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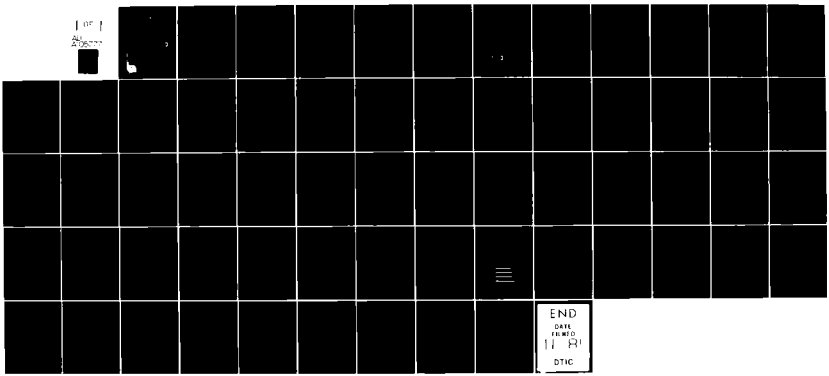

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OPERATING AND SUPPORT COSTS FOR COMMUNICATIONS SYSTEMS: Analysis and Recommendations

Joseph W. Stahl
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Robert P. Schiazza
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A review and analysis of communications equipment support cost factors, this paper provides some updated cost factors for DCA equipment as defined in the existing DCA Circular 600-60-1. The factors are designed for use in planning estimates where detailed equipment information is unavailable. In some categories factors are developed for generic equipment types, such as multiplexers, radios, satellite terminals, etc.

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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Defense Communications Agency under Contract DCA 100-80-C-0045. The study was under the technical direction of Messrs. Irwin L. Seidel and Richard C. Brannon of the Comptroller Directorate, Cost and Economic Analysis Division. Mr. Joseph W. Stahl was the IDA project leader.

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INTRODUCTION

The Defense Communications Agency (DCA) has a requirement to estimate operating and support (O&S) costs for communications systems. One of the uses of these O&S costs is for inclusion in the *Defense Communications System Five Year Program,* which is part of the Department of Defense Planning, Programming and Budgeting System. Costs for this program are developed through use of Cost Estimating Relationships (CERs). DCA has published Circular 600-60-1, *Cost and Planning Factors Manual* [1] which contains the CERs used in developing operating and support cost estimates for communications equipment. IDA was tasked to review and update these CERs.

The contract required IDA to "review and update the means for estimating communications system support costs." The effort was confined to "provide the information required for a rewrite of Section C and the Maintenance portions of Section D of the Defense Communications Agency's *Cost and Planning Factors Manual* (CPFM), DCAC 600-60-1." Therefore, the chapters of this paper reflect the structure and the language of the existing DCAC 600-60-1 document [1]. The cost categories are those in DCAC 600-60-1 except for recommendations for new cost categories. We have also utilized the definitions and terminology in the DCA Circular except where we were aware that the data available did not conform to those definitions.

We were specifically tasked to identify information on ground-based strategic communications equipment. What we hoped to accomplish was to develop and verify cost factors for various cost categories by generic equipment type such as radios, multiplexers, modems, etc. We were able to locate a few reports and

some contract data; however, we were unable to accumulate sufficient data to perform any extensive analyses. A pervasive problem with the reports containing Cost Estimating Relationships (CERs) is that they rarely include basic data used in developing the CERs. Accordingly, data on costs of specific equipment, quantities purchased, physical characteristics, etc. are scarce. Therefore, we relied upon simple percentages of the Prime Mission Equipment (PME) cost for guidance in developing cost factors. This method eliminates the problem of normalizing all the dollars into some constant year dollars; the resulting factors can be used directly with the current (then-year) dollar costs of future equipment.

In the course of our research we also identified several studies now in progress and future data collection systems that will allow accumulation of support cost data in the future. In addition, we identified and have listed organizations and their key personnel that are sources of information on cost aspects of equipment used in the communications systems within the Department of Defense.

Chapter I

CONTRACTOR TRAINING COSTS[1]

In the area of contractor training costs we were unable to identify any new cost factors for courses taught by the contractors; however, we were able to acquire some cost factors for initial training and training equipment. The Electronic Systems Division's *Cost Factor Study* (1978) [2] recommends using between 4 and 10 percent of the cost of the Prime Mission Equipment (PME) for the cost of initial training equipment. If computer programming (software) is not an integral element of the PME, but a separate entity, then the factor must be adjusted upward to reflect programming (software) training costs. This range of percentages is higher than the data provided by the U.S. Army Communications Systems Agency [3,4,5]. For the AN/FRC-155-162 Series of Radios (1977), the training equipment cost was one percent of the PME cost. For the TD 1193 Multiplexer (AN/FCC-99) and the digital microwave radio (1980), the cost of the contractor training was 1.6 percent of the cost of the PME.[2] The data on the AN/FCC-98 Multiplexer provided 0.4 percent of the PME cost for training equipment only; the cost of instruction was still to be determined as of January 1981. The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* [6] dated September 1976 gives the costs of several contracts. These contracts had the following percentages of PME for training-related costs:

---

[1]This chapter corresponds to Chapter 16 of DCAC 600-60-1.

[2]Equipment = 0.8 percent + installation = 0.2 percent + instruction = 0.6 percent.

European Wideband Communications System 68 training course (1969)	0.2 percent
DCS Microwave Radio (not Digital) three-week course + tools and test equipment to support the course (1973)	1.8 percent
Spanish Territorial Command Net course + equipment and materials (1974)	3.1 percent

From these figures it is obvious that the percentage varies with the content of the category identified as training. The problem is that in most cases where the elements of the training (i.e., equipment, instruction, and materials) have been combined, the percentages for these elements can not be determined. As a result, identifying a percentage for use is difficult, but the range in the Electronic Systems Division (ESD) study appears conservative compared to the actual costs we were able to locate. Therefore, we would recommend using the low end (about 4 percent) of the ESD range (4 to 10 percent) for planning purposes when more detailed information is not available.

Recommendation:

Four percent of PME cost for contractor training.

When more information is available, such as number of sites, skill level of the personnel to be trained, class duration, and number of persons to be trained, it is recommended that the current DCAC 600-60-1 procedures be followed.

It should be noted that some costs for training have not been included here, but are included elsewhere. These costs cover such items as:

(1) pay and allowances
(2) per diem
(3) transportation of people.

Also, as a general rule of thumb, the ESD uses a factor from the *Cost Analysis of the Combat Theater Communications Baseline, Switching Subsystem and Communications Control* dated 1974 [7],

for annual training costs (all elements) equal to approximately one-third of the cost of the initial training.

Chapter II

TEST, PECULIAR, AND COMMON SUPPORT EQUIPMENT COSTS[1]

In this area the costs are often incomplete because the cost of common support equipment is *not* included. We attempted to collect simple cost factors and actual cost data for support equipment for appropriate communications equipment. We were moderately successful in this endeavor. One factor that is changing the cost of support equipment is the expanding use of large automatic testers with the capability to test many types of equipment by changing the software in the tester. The increasing use of Built-In Test Equipment (BITE) is also changing the types and quantities of support equipment. The Air Force and Army treat test, peculiar, and common support equipment costs differently; accordingly, they are discussed separately below.

A. AIR FORCE

The cost factors and cost data we were able to collect are as follows: The *ESD Cost Factor Study* (1978) [2] recommends using two percent of the PME RDT&E cost for the cost of development peculiar support equipment; the range is one percent to two percent. The ESD study does not include common support equipment. Since publication of this study, ESD is now using 9 percent of PME acquisition cost for peculiar support equipment acquisition. The Digital European Backbone (DEB), a current

[1]This chapter corresponds to Chapter 17 of DCAC 600-60-1.

Air Force project, is allocating only 1.2 percent of the cost of the PME annually for *leasing* test equipment (1981) [8]. This was the only cost for leasing of test equipment that was found. If the *lease cost* is converted to a purchase cost assuming a 10-year life and a cost of capital of 10 percent, then its equivalent purchase cost would be about 8 percent of the PME cost.

The Air Force factors for common support equipment we identified are from the *Seek Score Cost Study* of 15 September 1978 [9] which references AFLC. The study recommends the use of 5.4 percent of the appropriate PME cost (for both Development and Acquisition) for common support equipment costs. These were the only Air Force data we located for common support equipment.

Although the Air Force data are not robust, they indicate that the factors presented in DCAC 600-60-1 may be somewhat high. Since the Air Force data are more recent, we recommend the use of the lower factors presented on page 8 for support equipment for Air Force systems.

B. ARMY

In searching for cost data for Army equipment we noted that the Army communications agencies do not use the terms "Common" and "Peculiar" for support equipment; they use the terms "test" or "tooling and test" equipment. These terms include test, peculiar, and common support equipment.

We did not find any data for development costs for support equipment. Therefore, our recommendation is to continue to use the present DCAC 600-60-1 factors for Army development costs.

The data we were able to locate on Army equipment were for acquisition costs which vary because of the differences in the programs. The AN/FCC-98 Multiplexer has only 0.2 percent

of the PME cost allocated to test equipment (1981) [5]. The AN/FRC-155-162 series of radios has 3.2 percent of the PME cost charged to test equipment (1977) [3]. These percentages are less than the 10 percent recommended in U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6]. This handbook notes that the percentage can be reduced when BITE is used and this may be occurring. The actual data included in the handbook provide the following percentages of PME cost:

European Wideband Communications System 68 (1969)	6.3 percent
European Wideband Communications System 69 (1969)	2.7 percent
Spanish Territorial Command Net (1974)	4.8 percent
Digital Subscriber Terminal Equipment (1971)	3.4 percent
Foresight Sierra (1970)	6.2 percent
Indonesian Communications (1971)	18.9 percent
Average =	7.1 percent
Median =	5.5 percent

A Mitre Study (1975) [10] of satellite terminal costs includes one additional data point. The U.S. Army Satellite Communications Agency contracted with RCA to develop a family of satellite terminals (TSQ-118, TSC-85(1), -85(2), -86, and MSC-59) and the cost data in the Mitre Study include 6 percent of the PME cost for test equipment for these terminals.

As can be seen from the above data the percentages vary; however, the percentages usually are less than the 10 percent as given in the previously referenced Army handbook [6]. The average of the nine Army data points is 5.7 percent. Note that the two most recent points are both less than this percentage which may indicate the increasing use of BITE. Therefore, for Army systems we would recommend using approximately 6 percent of the acquisition PME cost for test, peculiar, and common support equipment. The Army is involved in a study entitled

"Direct Support Automatic Test Support System" [11]. This study includes collecting historical cost data on support equipment; we recommend that DCA monitor this study as a future source of data.

Recommendations:

	Air Force	Army
Development Support Equipment as Percent of PME Development Cost		
• Common Support Equipment	5	Use present DCAC 600-60-1 factors
• Peculiar Support Equipment	2	
Acquisition Support Equipment as Percent of PME Acquisition Cost		
• Common Support Equipment	5	6
• Peculiar Support Equipment	9	

We would like to note that as more information becomes available the factors we have recommended may need modification. For example, the factors might be raised due to:

(1) large scale depot card testers, both hardware and software being required,

(2) large number of hot mockups required,

(3) location of the system; overseas or remote may require additional support equipment,

(4) high system availability requiring extra support equipment.

Similarly, the factors might be reduced due to:

(1) no hot mockup required,

(2) utilization of existing support equipment.

Chapter III

SYSTEM TEST AND EVALUATION[1]

In attempting to collect cost data on System Test and Evaluation a basic problem was identified. In several cases the cost of the testing has been added to the cost of installation. This was true of the actual costs of several projects included in the U.S. Army Communications System Agency's *Cost Analysis Handbook* (1976) [6].

A. DEVELOPMENT

For the costs of System Test and Evaluation of development programs, the *ESD Cost Factor Study* (1978) [2] recommends using 18 percent of the PME development cost with a range of 18-25 percent. The data on the U.S. Army Satellite Communications Agency's *Terminals for Special Ammunition Sites* (1974) [12] indicated 14.5 percent of the PME development cost for development System Test and Evaluation. The *Seek Score Cost Study* (1978) [9] used 25 percent of the PME development cost for development System Test and Evaluation. Based on these data we recommend using the 18 percent found in the ESD Study for development System Test and Evaluation.

B. ACQUISITION

The data we located for System Test and Evaluation costs in the acquisition phase consist of two points. The AN/FRC-155-162 Series of Radios (1977) [3] used 10.8 percent of the PME

[1]This chapter corresponds to Chapter 18 of DCAC 600-60-1.

acquisition cost for System Test and Evaluation. The *Seek Score Cost Study* (1978) [9] used 5 percent of the PME acquisition cost for acquisition System Test and Evaluation costs. Based on the definition of the current factor in DCAC 600-60-1, we would recommend using 5 percent of the PME acquisition cost for acquisition System Test and Evaluation costs.

Recommendations:

- 18 percent of the PME development cost for development system test and evaluation.
- 5 percent of the PME acquisition cost for acquisition system test and evaluation.

In addition, we would advise the user of these factors to note that the factors we recommended may need modification depending on such additional information as:

(1) The required location of the system test,

(2) The required availability and maintainability,

(3) In the development testing the number of prototypes may reduce the duration of the system test by using simultaneous testing,

(4) The state-of-the-art of the configuration, if not new, may reduce the requirements for system tests in the development phase.

Chapter IV

SYSTEM/PROJECT MANAGEMENT[1]

The area of System/Project Management cost was one where we did not find a documented cost factor in any costing manual. The *ESD Cost Factor Study* (1978) [2] has a discussion of this cost category which says that they were unable to determine a simple relationship usable for estimating the cost of System/Project Management. The author attributes this to two elements. The first is that contractors' accounting systems allocate these costs very differently. The second is that the definitions/scope of this category also varies greatly between projects. Therefore, ESD was unsuccessful in developing a usable relationship.

The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] does not have a cost category identified such that it can be associated with System/Project Management. Examining the actual costs for projects included in the handbook is also unproductive as most of them follow the cost format in the handbook. Given these problems, the following data points that we were able to acquire should be judged in light of the comments in the ESD study.

A. DEVELOPMENT

In the development cost for the U.S. Army Satellite Communications Agency's *Terminals for Special Ammunition Sites* (1974) [12], 3.2 percent of the PME development cost for System

[1]This chapter corresponds to Chapter 19 of DCAC 600-60-1.

Management was included for development. It also included 7.9 percent for Development Systems Engineering/Integration. This is a problem since the DCA Circular 600-60-1 has Systems Engineering included as part of the section--SYSTEM/PROJECT MANAGEMENT. However, Integration is included in the circular in another chapter, INTEGRATION AND ASSEMBLY. Therefore, it would be desirable to know how much was included for Integration, but it is impossible to determine the amount for Integration from the report. As a result, the 7.9 percent is high by an unknown amount. The sum of the two percentages is 11.1 percent. We also acquired the *Seek Score Cost Study* (1978) [9]. It contains a factor of 20 percent of the PME development cost for System/Project Management with the note that the percentage has been reduced due to the "industry's prior history with subject equipment." This was the only datum we acquired on development System/Project Management. The existing DCAC 600-60-1 does not contain a factor for development System/Project Management. We recommend that this area be investigated further to develop a cost factor.

8. ACQUISITION

The cost datum we obtained for acquisition costs comparable to the current DCAC 600-60-1 is as follows: The *Seek Score Cost Study* (1978) [9] contains 20 percent of the PME acquisition cost for acquisition System/Project Management with the note that the percentage has been reduced due to the "industry's prior history with subject equipment."

Another source is a Mitre Memorandum (1975) [10] which includes cost data for satellite terminals. The first data of interest are for a series of tactical satellite communications terminals built by RCA for the U.S. Army Satellite Communications Command. For this family of terminals (TSQ-118, TSC-85(1), -85(2), -86, and MSC-59), 6.1 percent of the PME

acquisition cost was allocated for the Program Management. Also in the memorandum are some acquisition data for the FSC-78 terminal. These data include 11 percent of the PME cost for "Management" with no further explanation.

Comparing these percentages with the current DCA factors of 10 percent of the PME acquisition cost for each of the elements, Project Management and System Engineering, we would recommend that these percentages continue to be used.

Recommendations:

- Further investigation required to develop factor for development system/project management.
- 10 percent of PME acquisition cost for acquisition system/project management.

Chapter V

DATA - TECHNICAL SUPPORT DOCUMENTATION[1]

Data is an area where a major problem is to determine what has been included and what has been excluded. The first source we identified was the *ESD Cost Factor Study* (1978) [2]. It contains a cost category entitled "Data (Technical and Management)" which includes "Technical manuals, technical orders, and provisioning data, along with management data." The recommended percentage of the PME cost is 10 percent with a range of 8 to 12 percent.

For the *Digital European Backbone System* (1981) [8], the Air Force is allocating 2.35 percent of the PME cost for Digital Systems Operating Manuals and another 2.35 percent for "Data (Fault Alarm, Restoral, Tech Control, etc.)" or a total of 4.7 percent of the PME cost. The Air Force's *UHF Satellite Communications Terminals and Associated Family of UHF Modular Transceivers* (1975) [13] provided 9 percent of the PME cost for Data.

A Mitre Memorandum entitled *Satellite Terminal Cost Data Base* (1975) [10] includes the following percentages of PME cost for data:

TSQ-118, TSC-85(1), -85(2), -86, and MSC-59	4.0 percent
FSC-78	1.6 percent

These satellite terminals were procured under Army contracts.

[1]This chapter corresponds to Chapter 20 of DCAC 600-60-1.

The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] contains a section entitled "Documentation," which is defined as "all the paper required to support the equipment or system in question--technical manuals, system manuals, item descriptions, provisioning documentation, system engineering plan, maintainability and reliability plans, PERT, RPSTL's, etc." The handbook also says, "It is risky to assign a single factor for documentation." It then provides a list of projects with the percentage for documentation of the contract hardware cost (with and without modifications). These are the applicable contracts:

Contract	Without Modifications (Percent)	With Modifications (Percent)
Automated Message Processing System AMPS (Phase II)	14.1	6.2
Digital Subscriber Terminal Equipment	3.0	1.9
Low Level Signaling Unit	9.8	10.5
MD-674 (MODEM)	2.4	2.2
EWCS-Original Contract	17.9	14.7
EWCS-69	27.2	27.2
EWCS-70	11.9	12.4
INDOCOM	8.1	8.1
ROKA Upgrade	5.1	7.7
European Wideband Communications System-68 (1969)	12.4	-
DCS Microwave Radio (not Digital) (1975)	24.5	-
Foresight Sierra (1970)	6.7	-

The average percentage for documentation for the twelve systems is 11.9 percent of the cost of the original contract hardware without modifications.

We obtained three other data points. The first is a percentage for a combined contract for the AN/FCC-99 Multiplexer and the Digital Microwave Radio (1980) [4]. The form of the cost elements does not allow us to separate the data costs into two percentages, one for the multiplexer and another for the radio; therefore we only have a combined percentage of 37.8 percent of the PME cost for the data. The AN/FCC-98 Multiplexer (1981) [5] has only 4 percent of the PME cost for documentation. And finally the AN/FRC-155-162 Series of Radios (1977) [3] has 16.4 percent of the PME cost allocated for Data.

In summary, the percentages have a range of 1.6 percent to 37.8 percent of the PME cost. If the data are separated by service, the ranges are: Army 1.6 percent to 37.8 percent; Air Force 4.7 percent and 9.0 percent. The average of the two Air Force points is 6.9 percent. This is less than the recommended percentage (10 percent) in the ESD Study [2]. The average of the Army data (17 points) is 12.2 percent with a standard deviation of 10.1 percent.

Although the average of the two Air Force points is only 6.9 percent, as a result of discussions with personnel knowledgeable of the field, we recommend continued use of the 10 percent given in the *ESD Cost Factor Study* [2] for Air Force projects. For Army projects we recommend approximately 12 percent of the cost of the PME for the cost of Data. This is a different approach from that of Chapter 20 of DCAC 600-60-1. Both Air Force and Army factors are based on total PME cost, whereas the DCAC 600-60-1 factors are based on first unit PME cost. Since the service factors are more recent, we recommend their use.

Recommendations:

- Air Force: 10 percent of PME acquisition cost for data - technical support documentation.
- Army: 12 percent of PME acquisition cost for data - technical support documentation.

Chapter VI

INITIAL SPARES AND REPAIR PARTS[1]

This cost category is one where what should be spent versus what actually is spent is a continuing problem. Our objective was to attempt to collect actual cost data by equipment type. For equipment acquired by the Army we were successful in doing this. For Air Force equipment we were unable to locate sufficient data to identify different percentages for various equipment types. We have accumulated data in two forms. The first is for a specific type of equipment; the second is for a specific system, which includes some combination of equipment types and quantities.

A. DEVELOPMENT

We only acquired two factors for initial spares for the development phase. The Air Force *Seek Score Cost Study* (1978) [9] uses 20 percent of the PME development cost for initial development spares. The study says the factor was supplied by AFLC. The U.S. Army Satellite Communications Agency's *Terminals for Special Ammunition Sites* (1974) [12] had 34.2 percent of the PME development cost for initial spares and repair parts.

B. ACQUISITION

1. Air Force

The *ESD Cost Factors Study* (1978) [2] has the cost of initial spares broken out into three major categories plus

[1]This chapter corresponds to Chapter 22 of DCAC 600-60-1.

an average for a system. These percentages of PME cost are as follows:

Category	Recommended Percent	Percent Range
Navigation and Surveillance	30	30-35
Communications	19	19-22
Computers	8	- -
Average System Containing a Combination of Equipment Types	23	23-35

We were also able to acquire the percentage for initial spares being used for the Digital European Backbone System (DEBS) [8]. This percentage is 7.8 percent of the PME cost. These were the only data located for Air Force equipment or projects; therefore, our recommendation is that the ESD Study [2] percentages be used.

2. Army

We were more successful in acquiring data for the Army's specific equipment types and systems. In two places system data were found, where a system consists of some combination of different types and quantities of equipment. The *Cost Estimating Handbook (Methods and Factors)* (1980) [14] recommends using 15 percent of the PME cost for initial spares for all systems. The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] contains actual cost data on several systems. These systems had the following percentages of PME cost for spares:

European Wideband Communications System-68 (1969)	29.2 percent
European Wideband Communications System-69 (1969)	28.6 percent
Digital Subscriber Terminal Equipment (1971)	29.0 percent

Foresight Sierra (1970)	19.7 percent
Indonesian Communications Systems (1971)	15.5 percent
Average =	24.4 percent

For individual equipment types we collected two types of data. The first were percentages for generic equipment types. The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] recommends the following percentages of PME cost for these generic equipment types:

Radios	35 percent
Antennas, Towers Waveguides	10 percent
Multiplexer Equipment	25 percent
Teletype Equipment	20 percent
Technical Control	15 percent
Speech plus Terminal	15 percent
Generator Equipment	15 percent
Batteries, Battery Chargers	10 percent

In discussions with the Communications Systems Agency [15] they stated that currently the percentages being used are:

Radios	35 percent
Multiplexers	25 percent
Other Electronic Equipment	20 percent

The second type of data were for specific equipment. We received two data points for radios. The U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] contains contract costs for the DCS Microwave Radio. These costs include 35.3 percent of the PME for spares. In addition, we acquired data for the AN/FRC-155-162 Series of Radios (1977) [3] which had a percentage of 28.3 percent of the PME cost for spares. Both these figures are close to the recommended percentage of 35 percent in the *Cost Analysis Handbook* previously discussed.

The U.S. Army Satellite Communications Agency provided us spares cost as a percentage of PME for two multiplexers: the TD1373 - 30 percent, and the ADT - 30 percent [16]. The Communications Systems Agency (CSA) provided an equivalent percentage for the AN/FCC-98 [5], but the figure is much lower--10.7 percent of the PME cost. This is also lower than what CSA says they are using (25 percent) and what their handbook recommends (25 percent). We recommend using 25 percent of PME cost for the cost of initial spares and repair parts for multiplexers.

We acquired four data points for satellite terminals. They included the Mitre Memorandum (1975) [10], which includes the family of terminals TSQ-118, TSC-85(1), -85(2), -86, and MSC-59 with a percentage of the PME cost of 15 percent. The last three points were provided by the Satellite Command in a meeting at Fort Monmouth [16]: the AN/TSC-86 Satellite Ground Station (terminal) - 18.5 percent; the AN/USC-28 Satellite Communications Set - 30 percent; and the AN/GSC-39 Satellite Communications Terminal - 14.4 percent. Note that the TSC-86 is included in the Mitre study also, and the percentage has increased from 15 to 18.5 percent. The average of the four points is 19.0 percent. We would recommend using 20 percent of the PME cost for initial spares and repair parts for satellite terminals.

The percentages for actual equipment supplied by the Satellite Communications Agency [16] for antennas are as follows:

OE-2222 G/T 34	9.6 percent
Multiple Beam Torus	9.6 percent
AS 3199	10.0 percent
ADT Bandpass	30.0 percent

Except for the ADT Bandpass, the percentages all agree with the 10 percent recommended in the Communications Systems Agency's

Cost Analysis Handbook [6]. Therefore we also recommend using 10 percent of the PME cost for the cost of initial spares for antennas.

The three modems for which data were identified are the MD-1002 QPS - 25 percent; the GMF AJ Modem - 8.5 percent; and the Non-Nodal Modem - 16 percent [16]. These percentages were all supplied by the Satellite Communications Agency. The Communications Systems Agency treats modems as other electronic equipment which uses 20 percent as the recommended percentage. We recommend that 20 percent of PME cost be used for the cost of initial spares and repair parts for other electronic equipment including modems.

In addition, the Satellite Communications Agency supplied us with single data points for several other equipment types. These are:

DCSS Rack	20.0 percent
Burst Error Coder	33.0 percent
Teletypewriter	30.0 percent
Remote I/O Unit	40.0 percent
Remote Clock	10.0 percent
Power Combiner	20.0 percent
ADP Link Power Control	.0 percent
DSCS/GMF Control Link	[illegible]4 percent
Supply and Maintenance Shelter	15.0 percent
Test Set TS3580	30.0 percent
Average =	25.8 percent

This average is close to the 20 percent for other electronic equipment recommended by the Communications Systems Agency.

Recommendations:

Equipment Type	Initial Spares and Repair Parts (as percent of PME cost)	
	Percent	Percent Range
Air Force		
• Navigation & Surveillance	30	30-35
• Communications	19	19-22
• Computers	8	-
• Complete System	23	23-35
Army		
• Multiplexers	25	-
• Satellite Terminals	20	-
• Antennas	10	-
• Other, Including Modems	20	-

All of the recommended percentages should be modified to reflect any additional information available such as:

(1) Special system reliability and availability requirements,

(2) Site location requirements,

(3) The need for expedited delivery of certain spares.

Chapter VII

TRANSPORTATION OF THINGS[1]

The first action we took in updating this section was to determine if DODI 7510.4 (which is the reference for the factors of Tables 24-8 and 24-9 in the DCA Circular 600-60-1) had been revised. As of June 1981, DODI 7510.4 had not been updated since the reference in the present circular.

The transportation cost factors in the U.S. Army Communications Systems Agency's *Cost Analysis Handbook* (1976) [6] are the same as those in the DCA circular. However, the *Cost Estimating Handbook (Methods and Factors)* (1980) [14] has two Cost Estimating Relationships (CERs) that have been generated by performing a regression analysis. Based on a study of the transportation cost of 15 different items, including radios, telephone sets, and shelters, the following CERs were developed:

$$C = -6568.93 + 0.03116X_1 + 1155.24 \ln X_2$$

where

C = cost in FY 78 $
X_1 = weight in pounds
X_2 = distance in miles.

The coefficient of correlation of the regression analysis was $R^2 = 0.994$; the Standard Error was 1529.58, and the F ratio was 1040.48. The range of the sample was:

Weight - 3,667 to 2,576,000 lbs.
Distance - 108 to 3,552 miles.

[1]This chapter corresponds to Section 3 of Chapter 24 of DCAC 600-60-1.

The second equation uses only weight since the distance may not be known in the planning stage.

$$C = 1091.34 + 0.03114X$$

where

C = cost in FY 78 $

X = weight in pounds.

The coefficient of correlation was $R^2 = 0.988$, the Standard Error was 2116.25, and the F ratio was 1164.04.

When the required information is available, we recommend that the factors in the existing circular be used until a new DODI 7510.4 is issued. The regression equations are to be used when only approximations of weight and distance to be shipped are available.

Recommendation:

Continue to use factors of DCAC 600-60-1.

Chapter VIII

DEPOT MAINTENANCE[1]

Depot Maintenance cost data for Communications-Electronic (C-E) equipment are not at present being collected in any consistent manner. We found that the Army's data collection system does not allow one to determine the depot costs. We had no success in locating any studies that would allow assumptions to be made about depot costs. This is because the Army's system is designed to supply cost data for an organization (such as a battalion) which contains many types of equipment. Therefore, allocating costs to particular items is very difficult.

In the Air Force some raw data exist at the depots that have not been automated or analyzed yet. As a result, we were able to obtain only two data points that were generated at our request as examples. To develop costs for a more extensive sample was not possible since the Sacramento Air Logistic Center, which has responsibility for C-E equipment, has no formal requirement to collect and supply such cost data. When the Visibility and Management of Operating and Support Costs (VAMOSC) data collection system (discussed in Chapter XI) is implemented, then these depot costs will be collected and be available via regular reports.

[1]This chapter corresponds to Section 3 of Chapter 26 of DCAC 600-60-1.

The Depot Maintenance costs which we were able to acquire are:

AN/GRR-23(V) low cost radio based on three years of data	6.5 percent of PME cost per year
AN/FRC-39 and -39(V) high cost radio based on five years of data	0.9 percent of PME cost per year

These costs consist of 30 percent parts and 70 percent labor/overhead [17]. We do not feel that these points are sufficient to project depot costs for radios or any other type of equipment. The development of appropriate factors must wait for the development of planned data collection systems such as the VAMOSC system. See Chapter XI for a discussion of future data collection systems.

If the user has specific information available about the technical and physical characteristics of the equipment, we would recommend consulting the most current AFLC Pamphlet 173-10 [18] which contains specific depot factors such as labor rates in dollars per hour and item management costs.

Recommendation:

Continue to use factors of DCAC 600-60-1.

Chapter IX

CONTRACTOR MAINTENANCE COST[1]

In this chapter we will develop cost estimating relationships (CERs) for contractor maintenance cost for:

- Facsimile equipment
- Teleprinters
- Intelligent terminals
- Non-Intelligent terminals
- Communications processors.

The literature indicates that manufacturers often offer a variety of maintenance contract options. Typical of those contracts described as "standard" is a "standard maintenance contract" covering Hewlett-Packard 2640B terminals which provides for "on-call, prime shift maintenance with no charge for parts or labor."

The following data sources (current as of March 1981)[2] were used:

- *Auerbach Computer Technology Reports*
- *Auerbach Data World*
- *Data Pro Reports.*

The data analyzed for items within each category included purchase price, annual cost for a "standard" maintenance contract, and data relating to selected operational and

[1]This chapter does not correspond to any current chapter of DCAC 600-60-1.

[2]These reports are compiled in loose-leaf notebooks and are continuously updated by additions and deletions.

physical characteristics for each equipment category. The sets of selected parameters for each category are indicated in Table 1.

Table 1. SELECTED PARAMETERS BY EQUIPMENT CATEGORY

Equipment Category	No. of Parameters	Parameter List	Units
Facsimile Equipment	2	• vertical resolution • time required to transmit one 8-1/2" x 11" page	lines per inch vertical seconds
Teleprinters (Impact and Non-Impact)	2	• print speed • data transmission rate	characters per second (cps) bits per second (bps)
Intelligent Terminals	2	• main memory capacity (max.) • data transmission rate	Kilobytes (KB) Kilobits per second (Kbps)
Non-intelligent Terminals	1	• data transmission rate	bps
Communications Processors	5	• number of half-duplex lines up to 1800 bps • cycle length • word length • data transmission rate • main memory capacity	number of half-duplex lines microseconds (μsec) bits per word (bpw) Kbps KB

Two statistical techniques were applied, using computer programs found in General Electric's *Statistical and Mathematical Programs*, a user's guide for Mark II time-sharing system users (revised edition, 1970). The two programs used were MREG, which performs multiple linear regression analysis, and MANDSD, which calculates the mean, variance, and standard deviation for sets of individual values or frequency distributions. Tables 2 through 6 summarize the input data for these analyses.

Table 2. COMMUNICATIONS PROCESSORS

Observation Number	Manufacturer and Model	Annual Contractor Maintenance Cost ($)	Purchase Price ($)	Year	Annual Contractor Maintenance/ Purchase Price	Purchase Price in 1980 Dollars	Number of HDX Lines @ 1800 bps	Cycle Length μsec	Word Length bpw	Data Transmission Rate Kbps	Main Memory Capacity (max.) KB	Used as Input for MANDSD	Used as Input for MREG
1	Computer Communications CC-8	4,272	60,295	1979	.0709	65,189	240	.30	16	230.4	64	x	x
2	Computer Communications CC-80	4,452	93,595	1979	.0476	101,192	1,232	.30	16	230.4	512	x	x
3	Computer Communications CC-85	6,192	123,595	1979	.0501	133,627	1,232	.30	16	230.4	512	x	x
4	Honeywell Datanet 6678	5,892	190,870	1979	.0309	206,363	96	.44	18	72.0	512	x	x
5	IBM-DPD 3705-11	4,110	68,116	1980	.0603	68,116	352	1.00	18	230.4	512	x	x
6	Memorex 1380	5,808	51,696	1980	.1123	51,696	216	.54	16	230.4	64	x	x
7	Modular Computer Systems MC/11/26/CP2	6,276	56,660	1980	.1108	56,660	256	1.00	16	-[a]	64	x	
8	MC/11/26 CP2	5,256	57,710	1980	.0911	57,710	256	.80	16	-[a]	32	x	
9	MC/11/45 CP2	7,356	88,860	1980	.0828	88,860	256	.60	16	-[a]	1024	x	
10	Univac DCP	3,528	73,604	1978	.0479	86,637	256	.92	16	56.0	128	x	x
11	NCR Comtem 3690	9,336	184,325	1980	.0506	184,325	512	.52	64	230.4	4096	x	x
12	CDC 2551-1	6,720	64,634	1980	.1040	64,634	32	.55	18	56.0	262	x	x
13	CDC 2551-2	7,260	74,634	1980	.0973	74,634	254	.55	18	56.0	262	x	x

[a]Data not available.

Sources: *Auerbach Computer Technology Reports* and *Data Pro Reports*.

Table 3. FACSIMILE EQUIPMENT

Observation Number	Manufacturer and Model	Annual Contractor Maintenance Cost ($)	Purchase Price ($)	Year	Annual Contractor Maintenance/ Purchase Price	Purchase Price in 1980 dollars	Maximum lines per inch Vertical	Minimum seconds per 8.5 x 11" Page	Used as Input for MANDSD	Used as Input for MRLG
1	Graphic Services, Inc., dex 1	250	900	1979	.2778	973	88	360	x	x
2	" dex 180, 181, 182	300	1,976	1979	.1518	2,136	88	180	x	x
3	" dex 580	300	2,350	1979	.1277	2,541	88	180	x	x
4	" dex 1102	175	3,000	1979	.0583	3,244	96	120	x	x
5	" dex 3400	375	2,350	1979	.1596	2,541	88	360	x	x
6	" dex 4400	300	5,000	1979	.0600	5,406	17.6	120	x	x
7	" dex 5100	1,600	13,500	1979	.1185	14,596	19.6	-[a]	x	
8	" dex Broadcaster	375	9,000	1979	.0417	9,731	88	180	x	x
9	Rapifax 100	1,140	9,600	1980	.1188	9,600	200	35	x	x
10	Rapifax System 50	1,620	14,500	1980	.1117	14,500	200	35	x	x
11	Rapifax Dacom 4108	1,200	10,550	1980	.1137	10,550	200	30	x	x
12	Rapifax Dacom 412	1,380	18,000	1980	.0767	18,000	200	25	x	x
13	Stewart-Warner 240	600	4,495	1979	.1335	4,860	96	180	x	x
14	3M Remote Copier 600	370	1,795	1980	.2061	1,795	96	240	x	x
15	3M Portable Remote 603	150	1,195	1980	.1255	1,195	96	180	x	x
16	3M 9600	600	15,790	1980	.0380	15,790	96	36	x	x
17	Xerox 111	190	945	1980	.2011	945	96	240	x	x
18	Xerox 410	355	3,295	1980	.1077	3,295	96	240	x	x
19	Xerox 485	480	6,500	1980	.0738	6,500	96	60	x	x

[a]Data not available.

Source: *Auerbach Computer Technology Reports*

Table 4. TELEPRINTERS

Observation Number	Manufacturer and Model	Annual Contractor Maintenance Cost ($)	Purchase Price ($)	Year	Annual Contractor Maintenance/ Purchase Price	Purchase Price in 1980 Dollars	Characters per second (cps)	Bits per second (bps)	Used as Input for MANDSD	MREG Impact	MREG Non-Impact
1	AJ 832	396	4,180	1980	.0947	4,180	30	450	x	x	
2	AJ 860	408	2,830	1980	.1442	2,830	60	1,200	x	x	
3	Data General Dasher TPI 6040	336	2,650	1980	.1268	2,650	60	600	x	x	
4	Data General Dasher TPI 6042	300	2,400	1980	.1250	2,400	30	600	x	x	
5	DEC LA 120 Decwriter II	228	2,100	1979	.1086	2,271	30	300	x	x	
6	DEC LA 120 Decwriter III	300	2,930	1979	.1024	3,168	30	9,600	x	x	
7	GE Terminet 30	636	3,400	1980	.1871	3,340	30	1,200	x	x	
8	GE Terminet 200	390	3,128	1980	.1247	3,128	120	1,200	x	x	
9	GE Terminet 300	786	6,444	1980	.1220	6,444	30	300	x	x	
10	GE Terminet 1200	954	7,466	1980	.1278	7,466	120	1,200	x	x	
11	GE Terminet 1232	792	5,616	1980	.1410	5,616	120	1,200	x	x	
12	IBM 3767 Model 1	756	8,287	1980	.0912	8,287	40	2,400	x	x	
13	IBM 3767 Model 2	840	9,177	1980	.0915	9,177	80	2,400	x	x	
14	IBM 3767 Model 3	1,128	10,832	1980	.1041	10,832	120	2,400	x	x	
15	Perkin-Elmer Carousel 350	558	4,864	1979	.1147	5,259	30	1,200	x	x	
16	Teletype 35	300	3,953	1980	.0759	3,953	72	110	x	x	
17	Telex TC 241	432	5,880	1979	.0735	6,357	40	1,800	x	x	
18	Univac 475	450	3,172	1980	.1419	3,172	10	110	x	x	
19	Univac 500	450	3,560	1980	.1264	3,560	30	300	x	x	
20	WU 1232	774	4,684	1979	.1652	5,064	120	1,200	x	x	
21	Xerox 1710	450	3,345	1980	.1345	3,345	45	300	x	x	
22	Xerox 1720	480	3,345	1980	.1435	3,345	45	1,200	x	x	
23	Xerox 1740	480	3,765	1980	.1275	3,765	45	1,200	x	x	
24	Xerox 1750	480	3,555	1980	.1350	3,555	40	1,200	x	x	
25	Computer Devices Miniterm 1201	192	2,137	1980	.0898	2,137	30	300	x		x
26	Computer Devices Miniterm 1204	336	2,985	1980	.1126	2,985	50	300	x		x
27	Computer Transceiver Execuport Series T-4000	312	3,645	1976	.0856	3,941	30	300	x		x
28	TI-732	240	1,670	1980	.1437	1,670	13	100	x		x
29	TI-733	240	1,745	1980	.1375	1,745	30	300	x		x
30	TI-743	210	1,195	1980	.1757	1,195	30	300	x		x
31	Teletype 30	288	1,149	1980	.2507	1,149	72	110		x	
32	Xerox 1760	660	2,990	1980	.2207	2,990	200	4,800		x	

Source: [illegible]

Table 5. INTELLIGENT TERMINALS

Observation Number	Manufacturer and Model	Annual Contractor Maintenance Cost ($)	Purchase Price ($)	Year	Annual Contractor Maintenance/ Purchase Price	Purchase Price in 1978 Dollars	Main Memory Capacity (KB)	Data Transmission Rate (Kbps)	Used as Input for MANDSD	Used as Input for MREG
1	ADD 70	540	8,495	1978	.0636	8,495	64	9.6	x	x
2	Braegen 1, Remote 1	1,872	36,380	1978	.0515	36,380	256	9.6	x	x
3	Burroughs T6383	1,302	17,500	1978	.0744	17,500	64	9.6	x	x
4	Burroughs 3971	1,302	20,000	1978	.0651	20,000	64	9.6	x	x
5	Burroughs 5100	900	15,000	1978	.0600	15,000	32	9.6	x	x
6	Datapoint 1100	852	13,780	1978	.0618	13,780	16	9.6	x	x
7	Decstation 78	1,014	10,270	1978	.0987	10,270	32	19.2	x	x
8	Four-Phase IV-30	1,680	25,000	1980	.0672	21,240	24	9.6	x	x
9	Four-Phase IV-50	4,932	93,145	1980	.0529	79,138	96	9.6	x	x
10	Four-Phase IV-70	3,792	68,115	1980	.0557	57,871	96	9.6	x	x
11	Four-Phase IV-90	11,160	175,865	1980	.0635	149,418	352	9.6	x	x
12	Harris 8180	2,736	28,160	1978	.0972	28,160	96	4.8	x	x
13	Harris 8210	8,076	100,925	1978	.0800	100,925	64	9.6	x	x
14	Harris 8220	6,228	18,847	1978	.0790	18,847	64	9.6	x	x
15	Harris 8770	2,868	35,314	1978	.0812	35,314	64	4.8	x	x
16	IBM 3735	1,236	14,279	1979	.0866	14,279	64	4.8	x	x
17	ICL 1501	540	5,020	1978	.1076	5,020	16	9.6	x	x
18	ICL 1503	1,740	15,600	1978	.1115	15,600	16	9.6	x	x
19	Incoterm SPD 10/20	480	6,090	1978	.0788	6,090	4	9.6	x	x
20	Incoterm SPD 20/20	816	12,170	1978	.0671	12,170	64	9.6	x	x
21	Incoterm SPD 20/40	2,076	27,525	1978	.0754	27,525	64	9.6	x	x
22	MDS 2300	1,068	13,480	1978	.0792	13,480	16	9.6	x	x
23	MDS 21/40	636	9,223	1978	.0690	9,223	64	9.6	x	x
24	MDS 21/50	960	14,950	1978	.0642	14,950	128	9.6	x	x
25	NCR 449	1,080	17,900	1978	.0603	17,900	32	9.6	x	x
26	SYCOR 258	396	5,630	1978	.0703	5,630	2	4.8	x	x
27	TI 771/1, 771/2	1,032	9,145	1980	.1128	9,145	64	9.6	x	x
28	TI 774/2	3,420	27,400	1980	.1248	27,400	352	9.6	x	x
29	TI 774/3	4,584	36,750	1980	.1247	36,750	352	9.6	x	x
30	TI 774/4	6,264	52,400	1980	.1195	52,400	352	9.6	x	x

Source: *Auerbach Computer Technology Reports.*

Table 6. NON-INTELLIGENT TERMINALS

Observation Number	Manufacturer and Model	Annual Contractor Maintenance Cost ($)	Purchase Price ($)	Year	Annual Contractor Maintenance/ Purchase Price	Purchase Price in 1979 Dollars	Data Transmission Rate (bps)	Used as Input for MANDSD	MREG
1	ADD Regent 100	216	1,435	1979	.1505	1,435	600	x	x
2	ADD Regent 200	240	1,915	1979	.1253	1,915	600	x	x
3	ADD Regent 620	264	2,250	1979	.1173	2,250	9,600	x	x
4	Beehive I	300	2,180	1973	.1376	3,449	4,800	x	x
5	Beehive II	300	2,452	1973	.1223	3,879	4,800	x	x
6	Beehive III	300	2,672	1973	.1123	4,227	4,800	x	x
7	CDC 711-10	276	3,675	1975	.0751	5,066	4,800	x	x
8	CDC 711-10	276	4,011	1975	.0688	5,530	4,800	x	x
9	CDC 713-10	216	2,095	1975	.1031	2,881	300	x	x
10	DGC 6093	216	3,318	1980	.1139	3,068	19,200	x	x
11	DGC 6052	378	2,718	1980	.1214	2,514	19,200	x	x
12	DGC 6053	330	3,018	1980	.1094	2,791	19,200	x	x
13	Datagraphix 132A	330	3,950	1979	.1063	3,950	9,600	x	x
14	Datagraphix 132A	420	4,450	1979	.1079	4,450	9,600	x	x
15	Datagraphix 132B	480	4,450	1979	.1160	4,450	9,600	x	x
16	Datagraphix 132B	516	4,950	1979	.1164	4,950	9,600	x	x
17	Delta Data 4300E	576	3,500	1979	.0960	3,500	9,600	x	x
18	Delta Data 4500	336	3,750	1979	.0896	3,750	9,600	x	x
19	Delta Data 4501	336	4,000	1979	.0840	4,000	9,600	x	x
20	Delta Data 4502	360	4,450	1979	.0809	4,450	9,600	x	x
21	Delta Data 7100, 7300	360	4,600	1980	.0783	4,255	19,200	x	x
22	DEC VT 55	300	2,495	1979	.1202	2,495	9,600	x	x
23	IBM 3101-10	216	4,555	1979	.0474	4,555	2,400	x	x
24	IBM 8775-1	312	4,297	1979	.0726	4,297	2,400	x	x
25	IBM 8775-12	360	4,758	1979	.0757	4,758	2,400	x	x
26	Lear Siegler ADM-3A	144	1,098	1980	.1312	1,015	19,200	x	x
27	Lear Siegler ADM-31	312	1,580	1980	.1975	1,461	9,600	x	x
28	Lear Siegler ADM-42	360	1,845	1980	.1951	1,707	9,600	x	x
29	Memorex 1377	324	3,055	1980	.1061	2,826	2,400	x	x
30	NCR 796-401	324	3,100	1980	.1045	2,867	9,600	x	x

Source: *Auerbach Computer Technology Reports*

Multiple linear regression analyses were performed on the data, using the ratio annual contract maintenance cost (then-year dollars)/purchase price (then-year dollars) as the dependent variable. The program MREG was run with various combinations of the selected parameters used as the independent variables for each equipment category. For all categories but communications processors and facsimile equipment, the resultant multiple correlation coefficients ranged from 0.13 to 0.38 (see Table 7) when all available parameters were used as independent variables. With fewer independent variables, the multiple correlation coefficients were consistently smaller.

Table 7. MULTIPLE LINEAR CORRELATION COEFFICIENTS BY EQUIPMENT CATEGORY

Equipment Category	No. of Observations	No. of Independent Variables	Multiple Linear Correlation Coefficient
Communications processors	10	5	.77
Facsimile equipment	18	2	.75
Non-impact teleprinters	6	2	.30
Impact teleprinter	26	2	.38
Intelligent terminals	30	2	.35
Non-intelligent terminals	30	1	.13

When the multiple linear regression analyses yielded such disappointing results, a less sophisticated statistical technique was applied which yielded more satisfactory results. The program MANDSD was used to calculate the mean, standard deviation and variance of the ratio annual contract maintenance cost (then-year dollars)/equipment purchase price (then-year dollars) for each equipment category. The results of these analyses are shown in Table 8. The standard deviations

Table 8. MAXIMUM LIKELIHOOD ESTIMATES OF POPULATION PARAMETERS, BASED ON OBSERVED ANNUAL CONTRACT MAINTENANCE COST/PURCHASE PRICE

Equipment Category	No. of Observations	Annual Contract Maintenance Cost / Purchase Price		
		Mean	Standard Deviation	Sample Variance
Communications processors	13	.0736	.0269	.00071
Facsimile equipment	18	.1269	.0592	.00350
Teleprinters	30	.1225	.0273	.00074
Intelligent terminals	30	.0801	.0216	.00047
Non-intelligent terminals	30	.1094	.0322	.00104

and variances are sufficiently low for the mean value of the ratio annual contract maintenance cost/purchase price to provide a tool for estimating contract maintenance costs of sufficient accuracy for use in long-range planning.

For the categories of communications processors and facsimile equipment, where the multiple linear correlation coefficients were .77 and .75, respectively, a choice of estimating tools exists. The mean of the ratio of annual contract maintenance cost/purchase price would be simpler to use than the regression equations, since only an estimate of the purchase price is required to obtain a contract maintenance cost estimate. Use of the regression equations, on the other hand, would require specific knowledge about the selected parameters for facsimile equipment or communications processors. Such specific knowledge may not be available in a long-range planning context.

In summary, the tool that we recommend for estimating annual contract maintenance costs is the mean of the ratio of annual contract maintenance cost (then-year dollars)/purchase price (then-year dollars), as found in Table 8. Calling this mean ratio M, and given an estimated purchase price $\hat{p}$,

Estimated annual contract maintenance cost = $M\hat{p}$.

Recommendations:

Equipment Type	Annual Contractor Maintenance Cost (as percent of PME Cost)
• Communications Processors	7
• Facsimile Equipment	13
• Teleprinters	12
• Intelligent Terminals	8
• Non-Intelligent Terminals	11

Note that the factors we developed are based on "standard" maintenance contracts; the factors should be modified if more information is available. Such information might include:

(1) Site location in relation to the contractor's maintenance facilities,

(2) Special requirements on contractor response time to a reported problem.

Chapter X

SOFTWARE[1]

This is a topic that currently is not discussed in the existing DCA Circular 600-60-1. However, with the implementation of DoD Directive 5000.39, *Acquisition and Management of Integrated Logistic Support for Systems and Equipment* (January 17, 1980) [19], there is a requirement to include in Integrated Logistic Support Cost estimates an element entitled "Computer Resources Support." Therefore, we recommend that a new chapter or section be added to the DCA Circular to at least discuss this topic.

The basic problem that we encountered in our research into this topic was that this is a new cost category. This means that definitions and terminology are often conflicting and unclear. As a result, consistent cost and technical data have not been collected. The reports we were able to acquire generally assumed one of two possibilities: either extensive technical analyses are available to allow calculation of the number of "lines of code" or "instructions"; or the number of "lines of code" or "instructions" are already known.

Most of the reports we examined were primarily designed to facilitate derivation of development and procurement costs for software. We did not find any reports that dealt extensively with software maintenance. What we did find were preliminary data that show "Update and Maintenance" as a percentage of the total life cycle cost of the software. These data show "Update

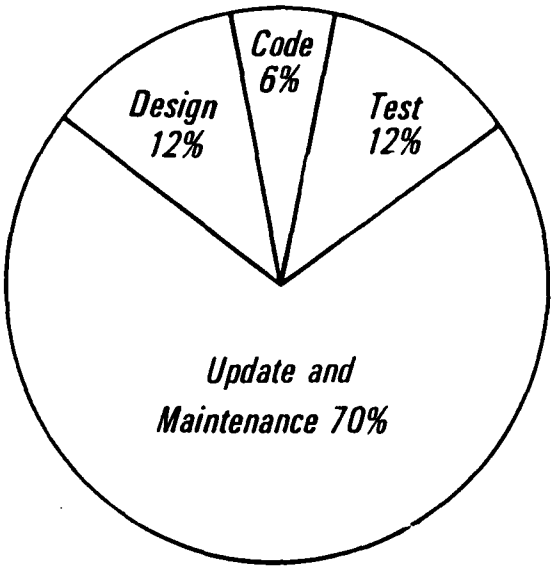
[1]This chapter does not correspond to any current chapter of DCAC 600-60-1.

and Maintenance" as a percentage of the total life cycle cost of the software. These data show "Update and Maintenance" (for a ten-year life) as 70 percent of the total life cycle cost, according to the Software Cost Estimating Workshop (1980) [20] held at the Electronic Systems Division (Figures 1 and 2). For software systems that have not yet been developed, maintenance costs estimated as a percentage of total software costs are subject to large error because the development costs themselves are difficult to estimate. Hence, the estimate of maintenance costs results from the product of two other estimates subject to large errors.

A U.S. Army Electronics Command Report ECOM-4535 (1977) [21] assumes a cost factor "which places modifications and retrofits to software at four to five times the cost of the initial product." This is approximately twice the ESD cost ratio of 2.3 to 1 for Update and Maintenance versus the cost of the acquisition of the initial software (Figures 1 and 2).

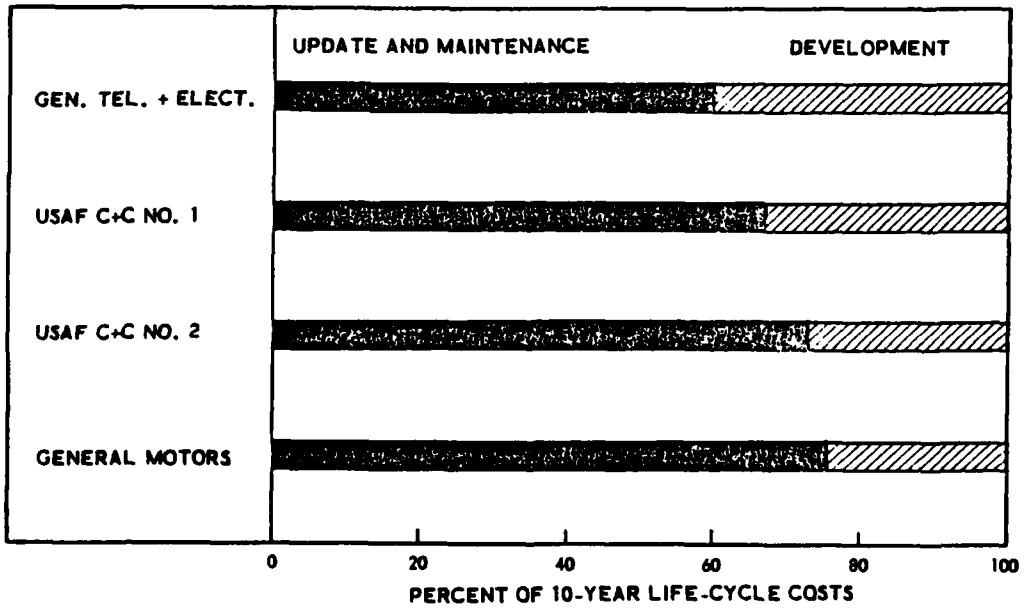
Estimating the costs for Updates and Maintenance can be approached reasonably by recognizing the separation and treatment of Update and Maintenance as two distinct but related efforts. The Update effort is comparable to the efforts and tasks generally involved in software development. The Maintenance effort is concerned with the general day-to-day operation and routine efforts that are relatable to the existing programs.

For the Update effort, costs are derived by application of the same models (e.g., Doty, Telecote, TRW, Barron, etc. [21]) as are employed in software development for determining sizing, schedule, manpower and cost. Figure 3 portrays the distribution of the Software Maintenance Effort and is further amplified by Figure 4. This chart identifies and enumerates the specific tasks and the distribution of these tasks as percentages of the Total Maintenance Effort. Figure 5 details the Update tasks and the distribution thereof.



TRW.

Figure 1. SOFTWARE LIFE CYCLE COST BREAKDOWN RATIO



TRW.

Figure 2. SOFTWARE LIFE CYCLE COST BREAKDOWN

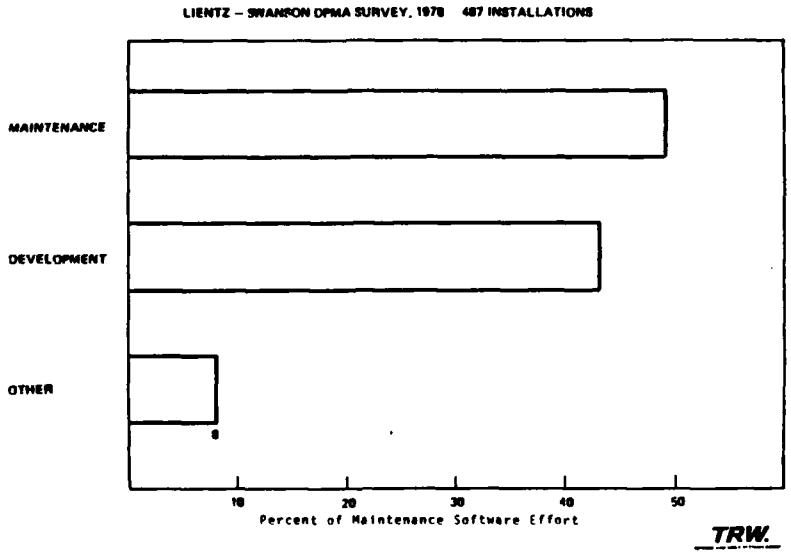


Figure 3. DISTRIBUTION OF SOFTWARE MAINTENANCE

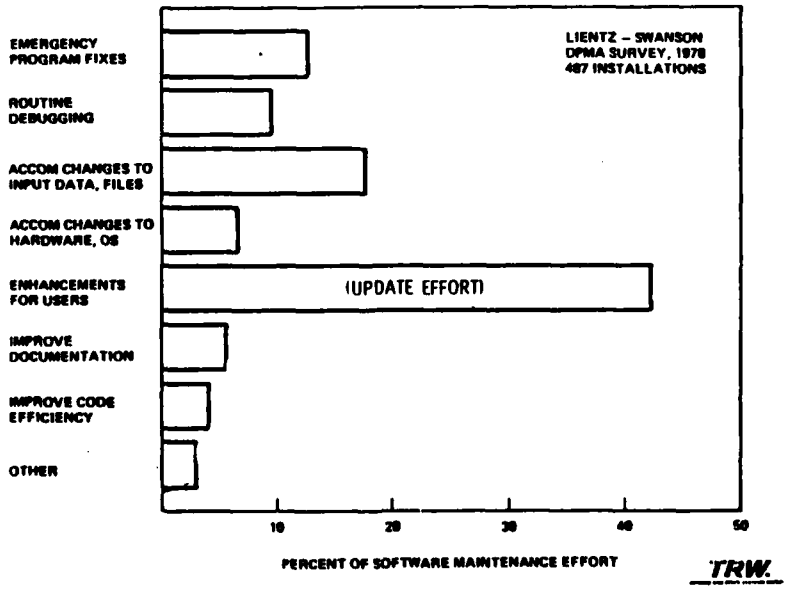


Figure 4. DISTRIBUTION OF SOFTWARE UPDATE AND MAINTENANCE EFFORT

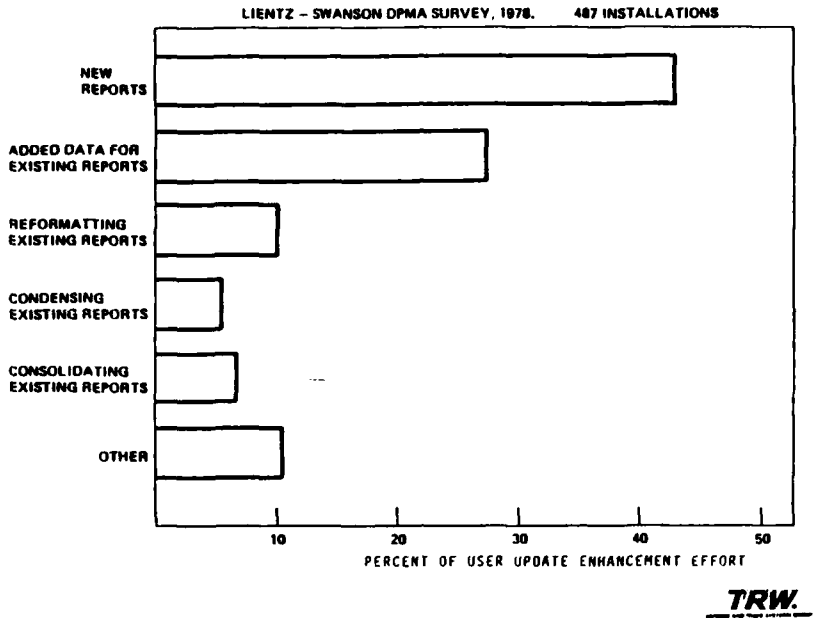


Figure 5. DISTRIBUTION OF USER-ENHANCEMENT UPDATE EFFORT

ESD, as part of the Software Cost Estimating Workshop (1980) [20], recommends using the following productivity and labor rates:

Productivity Rates

1.4 Instructions per Man-day:	Real Time Control Program
4.8 Instructions per Man-day:	Non-real Time or Quasi-real Time Program
8 to 16 Instructions per Man-day:	Non-real Time using higher order language or data reduction or simulation program

Average Cost for Software Labor ($78)

Direct Labor Cost = $22/hour

Supervisory Labor Cost = $29/hour

One Supervisor per Eleven Direct Workers

Engineering Overhead = 102% of Direct + Supervisory Labor Cost

General and Administrative = 16.5%

Fee = 15%

Chapter XI

FUTURE DATA COLLECTION SYSTEMS

At present there are two data collection systems being developed that will provide actual operating and support cost data on Communications-Electronic (C-E) equipment. The Air Force is developing the Visibility and Management of Operating and Support Costs (VAMOSC) system. This system is scheduled to produce reports in March 1982. Figures 6 through 11 are taken from the VAMOSC *Draft Users Manual* [22] and are included as samples of the type of cost data that will be available to DCA. The VAMOSC system will provide integrated logistics support cost reports on selected C-E equipment. These reports will allow collection of cost data in a consistent form and content from which to develop CERs and verify/update existing DCA cost factors. The formats of the reports have been examined and will be useful to DCA analysts. The supporting documentation for the reports has been reviewed and several suggestions made to the VAMOSC project office. As a part of this process the critical design review for the system was attended. At this meeting it was stressed that an important activity for DCA is to identify those pieces of C-E equipment on which DCA desires the Air Force to collect data. The VAMOSC office will supply an initial list of equipment, but as new equipment is fielded and DCA wants data on this equipment collected, the Air Force must be notified.

The Army has a comparable system under development. It is termed the Operating and Support Cost Management Information System (O&SCMIS) [23]. The Army plans to begin generating

reports some time in 1984. The report format that the Army is developing (Figure 12) is different from that of the Air Force and both are different from that provided in DODD 5000.39, *Acquisition and Management of Integrated Logistic Support for Systems and Equipment*. The Air Force has stated that the VAMOSC User's Guide will provide a cross reference between the cost categories in the DODD 5000.39 format and those in the VAMOSC reports. At the present time, the Army does not have such a cross reference, but it could be added at a future date.

Overall, these systems will provide DCA with consistent cost data when they have been operational for several years. Therefore, the development of the systems should be monitored for their possible use for DCA data requirements.

The Navy has an existing data collection system for aircraft--the *NALCOMIS-O&S/VAMOSC-AIR Maintenance Subsystem Report* (1980) [24]. A similar system is being developed for ships and is in the testing stage now. Any equipment that DCA would probably be interested in would be included in the ship data which are not available yet. There is no plan at the present time to have a separate set of reports on communication-electronic equipment.

TMS _____ SRD _____

NOMENCLATURE _____ FY _____

QUANTITY _____

COSTS
(THOUSANDS OF DOLLARS)

Operating and Support Cost - TMS Total
Unit Mission Personnel
  Operations Personnel
  Base Maintenance Personnel
  Unit Administrative Personnel
  Supply Support Personnel

Unit Level Consumption
  Fuel
  Maintenance Material
  Utilities
Depot Level Maintenance
Replacement Investment
Installation Support
  Base Operating Support
  Real Property Maintenance
  Communications
  Medical (Health Care)
Indirect Personnel Cost
  Misc Operations and Maintenance (TDY)
  Permanent Change of Station
Depot Non-Maintenance
    Material Management (Incl. Procurement)
    Material Distribution
    Engineering Support (Contractor)
    Transportation and Packaging
Advanced Training

Figure 6. C-E O&S COST REPORT

XXX

NSN	SRD	ACQUISITION COST	REPLACEMENT FACTOR	AVERAGE ANNUAL INVENTORY

WHERE XXX = A TMS
ZZ = A FISCAL YEAR

Figure 7. BASIC DATA

XXX

NSN	DEPOT MAINTENANCE QUANTITY	PROGRAM COST	RECOVERABLE ALLOCATION FACTOR	AVERAGE ANNUAL INVENTORY	ALLOCATED DEPOT MAINTENANCE COSTS	NORMALIZED ALLOCATED COSTS
				TOTAL		

WHERE XXX = A TMS
ZZ = FISCAL YEAR

Figure 8. ANNUAL DEPOT MAINTENANCE COSTS - FY ZZ

XXX

NSN	DEPOT MAINT QUANTITY	DEPOT CONDEMN QTY	BASE CONDEMN QTY	UNIT REPLACEMENT COST	RECOV ALLOC FACTOR	ALLOCATED REPLACEMENT COST	NORMALIZED ALLOCATED REPLACEMENT INVESTMENT COST

WHERE XXX = A TMS
ZZ = A FISCAL YEAR

Figure 9. REPLACEMENT INVESTMENT COSTS - FY ZZ

XXX

NSN	RECOV ALLOC FACTOR	AVERAGE ANNUAL INVENTORY	UNPACKAGED WEIGHT (LBS)	ONE-WAY QUANTITY	ROUND TRIP QUANTITY	ONE-WAY PACKAGING AND TRANSPORTATION COSTS	ROUND TRIP PACKAGING AND TRANSPORTATION COSTS	ALLOCATED PKG AND TRANS COST	NORMALIZED ALLOCATED PKG AND TRANS COST
							TOTAL		

WHERE XXX - A TMS
ZZ - A FISCAL YEAR

Figure 10. PACKAGING AND TRANSPORTATION COSTS - FY ZZ

TMS

FY	DEPOT MAINT COST	% OF TOTAL COST	REPLACEMENT INVESTMENT COST	% OF TOTAL COST	TRANSPOR-TATION & PACKAGING COST	% OF TOTAL COST	BASE MAINT LABOR COST	% OF TOTAL COST	BASE MAINT MATERIAL COST	% OF TOTAL COST	TOTAL LOGISTIC SUPPORT COST

Figure 11. NORMALIZED HISTORICAL ANNUAL LOGISTIC SUPPORT COST

Expanded Cost Breakdown Structure

DA PAM 11-4 Cost Breakdown Structure

3.0	OPERATING & SUPPORT COST
3.01	MILITARY PERSONNEL
3.011	CREW PAY & ALLOWANCES
3.012	MAINT PAY & ALLOWANCES
3.013	INDIRECT PAY & ALLOW
3.014	PERM CHANGE OF STATION
3.02	CONSUMPTION
3.021	REPLENISHMENT SPARES
3.022	PETROLEUM, OILS, & LUB
3.023	UNIT TRNG AMMO & MSLES
3.03	DEPOT MAINTENANCE
3.031	LABOR
3.032	MATERIEL
3.033	TRANSPORTATION
3.04	MODIFICATIONS, MATERIEL
3.05	OTHER DIRECT SPT OPS
3.051	MAINTENANCE, CIV LABOR
3.052	OTHER DIRECT
3.06	INDIRECT SUPPORT OPS
3.061	PERSONNEL REPLACEMENT
3.062	TRANS, PATIENTS, PRIS
3.063	QUARTERS MAINT & UTIL
3.064	MEDICAL SUPPORT
3.065	OTHER INDIRECT

3.0	OPERATING & SUPPORT COST
3.01	MILITARY PERSONNEL
3.011	CREW PAY & ALLOWANCES
3.012	MAINT PAY & ALLOWANCES
3.0121	ORGANIZATIONAL LEVEL
3.0122	DIRECT SUPPORT LEVEL
3.0123	GENERAL SUPPORT LEVEL
3.013	INDIRECT PAY & ALLOWANCES
3.014	PERM CHANGE OF STATION
3.02	CONSUMPTION
3.021	REPLENISHMENT SPARES
3.0211	ORGANIZATIONAL LEVEL
3.02111	CONSUMABLES-ORG
3.02112	REPAIRABLES-ORG
3.0212	DIRECT SUPPORT LEVEL
3.02121	CONSUMABLES-DS
3.02122	REPAIRABLES-DS
3.0213	GENERAL SUPPORT LEVEL
3.02131	CONSUMABLES-GS
3.02132	REPAIRABLES-GS
3.022	PETROLEUM, OILS, & LUB
3.023	UNIT TRNG AMMO & MSLES
3.03X	DEPOT MAINTENANCE
3.031X	DIRECT LABOR
3.032	MATERIEL
3.033	TRANSPORTATION
3.034	CONTRACT
3.035	OTHER
3.04X	MODIFICATIONS
3.041	DIRECT LABOR
3.0411	INCRSD PERFORM MODS
3.0412	SAFETY/DEF CORR MODS
3.042	MATERIEL
3.0421	INCRSD PERFORM MODS
3.0422	SAFETY/DEF CORR MODS
3.043	CONTRACT
3.0431	INCRSD PERFORM MODS
3.0432	SAFETY/DEF CORR MODS
3.044	OTHER
3.0441	INCRSD PERFORM MODS
3.0442	SAFETY/DEF CORR MODS
3.05X	OTHER DIRECT SPT OPS
3.051	MAINTENANCE, CIV LABOR
3.0511	ORGANIZATIONAL LEVEL
3.0512	DIRECT SUPPORT LEVEL
3.0513	GENERAL SUPPORT LEVEL
3.052X	OTHER DIRECT
3.053	UNIT TRAINING
3.06	INDIRECT SUPPORT OPS
3.061	PERSONNEL REPLACEMENT
3.0611	ACCESSION
3.0612	SEPARATION
3.0613	TRAINING
3.062	TRANS, PATIENTS, PRIS
3.063	QUARTERS MAINT & UTIL
3.064	MEDICAL SUPPORT
3.065	OTHER INDIRECT
3.0651	ADMIN & PERS SPT
3.0652	SMALL ARMS QUALIF
3.0653	SUPPLY SUPPORT
3.0654	BASE OPERATIONS

Figure 12. ARMY COST BREAKDOWN STRUCTURE

Chapter XII

SUMMARY

The intent of this paper was to develop new and revised support cost factors for equipment that DCA is planning to acquire and field in the future. In the process of attempting to locate cost data for appropriate equipment, we found that very little historical data exist for any communications equipment. This is because at present there are no data collection systems for the data needed to develop support costs for communications equipment. In some cases, however, special studies have been done for specific items or systems, and we were able to develop some O&S cost factors based on these data. Cost factors were developed for the following cost elements:

(1) Contractor Training
(2) Test, Peculiar, and Common Support Equipment
(3) System Test and Evaluation
(4) System/Project Management
(5) Data-Technical Support Documentation
(6) Initial Spares and Repair Parts
(7) Transportation of Things
(8) Contractor Maintenance.

In addition, conditions that may cause increases or decreases in the cost factors have been identified whenever possible.

We identified several data collection systems being implemented by the services that will make possible the development of better support cost CERs in the future. In order to make sure that the desired data are collected, DCA should

identify to the services the specific items of equipment for which data are desired. In parallel with this effort, corresponding data on acquisition costs of these items of equipment, quantities purchased, physical characteristics, etc., should be collected from other sources so that CERs relating O&S costs to these other equipment characteristics can be developed.

In examining the present cost categories in DCAC 600-60-1 [1] two cost categories are not included that we feel should be. We recommend that a new chapter/section be included to discuss contractor maintenance. We feel this is important because it is a way of supplying maintenance that is increasingly being examined and utilized. The second chapter/section should discuss software costing. Software is a large dollar item which is receiving increasing visibility. It is also required as a line item in Integrated Logistics Support Cost estimates covered by DODD 5000.39 [19].

We recommend that DCA assist the user by expanding the existing definitions to include more examples of external conditions that affect the factors in the circular. These should be for the user who has more information so he can adjust the factor up or down based on his additional information.

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