORDERED IN NORMAL INPUT ORDER')
10200 FORMAT (/,' PART',5X,'MSN',14X,'DESCRIPTION',7X,' COST OST FAIL',' 
     + RT NRTS  BCY  DCY  DRT BCON DCON QPA  ESS     CLASS  INIT STK')
10300 FORMAT (/)
10400 FORMAT (9X,A16,2X,A16,F8.0,F3.0,F8.6,F5.2,3F5.0,2F5.2,1X,F3.0,I5,1
     +0X,I10)
10500 FORMAT (1X,I4,4X,A16,2X,A16,F8.0,F3.0,F8.6,F5.2,3F5.0,2F5.2,1X,F3.
     +0,I5,1X,A8,F10.1)
10600 FORMAT (' TOTAL NR PARTS=',I4,'    NR USED=',I4)
10700 FORMAT (1X,F14.0,F15.0,I5)
10800 FORMAT (1X,F9.1,I5,5X,10I5)
10900 FORMAT (//,' FULL SUB ITEMS FOR POLICY',I3)
11000 FORMAT (1X,I4,4X,A16,2X,A16,F8.0,3X,F8.6,F5.2,2F5.0,5X,2F5.2,1X,10
```

```
     +X,'FULL SUB',F10.0)
11100 FORMAT (//,'   NO SUB ITEMS FOR POLICY',I3)
11200 FORMAT (1X,I4,4X,A16,2X,A16,F8.0,3X,F8.6,F5.2,2F5.0,5X,2F5.2,1X,10
     +X,'  NO SUB',F10.0)
11300 FORMAT (16F5.1)
11400 FORMAT (16F5.2)
11500 FORMAT (/,104X,' DEPLOYED')
11600 FORMAT (' RANK PART',8X,'MSN',18X,'DESCRIPTION',13X,'COST','     CL
     +ASS',2X,'DSERV DUNSR WRSRV WRUNS  DAY1  DAY2- TOT NC')
11700 FORMAT (2I5,5X,A16,5X,A16,1X,F14.0,1X,A6,1X,5F6.0,2F7.0)
11800 FORMAT (//,' UNADJUSTED PARTS DEPLOYMENT BY DAY INTERVAL')
11900 FORMAT (/,'       -5    -10    -15    -20    -25    -30    -35    -40    -45'
     +,'   -50    -55    -60    -65    -70    -75    -80    -85    -90    -95','
     + -100')
12000 FORMAT ('  -105  -110  -115  -120')
12100 FORMAT (I5,2X,A16,2X,A16)
12200 FORMAT (1X,20F6.0)
12300 FORMAT (//,' ADJUSTED (FOR DEPOT STKS) PARTS DEPLOYED BY INTERVAL'
     +)
12400 FORMAT (I5,2X,A16,2X,A16,7X,'* WARNING* DEPOT UNSERV STK W/ DEP','
     +OT REPAIR TIME=0 (CHGED TO 1)')
12500 FORMAT (//,10X,'SCENARIO INPUT DATA SUMMARY')
12600 FORMAT (//,5X,'CST OFFSET=',F6.1,' DAYS    DESIRED CONVERGECE=',F5
     +.3,3X,'MAX ITERATIONS=',I7,3X,'MAX ESSENTIALITY=',I3)
12700 FORMAT (/,5X,'  MAX FLY HRS/ACFT/DAY=',F5.1,4X,'ADD-ON COST LI','M
     +IT=',F12.0,3X,'TOTAL (INIT INV=0) RQMT COST LIMIT=',F13.0)
12800 FORMAT (/,5X,' COST OF CURRENT INVENTORY=',F14.0)
12900 FORMAT (/,13X,'CUM ACFT   PROGRAM   MIN REQ    ACFT    CUM ACFT')
13000 FORMAT (7X,'DAY    DEPLOYED    FLY HRS      AVAIL     LOST',7X,'LOST')
13100 FORMAT (5X,I5,F11.0,F10.0,F10.2,F8.1,F11.1)
13200 FORMAT (//,10X,' ******  OPTIONS CHOSEN FOR THIS RUN ******')
13300 FORMAT (////,5X,'ISEL=',I3,'  ** ONLY THE TOTAL(INIT STK=0)',' RQM
     +TS ARE COMPUTED IN THIS RUN   **')
13400 FORMAT (////,5X,'ISEL=',I3,'  ** ONLY THE RESIDUAL(INIT STK=CURR',
     +' INV) RQMTS ARE COMPUTED IN THIS RUN   **')
13500 FORMAT (////,5X,'ISEL=',I3,'  ** BOTH THE TOTAL(INIT STK=0) AND''
     +RESIDUAL(INIT STK=CURR INV) RQMTS ARE COMPUTED IN THIS RUN **')
13600 FORMAT (//,5X,'NFS=',I3,'  ** FULL SUB SET IS CHOSEN ACCORDING','
     +TO A DEPOT REPAIR CYCLE EXCEEDING',F12.0,' DAYS OR NRTS ','EXCEEDI
     +NG',F6.3,/,15X,'OR RETAIL REPAIR TIME  EXCEEDING',F8.0,'  OR FAILU
     +RE RATE EXCEEDING',F9.6)
13700 FORMAT (//,5X,'NFS=',I3,'  ** FULL SUB SET IS SPECIFIED BY INPUT')
13800 FORMAT (//,5X,'IORD=',I3,'  ** COMPUTED RQMTS LISTS WILL BE IN ','
     +ORDER OF DECREASING UNIT COST OF PART')
13900 FORMAT (//,5X,'IORD=',I3,'  ** COMPUTED RQMTS LISTS WILL BE IN ','
     +ORDER OF DECREASING RQMT AMOUNT FOR PART')
14000 FORMAT (//,5X,'IOPT1=',I3,'  ** ONLY ASSESSMENT CASES WILL BE ','D
     +ONE IN THIS RUN')
14100 FORMAT (//,5X,'IOPT1=',I3,'  ** BOTH ASSESSMENT AND RQMT CASES','
     +WILL BE DONE IN THIS RUN')
14200 FORMAT (//,5X,'IOPT2=',I3,'  ** THE FULL SUB PART SETS USED IN','
     +ASSESSMENT CASES WILL NOT BE PRINTED')
14300 FORMAT (//,5X,'IOPT2=',I3,'  ** THE FULL SUB PART SETS USED IN','
     +ASSESSMENT CASES WILL  BE PRINTED')
14400 FORMAT (//,5X,'IOPT3=',I3,'  ** THE NO SUB PART SETS USED IN',' AS
     +SESSMENT CASES WILL NOT BE PRINTED')
14500 FORMAT (//,5X,'IOPT3=',I3,'  ** THE NO SUB PART SETS USED IN',' AS
     +SESSMENT CASES WILL  BE PRINTED')
14600 FORMAT (//,5X,'IOPT4=',I3,'  ** THE UNCONSTR COST RQMTS LISTS',' W
     +ILL NOT BE PRINTED(BUT ARE COMPUTED)')
14700 FORMAT (//,5X,'IOPT4=',I3,'  ** THE UNCONSTR COST RQMTS LISTS',' W
     +ILL  BE PRINTED ')
14800 FORMAT (//,5X,'IOPT5=',I3,'  ** THE CUM RQMT BY DAY COST LISTS','
     +WILL NOT BE PRINTED ')
14900 FORMAT (//,5X,'IOPT5=',I3,'  ** THE CUM RQMT BY DAY COST LISTS','
     +WILL  BE PRINTED ')
15000 FORMAT (//,5X,'IPRT=',I3,'  ** THE SCENARIO INPUT DATA SUMMARY','
     +WILL NOT BE PRINTED ')
15100 FORMAT (//,5X,'IPRT=',I3,'  ** THE SCENARIO INPUT DATA SUMMARY','
     +WILL  BE PRINTED ')
15200 FORMAT (//,5X,'IPRT1=',I3,'  ** THE FULL SUB AND NO SUB PART ',' S
     +ETS (FOR RQMT CASES) WILL NOT BE PRINTED',/,13X,'NOR WILL ','THE I
     +NPUT-ORDERED AND COST-ORDERED PARTS INPUT LISTS ')
15300 FORMAT (//,5X,'IPRT1=',I3,'  ** THE FULL SUB AND NO SUB PART ',' S
     +ETS (FOR RQMT CASES) WILL BE PRINTED',/,13X,'AS WILL ','THE INPUT-
     +ORDERED AND COST-ORDERED PARTS INPUT LISTS ')
15400 FORMAT (//,5X,'INT=',I3,'  ** THE PARTIAL SUB RQMT ALGORITHM',' WI
     +LL TEST AT INTERVALS OF',I3,' (ALLOWABLE NMCS ACFT) ')
15500 FORMAT (/,' ITEMS RANK ORDERED BY  DECREASING PART COST')
15600 FORMAT (1H1)
15700 FORMAT (//,20X,'*** CONSTRAINED COST SOLUTION EVALUATION',' REPORT
     + ***',///)
```

```
15800 FORMAT (1H1,//,10X,'THE UNCONSTR COST TOTAL RQMT SOLUTION IS',' AL
     +SO THE CONSTR COST TOTAL RQMT SOLUTION')
15900 FORMAT (1H1,//,10X,'THE UNCONSTR COST RESIDUAL RQMT SOLUTION IS','
     + ALSO THE CONSTR COST RESIDUAL RQMT SOLUTION')
16000 FORMAT (//,10X,'ALL (NO SUB)  PARTS ARE AFFORDABLE IN CONSTRAINED'
     +,' COST SOLUTION 1')
16100 FORMAT (//,10X,'ALL FULL SUB  PARTS ARE AFFORDABLE IN CONSTRAINED'
     +,' COST SOLUTION 1')
16200 FORMAT (//,5X,F12.0,3X,'APPROXIMATED BY',F12.0,'  CUM FULL SUB','
     +PART COST THRU DAY',I4,'  IS USED TO BUY FULL SUB PARTS')
16300 FORMAT (//,10X,'CONSTR COST LIMIT=',F12.0,3X,'OF WHICH',F12.0,3X,'
     +CAN BE USED TO BUY (NO SUB) PARTS OF THE  UNCONSTR COST SOL')
16400 FORMAT (//,10X,'NO  FULL SUB  PARTS ARE AFFORDABLE IN CONSTRAINED'
     +,' COST SOLUTION 1')
16500 FORMAT (//,5X,'THE FIRST CONSTR COST SOL YIELDS AN AVG FRAC',' PGM
     + FLY HRS ACH=',F5.3)
16600 FORMAT (//,5X,'THE 2ND(SUSTNBLTY) CONSTR COST SOL YIELDS AN',' AVG
     + FRAC FH ACH=',F5.3)
16700 END
```

(NOT USED)

SUBROUTINE CCCAP

```
      SUBROUTINE CCCAP (IND,LIMIT,CONVF,TTFH,KNTC,IP,FNC)
C NAME: CCCAP              TYPE: SUBROUTINE
C
C PURPOSE: THE CCCAP  (CONSTRAINED COST CAPABILITY ASSESSMENT) SUBROUTINE
C COMPUTES FLEET CAPABILITY ASSESSMENT (AVG AVAILABILITY,FRACTION FLYING
C PROGRAM ACHIEVED,FGM FLYING HRS /ACFT/DAY ) BASED ON THE CONSTRAINED COST
C SOLUTION BEING STOCKED IN THE WAR RESERVE
C
C CALLED BY: MAIN PROGRAM
C
C CALLS
C     -FUNCTION SR: COMPUTES CUMULATIVE NET DEMAND THRU A SPECIFIED DAY
C                   FOR A SPECIFIED PART
C
C FILES USED : INPUT - NONE
C              OUTPUT - UNIT 6 (PRINT)
C
      COMMON
     +    AC(I20),         ACL,             ADESC(300),      ALLOWI(120),
     +    ALLOWB(I20),     AMSN(300),       ASURV(I20),      AVAVG(6),
     +    AVM(I20),        BCY(300),        BF(300),         CASE,
     +    COMDA(300),      CF(300),         CL,              CMINT,
     +    CNCS(300),       COST(300),       CRNCS(300),      DCOSTI(300),
     +    DCOSTF(120),     DCY(300),        DF(300),         DMD(300),
     +    DOD(300),        FHA(I20),        FHM,             FHPAPD(3,120),
     +    FHR(120),        ICOST,           IOCC(2),         IFHC(I20),
     +    IFS(300),        IMSFL,           INS(300),        INT,
     +    IPT(100),        IRC(300),        IRO(300),        ISHORT,
     +    NP,              NP1,             NP2,             NW,
     +    PTDEP(300,24),   QPA(300),        RNC(120),        RNCS(300),
     +    SM(I20,100),     SRMAX1(300),     STK(300),        SUMB(I20),
     +    TRNCS(300),      TSTK(300),       TSUMB
      DIMENSION
     +    OMOT(300),       FHNC(I20),       FHNZ(I20)
      CHARACTER*16
     +    ADESC,           ADSC,            AMSN,            CASE
      BMAX=0.
      AVAVG(1)=0.
      AVAVG(3)=0.
      TFHNC=0.
      TSURV=0.
      TNCO=0.
      DO 100 I=1,NW
        TSURV=TSURV+ASURV(I)
        SUMB(I)=0.
        DO I00 K=I,3
  100 FHPAPD(K,I)=0.
      DO 200 J=I,NP
        DOD(J)=0.
        OMOT(J)=0.
  200 OMD(J)=0.
      XX=ASURV(1)
      TAV=0.
      DO I200 I=1,NW
        IA=(I-1)/5+1
        DO 300 J=1,NP
  300   RNCS(J)=RNCS(J)+(IND-1)*PTDEP(J,IA)/5.
        IF (I.GT.1) XX=RNC(I-1)*ASURV(I-1)+AC(I)-AC(I-I)
        FHA(I)=AMIN1(XX*FHM,FHR(I))
        INDX=0
        IF (NP2.EQ.0) GO TO 600
  400   DO 500 K=1,NP2
          II=INS(K)
          XX=OMOT(II)
          OMOT(II)=SR(I,II,XX)
          ZP=OMOT(II)-RNCS(II)
  500   SUMB(I)=SUMB(I)+AMAX1(0.,ZP)
  600   IF (NP1.EQ.0) GO TO 800
        BMAX=0.
        DO 700 K=1,NP1
          II=IFS(K)
          XX=OMOT(II)
          OMOT(II)=SR(I,II,XX)
          BOFCS=(OMOT(II)-RNCS(II))/QPA(II)
          IF (BOFCS.LE.0.) BOFCS=0.
          BMAX=AMAX1(BMAX,BOFCS)
  700   CONTINUE
  800   AUNCS=AMAX1(0.,ASURV(I)-SUMB(I)-BMAX)
        FHNC(I)=AMIN1(FHR(I),AUNCS*FHM)
        FHPAPD(3,I)=AMIN1(FHM,FHR(I)/(AUNCS+.0I))
        FHNZ(I)=FHNC(I)/(FHR(I)+.000001)
```

```
          AUNCS=AUNCS/(ASURV(I)+.00001)
          Z=ABS(FHNC(I)-FHA(I))
          INDX=INDX+1
          IF (INDX.GE.LIMIT.OR.(Z/(TTFH+1.)).LE.(CONVF/NW).OR.INDX.GT.30)
     +    GO TO 1000
          FHA(I)=.5*(FHA(I)+FHNC(I))
          BMAX=0.
          SUMB(I)=0.
          DO 900 J=1,NP
  900     DMOT(J)=DMO(J)
          GO TO 400
 1000     TFHNC=TFHNC+FHNC(I)
          DO 1100 J=1,NP
 1100     DMO(J)=DMOT(J)
          TNCO=TNCO+Z
          RNC(I)=AUNCS
          TAV=TAV+RNC(I)*ASURV(I)
 1200 CONTINUE
      Z=100.*TNCO/(TFHNC+.001)
      FNC=TFHNC/TTFH
      IF (IP.EQ.0) RETURN
      DO 1400 I=1,NW
          SUMB(I)=SUMB(I)/(ASURV(I)+.00001)
          AX=1.-(ALLOWB(I)/(ASURV(I)+.000001))
          IF (MOD(I-1,50).NE.0) GO TO 1300
          WRITE (6,1500) CASE
          IF (ICOST.EQ.1.AND.IND.EQ.1) WRITE (6,1600)
          IF (ICOST.EQ.1.AND.IND.EQ.2) WRITE (6,1700)
          IF (ICOST.EQ.0) WRITE (6,1800) KNTC
          IF (ICOST.EQ.1) WRITE (6,1900) CL
          WRITE (6,2000)
          WRITE (6,2100) Z
          WRITE (6,2000)
          WRITE (6,2200)
          WRITE (6,2000)
          WRITE (6,2300)
          WRITE (6,2400)
          WRITE (6,2000)
 1300     AVAVG(1)=AVAVG(1)+RNC(I)*ASURV(I)/TSURV
          AVAVG(3)=AVAVG(3)+FHPAPD(3,I)*RNC(I)*ASURV(I)/TAV
 1400 WRITE (6,2500) I,RNC(I),AX,I,FHNZ(I),FHPAPD(3,I)
      WRITE (6,2600) AVAVG(1),AVAVG(2),FNC,AVAVG(3)
      RETURN
 1500 FORMAT (1H1,30X,'CASE= ',A16)
 1600 FORMAT (/,20X,'** FORCE  CAPABILITY WITH CONSR COST TOTAL  ','RQMT
     + SOLUTION STOCKED AT RETAIL(NO POST D-DAY PARTS DEPLOYED) *')
 1700 FORMAT (/,20X,'** FORCE  CAPABILITY WITH CONSR COST RESIDUAL  ','R
     +QMT SOLUTION STOCKED & DEPLOYED **')
 1800 FORMAT (/,20X,'** FORCE  CAPABILITY GIVEN  THE CURRENT',' INV','EN
     +TORY STKED & DEPLOYED FOR SUBSTITUTION POLICY',I3,' **')
 1900 FORMAT (///,10X,'COST LIMIT OF',F12.0)
 2000 FORMAT (/)
 2100 FORMAT (' TOTAL  FLY HRS CONVERGED TO',' WITHIN',F7.3,' PERCENT')
 2200 FORMAT (3X,'ACFT AVAIL',29X,' FRAC FH ACH',3X,'FH/AC/DAY')
 2300 FORMAT (15X,'PART',26X,'PART',10X,'PART')
 2400 FORMAT (6X,'DAY',7X,'SUB',3X,'REQ AVAIL',6X,'DAY',6X,'SUB',11X,'SU
     +B')
 2500 FORMAT (5X,I4,5X,F5.3,7X,F5.3,5X,I4,4X,F5.3,6X,F8.1)
 2600 FORMAT (/,' AVG AVAIL',5X,F5.3,7X,F5.3,12X,F5.3,10X,F5.1)
      END
```

SUBROUTINE CCLIST

```
      SUBROUTINE CCLIST (IG,IORD,IND)
C NAME: CCLIST             TYPE: SUBROUTINE
C
C PURPOSE: THE CCLIST (CONSTRAINED COST REQUIREMENTS LIST) SUBROUTINE
C PRINTS THE CONSTRAINED COST REQUIREMENTS SOLUTION.
C
C CALLED BY: MAIN PROGRAM
C
C CALLS
C     -SUBROUTINE MAXC: ORDERS THE LIST OF RQUIREMENTS TO BE PRINTED
C
C             OUTPUT - UNIT 6 (PRINT)
C
      COMMON
     +     AC(120),          ACL,              ADESC(300),       ALLOWI(120),
     +     ALLOWB(120),      AMSN(300),        ASUPV(120),       AVAVG(6),
     +     AVM(120),         BCY(300),         BF(300),          CASE,
     +     CDMDA(300),       CF(300),          CL,               CMINT,
     +     CNCS(300),        COST(300),        CPNCS(300),       DCOSTI(300),
     +     DCOSTF(120),      DCY(300),         DF(300),          DMD(300),
     +     DDD(300),         FHA(120),         FHM,              FHPAPD(3,120),
     +     FHR(120),         ICOST,            IOCC(2),          IFHC(120),
     +     IFS(300),         IMSEL,            INS(300),         INT,
     +     IPT(100),         IRC(300),         IRO(300),         ISHORT,
     +     NP,               NP1,              NP2,              NW,
     +     PTCFP(300,24),    UPA(300),         RNC(120),         RNCS(300),
     +     SP(120,100),      SRMAX1(300),      STK(300),         SUMB(120),
     +     TRNCS(300),       TSTK(300),        TSUMB
      CHARACTER*16
     +     ADESC,            ADSC,             AMSN,             CASE
      IF (IORD.LE.0) GO TO 300
      DO 100 I=1,NP
         IRO(I)=0
  100 DDD(I)=RNCS(I)
      NDUMMY=NP
      DO 200 K=1,NP
         CALL MAXC (NDUMMY,NOUT)
         IRO(K)=NOUT
         II=IRO(K)
  200 DDD(II)=-1.
  300 DO 500 I=1,NP
         II=IRO(I)
         IF (IORD.LE.0) II=IRC(I)
         IF (MOD(I-1,50).NE.0) GO TO 400
         WRITE (6,600) CASE
         IF (IND.EQ.1) WRITE (6,700)
         IF (IND.EQ.2) WRITE (6,800)
         WRITE (6,900)
         IF (IG.EQ.1) WRITE (6,1000) CL,ACL
         IF (IG.EQ.2) WRITE (6,1100) CL,ACL,IOCC(IND)
         WRITE (6,1200)
         WRITE (6,900)
         WRITE (6,1300)
         WRITE (6,900)
  400    CNCS(II)=COST(II)*RNCS(II)
         TC=100.*CNCS(II)/(ACL+.000001)
  500 WRITE (6,1400) I,II,AMSN(II),ADESC(II),RNCS(II),CNCS(II),TC
      RETURN
  600 FORMAT (1H1,30X,'CASE= ',A16)
  700 FORMAT (/,' TOTAL(INIT STK=0)  STK RQMTS BY POLICY ')
  800 FORMAT (/,30X,'RESIDUAL(INIT STK=CURR STK) STK RQMTS BY POLICY ')
  900 FORMAT (/)
 1000 FORMAT (//,10X,'COST LIMIT OF',F12.0,' APPROXIMATED BY',F12.0,' US
     +ING A COMBINED (CHEAPEST NO SUB PARTS)/SUSTNBLTY SOL ')
 1100 FORMAT (//,10X,'COST LIMIT OF',F12.0,' APPROXIMATED BY',F12.0,' US
     +ING A SUSTAINIBILITY SOLUTION FOR COST THRU',I4,' DAYS')
 1200 FORMAT (/,66X,'PARTIAL SUPST')
 1300 FORMAT (10X,'PART NR',17X,'PART',21X,'RQMNT',7X,'COST  %COST')
 1400 FORMAT (2X,I5,I10,5X,A16,2X,A16,F8.1,F12.0,F6.2,4X)
      END
```

(NOT USED)

SUBROUTINE NCRNC

```
      SUBROUTINE NCRNC (ND,I2,IND)
C NAME: NCRNC             TYPE: SUBROUTINE
C
C PURPOSE: THE NCRNC  (NO CANNIBALIZATION REQUIREMENTS) SUBROUTINE
C GENERATES  A LEAST COST REMNTS MIX OF SPARE PARTS NEEDED TO ACHIEVE A
C FLEET  FLYING HR PROGRAM/AVAILABILITY OBJECTIVE USING A USER-SPECIFIED
C PARTS  REPLACEMENT POLICY AND UNCONSTRAINED  COSTS.
C
C CALLED BY: SUBROUTINE UCROPS
C
C CALLS
C     -FUNCTION SR: COMPUTES CUMULATIVE NET DEMAND THRU A SPECIFIED DAY
C                   FOR A SPECIFIED PART
C
C FILES USED : NO FILES READ OR WRITTEN
C
      COMMON
     +    AC(120),          ACL,              ADESC(300),       ALLOW1(120),
     +    ALLOWB(120),      AMSN(300),        ASUPV(120),       AVAVG(6),
     +    AVM(120),         BCY(300),         BF(300),          CASE,
     +    COMDA(300),       CF(300),          CL,               CMINT,
     +    CNCS(300),        COST(300),        CRNCS(300),       DCOSTI(300),
     +    DCOSTF(120),      DCY(300),         DF(300),          DMC(300),
     +    DOD(300),         FHA(120),         FHM,              FHPAPO(3,120),
     +    FHF(120),         ICOST,            IDCC(2),          IFHC(120),
     +    IFS(300),         IMSEL,            INS(300),         INT,
     +    IPT(100),         IRC(300),         IRO(300),         ISHORT,
     +    NP,               NP1,              NP2,              NW,
     +    PTDEP(300,24),    QPA(300),         RNC(120),         RNCS(300),
     +    SM(120,100),      SRMAXI(300),      STK(300),         SUMB(120),
     +    TRNCS(300),       TSTK(300),        TSUMB
      DIMENSION
     +    SUMBZ(120),       SUMP(120)
      CHARACTER*16
     +    ADESC,            ADSC,             AMSN,             CASE
      NA=ALLOWB(ND)+.5
      IF (I2.LT.NA) GO TO 200
      SUMR=0.
      TSUMB=0.
      DO 100 L=1,ND
        SUMP(L)=0.
  100 SUMBZ(L)=0.
  200 TOTZ=0.
      DO 700 K=1,NP2
        II=INS(K)
        IF (I2.LT.NA) GO TO 400
        COMDA(II)=0.
        CRNCS(II)=RNCS(II)
        IF (IND.EQ.2) CRNCS(II)=TSTK(II)+RNCS(II)
        DO 300 I=1,ND
          COMD=COMDA(II)
          COMDA(II)=SR(I,II,COMD)
          IF  (IND.EQ.2) SUMP(I)=SUMP(I)+AMAX1(0.,(CRNCS(II)-COMDA(II)))
          SUMBZ(I)=SUMBZ(I)+COMDA(II)
          TSUMB=AMAX1(SUMBZ(I)-SUMR+SUMP(I),0.)
          IF  ((TSUMB-CRNCS(II)).GE.ALLOW1(I)) CRNCS(II)=TSUMB-ALLOW1(I)
  300   CONTINUE
        SUMR=SUMR+CRNCS(II)
        GO TO 700
  400   ZINT=MIN0(INT,NA-I2)
        IF (I2.GE.(TSUMB+.5)) RETURN
        IL=INS(NP2-K+1)
        IF ((CRNCS(IL)+(IND-1)*ZINT*TSTK(IL)).GE.COMDA(IL)) GO TO 700
        Z=CRNCS(IL)+ZINT
        TZ=Z+(IND-1)*ZINT*TSTK(IL)-COMDA(IL)
        IF (TZ.LE.0) GO TO 500
        CRNCS(IL)=COMDA(IL)-(IND-1)*ZINT*TSTK(IL)
        TOTZ=TOTZ+ZINT-TZ
        IF (TOTZ.LT.ZINT) GO TO 700
        CRNCS(IL)=CRNCS(IL)-TOTZ+ZINT
        GO TO 600
  500   CRNCS(IL)=CRNCS(IL)+AMIN1(ZINT-TOTZ,ZINT)
  600   TSUMB=TSUMB-ZINT
        RETURN
  700 CONTINUE
      IF (I2.EQ.NA) TSUMB=TSUMB-CRNCS(II)
      IF (I2.LT.NA.OR.IND.EQ.1) RETURN
      DO 800 K=1,NP2
        J=INS(K)
  800 CRNCS(J)=CRNCS(J)-TSTK(J)
      RETURN
      END
```

(NOT USED)

SUBROUTINE UCCAP

```
      SUBROUTINE UCCAP (INO)
C NAME: UCCAP              TYPE: SUBROUTINE
C
C PURPOSE: THE UCCAP (UNCONSTRAINED COST CAPABILITY ASSESSMENT) SUBROUTINE
C COMPUTES FLEET CAPABILITY (AVG AVAILABILITY,PGM FLYING HRS/ACFT/DAY) BASE
C ON THE UNCONSTRAINED COST SOLUTION RQMNT BEING STOCKED IN THE WAR RESERVE
C
C CALLED BY: MAIN PROGRAM
C
C CALLS
C     -FUNCTION SR: COMPUTES CUMULATIVE NET DEMAND THRU A SPECIFIED DAY
C                   FOR A SPECIFIED PART
C
C FILES USED : INPUT - NONE
C              OUTPUT - UNIT 6(PRINT)
C
      COMMON
     +    AC(120),        ACL,            ADESC(300),     ALLOW1(120),
     +    ALLOWB(120),    AMSN(300),      ASURV(120),     AVAVG(6),
     +    AVM(120),       BCY(300),       BF(300),        CASE,
     +    COMDA(300),     CF(300),        CL,             CMINT,
     +    CNCS(300),      COST(300),      CRNCS(300),     DCOSTI(300),
     +    DCOSTF(120),    DCY(300),       DF(300),        DMD(300),
     +    DOD(300),       FHM(120),       FHM,            FHPAPD(3,120),
     +    FHR(120),       ICOST,          IOCC(2),        IFHC(120),
     +    IFS(300),       IMSEL,          INS(300),       INT,
     +    IPT(100),       IRC(300),       IRD(300),       ISHORT,
     +    NP,             NP1,            NP2,            NW,
     +    PTOEP(300,24),  QPA(300),       PNC(120),       PNCS(300),
     +    SM(120,100),    SRMAXI(300),    STK(300),       SUMB(120),
     +    TRNCS(300),     TSTK(300),      TSUMB
      CHARACTER*16
     +    ADESC,          ADSC,           AMSN,           CASE,
     +    RAV
      TAV=0.
      TAV1=0.
      DO 100 I=1,NP
        TSTK(I)=STK(I)
        DOD(I)=0.
  100 DMD(I)=0.
      DO 300 L=1,NW
        DO 200 I=1,3
  200   FHPAPD(I,L)=0.
  300 SUMB(L)=0.
      DO 400 I=1,3
  400 AVAVG(I)=0.
      DO 1000 I=1,NW
        IA=(I-1)/5+1
        DO 500 J=1,NP
  500   TSTK(J)=TSTK(J)+PTOEP(J,IA)/5.
        BMAX=0.
        IF (NP2.EQ.0) GO TO 700
        DO 600 K=1,NP2
          II=INS(K)
          X=DMD(II)
          DMD(II)=SR(I,II,X)
          ZP=PNCS(II)
          IF (INO.EQ.2) ZP=PNCS(II)+TSTK(II)
  600   SUMB(I)=SUMB(I)+AMAX1(0.,DMD(II)-ZP)
  700   IF (NP1.EQ.0) GO TO 900
        DO 800 K=1,NP1
          II=IFS(K)
          X=DMD(II)
          DMD(II)=SR(I,II,X)
          ZP=PNCS(II)
          IF (INO.EQ.2) ZP=PNCS(II)+TSTK(II)
          BOFCS=(DMD(II)-ZP)/QPA(II)
          IF (BOFCS.LE.0.) BOFCS=0.
          BMAX=AMAX1(BMAX,BOFCS)
  800   CONTINUE
  900   RNC(I)=AMAX1(0.,ASURV(I)-BMAX-SUMB(I))/(ASURV(I)+.0001)
        FHPAPD(1,I)=AMIN1(FHM,FHR(I)/(ASURV(I)-BMAX-SUMB(I))+.0001)
        TAV1=TAV1+RNC(I)*ASURV(I)
 1000 CONTINUE
      TSURV=0.
      DO 1200 I=1,NW
        AX=1.-(ALLOWB(I)/(ASURV(I)+.000001))
        IF (MOD(I-1,50).NE.0) GO TO 1100
        WRITE (6,1400) CASE
        WRITE (6,1500)
        IF (INO.EQ.1) WRITE (6,1600)
```

```
            IF (IND.EQ.2) WRITE (6,1700)
            WRITE (6,1800)
            WRITE (6,1900)
            WRITE (6,1800)
            WRITE (6,2000)
            WRITE (6,2100)
            WRITE (6,1800)
 1100       TSURV=TSURV+ASURV(I)
            AVAVG(1)=AVAVG(1)+RNC(I)*ASURV(I)
            AVAVG(2)=AVAVG(2)+AX*ASURV(I)
            AVAVG(3)=AVAVG(3)+FHPAPO(1,I)*RNC(I)*ASURV(I)/(TAV1+.0001)
            RAV='  FLYING HR PROG'
            IF (IFHC(1).EQ.1) RAV=' AVAIL CONSTRAIN'
 1200 WRITE (6,2200) I,RNC(I),AX,RAV,AVM(I),FHPAPO(I,I),I
      DO 1300 K=1,2
 1300 AVAVG(K)=AVAVG(K)/TSURV
      WRITE (6,2300) (AVAVG(K),K=1,3)
      RETURN
 1400 FORMAT (1H1,30X,'CASE= ',A16)
 1500 FORMAT (/,30X,'** FORCE  CAPABILITY GIVEN THAT THE COMPUTED',' REQ
     +UIREMENT (FOR EACH POLICY) IS STOCKED **')
 1600 FORMAT (//,15X,'*** CASES ASSUME TOTAL(INIT STK=0) REQMTS',' ARE S
     +TOCKED AT RETAIL (NO POST 0-DAY PARTS DEPLOYED) ***')
 1700 FORMAT (//,15X,'*** CASES ASSUME RESIDUAL(INIT STK=CURR STK)',' RE
     +QMTS  ARE STOCKED AND DEPLOYED  ***')
 1800 FORMAT (/)
 1900 FORMAT (/,9X,'AIRCRAFT AVAILABILITY',30X,'FLY HRS/AC /DAY')
 2000 FORMAT (25X,'PART',38X,'PART')
 2100 FORMAT (18X,'DAY',5X,'SUB',' REQ AVAIL   AVAIL',' SOURCE',' AVAIL
     +',7X,'SUB',5X,'DAY')
 2200 FORMAT (17X,I4,F8.3,6X,F5.3,A16,F5.2,F10.1,I8)
 2300 FORMAT (/,1X,'   AVERAGE= ',11X,F5.3,6X,F5.3,21X,F10.1)
      END
```

SUBROUTINE UCRQPS

```
      SUBROUTINE UCRQPS (IND,IOPT4,IOPT5,IORD)
C NAME: UCRQPS          TYPE: SUBROUTINE
C
C PURPOSE: THE UCRQPS (UNCONSTRAINED COST RQMNTS-PARTIAL SUBSTITUTION)
C SUBROUTINE COMPUTES AND PRINTS THE LEAST COST RQMNTS MIX OF SPARE PARTS
C PARTS NEEDED,GIVEN UNCONSTRAINED FUNDS,TO ACHIEVE THE CASE OBJECTIVE
C
C CALLED BY: MAIN PROGRAM
C
C CALLS
C      -FUNCTION SR: COMPUTES CUMULATIVE NET DEMAND THRU A SPECIFIED DAY
C                    FOR A SPECIFIED PART
C      -SUBROUTINE MAXC: ORDERS LIST OF PART RQMNTS TO BE PRINTED
C      -SUBROUTINE NCRNC: COMPUTES THE  RQMNT SOLUTION FOR THE 'NO SUB' PART
C                         SET AND A SPECIFIC ALLOWED STOCKOUT FOR THAT SET
C
C FILES USED : INPUT - NONE
C              OUTPUT - UNIT 6 (PRINT)
C
      DIMENSION
     *    RMIN(300)
      COMMON
     *    AC(120),        ACL,            ADESC(300),     ALLOW1(120),
     *    ALLOWB(120),    AMSN(300),      ASURV(120),     AVAVG(6),
     *    AVM(120),       BCY(300),       BF(300),        CASE,
     *    CDMDA(300),     CF(300),        CL,             CMINT,
     *    CNCS(300),      COST(300),      CRNCS(300),     DCOST1(300),
     *    DCOSTF(120),    DCY(300),       DF(300),        DMD(300),
     *    DOD(300),       FHM(120),       FHM,            FHPAPD(3,120),
     *    FHR(120),       ICOST,          IOCC(2),        IFHC(120),
     *    IFS(300),       IMSEL,          INS(300),       INT,
     *    IPT(100),       IRC(300),       IRO(300),       ISHORT,
     *    NP,             NP1,            NP2,            NW,
     *    PTDEP(300,24),  QPA(300),       RNC(120),       RNCS(300),
     *    SM(120,100),    SRMAX1(300),    STK(300),       SUMB(120),
     *    TRNCS(300),     TSTK(300),      TSUMB
      CHARACTER*16
     *    ADESC,          ADSC,           AMSN,           CASE
      DO 100 K=1,IMSEL
        DO 100 I=1,120
  100 SM(I,K)=0.
      DO 200 J=1,NP
         TSTK(J)=STK(J)
         RNCS(J)=0.
         CRNCS(J)=0.
         CDMDA(J)=0.
  200 SRMAX1(J)=-999.
      DO 300 I=1,NW
         ALLOW1(I)=ALLOWB(I)
         DCOST1(I)=0.
  300 DCOSTF(I)=0.
      DO 1600 I=1,NW
         IA=(I-1)/5+1
         TALLOW=ALLOWB(I)
         CMINT=99999999999.
         NA=ALLOWB(I)+1.5
         DO 400 J=1,NP
            TSTK(J)=TSTK(J)+PTDEP(J,IA)/5.
  400    RMIN(J)=0.
         ZINT=INT
         IADD=0
         IF (MOD(NA-1,INT).NE.0) IADD=1
         MULT=((NA-1)/INT)+IADD
         NAD=MULT*INT+1
         LAST=0
         DO 1500 L1=1,NAD,INT
            L2=MIN0(L1,NA)
            I1=L2-1
            I2=NA-I1-1
            ALLOW1(I)=I2
            IF (NP1.EQ.0) GO TO 700
            DO 600 JA=1,NP1
               J=IFS(JA)
               IF (L2.GT.1) GO TO 500
               CDMD=CDMDA(J)
               CDMDA(J)=SR(I,J,CDMD)
               XXX=CDMDA(J)
               IF (IND.EQ.2) XXX=XXX-TSTK(J)
               IF (XXX.GE.SRMAX1(J)) SRMAX1(J)=XXX
               CRNCS(J)=AMAX1(0.,SRMAX1(J))
               GO TO 600
```

```
 500        IF (L1.GE.NA) ZINT=NA-LAST
              CRNCS(J)=AMAX1(0.,CRNCS(J)-ZINT*QPA(J))
 600      CRNCS(J)=AMAX1(CRNCS(J),RNCS(J))
 700      IF (NP2.GT.0) CALL NCRNC (I,I2,IND)
          TOTC=0.
          DO 800 J=1,NP
 800      TOTC=TOTC+COST(J)*CRNCS(J)
          IF (TOTC.GE.CMINT) GO TO 1000
          TALLOW=I2
          CMINT=TOTC
          DO 900 J=1,NP
 900      RMIN(J)=CRNCS(J)
1000      IF (L2.NE.NA.AND.NP1.NE.0) GO TO 1400
          DO 1200 J=1,NP
            RNCS(J)=AMAX1(RMIN(J),RNCS(J))
            DCOSTF(I)=DCOSTF(I)+RNCS(J)*COST(J)
            DO 1100 M=1,IMSEL
              IF (J.EQ.IPT(M)) SM(I,M)=RNCS(J)
1100        CONTINUE
1200      CNCS(J)=COST(J)*RNCS(J)
          IF (NP1.EQ.0) GO TO 1600
          DO 1300 J=1,NP1
            II=IFS(J)
1300      DCOST1(I)=DCOST1(I)+RNCS(II)*COST(II)
1400      IF (NP1.EQ.0) GO TO 1600
1500    LAST=L1
        ALLOW1(I)=TALLOW
1600 CONTINUE
     IF (ICOST.EQ.1) RETURN
     WRITE (6,2800) CASE
     IF (IND.EQ.1) WRITE (6,2900)
     IF (IND.EQ.2) WRITE (6,3000)
     IF (ICOST.EQ.1) WRITE (6,3100) CL,ACL,IDCC(IND)
     WRITE (6,3200)
     WRITE (6,3300) CMINT
     IF (ICOST.EQ.1) RETURN
     IF (IORD.LE.0) GO TO 1900
     IF (ICOST.EQ.1) RETURN
     IF (IOPT4.LE.0.AND.ICOST.EQ.0) GO TO 2200
     DO 1700 I=1,NP
        IRO(I)=0
1700 DDD(I)=RNCS(I)
     NDUMMY=NP
     DO 1800 K=1,NP
        CALL MAXC (NDUMMY,NOUT)
        IRO(K)=NOUT
        II=IRO(K)
1800 DDD(II)=-1.
1900 DO 2100 I=1,NP
        II=IRO(I)
        IF (IORD.LE.0) II=IRC(I)
        IF (MOD(I-1,50).NE.0) GO TO 2000
        WRITE (6,2800) CASE
        IF (IND.EQ.1) WRITE (6,3400)
        IF (IND.EQ.2) WRITE (6,3500)
        WRITE (6,3600)
        IF (ICOST.EQ.1) WRITE (6,3100) CL,ACL,IDCC(IND)
        WRITE (6,3700)
        WRITE (6,3600)
        WRITE (6,3800)
        WRITE (6,3600)
2000    TC=100.*CNCS(II)/(CMINT+.000001)
2100 WRITE (6,3900) I,II,AMSN(II),ADESC(II),RNCS(II),CNCS(II),TC
2200 IF (ICOST.EQ.1) RETURN
     ICOST=1
     IF (IOPT5.LE.0) GO TO 2500
     NN=IMSEL/5
     IF (MOD(IMSEL,5).NE.0) NN=NN+1
     IF (NN.GT.20) NN=20
     DO 2400 L=1,NN
        M1=IPT(1+(L-1)*5)
        M2=IPT(2+(L-1)*5)
        M3=IPT(3+(L-1)*5)
        M4=IPT(4+(L-1)*5)
        M5=IPT(5+(L-1)*5)
        DO 2300 I=1,NW
           IF (MOD(I-1,50).NE.0) GO TO 2300
           WRITE (6,2800) CASE
           IF (IND.EQ.1) WRITE (6,4000)
           IF (IND.EQ.2) WRITE (6,4100)
           WRITE (6,3600)
           WRITE (6,4200) M1,M2,M3,M4,M5
```

```
            WRITE (6,3600)
            WRITE (6,4300) AMSN(M1),AMSN(M2),AMSN(M3),AMSN(M4),AMSN(M5)
            WRITE (6,4300) ADESC(M1),ADESC(M2),ADESC(M3),ADESC(M4),ADESC(M
     *      5)
            WRITE (6,4400)
            WRITE (6,3600)
 2300     WRITE (6,4500) (I,SM(I,K+(L-1)*5),K=1,5)
 2400 CONTINUE
 2500 IOCC(IND)=0
      DO 2700 I=1,NW
        IF (MCO(I-1,50).NE.0) GO TO 2600
        WRITE (6,2800) CASE
        IF (IND.EQ.1) WRITE (6,4600)
        IF (IND.EQ.2) WRITE (6,4700)
        WRITE (6,3600)
        WRITE (6,4800)
 2600   IF (DCOSTF(I).GT.CL) GO TO 2700
        IDCC(IND)=I
        ACL=DCOSTF(I)
 2700 WRITE (6,4900) I,DCOSTF(I),DCOSTI(I)
      WRITE (6,3100) CL,ACL,IDCC(IND)
      RETURN
 2800 FORMAT (1H1,30X,'CASE= ',A16)
 2900 FORMAT (/,10X,'TOTAL(INIT STK= 0) COST OF POLICIES')
 3000 FORMAT (/,10X,'RESIDUAL(INIT STK=CURR STK) COST OF POLICIES')
 3100 FORMAT (//,10X,'COST LIMIT OF',F12.0,' APPROXIMATED BY',F12.0,' TH
     *E CUM RQMT COST THRU DAY',I4)
 3200 FORMAT (/,'  POLICY              TOT COST')
 3300 FORMAT (/,' PART  SUB',F14.0)
 3400 FORMAT (/,' TOTAL(INIT STK=0)  STK RQMTS BY POLICY ')
 3500 FORMAT (/,30X,'RESIDUAL(INIT STK=CURR STK) STK RQMTS BY POLICY ')
 3600 FORMAT (/)
 3700 FORMAT (66X,'PART  SUBST')
 3800 FORMAT (10X,'PART NR',17X,'PART',21X,'RQMNT',7X,'COST  %COST')
 3900 FORMAT (2X,I5,I10,5X,A16,2X,A16,F8.1,F12.0,F6.2,4X)
 4000 FORMAT (/,42X,'CUM TOTAL RQMT(INIT STK=0) REQUIRED THRU GIVEN DAY'
     *)
 4100 FORMAT (/,42X,'CUM ADD-ON RQMT(INIT STK=CURR INV) REQUIRED ','THRU
     * GIVEN DAY')
 4200 FORMAT (13X,5(6X,'PART NR',I5,6X))
 4300 FORMAT (13X,5(A16,8X))
 4400 FORMAT (15X,'DAY',21X,'DAY',21X,'DAY',14X,'DAY',21X,'DAY')
 4500 FORMAT (8X,5(I10,F8.1,6X))
 4600 FORMAT (/,12X,'CUM TOTAL(INIT STK=0) COST OF REQ THRU GIVEN DAY')
 4700 FORMAT (/,12X,'CUM RESIDUAL(INIT STK= CURR STK) COST OF REQ THRU',
     *' GIVEN DAY')
 4800 FORMAT (/,6X,'DAY',3X,'   PART SUB')
 4900 FORMAT (6X,I3,3X,2F11.0)
      END
```

(NOT USED)

SUBROUTINE MAXC

```
      SUBROUTINE MAXC (NDUMMY,NOUT)
C NAME: MAXC            TYPE: SUBROUTINE
C
C PURPOSE: THE MAXC SUBROUTINE FINDS THE SUBSCRIPT OF THE LARGEST(IN VALUE
C          MEMBER OF AN ARRAY (DOO(J))
C
C
C CALLED BY:
C          - MAIN PROGRAM
C          - SUBROUTINE UCR2PS
C          - SUBROUTINE CCLIST
C
C CALLS : NONE
C
C FILES USED : NO FILES READ OR WRITTEN
C
      COMMON
     +     AC(120),        ACL,            ADESC(300),     ALLOWI(120),
     +     ALLOWB(120),    AMSN(300),      ASURV(120),     AVAVG(6),
     +     AVM(120),       BCY(300),       BF(300),        CASE,
     +     COMDA(300),     CF(300),        CL,             CMINT,
     +     CNCS(300),      COST(300),      CRNCS(300),     DCOSTI(300),
     +     DCOSTF(120),    DCY(300),       DF(300),        DMD(300),
     +     DOO(300),       FHF(120),       FHM,            FHPAPD(3,120),
     +     FHR(120),       ICOST,          IOCC(2),        IFHC(120),
     +     IFS(300),       IMSEL,          INS(300),       INT,
     +     IPT(100),       IRC(300),       IRO(300),       ISHORT,
     +     NP,             NPI,            NP2,            NW,
     +     PTOFP(300,24),  OPI(300),       RNC(120),       RNCS(300),
     +     SM(120,100),    SRMAX1(300),    STK(300),       SUMB(120),
     +     TRNCS(300),     TSTK(300),      TSUMB
      CHARACTER*16
     +     ADESC,          ADSC,           AMSN,           CASE
      SMAX=-1.
      JMAX=1
      DO 100 J=1,NDUMMY
        X=DOO(J)
        ZMAX=AMAX1(SMAX,X)
        IF (ZMAX.LE.SMAX) GO TO 100
        JMAX=J
        SMAX=ZMAX
  100 CONTINUE
      NOUT=JMAX
      RETURN
      END
```

(NOT USED)

FUNCTION SR

```
      FUNCTION SR (I,J,CDMO)
C NAME: SR                 TYPE: FUNCTION
C
C PURPOSE: THE SR (STOCK REQUIRED) FUNCTION CALCULATES THE CULMULATIVE
C          NET DEMAND THRU A SPECIFDIED DAY FOR A SPECIFIED PART BASED
C          ON A SPECIFIED FLYING PROGRAM. INITIAL INVENTORY =0 IS
C          ASSUMED IN THIS CALCULATION. NET DEMANDS IS BASICALLY
C          FAILED ITEMS OFFSET BY RETURNING REPAIRS. IN A SENSE IT'S THE
C          NET NR OF 'HOLES' (CAUSED BY THE ITEM) WHICH ARE PRESENT ON
C          A SPECIFIED DAY ,ASSUMING A ZERO INITIAL INVENTORY.
C
C
C CALLED BY:
C          - SUBROUTINE UCRQPS
C          - SUBROUTINE UCCAP
C          - SUBROUTINE CCCAP
C
C CALLS : NONE
C
C FILES USED : NO FILES READ OR WRITTEN
C
C
      COMMON
     +    AC(120),         ACL,             ADESC(300),      ALLOW1(120),
     +    ALLOWB(120),     AMSN(300),       ASURV(120),      AVAVG(6),
     +    AVM(120),        BCY(300),        BF(300),         CASE,
     +    CDMOA(300),      CF(300),         CL,              CMINT,
     +    CNCS(300),       COST(300),       CRNCS(300),      DCOSTI(300),
     +    DCCSTF(120),     DCY(300),        DF(300),         DMD(300),
     +    DOD(300),        FHA(120),        FHM,             FHFAPD(3,120),
     +    FHR(120),        ICOST,           IOCC(2),         IFHC(120),
     +    IFS(300),        IMSFL,           INS(300),        INT,
     +    IPT(100),        IRC(300),        IRO(300),        ISHORT,
     +    NP,              NP1,             NP2,             NW,
     +    PTDEP(300,24),   OPA(300),        PNC(120),        RNCS(300),
     +    SM(120,100),     SRMAX1(300),     STK(300),        SUMB(120),
     +    TRNCS(300),      TSTK(300),       TSUMB
      CHARACTER*16
     +    ADESC,           ADSC,            AMSN,            CASE
      IO=I-DCY(J)
      IB=I-BCY(J)
      DRR=0.
      BRR=0.
      IF (IO.GT.0) DRR=DF(J)*FHA(IO)
      IF (IB.GT.0) BRR=BF(J)*FHA(IB)
      SR=CDMO+CF(J)*FHA(1)-DRR-BRR
      RETURN
      END
```

(NOT USED)

SUBROUTINE DIST

```
      SUBROUTINE DIST (IFDAY,ILDAY,DAMT,K)
C NAME: DIST                TYPE: SUBROUTINE
C
C PURPOSE: THE DIST  (PARTS DISTRIBUTION) SUBROUTINE DISTRIBUTES THE
C STARTING SPARES STOCK OF A PART TYPE OVER A SERIES OF 5-DAY INTERVALS
C
C CALLED BY: MAIN PROGRAM
C
C CALLS : NONE
C
C FILES USED : NO FILES READ OR WRITTEN
C
      COMMON
     +      AC(120),        ACL,            ADESC(300),     ALLOW1(120),
     +      ALLOWB(120),    AMSN(300),      ASURV(120),     AVAVG(6),
     +      AVM(120),       BCY(300),       BF(300),        CASE,
     +      COMDA(300),     CF(300),        CL,             CMINT,
     +      CNCS(300),      COST(300),      CRNCS(300),     DCOST1(300),
     +      DCOSTF(120),    DCY(300),       DF(300),        DMD(300),
     +      DDD(300),       FHA(120),       FHM,            FHPAPD(3,120),
     +      FHR(120),       ICOST,          IDCC(2),        IFHC(120),
     +      IFS(300),       IMSEL,          INS(300),       INT,
     +      IPT(100),       IRC(300),       IRO(300),       ISHORT,
     +      NP,             NP1,            NP2,            NW,
     +      PTDEP(300,24),  QPA(300),       RNC(120),       RNCS(300),
     +      SM(120,100),    SRMAX1(300),    STK(300),       SUMB(120),
     +      TRNCS(300),     TSTK(300),      TSUMB
      CHARACTER*16
     +      ADESC,          ADSC,           AMSN,           CASE
      D1=-((IFDAY-1)/5)*5+IFDAY-1
      DL=-((ILDAY-1)/5)*5+ILDAY
      I1=MIN0(24,(IFDAY-1)/5+1)
      IL=MIN0(24,(ILDAY-1)/5+1)
      IF (I1.LT.IL) GO TO 100
      PTDEP(K,I1)=PTDEP(K,I1)+(DL-D1)*DAMT
      RETURN
  100 DO 200 I=I1,IL
        IF (I.EQ.I1) PTDEP(K,I)=PTDEP(K,I)+(5.-D1)*DAMT
        IF (I.EQ.IL) PTDEP(K,I)=PTDEP(K,I)+DL*DAMT
        IF (I.GT.I1.AND.I.LT.IL) PTDEP(K,I)=PTDEP(K,I)+5.*DAMT
  200 CONTINUE
      RETURN
      END
```

APPENDIX C

REFERENCES

1. Penn, Saul, et al., Aircraft Spare Stockage Methodology (Aircraft Spares) Study, CAA-SR-84-12, US Army Concepts Analysis Agency, April 1984 (UNCLASSIFIED)

2. Bauman, Walter J., PARCOM User's Guide, CAA-D-84-10, US Army Concepts Analysis Agency, November 1984 (UNCLASSIFIED)

3. Bauman, Walter J., PARCOM Functional Description, CAA-D-84-15, US Army Concepts Analysis Agency, November 1984 (UNCLASSIFIED)

4. Steinhagen, Carl, et al., Maximizing Daily Helicopter Flying Hours Study (MAX FLY Study), CAA-SR-83-11, US Army Concepts Analysis Agency, August 1983 (SECRET)

GLOSSARY

AC	aircraft
acft	aircraft
AFH	achieved flying hours
ASL	authorized stockage list
AVAIL	availability
CAA	US Army Concepts Analysis Agency
CUM	cumulative
DC	depot condemnation rate
DCSLOG	Deputy Chief of Staff for Logistics
DEPL	deployed
DRT	depot repair time
EFH	estimated flying hours
EST	estimated
FHP	flying hour program
FS	full substitution
HR	hour
INIT	initial inventory
M	million
MAX	maximum
MAX FLY	Maximizing Daily Helicopter Flying Hours (study)
MIN	minimum
NMCS	not mission capable due to supply
NRTS	not repairable at this station
NS	no substitution
NSN	national stock number

OPTP	Overview/PARCOM Turnkey Project
ORIG	original initial inventory
OST	order and ship time
PARCOM	Parts Requirements and Cost Model
PGM	program
PLL	prescribed load list
PT	part
QPA	quantity per application
RET	returned
RQMT	requirement
RQR	required
RT	rate
SOL	solution
STK	cumulative stock distributed
SURV	surviving
USAVSCOM	US Army Aviation Systems Command

CAA (Concepts Analysis Agency, United States Army)	PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL (PARCOM PARTIAL SUBSTITUTION)	STUDY SUMMARY CAA-TP-84-11

THE REASON FOR PERFORMING THE STUDY was that the two models recommended by the Aircraft Spares Study, Overview and PARCOM, could treat a full-substitution or a no-substitution part replacement policy but lacked the ability to represent a more realistic partial-substitution replacement policy. Of the two models, PARCOM was judged to be the better candidate for incorporation of a partial-substitution capability.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The basic PARCOM (Parts Requirements and Cost Model), developed for the Aircraft Spares Study, was extended to include the effects of partial-substitution replacement policies and deployment of initial stocks over time.

(2) The resulting extended model relates spare requirements to a flying hour/aircraft availability objective, parts replacement policy, and stockage deployment schedule--all subject to optional cost constraints. Example applications illustrated the plausibility of the model logic.

(3) The extended PARCOM significantly expands the range of application and results of the basic PARCOM methodology. As such, its implementation, in place of basic PARCOM, is warranted.

THE MAIN ASSUMPTION was that partial substitution can be usefully defined in terms of a partition of part types into a full-substitution part set and a no-substitution set.

THE PRINCIPAL LIMITATION was that definitions of partial substitution other than the assumed definition might not be addressable by the extended PARCOM.

THE SCOPE OF THE STUDY addressed the relationship of spare requirements and fleet capabililty for a notional Army aviation program to a flying hour/availability objective, part replacement (substitution) policy, and stockage deployment schedule--all subject to optional cost constraints. The study applied the subject model to an example, using four part types over 5 days, and to an all-up case, treating an AH-1S scenario involving 334 part types over 120 days.

THE STUDY OBJECTIVES were:

(1) To evaluate the potential for extending the capability of the basic PARCOM, developed in the Aircraft Spares Study, to include partial substitution and other desirable features lacking in the basic PARCOM.

(2) To make the above extensions and to report on and illustrate the application of the extended PARCOM and methodology.

THE BASIC APPROACH was:

(1) To assess the limitations of the basic PARCOM.

(2) To select features and capabilities, to include partial substitution, for incorporation into an extended PARCOM.

(3) To develop an extended PARCOM incorporating the selected capabilities.

(4) To report on the nature of the extended PARCOM methodology and model through exposition and illustrative example applications.

THE STUDY SPONSOR was the Deputy Chief of Staff for Logistics, Headquarters, Department of the Army.

THE STUDY EFFORT was conducted by Mr. Walter J. Bauman, Force Systems Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be directed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FS, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

CAA (Concepts Analysis Agency, United States Army)	PARTIAL SUBSTITUTION AND OTHER MODIFICATIONS TO THE PARCOM MODEL (PARCOM PARTIAL SUBSTITUTION)	STUDY SUMMARY CAA-TP-84-11

THE REASON FOR PERFORMING THE STUDY was that the two models recommended by the Aircraft Spares Study, Overview and PARCOM, could treat a full-substitution or a no-substitution part replacement policy but lacked the ability to represent a more realistic partial-substitution replacement policy. Of the two models, PARCOM was judged to be the better candidate for incorporation of a partial-substitution capability.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The basic PARCOM (Parts Requirements and Cost Model), developed for the Aircraft Spares Study, was extended to include the effects of partial-substitution replacement policies and deployment of initial stocks over time.

(2) The resulting extended model relates spare requirements to a flying hour/aircraft availability objective, parts replacement policy, and stockage deployment schedule--all subject to optional cost constraints. Example applications illustrated the plausibility of the model logic.

(3) The extended PARCOM significantly expands the range of application and results of the basic PARCOM methodology. As such, its implementation, in place of basic PARCOM, is warranted.

THE MAIN ASSUMPTION was that partial substitution can be usefully defined in terms of a partition of part types into a full-substitution part set and a no-substitution set.

THE PRINCIPAL LIMITATION was that definitions of partial substitution other than the assumed definition might not be addressable by the extended PARCOM.

THE SCOPE OF THE STUDY addressed the relationship of spare requirements and fleet capabililty for a notional Army aviation program to a flying hour/availability objective, part replacement (substitution) policy, and stockage deployment schedule--all subject to optional cost constraints. The study applied the subject model to an example, using four part types over 5 days, and to an all-up case, treating an AH-1S scenario involving 334 part types over 120 days.

THE STUDY OBJECTIVES were:

(1) To evaluate the potential for extending the capability of the basic PARCOM, developed in the Aircraft Spares Study, to include partial substitution and other desirable features lacking in the basic PARCOM.

(2) To make the above extensions and to report on and illustrate the application of the extended PARCOM and methodology.

THE BASIC APPROACH was:

(1) To assess the limitations of the basic PARCOM.

(2) To select features and capabilities, to include partial substitution, for incorporation into an extended PARCOM.

(3) To develop an extended PARCOM incorporating the selected capabilities.

(4) To report on the nature of the extended PARCOM methodology and model through exposition and illustrative example applications.

THE STUDY SPONSOR was the Deputy Chief of Staff for Logistics, Headquarters, Department of the Army.

THE STUDY EFFORT was conducted by Mr. Walter J. Bauman, Force Systems Directorate, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be directed to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-FS, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.