USACERL Technical Report P-91/29, Volume I
May 1991

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

Maintenance Resources by Building Use for U.S. Army Installations

Volume I: Main Text

by
Edgar S. Neely
Robert D. Neathammer

This research project provides improved maintenance resource data for use during facility planning, design, and maintenance activities. Data bases have been developed to assist planners in preparing DD Form 1391 documentation, designers in life-cycle cost component selection, and maintainers in resource planning. The data bases are useful to U.S. Army Corps of Engineers (USACE) designers at the district and installation levels,and resource programmers at USACE Headquarters, Army Major Commands, and installations. These research products may also be useful to other Government agencies and the private sector.

This report describes the building task maintenance and repair data bases. It is one of a series of special reports on building maintenance and repair. Volume I is the main text, Volume II is Appendices A through H, and Volume III is Appendices I through P.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1991	Final

4. TITLE AND SUBTITLE

Maintenance Resources by Building Use for U.S. Army Installations

5. FUNDING NUMBERS

RDTE dated 1980
REIMB 1984

6. AUTHOR(S)

Edgar S. Neely and Robert D. Neathammer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratory (USACERL)
2902 Newmark Drive, PO Box 4005
Champaign, IL 61824-4005

8 PERFORMING ORGANIZATION REPORT NUMBER

TR P-91/29

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

HQUSACE
ATTN: CEHSC-FM-R
20 Massachusetts Avenue, NW
Washington DC 20001

Office of the Chief of Engineers
ATTN: DAEN-ZCF-R
Pentagon
Washington DC 20310

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This research project has provided improved maintenance resource data for use during facility planning, design, and maintenance activities. Data bases and computer systems have been developed to assist planners in preparing DD Form 1391 documentation, designers in life-cycle cost component selection, and maintainers in resource planning. The data bases and computer systems are being used by U.S. Army Corps of Engineers (USACE) designers at the District and installation levels and by resource programmers at USACE Headquarters, and Army Major Commands and installations. These research products may also be useful to other Government agencies and the private sector.

This report describes the building task maintenance and repair data base. It is one of a series of special reports on building maintenance and repair. Volume I is the main text, Volume II is Appendices A through H, and Volume III is Appendices I through P.

14. SUBJECT TERMS			15. NUMBER OF PAGES
data bases	facilities	maintenance	30
life-cycle costs	cost analysis		16. PRICE CODE

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

FOREWORD

This research was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) and the Office of the Assistant Chief of Engineers under various research, development, testing, and evaluation (RDTE) and reimbursable funding documents. Work began under RDTE funding in 1980 and with reimbursable projects in 1984. The technical monitor for the RDTE part was Mr. Greg Tsukalas (CEHSC-FM-R) and for the reimbursable part was Ms. Val Corbridge (DAEN-ZCF-R).

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The Principal Investigators were Dr. Edgar Neely and Mr. Robert Neathammer (USACERL-FS). Dr. Michael O'Connor is Chief of USACERL-FS. Technical editing support was provided by Ms. Linda Wheatley, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

CONTENTS

SF298 1
FOREWORD 2

1 INTRODUCTION 5
Background
Research Performed and Reports Published
Objectives
Approach
Scope
Mode of Technology Transfer

2 PROBLEM DEFINITION 12

3 DATA BASE DEVELOPMENT 13
Introduction
Facility Groupings
Modeling of Buildings
Individual Building Calculation Process

4 DATA ANALYSIS 15
Introduction
Average Building Costs per Square Foot
Average Building Costs per Square Foot by Current Use
Average Replacement Task and Other Task Cost per Square Foot by Current Use
Unit Resources by Engineering System
Engineering System Cost Analysis
High Cost Component Analysis
High Cost Task Analysis
Statistical Evaluation Data

5 CONCLUSION 21
Data Bases
High Cost Components and Tasks
Army Standard Resource Predictions Versus Actual Requirements

REFERENCES 22

ACRONYMS 23

DISTRIBUTION

MAINTENANCE RESOURCES BY BUILDING USE FOR U.S. ARMY INSTALLATIONS

1 INTRODUCTION

Background

Maintenance* and repair (M&R) cost estimates are needed during planning, design, and operations/maintenance of Army facilities. During planning, life-cycle costs are needed to evaluate alternatives for meeting requirements (e.g., lease, new construction, renovate existing facilities). During design, M&R requirements for various types of components, such as built-up or shingle roofs, are needed so that the life-cycle cost can be minimized. Finally, once the facility has been constructed, outyear predictions of M&R costs are needed so that enough funds can be programmed to ensure Army facilities do not deteriorate from lack of proper maintenance.

The Directorate of Engineering and Construction (EC), Headquarters, U.S. Army Corps of Engineers (HQUSACE)**, asked the U.S. Army Construction Engineering Research Laboratory (USACERL) to coordinate the assembly of a single, centralized M&R data base for use by Corps designers. This research was required because reliable M&R data from installations and technical literature was not available for designers to support their life-cycle cost (LCC) analysis. One of the first research tasks was to determine if reliable data bases, adaptable for Corps use, existed in Government or private industry. Comprehensive data bases of maintenance costs for Government and private sector facilities did not exist. The little data available depended on widely varying standards of maintenance used on facilities for which the data was collected and thus was unreliable for prediction purposes. Recognizing this, HQUSACE asked USACERL to develop an M&R cost data base. This data is for U.S. Army Corps of Engineers (USACE) designers to use in performing life-cycle cost analyses during the design of new facilities. Initial results were presented in two USACERL reports.[1]

Soon after this request, the Facilities Programming and Budgeting Branch of the Facilities Engineering Directorate asked USACERL to develop prediction models for outyear maintenance requirements of the Army facility inventory. The Programming Office of EC—responsible for Military Construction, Army (MCA) planning—also requested that USACERL provide methods and automated tools to help installations perform economic analyses. Part of the objective was to allow analysts to obtain future maintenance cost data.

---

*Maintenance in this report means all work required to keep a facility in good operating condition; it includes all maintenance, repair, and replacement of components required over the life of a facility.

**At the time of this request, EC was part of the Office of the Chief of Engineers, which has since reorganized. EC is now the Directorate of Military Programs (MP).

[1] R.D. Neathammer, *Life-Cycle Cost Database Design and Sample Cost Data Development*, Interim Report P-120/ADA0997222 (U.S. Army Construction Engineering Research Laboratory [USACERL], February 1981); R.D. Neathammer, *Life-Cycle Cost Database: Vol I, Design*, and *Vol II, Sample Data Development*, Technical Report P-139/ADA126644 and ADA126645 (USACERL, January 1983), Appendices E through G.

In response to these requests, USACERL began a multiyear effort to develop a comprehensive M&R cost research program for buildings. This program is the key to all detailed estimation of future maintenance costs for Army facilities.

Research Performed and Reports Published

This is one of several interrelated reports addressing maintenance resource prediction in the facility life-cycle process. The total research effort is described in a USACERL Technical Report.[2]

The first research product was a data base containing maintenance tasks related to every building construction component. This data base provides labor, material, and equipment resource information. The frequency of task occurrence is also included. This information is published in a series of four USACERL Special Reports covering engineering systems: (1) architectural, (2) heating, ventilating, and air-conditioning (HVAC), (3) plumbing, and (4) electrical. The title for the series is *Maintenance Task Data Base for Buildings*.[3] Table 1 shows an example from this data base. This data is also available in electronic form. The data base is used on a personal computer with the Disk Operating System (DOS). This computer program allows a facility to be defined by entering the components and component quantities comprising the facility. The maintenance tasks for each component are used to determine the labor hour, equipment hour,and monetary resources required annually to keep the facility maintained.

The second research product was a component resource summary for the first 25 years of a facility. The tasks for the component were scheduled and combined into one set of annual resource requirements. This annual resource information is published in a series of four USACERL Special Reports titled *Building Component Maintenance and Repair Data Base*.[4] An example from this data base is shown in Table 2. The data base—also available in electronic form—can be used for special economic analyses (i.e., for a 20-year life using a 10 percent discount rate).

The third research product was a set of 25-year present worth factor tables for designers to use in selecting components for discount rates of 7 and 10 percent. The annual component resource values were multiplied by the appropriate present worth factor and added for the 25 years to produce one set of resource values. This information is published in a series of four USACERL Special Reports titled

---

[2] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Resource Prediction in the Facility Life-Cycle Process*, Technical Report P-91/10 (USACERL, March 1991).

[3] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/21 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Plumbing Systems*, Special Report P-91/18 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Electrical Systems*, Special Report P-91/25 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Architectural Systems*, Special Report P-91/23 (USACERL, May 1991).

[4] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Architectural Systems*, Special Report P-91/27 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/22 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Plumbing Systems*, Special Report P-91/30 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Electrical Systems*, Special Report P-91/19 (USACERL, May 1991).

Table 1

Typical Task Data Form

Task Code: 0311356

Component: SHINGLES System: ROOFING Subsystem: ROOF COVERING

Task Desription: REPLACE NEW OVER EXISTING - SHINGLED ROOF

Unit of Measure: SQUARE FEET Frequency of Occurence: H: 18.00 A: 20.00 L: 22.00
Once every (H,A,L) years

Persons per Team: 4 Task Duration: 4.5175 hours

Trade: REFRIG./AIR COND. Task Classification: 1

Labor Resources

Subtask Description	
1. SETUP/SECURE/TAKE DOWN LADDER	0.000160
2. REPLACE WITH NEW SHINGLE	0.012887
3. CLEAN UP	0.010000
4. REMOVE/REPLACE CONDENSER TUBE	0.900000

Material Resources

Description	Quantity	Unit Cost
SHINGLE	1.0 SF	0.2600
MASTIC	1.0 SF	0.1500
		0.4100

SUMMARY

Resources UOM	Direct	Indirect	Total
Labor Hours	0.023047	0.006914	0.029961
Material Cost $	0.410000		0.410000
Equipment Hours			0.014981

Table 2

Typical Component Summary

CACES No.: 031134 - Roll Roofing				031135 - Shingles		
Labor Hours	Materials $	Equipment Hours	YR	Labor Hours	Materials $	Equipment Hours
0.0076	0.0165	0.0039	1	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	2	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	3	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	4	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	5	0.0032	0.0330	0.0017
0.0090	0.0165	0.0046	6	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	7	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	8	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	9	0.0026	0.0220	0.0014
0.0414	0.7496	0.0207	10	0.0032	0.0330	0.0017
0.0076	0.0165	0.0039	11	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	12	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	13	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	14	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	15	0.0034	0.0330	0.0018
0.0090	0.0165	0.0046	16	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	17	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	18	0.0026	0.0220	0.0014
0.0090	0.0165	0.0046	19	0.0024	0.0220	0.0013
0.0414	0.7496	0.0207	20	0.0332	0.4675	0.0167
0.0076	0.0165	0.0039	21	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	22	0.0024	0.0220	0.0013
0.0090	0.0165	0.0046	23	0.0024	0.0220	0.0013
0.0076	0.0165	0.0039	24	0.0026	0.0220	0.0014
0.0076	0.0165	0.0039	25	0.0032	0.0330	0.0017

All data is per square foot of roof area.

Building Maintenance and Repair Data for Life-Cycle Cost Analyses.[5] Table 3 shows an example from this data base, which is also available in electronic form. The first three resource columns provide data to allow designers to calculate the life-cycle costs at any location by multiplying by the correct labor rate, equipment rate, and material geographic factor. The multiplication and addition have been performed for the Military District of Washington, DC, and results are given in the fourth column of the table. The right section of the table is information that can be entered into computer systems that perform life-cycle cost analysis.

A fourth research product was a PC system that allows facilities to be modeled by entering the components that comprise the facility.* Future years' resource predictions are produced by applying the individual tasks and then forming resource summaries by subsystems, systems, facilities, installations, reporting installations, Major Commands (MACOMs), and Army. A summary level computer system was also developed for the Department of the Army (DA) and MACOMs. The summary level system uses the most basic data contained in the current facility real property inventory files: (1) current facility use, (2) floor area, and (3) construction date. User's manuals have been published as USACERL ADP Reports.[6]

This report is the fifth research product. It describes data bases that have been developed to predict maintenance resources by building use.

Objectives

The objectives of this report are to describe the different data bases available for estimating maintenance resources by building use and to define the components and tasks that are the highest in cost over the building life.

Approach

The first task in the research project was to calculate the cost to maintain each individual building modeled according to Army maintenance standards. All buildings at Forts Bragg, NC; Leonard Wood, MO; Devens, MA; and Ord, CA were modeled and resource calculations predicted for the first 80 or 120 years of the building's life. Buildings were modeled by measuring the quantity of each component within each building.

---

[5] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Architectural Systems*, Special Report P-91/17 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/20 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Plumbing Systems*, Special Report P-91/24 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Electrical Systems*, Special Report P-91/26 (USACERL, May 1991).

* The Maintenance Resource Prediction Model is currently supported by USACERL Facility Systems Division but will be transferred to USAEHSC in FY91.

[6] E.S. Neely, R.D. Neathammer, and J.R. Stirn, *Maintenance Resource Prediction Model (MRPM) User's Manual*, ADP Report P-91/02/ADA229150 (USACERL, October 1990); E.S. Neely, *Maintenance Resource Prediction Model Summary System (MRPMSS) User's Manual*, ADP Report P-91/03/ADA228907 (USACERL, October 1990).

Table 3

Life-Cycle Cost Analysis

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)

COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%)				PRESENT MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS						
		By Resources			Washington D.C. Total	Annual Maintenance and Repair			Replacement and High Costs Tasks			
	um	labor	material	equipment		labor	material	equipment	Yr	labor	material	equipment
ARCHITECTURE												
ROOFING												
ROOF COVERING												
BUILTUP ROOFING	SF	0.03987	0.37166	0.01994	1.25	0.00487	0.03167	0.00244	28	0.04938	0.70490	0.02469
PLACE NEW MEMBRANE OVER EXISTING–BUILDUP									14	0.02414	0.69960	0.01207
MOD. BIT./THERMOPLASTIC	SF	0.02415	0.33009	0.01208	0.86	0.00245	0.03218	0.00123	20	0.05659	0.85860	0.02829
THERMOSETTING	SF	0.01687	0.23941	0.00833	0.61	0.00173	0.02202	0.00086	20	0.03683	0.69960	0.01841
SLATE	SF	0.01809	0.10432	0.00904	0.50	0.00253	0.01458	0.00126	70	0.06885	6.04200	0.03442
CEMENT ASBESTOS	SF	0.01760	0.24341	0.00881	0.63	0.00246	0.03403	0.00123	70	0.05437	0.75190	0.02718
TILE	SF	0.01519	0.20982	0.00759	0.54	0.00212	0.02933	0.00106	70	0.10169	3.07400	0.05084
ROLL ROOFING	SF	0.07155	0.42684	0.03578	2.01	0.00757	0.01556	0.00378	10	0.04141	0.74963	0.02070
SHINGLES	SF	0.02222	0.22137	0.01111	0.71	0.00262	0.02383	0.00131	40	0.04118	0.74497	0.02059
REPLACE NEW OVER EXISTING–SHINGLED ROOF									20	0.02996	0.43460	0.01498
METAL	SF	0.01422	0.11058	0.00711	0.42	0.00199	0.01546	0.00099	30	0.36265	2.17300	0.18132
FIBERGLASS RIGID STP. RCOF	SF	0.02161	1.15262	0.01080	1.63	0.00228	0.06266	0.00114	20	0.04543	6.01550	0.02272
CONCRETE, SEALED PANEL ROOF	SF	0.04260	0.11748	0.02131	1.06	0.00596	0.01642	0.00298	60	0.06123	24.07419	0.03061
CONCRETE, SEALED PANEL RF4	SF	0.03950	0.08408	0.01974	0.96	0.00552	0.01175	0.00276	300	0.04342	24.07419	0.02171
CONCRETE, SEALED POURED	SF	0.09872	0.62996	0.04936	2.81	0.01380	0.08807	0.00690	500	3.81056	18.03219	1.90528
FIBERGLASS, RIGID ROOF	SF	0.03832	1.15262	0.01915	2.00	0.00468	0.06266	0.00234	20	0.04133	6.01550	0.02066

See NOTES on the last page of this table for Explanation of Column Headings

The next task was to group the buildings by current use. The resources for the individual buildings were averaged to form several different summary data bases. Each summary data base was designed to be used with different levels of information that is currently available in the Army Integrated Facilities System (IFS) data base.

The third task was to determine the high cost components and tasks for all buildings and for each functional use group. The high cost tasks and components for the total building sample was compared with the summary from each installation to determine similarities and differences between installations.

Scope

The scope of this project includes all buildings that would be found within a typical Army installation. Historic and production facilities have not been addressed in this research project.

Mode of Technology Transfer

The tables pertinent to designer use will be issued as a supplement to Department of Army Technical Manual (TM) 5-802-1, *Economic Studies for Military Construction Design—Applications.* Portions of the data base will be integrated into the Corps of Engineers Cost Estimating System (CACES) and the DD Form 1391 Processor System. Data can be used to provide cost estimates for the Unconstrained Requirements Reports (URR) produced by the installations.

2 PROBLEM DEFINITION

In the facility life-cycle process, costs are incurred in construction, operation, maintenance, and disposal of a facility. Past emphasis during the planning, design, and construction phases has been on estimating initial construction costs. The impact of operating and maintaining facilities has always been a secondary consideration. In many cases, the operation and maintenance (O&M) costs are far greater than initial construction costs. Building owners are concerned with the total ownership costs of facilities rather than just the initial construction costs.

The Army realizes the importance of performing total life-cycle cost analyses for facilities at the design stage and accurately forecasting these costs for funds programming. In 1980 HQUSACE asked USACERL to develop a method of estimating future maintenance costs for buildings. In 1982 the programming branch of the former Facilities Engineering Directorate asked USACERL to develop effective models for forecasting facility maintenance resource requirements based on the actual facility.

Life-cycle cost studies are integral to facility design in the MCA program. Requirements for performing these studies are given in:

- Statutes, Code of Federal Regulations, and Executive Orders for performing analyses when energy is a key cost and for wastewater treatment plants[7]
- USACE *Architectural and Engineering Instructions: Design Criteria* (13 March 1987)
- Army Regulation (AR) 11-28, *Economic Analysis and Program Evaluation for Resource Management* for general economic analyses (1981)
- TM 5-802-1, *Economic Studies for Military Construction Design—Applications* (1988)

The main purpose of these studies is to minimize the life-cycle costs of Army facilities.

Initial, operation, and maintenance cost data are needed to perform life-cycle cost analyses on facility designs. Initial costs are usually easy to estimate with existing cost estimating systems such as CACES and standard publications such as Means or Dodge.[8] Operating costs can be estimated by using energy consumption models such as the Corps of Engineers' Building Loads Analysis and System Thermodynamics (BLAST) program or the Trane Company's Trace program. However, accurate estimates of maintenance costs are not available.

There are no comprehensive data bases of maintenance costs for building components either in the private sector or State/Federal Governments. Some historical data is available from the Building Owners' and Managers' Association reports. Within the Army, the IFS contains some historical data; however, it does not have a feature for retaining several types of a building component (e.g., having brick and wood exteriors or three types of floor covering). Moreover, the data in IFS has not been kept current. For example, one installation showed several family housing units as having wood siding when, in fact, they had been covered with aluminum siding several years earlier.

---

[7] Federal Register, Vol 55, No. 224, 20 November 1990; Title 10, Code of Federal Regulations, Part 436A, *Methodology and Procedures for Life Cycle Cost Analyses*; Public Law 95-217, *Clean Water Act*, 27 December 1977.

[8] *Means Site Work Cost Data* (R.S. Means Company, Inc.); *Dodge Construction Systems Costs* (McGraw-Hill).

3 DATA BASE DEVELOPMENT

Introduction

Six installations in the continental United States were selected to participate in this research project. Forts Leonard Wood; Benjamin Harrison, IN; and Sill, OK were selected by U.S. Army Training and Doctrine Command (TRADOC) headquarters. Forts Bragg, Devens, and Ord were selected by U.S. Army Forces Command (FORSCOM) headquarters.

Three tests of the Maintenance Resource Prediction Model (MRPM) system were made at the installations before it was decided to release the system to any installation for optional use. The first test consisted of modeling all family housing and selected unaccompanied personnel housing at the six installations. The MRPM system was found to work very well on housing facilities, but it was unclear if the system would work as well for other current use codes.

The second test consisted of modeling a sample of all other buildings at the six installations. The MRPM system was found to work very well on the sample; but, it was unclear if the system would work as well for an entire installation.

The third test modeled all major buildings at four installations (Forts Bragg, Wood, Devens, and Ord). This test proved that the system could accurately predict resource requirements for a complete installation. Headquarters, Department of Army (HQDA) tasked Forts Bragg and Leonard Wood to compare the MRPM task predictions with the actual tasks performed on each facility. Both installations reported that MRPM identified between 10 and 15 percent more work than was currently being identified. The tasks identified by MRPM but not by the installation were valid tasks that should have been performed to maintain the facilities by Army standards. Both installations stated that the MRPM system was accurate predicting individual building maintenance based on the actual work performed in the past and scheduled for the future. The Army maintenance steering committee recommended that the individual facility component MRPM system be made available to installations on a voluntary basis.

The steering committee believed that the Army would not invest the resources required to model buildings at additional installations. The steering committee wanted to gain as much useful information as possible and be able to apply this information to the entire Army inventory of building facilities. The only mandatory information available in the Army's IFS data base that is used by the model is: (1) the current use, (2) the construction year, and (3) the floor area. A summary MRPM system was developed to use the three items. Summaries of the detailed building resources were developed as described in this report.

The primary objective of the summary system is to predict the resources required to maintain a building to Army standards. Even though the Army is not maintaining its buildings according to Army standards, it is not the objective of the model to predict resources based upon the current method of maintenance, nor to address the problems that could occur if the required maintenance is not performed. The objective is to have the Army determine the one-time cost to bring a building up to standards and then use MRPM to predict the resources required to maintain the building in standard operating order.

Facility Groupings

The Army identifies the current use of every facility through a numerical coding system named the Facility Classes and Construction Categories Codes or F4C. This five-digit code identifies the building not only by use (e.g., administration building), but by occupant of the building (e.g., company administration building). Research performed for the Long Range Stationing Study and the Real Property Planning System (RPLANS) has shown that certain buildings can be used for many different functions with no alterations. These similar buildings have been combined into functional group codes as shown in Appendix A. Appendix B lists each current use code and the associated functional group code. The functional group codes are used in this research project to be consistent with the other Army systems.

Modeling of Buildings

Complete quantity surveys were performed by contract with Pennsylvania State University. Up to date as-built drawings were not available at the installations, so the quantity surveys were performed by walking through the buildings. Every building component, including light switches and plug outlets, was counted and stored for each building. The components and their quantities were entered into the MRPM computer system.

The summary model assumes that all maintenance tasks for a group of components, such as hollow core wooden doors, will be performed on the average frequency specified in the detailed task data base. The system also assumes that the individual tasks for this group of components will be uniformly scheduled between the low and high frequencies given for each task.

Individual Building Calculation Process

Each installation's actual labor shop effective rates and equipment dollar per hour charge rates were used in the calculations. The Washington, DC, material prices stored in the MRPM system were adjusted by the installation's location adjustment factor (given in Appendix C) to obtain local material costs.

Labor hour, equipment hour, material cost, labor cost, equipment cost, and total cost resource calculations were performed for the first 120 years for each building. Resources for each task were calculated and summarized for each component. Resource summaries were formed for the subsystem, system, and total facility.

All facility cost data at each installation were normalized to the Washington, DC, area by division and the appropriate location adjustment factors given in Appendix C. A summary analysis was performed for all buildings regardless of current use. The buildings were also grouped by the functional group codes shown in Appendix A. A separate analysis was performed for each functional group code.

4 DATA ANALYSIS

Introduction

The first objective was to develop several data bases. Each data base requires different information to be known before the data base can be applied. Data bases were developed to allow maintenance resource predictions with these conditions:

1. Predict an annual cost when only the building floor area is known.

2. Predict an annual cost when the floor area and the current functional use is known.

3. Predict an annual cost when the floor area, current use, and age of the facility are known. Report the costs by two categories: replacement tasks and all other tasks combined.

4. Predict the total labor hours, equipment hours, labor cost, material cost, and equipment cost when the floor area, current use, age, and average cost for labor and equipment per hour are given.

5. Predict the labor hours, equipment hours, labor cost, material cost and equipment cost when the floor area, current use, age, and individual shop costs for labor and equipment per hour are given.

The second objective was to determine the components and tasks assumed to be the cost drivers in building maintenance. This information could be used to determine the least amount of building data necessary to develop accurate resource predictions. This information could also be used to identify possible areas of future research to reduce total building maintenance cost. An analysis is required by engineering system, component, and task levels.

Average Building Costs per Square Foot

The total costs for all years for all buildings were added and then divided by the total square footage of all buildings, providing the average total cost per square foot reported on the first row in Table 4. When the only information available about a building is the square footage, the dollars per square foot reported for all buildings in Table 4 can be multiplied by the square footage to produce a cost estimate.

Average Building Costs per Square Foot by Current Use

Each of the 34 functional group codes was analyzed. The total costs for all years for all buildings having the same current use group code were added and then divided by the total square footage of all buildings in the functional group to produce the average total cost per square foot reported in Table 4. If the current use of the building and the square footage are available, the dollars per square foot for the correct current use code can be multiplied by the square footage to produce a cost estimate.

Table 4

Average Cost per Square Foot by Facility Type

Current Use Code	Facility Description	Cost Per Sq Ft
-----	All buildings	1.80
1712000	General instruction buildings	1.51
1713000	Applied instruction buildings	1.41
2111000	Aviation unit maintenance hangars	2.01
2141000	Organizational vehicle maintenance facilities	1.67
2142000	DS/GS vehicle maintenance shop	1.80
2180000	Special purpose maintenance shops	2.81
2190000	Maintenance - installation O&R	2.15
4210000	Ammunition storage facilities	0.64
4300000	Cold storage facilities	2.40
4420000	General purpose warehouse	0.97
5101000	Hospital	1.41
5401000	Dental clinic	2.74
5501000	Health clinic	2.37
6105000	General purpose admin.	2.37
7111100	Family housing 1900-1950	1.99
7111200	Family housing 1951--	1.38
7112000	Family housing (Capehart)	2.51
7113000	Family housing (Wherry)	2.70
7210000	UPH enlisted personnel	1.39
7218000	Trainee barracks	1.18
7220000	UPH dining facilities	1.57
7240000	UPH officers	1.62
7301000	Community fire station	1.90
7302000	Chapel center facilities	2.41
7401000	Auditorium/theatre facility	1.83
7401100	Bowling center	1.15
7401400	Child support center	2.44
7402100	Commissary	1.50
7402200	Arts and crafts center	1.30
7402500	Continuing education facility	0.97
7402800	Physical fitness center	1.50
7403200	Transient housing facilities	2.33
7404600	Consolidated open dining facility	1.56
7405300	Community retail store	1.41

Average Replacement Task and Other Task Cost per Square Foot by Current Use

Each of the 34 functional group codes was analyzed. The total cost for all replacement and high cost tasks were added to form one cost figure for each year or facility age. This total cost is known as the major replacement and high cost tasks (MRT). The total cost for each year was divided by the total floor area to produce dollar per square foot per year figures.

The total cost for all other tasks (all nonreplacement and all nonhigh-cost tasks) were added together to form one cost figure for each year or facility age. The total cost for each year was divided by the total floor area to produce dollar per square foot per year figures. This cost is known as the annual recurring maintenance cost (ARM). The steering committee voted to change the individual year values into a constant figure by averaging the data for years 11 through 80. The first 10 years were not included because the steering committee believed that the costs incurred to correct deficiencies in the original construction was comparable to the annual recurring maintenance average. Tables and graphs containing this data are shown in Appendices D and E, respectively. Both Appendices D and E are arranged by a two character unit cost identification (ID). Appendix A relates the two character IDs to the current use codes. The unit cost ID is listed in the Total Unit Cost ID column.

The analysis was performed for two additional categories. The total was divided into: (1) temporary, and (2) permanent and semipermanent buildings. This data is also shown in Appendices D and E.

Three pieces of facility information: (1) current use, (2) construction date, and (3) floor area, can be applied to the MRT and ARM unit costs to produce total cost figures. The addition of a fourth item, the type of construction (permanent, semipermanent, or temporary), allows the use of the more detailed data.

Unit Resources by Engineering System

Annual labor hours, equipment hours, and material costs were calculated by engineering system. The results are given in Appendix F. The actual shop effective labor hour and equipment hour charge rates can be applied in the calculations in addition to the three data items of (1) current use, (2) construction year, and (3) floor area.

The labor hours can be used to determine manpower loading for in-house and contract personnel. They can also be used to predict the probable level of contracting years, enabling the contracting office to plan its staffing requirements.

Engineering System Cost Analysis

Each of the current use facility groups was analyzed separately and a total analysis was performed for all buildings in the research program. Tables containing the engineering system labor hours, material cost, and equipment hours are shown in Appendix F. The tables are presented by functional group codes.

The average system cost percentages are summarized by functional groups in Table 5.

Table 5

Percentage of Cost by Engineering System

Current Use Code	Facility Description	03 Roofing	04 Exterior Closure	05 Interior Constr.	06 Interior Finishes	08 Plumbing	09 HVAC	11 Interior Elec.	12 Spec Int Elec Sys
----	All buildings	11.3	11.5	6.8	24.3	14.1	20.1	10.1	1.9
1712000	General instruction buildings	21.33	15.00	2.68	17.39	7.63	20.36	12.18	3.43
1713000	Applied instruction buildings	16.33	9.38	3.68	23.86	7.06	22.47	15.02	2.22
2111000	Aviation unit maint hangars	19.15	8.23	1.42	37.78	7.71	12.64	11.36	1.42
2141000	Org vehicle maint facilities	18.50	12.96	1.53	18.38	9.12	21.76	13.42	4.33
2142000	DS/GS vehicle maintenance shop	19.36	6.02	.94	13.32	6.62	33.73	19.16	.85
2180000	Special purpose maintenance shops	24.38	7.43	1.00	23.71	6.12	18.01	15.83	3.51
2190000	Maintenance - installation O&R	15.29	7.75	2.41	16.29	9.02	36.55	11.62	1.07
4210000	Ammunition storage facilities	35.17	14.60	.15	34.29	.28	.42	14.80	.30
4300000	Cold storage facilities	11.96	4.70	1.60	13.95	4.20	47.67	15.71	.20
4420000	General purpose warehouse	28.49	13.25	1.84	25.20	5.50	15.63	8.50	1.60
5101000	Hospital	7.08	5.89	6.93	24.88	9.75	28.73	13.50	3.23
5401000	Dental clinic	10.37	4.08	5.58	14.72	19.64	27.05	17.28	1.26
5501000	Health clinic	12.57	4.90	9.03	18.60	14.59	25.52	12.58	2.21
6105000	General purpose admin.	10.58	15.58	3.81	26.61	9.66	19.80	12.17	1.79
7111100	Family housing 1900-1950	5.76	18.78	5.72	25.54	18.05	17.56	7.65	.93
7111200	Family housing 1951--	8.83	11.53	7.63	31.14	16.73	15.83	7.82	.49
7112000	Family housing (Capehart)	10.63	11.35	9.36	23.38	17.04	18.17	8.88	1.19
7113000	Family housing (Wherry)	9.36	12.36	6.41	25.68	21.41	13.81	10.14	.83
7210000	UPH enlisted personnel	7.73	10.66	7.94	23.65	13.04	24.09	10.06	2.84
7218000	Trainee barracks	8.00	4.12	5.44	25.50	13.50	27.49	10.87	5.09
7220000	UPH dining facilities	11.81	12.40	2.70	15.16	8.79	35.15	11.35	2.64
7240000	UPH officers	5.93	10.87	15.48	19.54	16.56	19.78	9.97	1.88
7301000	Community fire station	13.42	13.00	2.90	14.72	11.80	20.27	8.81	2.90
7302000	Chapel center facilities	10.01	12.46	6.80	25.37	6.24	27.45	10.68	.99
7401000	Auditorium/theatre facility	14.57	10.94	2.18	18.13	6.43	29.57	11.80	6.37
7401100	Bowling center	25.27	4.15	2.29	22.78	8.80	22.42	12.24	2.03
7401400	Child support center	22.56	9.63	7.95	19.88	13.76	13.11	7.48	5.64
7402100	Commissary	25.83	5.20	1.13	18.18	4.64	25.11	10.81	9.11
7402200	Arts and crafts center	19.78	4.94	3.77	13.45	7.12	30.24	17.45	3.24
7402500	Continuing education facility	17.09	12.51	3.97	20.81	8.23	24.13	12.85	.42
7402800	Physical fitness center	17.58	9.69	1.50	37.61	8.08	16.24	7.83	1.48
7403200	Transient housing facilities	7.55	8.24	6.91	22.88	13.22	22.75	9.22	9.23
7404600	Consolidated open dining facility	12.39	6.98	5.02	21.38	7.14	26.85	11.48	8.75
7405300	Community retail store	16.20	8.53	3.62	23.43	6.16	23.69	15.96	2.40

Appendix G lists the systems from the highest cost for all buildings to the lowest cost system. The individual installation rankings and percentage of total cost are shown in the remaining columns of the table. This information is provided to show the variation between the individual installations in both ranking and percentages.

Analysis of the data for all buildings shows "interior finishes" has the largest percentage of cost at 24.3 percent. HVAC is a close second with 20.1 percent. The other systems are very close to one another, especially when special and interior electrical are added for a total of 12.0 percent.

Ranking of individual systems is fairly consistent from installation to installation. The percentages are very close for the interior finishes as well as most of the other systems, indicating that the average is a good indicator at the installation level.

High Cost Component Analysis

Each current use facility group was analyzed separately and a total analysis was performed for all buildings in the research program. Appendix I lists all component and task descriptions covered in the data base. Appendix J lists all components from the highest to the lowest percentage over the period for all buildings. This appendix is useful when it is necessary to determine the high cost components. Appendix K contains the same percentage data given in component order. This appendix is useful when the percentage for one specific component is desired.

Tables containing the high cost components for the functional groups are shown in Appendix L. The first table in the appendix contains the high cost components for all buildings. The remaining tables are presented by individual functional use codes. This information can be used to justify future research projects that address possible resource reductions through technology advances, productivity improvements, and cost reductions.

An analysis was performed for each functional use code. The total cost for each component during the first 120 years of building life was calculated for each individual installation and for the combination of all installations. The components were listed from the highest to the lowest cost component. The components costing more than 1 percent of the total cost for the combination of all buildings are listed first, with the percentage of the total cost shown in the third column.

The individual installation rankings and percentage of total cost are shown in the remaining columns of the table. This information is provided to show the variation between the individual installations in both ranking and percentages.

The five highest cost components for all buildings vary between 3 and 5 percent of the total cost. The 23 components that have percentages greater than 1 percent account for 46.50 percent of the total cost. Most components have very little effect on the total cost of the facility. A comparison of the individual installation rankings and percentages with the totals shows a large variation. The average data can be used to show trends throughout the Army but should not be used to determine actual installation trends.

Several components cost less than 1 percent for the combination but greater than 1 percent for an individual installation. These components are listed last. The percentage of the total is not recorded for these components.

High Cost Task Analysis

Each of the current use facility groups was analyzed separately and a total analysis was performed for all buildings in the research program. Appendix I lists all component and task descriptions covered in the data base. Appendix M contains a complete listing of all tasks from the highest percentage over the period to the lowest percentage for all buildings. This appendix is useful when it is necessary to determine the high cost tasks. Appendix N contains the same percentage data given by task order. This appendix is useful when the percentage for one specific task is desired. Tables containing the high cost tasks are shown in Appendix O. The first table in the appendix contains the high cost tasks for all buildings. The remaining tables are presented by individual functional use codes. This information can be used to justify future research projects that address possible resource reductions through technology advances, productivity improvements, and cost reductions.

An analysis was performed for each functional use code. The total cost for each task during the first 120 years of building life was calculated for each individual installation and for the combination of all installations. The tasks were listed from the highest to the lowest cost task. The tasks costing more than 1 percent of the total costs for the combination of all buildings are listed first, with the percentage of the total cost shown in the third column.

The individual installation rankings and percentage of total cost are shown in the remaining columns of the table. This information is provided to show the variation between the individual installations in both ranking and percentages.

The six highest cost tasks for all buildings vary between 2 and 4 percent of the total cost. The 18 tasks that have percentages greater than 1 percent account for 27.10 percent of the total cost. Most tasks have very little effect on the total cost of the facility. A comparison of the individual installation rankings and percentages with the totals shows a large variation. The average data can be used to show trends throughout the Army but should not be used to determine actual installation trends.

Several tasks cost less than 1 percent for the combination but greater than 1 percent for an individual installation. These tasks are listed last. The percentage of the total is not recorded for these tasks.

Statistical Evaluation Data

The unit costs were developed by Richardson and Kirmse, Inc., Roanoke, VA. The statistical evaluation data is given in Appendix P. Data includes the age of the building, the mean value for the unit costs, the standard deviation, and the 90 percent confidence level.

5 CONCLUSION

The Army has several different data bases that allow the average resource requirements to be estimated based on the limited amount of data available in the Army IFS data base. Further research to consider other factors not available in the IFS data base, but easily available to the installation, could improve resource predictions. Research into several areas is scheduled during 1991.

Data Bases

Each of the summary data bases developed from the individual facilities studied in this research program can be used to predict the average resources required to maintain a building according to Army standard maintenance procedures. This data can be used during development of planning documents such as DD Form 1391. The data can also be used to predict future resource requirements within the installation Directorate of Engineering and Housing.

Research scheduled for 1991 will modify the average figures to account for such factors as:

1. Travel distances from shop to buildings

2. Weather factors such as:
   - Temperatures
   - Freeze-thaw cycles
   - Winds
   - Hail storms
   - Sand storms
   - Precipitation

3. Installation maintenance program

4. Occupant effects including:
   - Hard use
   - Abuse
   - Vandalism

Additional research to determine the effects of the variance of task frequency, labor hours, equipment hours, and material costs will begin in 1991.

High Cost Components and Tasks

The high cost component and task data bases can be used as a starting point to determine possible areas for new research. A researcher can explore the probability of success of a new research venture in the high cost task or component area. The probability can be multiplied by the percentage of costs to determine the probable cost savings from the new research. If this approach is used by all research projects in an organization, a rational approach to scheduling research could be developed.

Army Standard Resource Predictions Versus Actual Requirements

The basic premise underlying this research is that the Army can bring a building up to standards by the application of a one-time expenditure of funds and then use the MRPM data bases to predict the costs to keep the building maintained to Army maintenance standards. In reality buildings may not be up to Army standards and are not maintained to Army standards.

Research is needed to determine the actual variations between the standards and actual field practices. The activities and resources required to perform this research will be identified during 1991.

REFERENCES

Dodge Construction Systems Costs (McGraw-Hill).

Federal Register, Vol 55, No. 224, 20 November 1990.

Means Site Work Cost Data (R.S. Means Company, Inc.).

Neathammer, R.D., *Life-Cycle Cost Database Design and Sample Cost Data Development*, Interim Report P-120/ADA0997222 (U.S. Army Construction Engineering Research Laboratory [USACERL], February 1981).

Neathammer, R.D., *Life-Cycle Cost Database: Vol I: Design* and *Vol II: Sample Data Development*, Technical Report P-139/ADA126644 and ADA126645 (USACERL, January 1983), Appendices E through G.

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Resource Prediction in the Facility Life-Cycle Process*, Technical Report P-91/10 (USACERL, March 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/21 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Plumbing Systems*, Special Report P-91/18 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Electrical Systems*, Special Report P-91/25 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Architectural Systems*, Special Report P-91/23 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Architectural Systems*, Special Report P-91/27 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/22 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler *Building Component Maintenance and Repair Data Base for Buildings: Plumbing Systems*, Special Report P-91/30 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Electrical Systems*, Special Report P-91/19 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Architectural Systems*, Special Report P-91/17 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/20 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Plumbing Systems*, Special Report P-91/24 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, J.R. Stirn, R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Electrical Systems*, Special Report P-91/26 (USACERL, May 1991).

Neely, E.S., R.D. Neathammer, and J.R. Stirn, *Maintenance Resource Prediction Model (MRPM) User's Manual*, ADP Report P-91/02/ADA229150 (USACERL, October 1990);

Neely, E.S., *Maintenance Resource Prediction Model Summary System (MRPMSS) User's Manual*, ADP Report P-91/03/ADA228907 (USACERL, October 1990).

Public Law 95-217, *Clean Water Act* (27 December 1977).

Title 10, Code of Federal Regulations, Part 436A, *Methodology and Procedures for Life Cycle Cost Analyses.*

ACRONYMS

ARM	annual recurring maintenance cost
BLAST	Building Loads Analysis and System Thermodynamics
CACES	Corps of Engineers Cost Estimating System
DA	Department of the Army
DOS	disk operating system
EC	Directorate of Engineering and Construction
F4C	Facility Classes and Construction Categories Codes
FORSCOM	U.S. Army Forces Command
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	heating, ventilation, and air-conditioning
ID	identification

ACRONYMS (Cont'd)

IFS	Integrated Facilities System
LCC	life-cycle cost
M&R	maintenance and repair
MACOM	major command
MCA	Military Construction, Army
MP	Director of Military Programs
MRPM	Maintenance Resource Prediction Model
MRT	major replacement and high cost task
O&M	operations and maintenance
RDTE	research, development, testing, and evaluation
RPLANS	Real Property Planning System
TRADOC	U.S. Army Training and Doctrine Command
URR	Unconstrained Requirements Reports
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory

DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CEMP-EC
ATTN: CERD-L

USAEHSC
ATTN: CEHSC-FM-R

Fort Belvoir, VA 22060
ATTN: CECC-R

Defense Technical Info, Center 22304
ATTN: DTIC-FAB (2)