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SOFTWARE ENGINEERING PRINCIPLES.(U)
JUL 80 L J CHMURA, P CLEMENTS, C L HEITMEYER

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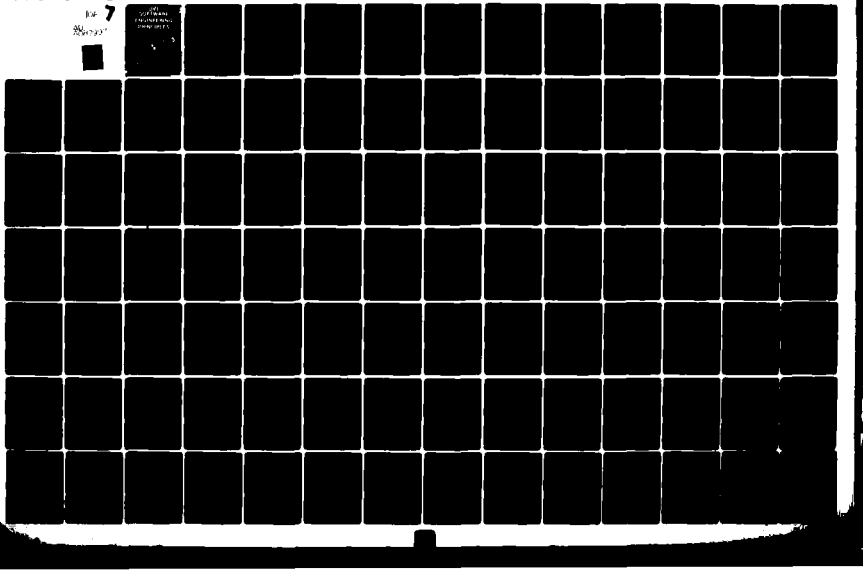

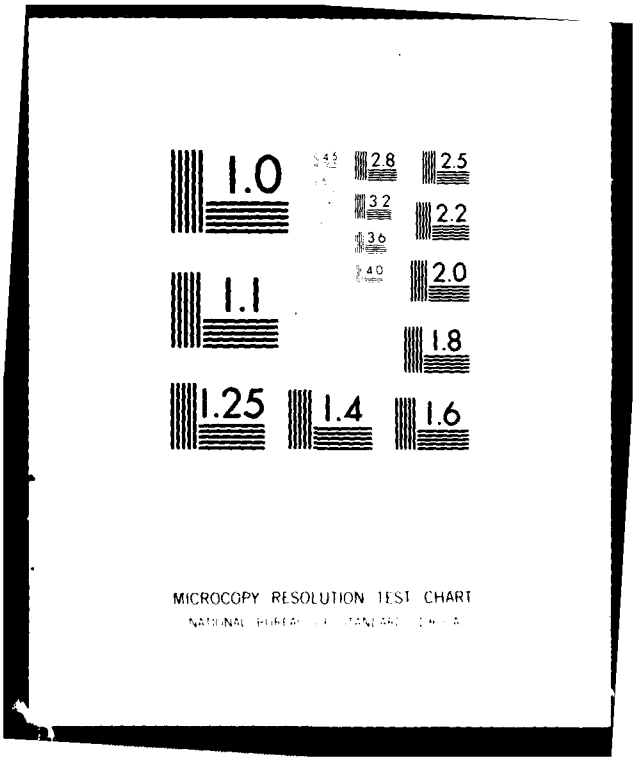
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LEVEL II

SOFTWARE ENGINEERING PRINCIPLES

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Communications Sciences Division
Naval Research Laboratory
Washington, D.C. 20375

Applied Science Department
U.S. Naval Academy
Annapolis, MD 21402

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

This is the notebook from the updated edition of the well-received course originated by the Naval Research Laboratory (NRL) and taught annually for the past five years. It is a two-week technical course for DoD personnel managing a software project or designing software. The purpose of the course is to improve the participant's ability to evaluate software requirements, specifications, design, correctness, and maintainability. Its purpose is not to transform the participant into an expert software designer.

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>The course concentrates on technical problems of software design. It introduces generally accpeted design practices, as well as software design research that may result in practical design practices in the near future. Topics covered include program families, information-hiding modules, hierarchical structures, abstract interfaces, formal specifications, responses to undesired events, documentation, and cooperating sequential processes.

Contents

Preface v
Schedule vii

Section 1 GENERAL

GEN.1 Course Overview 1-1
GEN.2 Personal Experiences 1-9
GEN.3 The A-7 Project 1-13
GEN.4 The MMS Project 1-19
GEN.5 Pseudo-Code Language Description 1-25
GEN.6 Glossary 1-39
GEN.7 Course Review 1-51

Section 2 PROGRAM FAMILIES

PF.1 Program Families: What and Why 2-1
PF.2 MP as a Family of Programs 2-9
*PF.3 MP as a Family of Programs 2-13
PF.4 A Minimal Member of the MP Family 2-15
*PF.5 A Minimal Member of the MP Family 2-19
PF.6 Family Development by Stepwise Refinement 2-21
PF.7 Applying the Program Family Principle 2-37
PF.8 Design Decisions in HAS Requirements 2-47
*PF.9 Design Decisions in HAS Requirements 2-49

Section 3 UNDESIRED EVENTS

UE.1 Desired Responses to Undesired Events 3-1
UE.2 MP and UEs 3-13
*UE.3 MP and UEs 3-15
UE.4 Intermodule Interfaces and UEs 3-17
UE.5 MP Intermodule Interfaces and UEs 3-23
*UE.6 MP Intermodule Interfaces and UEs 3-25
UE.7 The Uses Hierarchy and UEs 3-27

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CONTENTS

Section 4 INFORMATION-HIDING MODULES

MOD.1 Decomposition into Modules 4-1
MOD.2 Change and the Original MP Modular Structure 4-11
*MOD.3 Change and the Original MP Modular Structure 4-13
MOD.4 Modular Structure of Complex Systems 4-15
MOD.5 MP Secrets 4-23
*MOD.6 MP Secrets 4-25
MOD.7 Change and the Improved MP Modular Structure 4-27
*MOD.8 Change and the Improved MP Modular Structure 4-29
MOD.9 Identifying HAS Modules 4-31

Section 5 SPECIFICATIONS

SPEC.1 What are Specifications? 5-1
SPEC.2 Using an Informal Functional Specification 5-15
SPEC.3 Formal Functional Specifications 5-17
SPEC.4 Coding Specifications 5-25

Section 6 ABSTRACT INTERFACE MODULES

ABS.1 Abstract Interface Modules and Their Value 6-1
ABS.2 Using the MP Abstract Interface 6-17
*ABS.3 Using the MP Abstract Interface 6-25

Section 7 HIERARCHICAL STRUCTURES

HIE.1 Hierarchy Survey 7-1
HIE.2 Designing a Uses Hierarchy 7-13
HIE.3 Uses Hierarchy for an Address System 7-27
*HIE.4 Uses Hierarchy for an Address System 7-31

Section 8 LANGUAGE CONSIDERATIONS

LANG.1 Language Selection 8-1
LANG.2 Ada 8-11

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Section 9 PROCESS STRUCTURE

PROC.1 Process Structure of Software Systems 9-1
PROC.2 MP Process Structure 9-13
*PROC.3 MP Process Structure 9-17
PROC.4 Process Synchronization 9-19

Section 10 PROOFS OF CORRECTNESS

CORR.1 Introduction to Proofs of Correctness 10-1

Section 11 DOCUMENTATION

DOC.1 Documentation Guidelines 11-1

Section 12 MESSAGE PROCESSING (MP) SYSTEM

MP.1 The UGH Message Processing (MP) System 12-1
MP.2 MP Basic Modular Structure 12-7
MP.3 MP Detailed Modular Structure 12-13
*MP.4 MP Improved Modular Structure 12-33
*MP.5 MP Message Holder Module 12-37
*MP.6 MP Abstract Interface Module 12-49

Section 13 MILITARY ADDRESS SYSTEM (MADDS)

MADDS.1 The Military Address System (MADDS) 13-1
MADDS.2 MADDS Modular Structure 13-5
*MADDS.3 MADDS Modular Structure 13-7
MADDS.4 Using the Computer System 13-9
MADDS.5 Informal Functional Specifications for MADDS Modules 13-31
MADDS.6 MADDS Input Formats 13-51
MADDS.7 MADDS Output Formats 13-53
MADDS.8 MADDS Implementation Notes 13-55
*MADDS.9 MADDS Program Listings 13-57

*Distributed during course

CONTENTS

Section 14 HOST-AT-SEA (HAS) SYSTEM

HAS.1 The Host-At-Sea (HAS) Buoy System 14-1
HAS.2 HAS Data Acquisition and Transmission Software: Program Design Specification 14-5
*HAS.3 HAS Improved Modular Structure 14-37
HAS.4 A Structured View of HAS 14-43
HAS.5 Academic Poppycock 14-65
HAS.6 Separation of Concerns 14-71
HAS.7 Implementing Processes in HAS 14-77

Section 15 EVALUATIONS

EVAL.1 Comment Sheets 15-1
EVAL.2 Course Evaluation 15-11

Section 16 BIBLIOGRAPHY

BIB.1 Bibliography 16-1

*Distributed during course

Preface

Since 1973, the Information Systems Staff at the Naval Research Laboratory (NRL) has studied many of the managerial and technical problems connected with Navy software acquisition, development, and maintenance. One observation has been that persons responsible for software could benefit greatly from training in state-of-the-art software engineering technology. Another has been that a better job of software design is essential if software is to meet requirements and be maintained inexpensively. These two observations have led to the course "Software Engineering Principles," which addresses some important technical problems concerning software design. First taught in 1976 by NRL, the course is now presented annually by NRL together with the Naval Postgraduate School (NPS).

In "Software Engineering Principles," we introduce some important design principles that encourage production of correct, understandable, and easily changed software products. We also examine some software engineering research that may result in valuable design principles in the near future. The course will not turn you into an expert designer, but should improve your ability to evaluate software proposals, progress, and products. You should also better appreciate design approaches, design problems, and ongoing research.

Coverage of each course topic typically involves lectures, examples, exercises, sample solutions, and exercise discussions. The schedule is rigorous; therefore, we recommend that you summarize the major points raised in each lecture and exercise discussion. We encourage you to ask questions if you are having trouble isolating the major points of a topic or if you are confused by details. You should also challenge statements or sample exercise solutions that seem in error or that do not match your experience. In the past, student questions have led to many lively discussions, cleared up some hidden confusions, and sometimes resulted in changes to course materials.

The following persons have prepared this year's materials.

Louis Chmura
Paul Clements
Constance Heitmeyer
Kathryn Heninger
Jack Littley
David Parnas
John Shore
Janet Stroup
David Weiss

Daniel Jamerson and John Laine of CTEC, Inc. have adapted the course's programming assignment to the Naval Academy's computing environment.

PREFACE

Much of the material derives from earlier versions of the course. Louis Chmura, Kathryn Heninger, David Parnas, John Shore, and David Weiss, together with the following persons, developed those versions.

Honey Elovitz
John Guttag
Richard Hamlet
Cynthia Irvine
Rodney Johnson
Rudolph Krutar
Michael McClellan
Pam Mayo
Lee Nackman
Barbara Trombka
Helen Trop

Max Woods and Ruth Guthrie of NPS's Department of Continuing Education have handled numerous administrative matters connected with the course. The task of making the local arrangements for the presentation of the course in Annapolis has been the responsibility of Gary Westbrook of the Naval Academy.

Preparation of the notebook has been in the general charge of Janet Stroup who was ably assisted by Georgine Spisak, Sarah McCray, and Eleanor Walker. Their work was facilitated by the use of previous versions of the materials prepared by Mses. Stroup, Spisak, and Deborah Hatfield.

"Software Engineering Principles" originated as part of the NRL's Software Engineering Project, which the Naval Electronic Systems Command originally funded under Program Element 62721N, Task XF21-241-021.

Schedule

Day 1, Monday, 14 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders*
0800-0830	Registration			JLS
0830-0930	Course Overview	Lecture	GEN.1	DP
0930-0945	Break			
0945-1015	Personal Experiences	Exercise	GEN.2	DW
1015-1045	Results of Exercise	Discussion		DW
1045-1100	Break			
1100-1130	The A-7 Project	Lecture	GEN.3	DP
1130-1200	The MMS Project	Lecture	GEN.4	CH
1200-1315	Lunch			
1315-1415	Program Families: What and Why	Lecture	PF.1	CH
1415-1430	Break			
1430-1530	The UGH Message Processing (MP) System	Reading and discussion	MP.1	CH, FR
1530-1545	Break			
1545-1615	MP as a Family of Programs	Exercise	PF.2	CH
1615-1645	Results of Exercise	Discussion	PF.3	CH
	Pseudo-Code Language Description	Homework	GEN.5	

*CH: C. Heitmeyer DP: D. Parnas DW: D. Weiss EN: E. Newhire
FR: F. Rat JLS: J. Stroup JS: J. Shore KH: K. Heninger
LC: L. Chmura OD: O. U. DeZeeman PC: P. Clements

SCHEDULE

Day 2, Tuesday, 15 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0830	A Minimal Member of the MP Family	Exercise	PF.4	CH
0830-0900	Results of Exercise	Discussion	PF.5	CH
0900-0930	Pseudo-Code Language Description	Discussion	GEN.5	DW
0930-0945	Break			
0945-1045	Desired Responses to Undesired Events	Lecture	UE.1	DW
1045-1100	Break			
1100-1130	MP and UEs	Exercise	UE.2	DW
1130-1200	Results of Exercise	Discussion	UE.3	DW
1200-1315	Lunch			
1315-1445	Family Development by Stepwise Refinement	Lecture	PF.6	CH
1445-1500	Break			
1500-1530	Applying the Program Family Principle	Lecture	PF.7	CH
1530-1630	Decomposition into Modules	Lecture	MOD.1	DP
	MP Typical Modular Structure	Homework	MP.2 MP.3	

Day 3, Wednesday, 16 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
[illegible]	MP Typical Modular Structure	Discussion	MP.2 MP.3	DP
0830-[illegible]	Change and the Original MP Modular Structure	Exercise	MOD.2	DP
0900-0930	Results of Exercise	Discussion	MOD.3	DP
0930-[illegible]	Break			
0945-1045	Modular Structure of Complex Systems	Lecture	MOD.4	DP
1045-1100	Break			
1100-1130	MP Secrets	Exercise	MOD.5	LC
1130-1200	Results of Exercise	Discussion	MOD.6	LC
1200-1315	Lunch			
1315-1345	MP Improved Modular Structure	Reading	MP.4	DP
1345-1415	Change and the Improved MP Modular Structure	Exercise	MOD.7	DP
1415-1430	Break			
1430-1500	Results of Exercise	Discussion	MOD.8	DP
1500-1530	The Military Address System (MADDS)	Reading and discussion	MADDS.1	LC
1530-1545	Break			
1545-1615	MADDS Modular Structure	Exercise	MADDS.2	LC
1615-1645	Results of Exercise	Discussion	MADDS.3	LC
	Using the Computer System	Homework	MADDS.4	

Day 4: Thursday, 17 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0[illegible]	Intermodule Interfaces and UEs	Lecture	UE.4	DP
0900-0915	Break			
0915-0945	MP Intermodule Interfaces and UEs	Exercise	UE.5	LC
0945-1015	Results of Exercise	Discussion	UE.6	LC
1015-1030	Break			
1030-1130	What are Specifications?	Lecture	SPEC.1	DP
1130-1200	An Informal Functional Specification for the MP Message Holder Module	Exercise	SPEC.2 MP.5	LC
1200-1345	Lunch (Guest Speaker: Dr. Harlan Mills, IBM)			
1345-1415	Results of Exercise	Discussion		LC
1415-1430	Break			
1430-1600	Formal Functional Specifications	Lecture	SPEC.3	DP
1600-1615	Break			
1615-1730	Using the Computer System	Terminal	MADDS.4	PC

Day 5, Friday, 18 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0900	Abstract Interface Modules and Their Value (Part 1)	Lecture	ABS.1	JS
0900-0915	Break			
0915-1015	Abstract Interface Modules and Their Value (Part 2)	Lecture	ABS.1	JS
1015-1030	Break			
1030-1130	Using the MP Abstract Interface	Exercise	ABS.2 MP.6	KH
1130-1200	Results of Exercise	Discussion	ABS.3	KH
1200-1315	Lunch			
1315-1415	Informal Functional Specifications for MADDS Modules	Reading and discussion	MADDS.5	LC
1415-1430	Break			
1430-1530	Coding Specifications	Lecture	SPEC.4	JS
1530-1545	Break			
1545-1700	The Military Address System	Programming	MADDS.1- MADDS.9	PC
	Host-At-Sea (HAS) System	Homework	HAS.1	

Day 6, Monday, 21 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0830-0900	Host-At-Sea (HAS) System: Requirements Summary	Reading and discussion	HAS.1 PF.8	DP
0900-0915	Break			
0915-1015	HAS Program Design Specifications: HAS Data Acquisition and Transmission Software	Reading	HAS.2	DP
1015-1045	Evaluation of the Proposed HAS Modular Structure	Discussion	HAS.2	DP
1045-1100	Break			
1100-1200	Identifying HAS Modules	Exercise	MOD.9 HAS.1 HAS.2	DW
1200-1315	Lunch			
1315-1415	Results of Exercise	Discussion	HAS.3	DW
1415-1430	Break			
1430-1530	Hierarchy Survey	Lecture	HIE.1	DP
1530-1545	Break			
1545-1700	The Military Address System	Programming	MADDS.1- MADDS.9	PC

Day 7, Tuesday, 22 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0930	Designing a Uses Hierarchy	Lecture	HIE.2	KH
0930-0945	Break			
0945-1015	Uses Hierarchy for an Address System	Exercise	HIE.3	KH
1015-1045	Results of Exercise	Discussion	HIE.4	KH
1045-1100	Break			
1100-1200	The Uses Hierarchy and UEs	Lecture	UE.7	JS
1200-1315	Lunch			
1315-1415	Language Selection	Lecture	LANG.1	JS
1415-1430	Break			
1430-1700	The Military Address System	Programming	MADDS.1-MADDS.9	PC
	A Structured View of HAS	Homework	HAS.4 pp. 14-43 thru 14-47	

Day 8, Wednesday, 23 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0930	Process Structure of Software Systems	Lecture	PROC.1	KH
0930-0945	Break			
0945-1015	MP Process Structure	Exercise	PROC.2	KH
1015-1045	Results of Exercise	Discussion	PROC.3	KH
1045-1100	Break			
1100-1200	A Structured View of HAS	Reading and discussion	HAS.4, pp. 14-43 thru 14-47	JS
1200-1345	Lunch (Guest Speaker: CDR Ron Ohlander NAVELEX)			
1345-1515	Process Synchronization	Lecture	PROC.4	KH
1515-1530	Break			
1530-1600	Academic Poppycock	Reading and discussion	HAS.5	JS
1600-1730	The Military Address System	Programming	MADDS.1-MADDS.9	PC
	A Structured View of HAS	Homework	HAS.4 HAS.5	

Day 9, Thursday, 24 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0845	A Structured View of HAS	Debate	HAS.4 HAS.5	EN, OD
0845-0930	A Structured View of HAS	Discussion	HAS.4 HAS.5	KH, JS
0930-0945	Break			
0945-1045	Separation of Concerns	Reading	HAS.6	JS
1045-1100	Break			
1100-1200	Ada	Lecture	LANG.2	DW
1200-1315	Lunch			
1315-1445	Introduction to Proofs of Correctness	Lecture	CORR.1	JS
1445-1500	Break			
1500-1530	Implementing Processes in HAS	Reading	HAS.7	KH
1530-1700	The Military Address System	Programming	MADDS.1- MADDS.9	PC
	Implementing Processes in HAS	Homework	HAS.7	

Day 10, Friday, 25 July 1980

Time	Topic	Kind of Session	Relevant Material	Session Leaders
0800-0900	Implementing Processes in HAS	Reading	HAS.7	KH
0900-0915	Break			
0915-1015	Implementing Processes in HAS	Discussion	HAS.7	KH
1015-1030	Break			
1030-1200	Documentation Guidelines	Lecture	DOC.1	KH
1200-1315	Lunch			
1315-1415	Course Review	Lecture	GEN.7	JS
1415-1430	Break			
1430-1530	Course Evaluation	Evaluation	EVAL.2	JS

GEN.1 Course Overview

LECTURE

I. What is Software Engineering?

A. You already know programming?

B. You already have languages?

C. What then are the special characteristics of software?

1. Multiperson involvement

2. Multiversion production and maintenance

3. Handling of undesired events (UEs)

4. Usual common additional properties

a. Machine "near" — machine dependent

b. Large size

c. Efficiency, reliability important

d. Robustness important

II. Characteristics of Well-Structured Software

A. Can be verified one part at a time

B. Can be changed one part at a time

C. Can be read one part at a time and each part only once -- characteristics of both program and documentation, not just documentation

D. Subsets work -- ability to tailor to actual needs

E. Meaningful error messages

F. Effective utilization of resources

G. Extensibility from outside

III. Characteristics of Badly Structured Software

A. In one eye and out the other (smart people)

B. Must remember many arbitrary facts to understand code changes

C. Modification requires changes in unpredictable places

D. System integration a real effort

IV. Various Times at which Decisions are Made, e.g.,

A. Early design time

B. Program writing time

C. Compile time

D. Load time

E. Run time

V. Execution Postponement

VI. Three Software Structures

A. Module structure

B. Program-uses structure

C. Process structure

VII. The Meaning of Abstract and the Use of Abstractions

VIII. Goals of this Course: After You Finish, You Should

A. Be better able to recognize bad software design

B. Be able to recognize good software design

C. Be able to recognize contractor BS, snow, run-around, incompetence, etc.

D. Be able to evaluate contractor performance

E. Have a sense of the state of the art in software engineering

IX. Non-Goals of this Course

A. You will not be a system designer

B. You will not be a super programmer

...not b... ...sophy about software methodology

... Content... and Ref...

...nts (...p. i-iv)

...opics, ...ture examples

... ... (... ., GEN.1)

...at ... to be handed out during course (e.g., MADDS.9)

... ...c ... language description (GEN.5)

...ssary (...EN.6)

...rse ...luations

...mment sheets (EVAL.1)

...End of course (EVAL.2)

Bi...liography (BIB.1)

...ticles available

References for each section

...duction (pp. vii-xvi)

...l topics

...ssions

...ectures

b. case studies

c. exercises (collected)

d. discussions

3. Relevant materials

4. Session leaders (e.g., DP)

5. Programming assignment (time allocated)

6. Guest speakers

GEN.2 Personal Experiences

EXERCISE

Name: _____

This exercise gives you a chance to relate the topics mentioned in the overview lecture to your own experiences in software development.

Briefly describe your experiences, if any, for the situations listed below. Some of you will be asked to relate your "war stories" during a discussion period that follows.

1. Describe a situation in which a small change in the requirements resulted in many changes all over a system.

2. Describe a situation in which a subset of an existing system was needed, but it was not possible simply to remove the unneeded parts -- rewriting was necessary.

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3. Describe a situation in which the information that you needed in order to understand one module in a system was finally found somewhere else in the system documentation.

4. Describe a situation in which a decision that was made when a system was specified could and should have been postponed until assembly time or run time.

SOME ANSWERS IN RESPONSE TO GEN.2

Question 1. Describe a situation in which a small change in the requirements resulted in many changes all over a system.

1. "In 1976, it was requested that the Order of Merit System (at USMA) be dropped in favor of an alphabetical graduation scheme. This seemingly simple administrative decision required not only a complete overhaul of the term end processing system, but also impacted many seemingly unrelated areas -- such as the Army promotion list for the new graduates which was found to be based on the order of merit, also the branch drawing system -- based on order of merit."

2. "Requirement to utilize an optional H/W control selection to compensate for system level malfunction needed only single bit manipulation in H/W to effect. Result was 9 S/W module changes, some redesign in S/W because -- some S/W hard coded element not expecting it to ever change, some S/W read data base item and then overwrote it in S/W, some S/W got data base item from wrong place -- this was found 3 years after deployment and was costly to correct -- large documentation cost incurred."

3. "This example perhaps describes the converse of the question, i.e., a small change was not done because the overall impact was too costly. The simple change was to 'hard copy' upon operator command the results of menu changes on a CRT-like device. The program was designed such that the change required a pulling apart of the display code and restructuring it to accomplish the desired result."

Question 2. Describe a situation in which a subset of an existing system was needed, but it was not possible simply to remove the unneeded parts -- rewriting was necessary.

1. "USMA wanted to implement the Air Force 'CIAPS' system of providing procurement support to H's local procurement division. The 'AF' CIAPS system consisted of approximately 167 programs of which 'we' needed 16. Resulting problem was that CIAPS was developed for their base level Burroughs 3500 -- we were configured on H6000 -- and planning a conversion to Univac 1110. Rewrite was decided upon -- using the CIAPS programs as a basis."

2. "It was desired to update a sequential file using tape, as well as cards. However, because the formats of the input cards and tapes differed so greatly (several tape records - 1 card record) it was simpler to write a whole new program rather than try to incorporate the new requirement into the existing program."

"In developing a program for an agency which must communicate on TADIL-B, it was not possible to use an existing module which does TADIL-B processing for another agency. This has happened repeatedly. For every type agency which uses TADIL-B, there is a unique TADIL-B processor."

Question 3. Describe a situation in which the information that you needed to understand one module in a system was finally found somewhere else in the system documentation.

"Such a situation occurred in an EW system where parameters required by a controlling program which interacted with a number of distributed original processors were not specified in the documentation of the main control program. All of the distributed programs had to be examined to understand what the parameters being used and what the specific functions of the controlling program were."

"System documentation included a statement that read 'S+A=P pg 33Wrth' which meant page 33 in Wirth's book, Structure Plus Algorithms Equals Programs."

3. "Reviewed Navy personnel strength projections performed with a simulation model. Model was written to perform certain processes sequentially, and the processes shared common routines, i.e., rounding routines, random number generator, etc. In documentation, the descriptions of the common routines were spread out throughout system's description."

Question 4. Describe a situation in which a decision that was made when a system was specified could and should have been postponed until assembly time or run time.

1. "A data reduction system for handling A-7 flight data had to be able to handle flight recorder outputs from several different OFPs (Operation Flight Programs). The same variables were often in different positions on the different tapes. The programmer introduced an ungodly number of flags and complicated branching logic in order to handle all the 'special cases.'"

2. "Memory size of TRIDENT Command and Control system has grown throughout system development with impact on the executive and in many cases on the subsystem modules. It would appear that memory allocation could have been generalized in the development process and then after total requirements were known, memory allocation could have been determined."

3. "Because hardware must be procured at the beginning of development, no one can tell if it is sufficient for the job. Only after compilation (just how efficient is that compiler anyway?) should the exact amount of hardware be gotten. At the very least, some experimental coding must be done."

GEN.3 The A-7 Project

LECTURE

I. Problems with Tactical Software for DoD Aircraft as Seen by Navy's A-7 Maintainers

A. Mostly unstructured assembly language code

B. Little documentation

1. Design and analysis documents were not purchased from the contractor or have not been maintained

2. The reasons for doing things have been lost

C. Additions and deletions are risky

1. Almost impossible to assess impact or magnitude of a change

2. Ripple effect

3. Personnel making a change must understand entire program

4. Total program must be retested

3. Difficult to validate

1. No independent statement of the requirements except the code

2. Reliability always unknown

E. Training of personnel is difficult, requiring about 1 year before a significant contribution can be made

II. Claimed Benefit of Software Engineering Principles is Well-Structured Software

-- can be verified one part at a time

-- can be changed one part at a time

-- can be understood one part at a time

III. Questions

A. Why doesn't the DoD use software engineering principles?

1. No convincing test

2. No models to emulate

B. Would the DoD benefit from well-structured programs? How can we find out? -- By building and using one.

C. Is it feasible to follow software engineering principles while building embedded systems with tight memory and time constraints? How can we find out? -- By building an operational system and following the principles.

D. How much memory and execution time does good structure cost? How can we find out? -- By comparing two equivalent programs, one with good structure, one without.

E. What if we fail?

1. Learn why

2. Stop preaching non-truth

[illegible] the operational flight program for the Navy's A-7 [illegible] the following principles

	PROBLEMS					
PRINCIPLE	Low Level Code	Poor Doc.	Change Risky	Validation Hard	Training Hard	Requirements Change
Requirements Specification Techniques		X		X	X	X
Information Hiding Modules	X	X	X		X	X
Abstract Interfaces	X	X	X		X	X
Cooperating Sequential Processes	X			X	X	X
Process Synchronization Primitives	X	X	X			
Uses Hierarchy			X		X	X
Resource Monitor Modules	X		X			X
Formal Specifications			X			
Disciplined Programming	X		X	X	X	
Program Verification			X	X		

B. Stages

1. Define requirements, August 1978

2. Redesign program, November 1980

3. Rebuild program, July 1982

4. Undergo Naval Weapons Center (NWC) acceptance tests, November 1982

5. Compare new program to old, January 1983

C. Status

1. Software requirements specification for the A-7E aircraft

2. Publication of specification methodology

3. High-level design documentation for new A-7E program

4. Interface specifications for device modules: model of abstract interface methodology

5. Specifications for virtual machine

D. Influence on this course

V. References

Heninger, K. L. 1980. "Specifying Software Requirements for Complex Systems: New Techniques and Their Application." Trans. on Software Engineering, vol. SE-6, no. 1, pp. 2-13.

Heninger, K. L.; Kallander, J.; Parnas, D. L.; and Shore, J. E. 1978. Software Requirements for the A-7E Aircraft, Naval Research Laboratory Memorandum Report no. 3876.

GEN.4 The MMS Project

LECTURE

I. History of Message System Development in DoD

A. Military crises in late 1960s led to several Congressional investigations into military communications

B. Problems of military message systems uncovered by Congress

1. Delayed message delivery

2. Human errors

3. Lack of standardization

C. Congressional directives regarding future message system development in DoD

1. Centralized approach

2. Greater standardization

D. Areas of expected cost savings

1. Development

2. Maintenance

3. Documentation

4. Training

II. The Military Message Systems (MMS) Project

A. One message system will not suffice for DoD

1. Some organizations require special functions

2. Varying organizational procedures and preferences

3. Different computer hardware

4. Different terminals

5. Different incoming message volumes

6. Different message storage requirements

B. In future years, DoD will need several message systems with many common features but many differences as well

1. Project goal: Develop a family of military message systems using current software engineering principles

   a. Provide useful product to DoD

   b. Demonstrate the application of software engineering principles to a complex problem area in DoD

      a. family methodology

      b. requirements definition techniques

      c. abstract data types

      d. information-hiding modules

e. abstract interfaces

D. Stages

1. Requirements specification for family

2. Design specification for family

E. Status

1. Investigation of existing family members (HERMES, SIGMA, NMIC-SS)

2. Form shopping list

3. Requirements document

a. organization

b. functions

c. primitive operations

d. security analysis

III. Questions

A. Is it feasible to follow software engineering principles when building a set of systems with a wide range of characteristics?

B. Do the claimed benefits apply to large, complex systems or are they confined to small, simple programs?

IV. Reference

Heitmeyer, C. L.; and Wilson, S. H. 1980. "Military Message Systems: Current Status and Future Directions." IEEE Trans. on Communications, to be published.

GEN.5 Pseudo-Code Language Description

LECTURE

I. Introduction

Algorithms appear both in the lectures and in the material contained in this notebook to illustrate the concepts being introduced. These algorithms are abstract programs presented in a language similar to ALGOL and FORTRAN. This document describes the meanings of some of the language constructs.

II. General Comments

The language described below requires that all keywords be underlined. Keywords and operator symbols are listed at the end of this description. (See Tables 1-3.)

Identifiers are character strings of any length; special characters and numbers are permitted but identifiers must start with an alphabetic character (a-z).

All variables must have their data type declared. Variables must also be identified as local (private) or global to the routine in which they are used; subprogram parameters must also be identified (see Section IV).

Statements must end with a semi-colon. Statements can appear anywhere on the line (free field); several statements may occur on one line separated by semi-colons.

Character and string constants may be specified by enclosing the string or character in quotes ("s").

III. Statements

1. Assignment statement

Example: x:= y;

Explanation: := means assignment. The variable x is assigned the value represented by y.
Note that the statement must end with a semi-colon.

2. Comment statement

Example: comment This is a comment statement;

Explanation: Comments are prefaced by the keyword comment. All text between the keyword and the next semi-colon is assumed to be the comment text. Comments may be longer than one line.

3. Statement labels

Example:
```
labelname: x:= y; comment any statement may have a label
                                associated with it;
```

Explanation: Statement labels are represented by an identifier followed by a colon appearing before the statement being labeled.
Note: Since this language does not have a "go to", labels are used as explanatory phrases.

4. Compound statements

Example:
```
begin comment All the statements enclosed between begin and
                end comprise a compound statement;
    x:= y;
    y:= z * 3;
    label: temp:= y+5*x;
    first:= 1; second:= 2; comment three statements on one line;
end;
```

Explanation: A compound statement is a way of grouping several statements together; each statement is then executed sequentially. This is accomplished by enclosing the statements between begin and end. Any legal statement may appear within the begin-end pair.
Note: Whenever a compound consists of a single statement the begin and end may be omitted (see 5. below).

General form:

```
begin
   stm 1;
   stm 2;
    .
    .
    .
   stm n;
end;
```

where each stm i is a legal statement.

5. If statement

Example:
```
if x gt y
then x:= y;
else y:= x;
end-if;
```

Explanation: The if statement is used to test for a specified condition. In the above example, this test is for x greater than y. If the condition is true, the then part of the statement is executed. If the condition is false, the else part of the statement is executed. The else part is optional; if this part does not appear, execution continues with the next statement.

General form:

```
if logical expression
then compound
else compound
end-if;
```

where logical expression is any expression resulting in a true or false evaluation and compound is as defined in 4 above. (Note that in the preceding example, the compound statements each consist of a single statement with the begin-end pair omitted.)

6. While statement

Example:
```
while x le y do
  begin
     z:= A(I);
     x:= x+2;
     i:= x;
  end;
end-while;
```

Explanation: The while statement is used as a looping construct. As long as the expression following the while is true, the compound statement is executed.

General form:

```
while logical expression do compound end-while;
```

where logical expression and compound are as previously explained.

7. Case statement

Example:

```
case getmsgtype(message) of

    //ship//
        begin comment This compound statement is executed when the
                      value of getmsgtype(message) is ship;
        shiprec:= shiprec + 1;
        report_request:= true;
        end;

    //air//
        begin comment This compound statement is executed when the
                      value of getmsgtype(message) is air;
        airrec:= airrec +1;
        report_request:= true;
        end;

    //history//
        begin comment This compound statement is executed when the
                      value of getmsgtype(message) is history;
        historyrec:= historyrec + 1;
        report_request:= true;
        end;

end-case;
```

Explanation: In the above example, mnemonic names enclosed in double slashes (//) are used to represent different situations and their values.

The statements following the matched //name// field are then executed.

General form:

```
case arithmetic expression of
     //expression 1//
          compound
     //expression 2//
          compound
          .
          .
          .
     //expression n//
          compound
end-case;
```

where the value of arithmetic expression matches one of the expressions enclosed in slashes. When there is no match, execution continues after the end-case.

8. For statement

Example:
```
for I:= J step K until N do
    begin
       A[I]:= I+1;
       B[I]:= A[I+1];
    end;
end-for;
```

Explanation: The for statement provides a looping construct with parameterized step size. The loop variable I is initialized to J and incremented once for each traversal of the loop by the step value K until I is greater than the upper bound variable N. Each execution of the loop executes the instructions within the begin-end pair.

Note: This statement is equivalent to

```
I:= J;
while I le N do
   begin
      A[I]:= A[I] + 1;
      B[I]:= B[I] + 1;
         I:= I + K;
   end;
end-while;
```

General form: for var:= expression step expression until expression do compound end-for;

where var is a variable, expression is an arithmetic expression and compound is as previously explained.

IV. Data Types and Declarations

All variables must be declared. Declarations identify the variable's type and scope (see Section V). A variable may be private to the routine where it is used, it may be a global variable, or it may be a parameter to the routine.

1. integer, real, and array

Example:
```
integer x;
real y;
real reel1, reel2;
integer array z[1:10];
comment The following declaration defines a two dimensional
        array. Indices for the first dimension may take on
        values from 1 to 15, for the second dimension from 0 to
        30;
real array twodimensions[1:15, 0:30];
integer int1, int2, int3;
```

Explanation: integer indicates that the variable or variables following may assume only integer values.
real indicates that the variable or variables following may assume only real values.
integer array declares an array variable to be an array of integers. The array's dimensions are enclosed in brackets; lower bounds and upper bounds must both be indicated for all dimensions. All bounds must be integers. Arrays may be of any legal type: integer, real, character, string, semaphore (see below), etc.

Multidimensional arrays are declared by separating the dimensions by commas.

[illegible]ean

Example: boolean x;
boolean x, y, z;

Explanation: boolean variables are variables that may have only one of two possible values -- true or false.
Boolean is synonomous with logical.

3. string and character

Example: string str;
character char;

Explanation: String variables contain alphanumeric information. Such statements as str:= "THIS IS A STRING ASSIGNMENT"; are permitted provided str is declared a string.
Character variables may contain only one character and are equivalent to strings that are restricted to length one.

4. buffer

Example:
```
integer buffer buf;
real buffer buf2;
string buffer bufstr;
integer buffer array buf[1:5];
real buffer array buf[5:12];
```

Explanation: Buffer variables hold information of a specified data type. For example, integer buffer buf; means that buf holds integers. The only legal operations on buffers are accept and deposit. Accept removes one unit of information from the buffer specified; deposit places one unit of

information into the buffer specified. The unit of information is determined by the buffer's type. After accept, the buffer has one fewer item; deposit causes the value to be copied into the buffer. A buffer is a first-in first-out storage device. The number of spaces actually available in a buffer are specified at system generation time (details of the specification are not relevant here). Buffer space management is handled by the accept and deposit operations and is transparent to the buffer user. Accept (deposit) may result in delays of the programs using it when a buffer is empty (full).

Examples of the use of accept and deposit follow. Assume that buffer buf has previously had a value deposited.

```
begin
   integer buffer buf;
   integer item;
   accept (item, buf);
end;
```

The above example causes one integer from buffer buf to be removed from buf and placed into item; buf contains one less integer.

```
begin
   character buffer array buf[1:5];
   integer int;
   character char;
   int:= 2;
   char:= 'a';
   deposit (char, buf[int]);
end;
```

This example causes the character in char to be placed in the second buffer of the buffer array buf. The contents of char are unchanged.

5. program and procedure

Example:
```
procedure proc(x,y,z);
   program proc2(synch);
   reentrant procedure reentproc(a);
   integer procedure intproc(x,y,z);
```

Explanation: A procedure is a means of grouping together often-used code (sometimes called a subroutine); each time the procedure is called, the code is executed. If the procedure is a function (i.e., it returns a value), its declaration specifies the type of the returned value.

A program is used to specify the sequence of events within a process, i.e., the program defines the process. Several processes may be controlled by the same reentrant program (see below).

Reentrant procedures (reentrant programs) are procedures (programs) written in such a way that several processes may use the procedure (program) simultaneously. To accomplish this, the code must be separate from all data that is changed during execution. The code is shared but each process has its own copy of changeable variables.

Parameters to procedures and programs are enclosed in parentheses and separated by commas. Parameters must be declared within the procedure or program body to be of type parameter.

All declaration within a procedure or program must precede the executabel statements.

Example:
```
procedure proc(x,y,z);
parameter integer x;
parameter real y;
parameter string z;
```

Procedures are called as in ALGOL by using the procedure name and a list of parameters enclosed in parentheses.

Note that there is no restriction on the data types of parameters so procedure names may be passed as parameters to other procedures. Consequently, the following statements may occur:

```
procedure proc(parproc, x,y);
parameter procedure parproc;
```

6. semaphore

Example:
```
semaphore sem1;
semaphore array sem[1:10];
semaphore array sem[1:5];
```

Explanation: Semaphore is a variable type designed for the synchronization of processes that are proceeding in parallel at unknown speeds. Just as semaphores in railway systems are used to inform one train of the activities of another, semaphores in computer systems are used to inform one process of the activities of another.

There are only two legal operations on semaphores possible -- P and V; examples of their use are:

```
P(seml);
V(seml);
```

P and V are operators defined by Dijkstra for the data type semaphore. The P operation is used in a "Pass" attempt. It "lowers" the semaphore and a process may have to wait until the semaphore is passable. The V operation "raises" a semaphore to signify that a "Pass" attempt should be allowed to complete.

A semaphore array is a set of semaphores with the same name; they are distinguished by an integer subscript, e.g., sem[1], just as array elements. Semaphore arrays may only have one dimension unlike integer, real, or other types of arrays.

The major use of semaphore arrays occurs in descriptions of reentrant processes requiring different semaphores for different instances.

V. Scopes

The scopes of all variables must be declared. There are three possible scope declarations.

1) parameter
2) global
3) private

Examples:
```
procedure proc(x);
parameter integer x;
global integer y;
private integer z;
```

Explanation: parameter indicates that the variable is a parameter to the procedure; global indicates that the variable is global to the procedure; private indicates that the variable is private (local) to the procedure.

Table 1. Statement-relevant keywords

Keyword	Use
begin	indicates start of compound statement
end	indicates end of compound statement
case	indicates start of case statement
//item//	indicates compound statement in a case statement that should be executed if the arithmetic expression matches the item
of	part of case statement
end-case	indicates end of case statement
comment	indicates comment statement
for	indicates start of for statement
step	indicates the step value
until	indicates the upper bound
end-for	indicates end of for statement
if	indicates start of if statement
then	indicates start of the part of if statement to be executed if the expression is true
else	indicates start of the part of if statement to be executed if the expression is false
end-if	indicates end of if statement
infinite	used for the largest number that can be represented
null	used to represent a null value, nothing (different from zero)
true	logical value (type boolean)
false	logical value (type boolean)
while	indicates start of while statement
do	part of while statement
end-while	indicates end of while statement

Table 2. Declaration-relevant keywords

Keyword	Use
array	declares a variable to be an array
boolean	declares a variable to be a logical variable that may take on the values true or false
buffer	declares a variable to be a buffer
buffer array	declares a variable to be a specified number of buffers
character	declares a variable to be a character
global	declares a variable to be global
integer	declares a variable to be an integer
parameter	declares a variable to be a parameter to a procedure
private	declares a variable to be local to routine
procedure	procedure heading declaration
program	program heading declaration
real	declares a variable to be a real
reentrant	declares a procedure to be reentrant
semaphore	declares a variable to be a semaphore
semaphore array	declares a variable to be a specified number of semaphores
string	declares a variable to be a string

Table 3. Operator symbols

Operator symbol	Meaning
or	logical operator or
and	logical operator and
not	logical operator not
not equal	logical operator not equal
=	logical operator equal
<	logical operator less than
>	logical operator greater than
<=	logical operator less than or equal to
>=	logical operator greater than or equal to
:=	assignment operator
*	multiplication operator
+	addition operator
-	subtraction operator
/	division operator
**	exponentiation operator
;	indicates end-of-statement
:	indicates end-of-label-identifier
( )	parentheses used to alter precedences or enclose parameter lists
,	used to separate identifiers in declarations or parameter lists
[ ]	brackets used to enclose array indices and semaphore array indices
"str"	indicates a string or character constant

Table 3. (continued)

Operator symbol	Meaning
P	semaphore operator to request a "Pass"
V	semaphore operator to permit a "Pass"
accept	buffer operator to remove one item from a buffer
deposit	buffer operator to put one item into a buffer

GEN.6 Glossary

A

Abstract — a) as a verb (e.g., "to abstract from a representation") -- to ignore certain details in making a description or model of some object.
b) as an adjective (e.g., abstract interface) -- an abstract "X" is a model of X that omits certain details of X. Because certain details are not taken into consideration the abstraction represents many possible versions of the object that differ in the ignored details.

Abstract data type — (First, see Data type.) A class of variables that includes more than one data type. A description of an abstract data type describes the common properties of several data types. For example, 'arithmetic' is an abstract data type that includes 15 bit and 30 bit integers as well as floating point numbers. Some authors consider an abstract data type to be a data type whose implementation is hidden from users, who see only the type's abstract behavior.

Abstract interface — A model of an interface that is valid for more than one actual interface. All statements made about the abstract interface must be true of all of the actual interfaces that it models.

Abstract program — A program that is incomplete; some details necessary to have it run are omitted. It represents all programs that could be obtained by supplying the missing details in a way consistent with the incomplete description.

Access functions — A set of programs available to the users of a module that gives the users use of the facilities provided by the module.

Address space — The set of data item addresses that a program can use.

Algorithm — A precise description of possible sequences of operations. The algorithm is conditional if the sequence of actions depends on the data provided as input to the algorithm. The algorithm is non-deterministic if more than one sequence of operations is allowed for fixed values of the input data.

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B

Buffer — A storage device used to transfer information between system components. The buffer allows the information producers and the information consumers to proceed asynchronously. Producers insert items into the buffer; consumers remove items from the buffer. The system components need not wait for the others unless the buffer is full or empty. Sometimes the word "buffer" is used to mean a first-in-first-out (FIFO) buffer.

C

Coding specification — A coding specification for a given program is a document in which "pseudo-code" or abstract programs are used to constrain the selection of algorithms and data structures or to specify them completely. Whatever the extent of the constraints imposed, the coding specification should contain all information (or references) required to write complete and correct code for the program.

Critical section — A portion of a program that should not be executed simultaneously by several processes. One process entering a critical section must exclude other processes from entering the same section until the first process has left (known as mutual exclusion).

D

Data type — A class of variables (information holders) that can be used as operands for a common set of operators. For example, '8 digit integer' is a data type that can be used as an array index. Some authors define data type as a set of values together with a set of allowed operations. (See also Abstract data type.)

Deadlock — A system state in which a set of processes ceases to make progress because each member of the set is waiting for some other member of the set to complete some action.

Decision postponement — Progress in design is made by making decisions. Because early decisions are harder to reverse than later decisions, making decisions that are likely to be reversed later should be avoided. In decision postponement, decisions unlikely to be reversed are made to allow progress while waiting for the resolution of uncertainties. Abstraction is one method of decision postponement.

Design decision — At the start of a software design project, many programs are possible. As each interface is defined, statements written, etc., the set of possible products is reduced until, at the end, only one program remains. Each act that reduces the set of possible products is a design decision.

E

Embedded computer system — A computer system that is part of a larger system and must meet interfaces that are primarily determined by characteristics of the system in which it is embedded.

Extensible languages — Conventional languages provide a set of built-in features such as boolean variables and while statements. By means of subroutines or procedures one user can extend the facilities available to another user. These extensions are easily distinguished (in syntax, efficiency, and 'safety') from those features that are built into the language. An extensible language allows a user of the compiler to provide new features that can be used with the same efficiency and safety as those that were built into the compiler.

F

Fail-soft — A system is referred to as having fail-soft features if the occurrence of an undesired event (such as a hardware failure) results in a partial reduction of services rather than a total failure.

Family — A computer family is a set of computers with enough in common that it pays to study their common properties before looking at individual models. A program family is a set of programs with enough in common that one begins by studying the common properties and then proceeds to look at one or more of the family members. An abstract program is one way of representing a program family.

FIFO

A first-in-first-out (FIFO) queuing discipline is one in which items inserted into the storage device first are extracted from the device in the order inserted.

Formal specification

A statement, by means of mathematical axioms in a well understood mathematical notation, of the requirements that a module must meet.

Function

Used in three distinct senses in this course: a) the role that a system fulfills is often termed the system's function; b) the access programs of a module are often called functions, after FORTRAN (see also Access function); and c) a function is a mathematical mapping from a domain into a range. The syntax portion of formal specifications describes the domain and range of each access function.

H

Hierarchy

A binary relation on a set of objects defines a hierarchy of those objects if the relation is loop free. (See also Level.)

I

Information-hiding module

A set of programs that allows other programs to use a data structure or algorithm without having those other programs be sensitive to changes in the data structure or algorithm. The other programs use access functions that can be implemented in a compatible way for all allowable changes to the data structure or algorithm. The data structure or algorithm is termed the secret of the module. Equivalently, a module refers to a set of programs written by part of a programmer team. Modules being built by more than one person will themselves be divided into modules. In other discussions you may find "module" being used to mean separately compilable portions of a program, separately callable portions, or separately loadable portions of a program. We reserve the use of the word for portions of a program that are written independently. A module may consist of more than one subroutine or macro, the usual case in this course.

Interface — The set of assumptions that one program makes about another program. If program A violates the assumption(s) that program B makes about it, program B will not work properly. An interface may include assumptions about data structures, entry points, calling sequences, etc., as well as more subtle assumptions about the effects of the programs involved.

L

Level — Proper use of the word "level" in describing a software system depends on the definition of a loop-free binary relation between the components of the system. Call that relation R. If the relation R holds between c1 and c2 then R(c1,c2) = true. Level 0 is the set of components c such that there is no component d such that R(c,d) = true. Level i is the set of components c such that a) there is at least one component d in Level i-1 such that R(c,d), and b) if R(c,d) then d is in a lower level than i. The "real meaning" of level depends on the relation R, which should always be specified before using the terms "level" or "hierarchy."

M

Macro definition — Associating a name with a program segment known as the body of the macro. The macro name can be used as an abbreviation for the body. Some macro systems allow the definition of the macro body to be conditional.

Macro expansion — The process of taking a program text containing occurrences of the name of the macro (also called calls on the macro) and replacing those calls with the associated bodies. This process is called expansion because usually the body consists of more characters than the name so that the text becomes longer. That need not be the case. Sometimes a macro name may be 'expanded' to an empty string.

Memory allocator — A component of a software system that determines the location of sections of code and data in main memory and mass storage devices.

Module — See Information-hiding module.

Monitor — An information-hiding module in a software system that supervises the use of a given resource. All resource requests and resource releases are made by calling one of the module's access functions. If parallel processes are sharing a resource the monitor synchronizes their activities.

Multiprocessing — Computing on a system in which there are several programmable hardware units in use simultaneously. In normal usage, the term means that there are several CPU's although it can also be applied to systems in which there is one CPU and a set of peripheral programmable units such as channels or front-end processors.

Multiprogramming — Computing on a system in which a single programmable unit is used to execute a number of tasks that proceed independently of each other. In normal usage this refers to systems in which several user jobs may be in the midst of execution simultaneously by intermittent use of a single processor; the term may also be applied to systems in which several processes belonging to the same user job can be in the midst of execution simultaneously. (See also Process.)

Mutual exclusion — See Critical section.

O

O functions/ V functions — The access functions of a module may either change the information in the module or reveal (return) information stored by a module. Those that change the stored information are called operator functions or O-functions. Those that return information are called value functions, or V-functions. O-V functions that do both types of services are possible.

P

P & V — The operators defined by Dijkstra for the data type semaphore (see definition of semaphore). The P operation is used in a Pass attempt. A process may have to wait until the semaphore is passable. The V operation signifies that a Pass attempt should be allowed to complete.

Predicate — A property that may be true or false of some object or ordered tuple of objects. For example, green is a predicate that may be true or false about some object. Greater-than is a predicate that can be defined on pairs of numbers, so that for any specific pair of numbers it will be true or false. Complex predicates are defined in terms of boolean expressions and simpler predicates.

Procedure — The Algol term for a closed subroutine. Some procedures correspond to FORTRAN function subroutines and have a value so that they may appear in expressions. (See also Function.)

Process — A subset of the events in a system. We may describe one or more processes by means of a program that determines the sequence of events. If the system consists of more than one process, the sequence of events in different processes may be determined by the timing of outside events, the relative speeds of devices, scheduling algorithms, etc. This leads us to say that the relative speeds of processes should be considered unknown. (See also Sequential process.)

Program — A specification of an algorithm in a form sufficiently complete either to be executed directly on a computer or to be translated mechanically into a directly executable form. The notation used to specify the algorithm is called the programming language. If programs written in the language can be executed directly on the computer without translation, the language is called a machine language, and the programs are called machine language programs. For languages that are not machine languages, a program, called a translator, that translates from the language into machine language is usually supplied. Most programming languages allow the programmer to divide a program into independently executable components. The component in which execution starts is called the main program. Other components are called subprograms or subroutines. A method of executing subroutines is supplied by the programming language (the call statement in FORTRAN, the call and perform statements in COBOL). A subprogram is executed by calling (or invoking) it. In process structured systems, a program is used to determine the sequence of events for a process, and execution may begin concurrently in several programs (see also Process). A set of programs grouped together for the purpose of concealing a design decision is called an information-hiding module. (See also Information-hiding module.)

ode

A program that is not machine executable but is intended to describe the main steps in an algorithm. The software designer can concentrate on the design of an algorithm because the pseudo-code is not as tightly constrained as a real programming language might be.

Q

A first-in first-out storage device. In some documents, queue is used in a more general sense to refer to any mechanism capable of storing a set of objects. In that case, the speaker or writer must identify the discipline used for access.

R

/writer

The "reader/writer problem" is one of the standard problems in process synchronization. It refers to a situation in which several processes wish access to the same data item. Readers do not interfere with each other and may use the item simultaneously. Writers are updating the item and require exclusive access so that they do not interfere with each other or with readers. Computer science literature contains numerous discussions of this problem.

Ready/running/ blocked

The set of states of a process from the point of view of a processor allocator (scheduler). If a process has been allocated by a processor it is running. If it is waiting for some event that will be caused by another process, e.g., a resource becoming available, it is blocked. Processes that are not running or blocked and are waiting for a suitable processor to become available are called ready.

Real-time software

Software in which the programming must take "hard" real-time deadlines into account. A deadline is considered "hard" if the system will be considered to have failed if it delivers the needed results after the deadline.

Redundancy

The use of more information than the minimum needed to describe some situation fully. The extra information is redundant in that it can be computed from other information already supplied. Redundancy is necessary to check for the existence of errors. The more redundancy the greater the class of errors that can be detected and corrected.

Reentrant procedures	A procedure written in such a way that several processes or jobs may use it simultaneously. To accomplish this, the code must be separate from all data that is changed during execution. The code is shared but each process or job has its own copy of changeable variables.

S

Secret of a module	See Information-hiding module.
Semantics	The effect of executing a program or construct. Operational Semantics describes the effect by describing a possible implementation using programs that are assumed to be understood. Abstract Semantics describes the effect in terms of externally visible changes in the values of variables or the behavior of other programs.
Semaphore	A type of variable designed to facilitate the synchronization of processes that are proceeding in parallel at unknown speeds. Just as semaphores in railway systems are used to inform one train of the activities of another, semaphores in computer systems are used to inform one process of the activities of another. See P & V.
Separation of concerns	Refers to a method of simplifying the work of a designer or analyst by having him concentrate on just one aspect of a problem rather than try to deal with all aspects at once. For example, one would want the development of numerical algorithms to be separate from concern with memory allocation policies.
Sequential process	A process is a sequential process if the sequence of events in the process is determined by the algorithm describing the process rather than by the relative speed of other processes.
Sequencing decisions	A subset of design decisions. A design decision is termed a sequencing decision when it reduces the possible sequences of events that could occur in the system.
Specification	A statement of the requirements that a module must satisfy.

Stack — A last-in first-out storage device. Only the most recently inserted item can be read. When the most recently inserted item is removed, the item that could be read previously can be read again. The name is derived from the analogy of a stack of trays in a cafeteria. Only the top-most tray is visible.

Stepwise refinement — The process of programming by first writing abstract programs in which parts are named but not implemented, and then implementing those parts. The implementation may call on programs that are named but not yet implemented. The process stops when all unimplemented programs have been refined to calls on implemented programs or machine instructions.

Synchronization — The enforcement of timing constraints on parallel processes whose relative speed is unknown. If an event in process A cannot properly occur before an event in process B, A and B must be synchronized.

Syntax — The set of rules that determine what is a legal program in a language. Knowing the syntax of a language, one can tell whether or not a given program has a meaning but one cannot tell what the program does. The description of the effect of the legal programs is termed the semantics of the language.

T

Trap — A deviation from the normal flow of control of a program caused by the detection of some error (undesired event) in the execution of the program. For example, if the execution of a divide command in a program results in overflow, a trap occurs and a special routine for responding to that situation is invoked.

U

Undesired events (UE) — An error, such as a hardware or software error, incorrect or inconsistent data, user error, etc.

Uses relation — Given program A with specification S_a and program B, we say that A uses B if A cannot satisfy S_a unless B is present and satisfies some non-trivial specification S_b. The assumed specification S_b may differ for different users of B.

V

Variable	An information holder. The information held is stored and retrieved by means of access operators. Variables are often referred to by means of identifiers.
Virtual machine	A set of programs and data structures that can be used as if they were implemented in hardware. To meet this requirement it must be impossible for programs that use the virtual machine "instructions" to alter the programs that implement those instructions or subvert the resources used in their implementation.
Virtual memory	A mechanism that makes it possible for programs to use addresses that are different from physical memory addresses. The mechanism must function in such a way that the behavior of the program is absolutely independent of the actual memory address except for possible delays in time.

GEN.7 Course Review

LECTURE

I. Characteristics of Well-Structured Software

A. Can be written one independent part at a time

1. Writing later parts doesn't require rewriting earlier parts

2. Writing based on fixed, written specifications and assumptions -- reduces need to communicate or negotiate

B. Can be verified one part at a time

C. Can be changed one part at a time

D. Both program and documentation can be read one part at a time

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E. Subsets give ability to tailor software according to needs and resources

F. Effective utilization of resources

II. Groundwork for a Flexible Design -- Describe More than Functional Requirements

A. Possible changes -- systems can't be flexible in every way

B. Desired response to undesired events -- part of desired behavior but it helps to think about it separately

C. Useful subsets

III. Dividing the System into Modules

A. Review of modules

B. Hiding secrets based on expected changes

C. Finding good work assignments

D. Iterating for submodules

E. Other benefits of modularity

F. Examples from HAS

IV. Identifying and Specifying the Access Programs for Modules

A. Review of interfaces

B. Abstract interface modules

C. General module interfaces

D. Examples from HAS

V. Identifying Internal Programs

A. Part of the work assignment

B. Internal programs may be functions or process definitions

C. Examples from HAS

VI. Designing the Uses Hierarchy

A. Based on expected subsets

B. Based on implementation and testing considerations

C. Based on degradation considerations

D. Example from HAS -- see diagrams (pp. 1-58 to 1-60)

VII. Expressing Module Interfaces and Program Designs

A. Informal specifications

B. Formal specifications of module interfaces

C. Abstract programs for functions and process definitions

D. Examples

VIII. Processes

A. Could be executed in parallel

B. Capture major sequencing decisions

C. Allow changes in configuration

IX. Review in Terms of Basic Priciples

A. Information hiding

B. Separation of concerns

C. Being explicit about design decisions

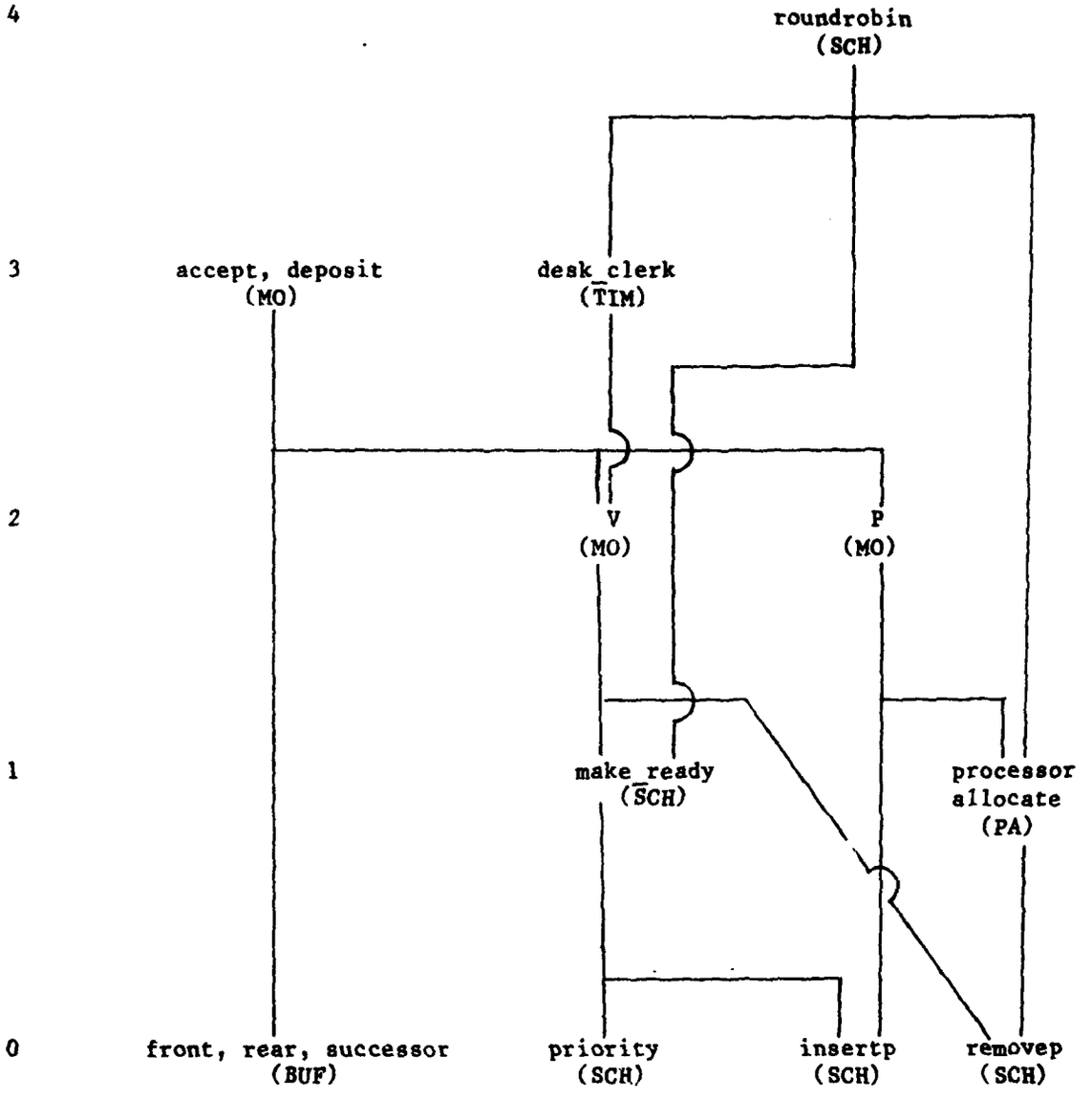
D. Deferring design decisions

E. Program families

F. Discipline in design

Discipline in documentation

Discipline in programming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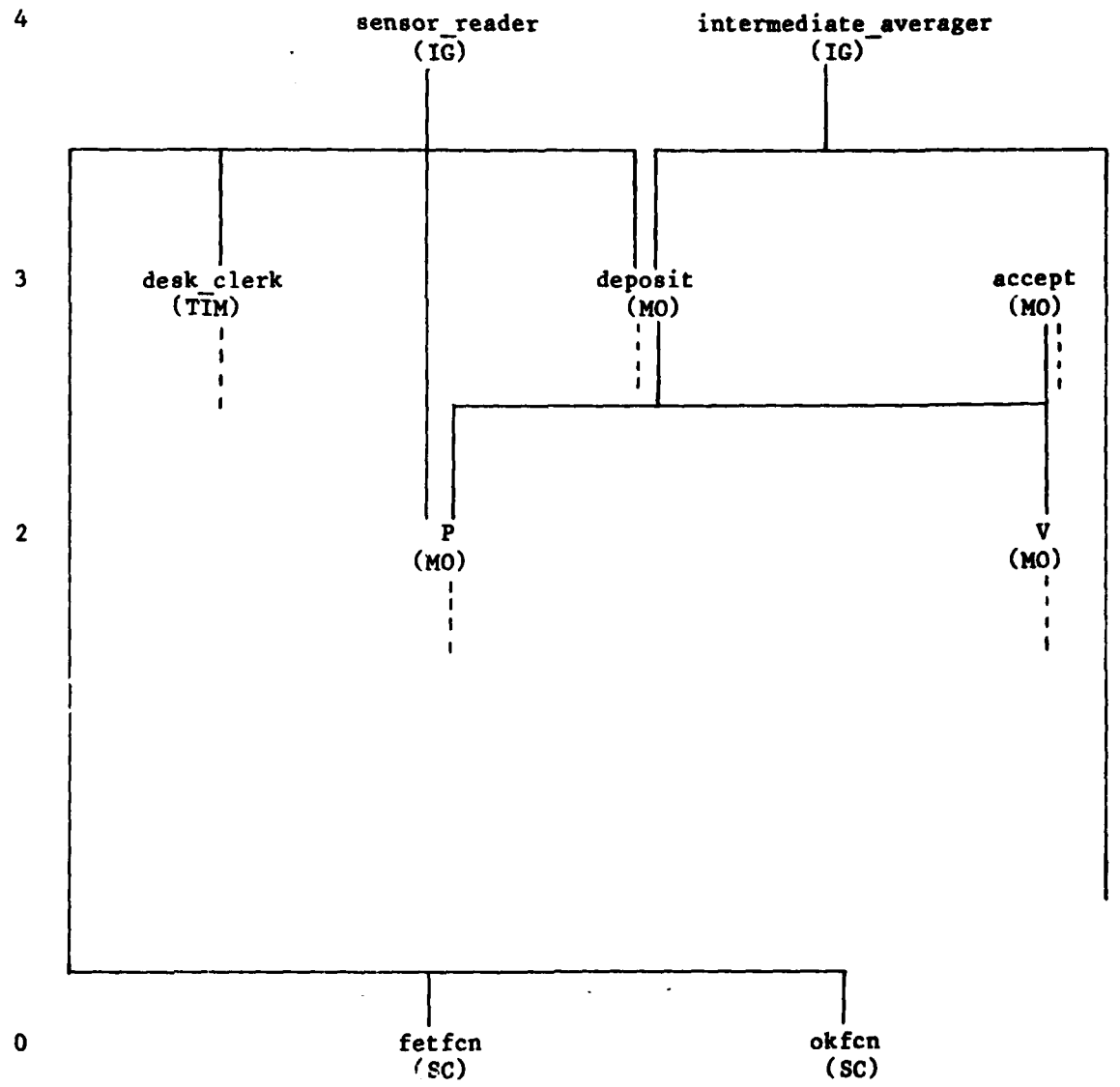
A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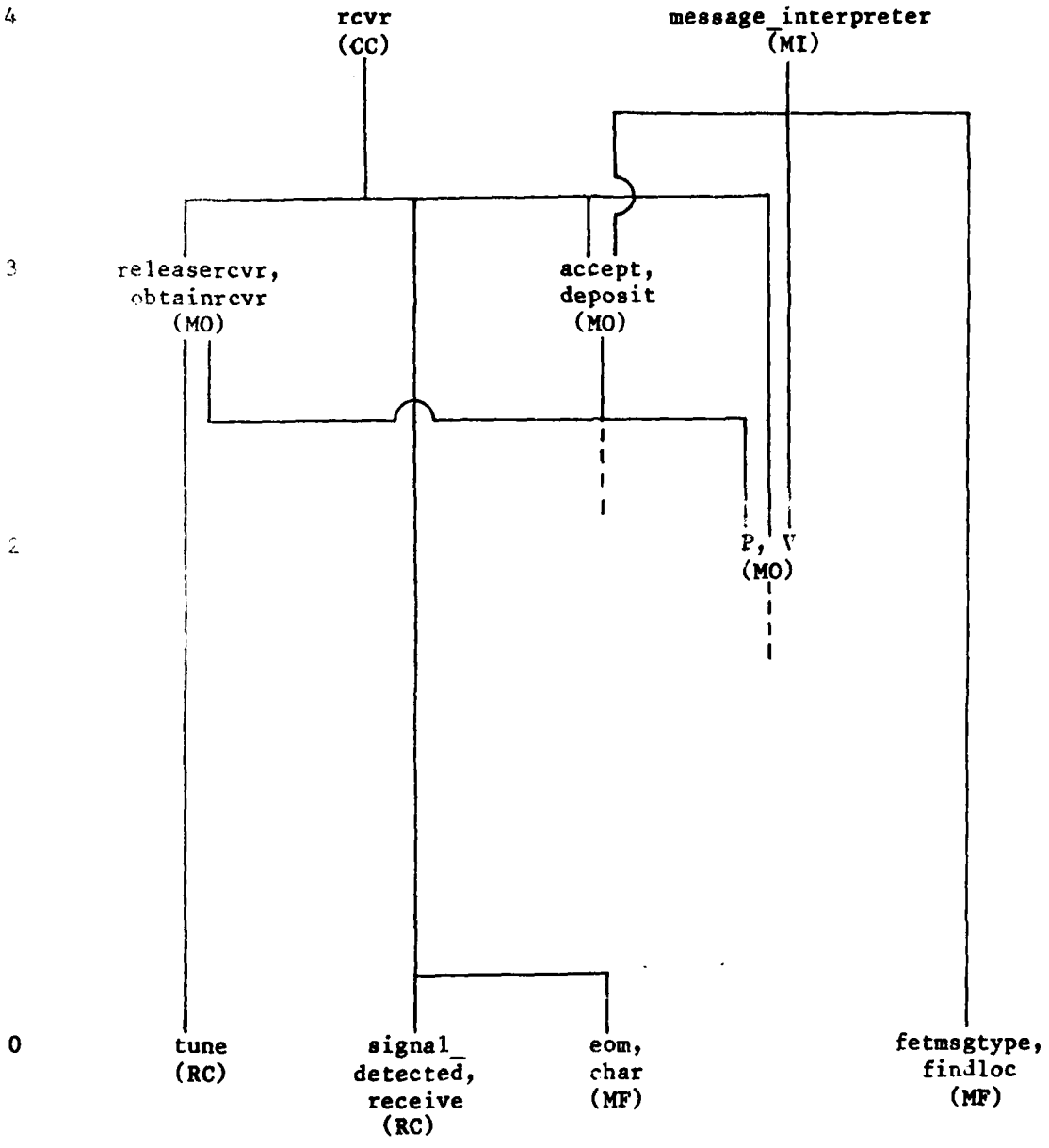
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0
tune
(RC)
signal_
detected,
receive
(RC)
eom,
char
(MF)
fetmsgtype,
findloc
(MF)

C

PF.1 Program Families: What and Why

LECTURE

I. Definition: A set of programs will be called a program family if they have so much in common that it pays to study their common characteristics before investigating the special properties of individual programs.

II. Hardware Analogy: System/370.

III. Typical Program Family: the various versions and releases of a manufacturer's operating system.

IV. Why do large organizations so often have sets of programs with similar functions?

A. Different parts of an organization develop programs with similar purposes without knowledge of each other.

B. A program developed on the basis of one set of constraints turns out to perform poorly under other conditions and is too hard to adjust.

C. General program is late in development; emergency project produces special case for immediate use. Incompatibilities result in long-term existence of system intended only as a temporary measure.

D. A program developed for a large installation turns out to be impractical or even unusable for a small one.

E. A program developed for a small installation turns out to be unable to make effective use of the resources of a large installation.

F. One user wants services which were not anticipated by the developers of an earlier system.

G. Different computers.

H. "I can do it better."

V. What are the disadvantages to an organization of having a set of similar, independently developed systems?

A. Incompatibilities lead to duplication of interfacing programs.

B. Maintenance personnel get confused by false similarities and misleading or superficial differences.

C. Organization-wide changes must be incorporated in each system.

D. Increased costs for storage, documentation, etc.

E. Effort to improve must be distributed and cannot be shared.

VI. What are the disadvantages to an organization of having programs which were not designed to change?

A. Some changes are made poorly.

B. Some changes cannot be made at all.

C. Maintenance and improvement costs are higher.

D. Readiness is impaired because of long completion times.

VII. Purpose of simultaneous development of a set of programs. (Program Family Development)

A. Maximize what they have in common.

B. Minimize the differences.

C. Localize the differences.

D. Reduce development costs by sharing common version.

E. Reduce maintenance costs by sharing among versions.

F. Reduce documentation costs, training costs, etc.

VIII. How can the members of a program family vary?

A. Programs can be functionally identical but make different resource trade-offs.

B. Programs can be identical except for size parameters.

C. Programs can be subsets of the same super program and/or subsets of each other.

D. Programs can be built on a common "base" (kernel) but provide different user interfaces to meet varying needs.

E. Programs can have a common "facade" but a different base.

IX. Sequential completion versus abstract design.

A. Why is the order of design decisions significant?

B. Decision trees.

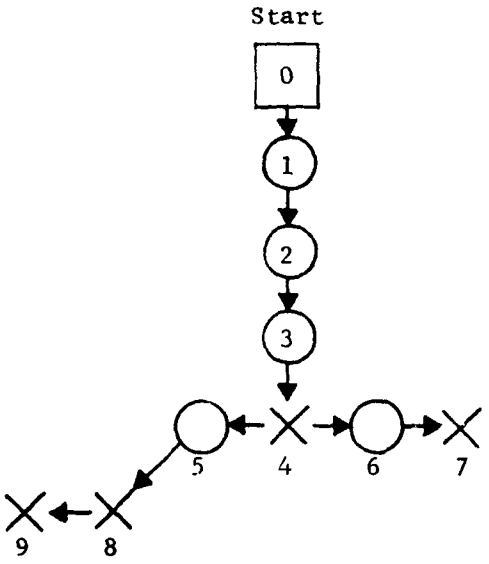

Figure 1 - Representation of development by sequential completion. Note: Nodes 5 and 6 represent incomplete programs obtained by removing code from program 4 in preparation for producing programs 1, 8, and 9.

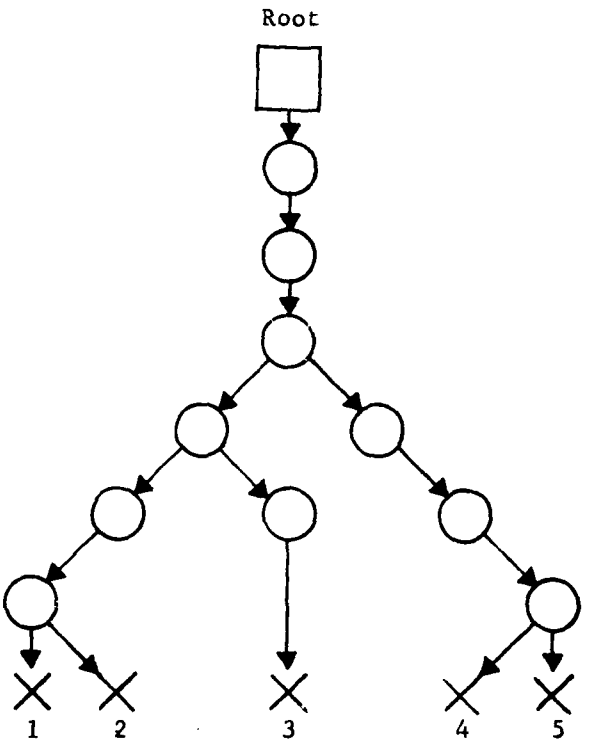

Figure 2 - Representation of program development using "abstract decisions."

Symbols:

is the set of initial possibilities;

is the incomplete program;

is the working program.

C. What possible orders have been proposed?

1. Outside in (top down).

2. Bottom up.

3. Most solid first.

D. Implications of thinking about the family -- how to tell good structures from bad.

X. Reference

Parnas, D. L. 1976. "On the Design and Development of Program Families." IEEE Trans. on Software Engineering, vol. SE-2, no. 1, pp.1-9.

PF.2 MP as a Family of Programs

EXERCISE

Name:_____

Answer each of the following questions by giving a list of brief reasons.

1. Why might different versions have different memory requirements?

2. a. List some reasons why we cannot assume the same type of terminal to be used in all MP installations.

   b. List several common properties, i.e., universal properties, that we can assume will be true of all terminals that will be used.

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3. Why might we have to use different programming languages for different versions?

4. Why might the information included in the logs be different in different versions?

5. Why might there be different operator interfaces on some versions of MP than on others?

PF.3 MP as a Family of Programs

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EXERCISE SOLUTION

The following answers are just some of the possibilities.

1. Why might different versions have different memory requirements?

   - Different numbers of users to be served.
   - Different response characteristics (dependent on minimum acceptable response time, AUTONOYS message load).
   - Different rates of incoming and outgoing message volumes.
   - Retention time for messages.
   - Functional capabilities chosen.
   - Internal message conventions.

2. a. List some reasons why we cannot assume the same type of terminal to be used in all MP installations.

      - Mobile terminals must be special ruggedized versions.
      - Some users may want inexpensive terminals.
      - Some users may want quiet terminals.
      - Some users may want sophisticated terminals.
      - May be <u>required</u> to use terminals already on ships.
      - Different print speeds.

   b. List several common properties, i.e., universal properties, that we can assume will be true of all terminals that will be used.

      - Accept characters one at a time and display them.
      - Send characters one at a time.
      - Will have letters A-Z and numbers 0-9 and no others can be assumed; cannot assume a character encoding.

3. Why might we have to use different programming languages for different versions?

   - The CPU's specified may not have any one language in common; writing a compiler is considered too expensive.

4. Why might the information included in the logs be different in different versions?

   - Different user requirements.
   - Different number of entries in the log.
   - Different methods of operation for the organization accessing the logs.

5. Why might there be different operator interfaces on some versions of MP than on others?

   - Different operator terminals (i.e., CRT or hard copy).
   - Different standard manual operator procedures that are wanted to be preserved.
   - Different levels of operator skills (sophisticated, naive).
   - Different captains on board may require tailored interface.

PF.4 A Minimal Member of the MP Family

EXERCISE

Name:_____

Document MP.1 described a "family" of full service message processing systems designed to be useful in demanding situations. The task of producing family members is inherently difficult and the programs are inherently large.

Examine the list of design decisions below and describe the smallest member of the family, Small MP (SMP), that could operate with reduced computer facilities and still provide some useful services. Describe the situations in which SMP could be used. Please assume the AUTONOYS message conventions will be used.

The minimal, useful member of a family is not necessarily more powerful than previous manual procedures. Think of it in terms of:

a. a trivial software system that can gradually be extended to the full-blown version by adding programs, and

b. a backup capability in case a large part of the computer goes down, making it impossible to run the full version any more.

By looking for such subsets, you can avoid an all-or-nothing approach during both development and operation.

1. The MP software can produce messages in the following formats: (The MP alternative is marked by "**.")

   a. simple formats incompatible with existing ones,
   **b. AUTONOYS,
   c. AUTONOYS plus error-correcting codes,
   d. any format, because there is general message-definition facility.

2. Because some AUTONOYS channels are noisy, an MP does the following:

   a. nothing, it accepts anything it sees (hears?),
   **b. checks for errors and notifies operator,
   c. checks for errors and makes "likely" corrections,
   d. uses formal error-correcting codes for all single, double, ..., errors,
   e. checks for errors and initiates auto retransmit when they are found.

3. An MP "screens" incoming messages as follows:

   a. it does not screen incoming messages, but merely accepts all,
   b. accepts only messages matching a built-in set of addresses,
   **c. accepts only messages matching an updatable watch list,
   d. accepts messages based on interactions with a centralized system that locates persons.

4. An MP routes messages as follows:

   a. the operator supplies routing information for each message,
   b. operator-supplied routing information is checked against internal constants,
   **c. the software automatically supplies routing indicators using an indicator list that the operator can update,
   d. the software automatically supplies routing indicators using an indicator list that is updated by AUTONOYS.

5. Possible processor configurations for supporting an MP are:

   a. no processors are used, there are only teletypes and hard-wired recognizers,
   **b. a single UGH-20,
   **c. a single UGH-VAN,
   **d. a single UGH-2PIE,
   e. combinations of b, c, and d.

6. An MP handles message traffic as follows:

   a. serially, one message at a time,
   b. in parallel, with many messages stored in core,
   **c. in parallel, using both core and mass storage to prevent loss of any message.

7. An MP retains messages as follows:

   a. not at all, no messages are retained,
   b. core copies are retained until space is needed,
   **c. all messages are retained for a fixed period of time,
   d. all messages, old ones are archived.

8. An operator can get information about messages as follows:

   a. by requesting a dump of core and mass memory,
   b. by supplying a special code or message ID,
   c. by supplying content information in a rigid format,
   **d. by using a flexible query language.

9. Software support for the operator interface consists of the following:

   a. minimal, the operator simply reads information printed at the console and types in complete messages,
   **b. there is a prompting package for message input by the operator, and there is the RMD option,
   c. there is a general text processing package usable for all aspects of system operation.

10. There is the following capability for on-line testing of an MP:

   a. none, any testing of an MP must be done off-line,
   **b. there is test generation and transmission controllable by the operator,
   c. there is auto test and evaluation,
   d. there is auto test and fault correction.

PF.5 A Minimal Member of the MP Family

EXERCISE SOLUTION

SMP, the new, small member of the MP family, would print any messages it received on a terminal, buffering messages if necessary.

SMP would not

1. provide redundancy checks or error correction,
2. screen messages for relevant ones,
3. check or add any routing information,
4. assist in preparation of messages,
5. retain messages after printing them,
6. provide any information retrieval or automatic logging, or
7. perform any self checking.

SMP would be useful for producing hard copies of messages that were received at a relay point connected by high quality transmission facilities to the sender. The hard copy could then be manually scanned, distributed, and logged.

SMP would be useful in developing and testing MP. It would provide minimal service in the event of a casualty to part of the computer.

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PF.6 Family Development by Stepwise Refinement

LECTURE

I. Review of the Decision Tree Representation of the Family Development Process

II. Dijkstra's Prime Number Program Development*

A. Decisions: one thousand primes, compute before print

```
begin  variable table p;
       fill table p with first thousand prime numbers;
       print table p;

end;
```

B. Debate about the order of decisions -- should one design "table" or an algorithm "fill with first thousand prime numbers"

---

* The original notation of this algorithm has been changed slightly in order to be consistent with the abstract programming language presented in GEN.5.

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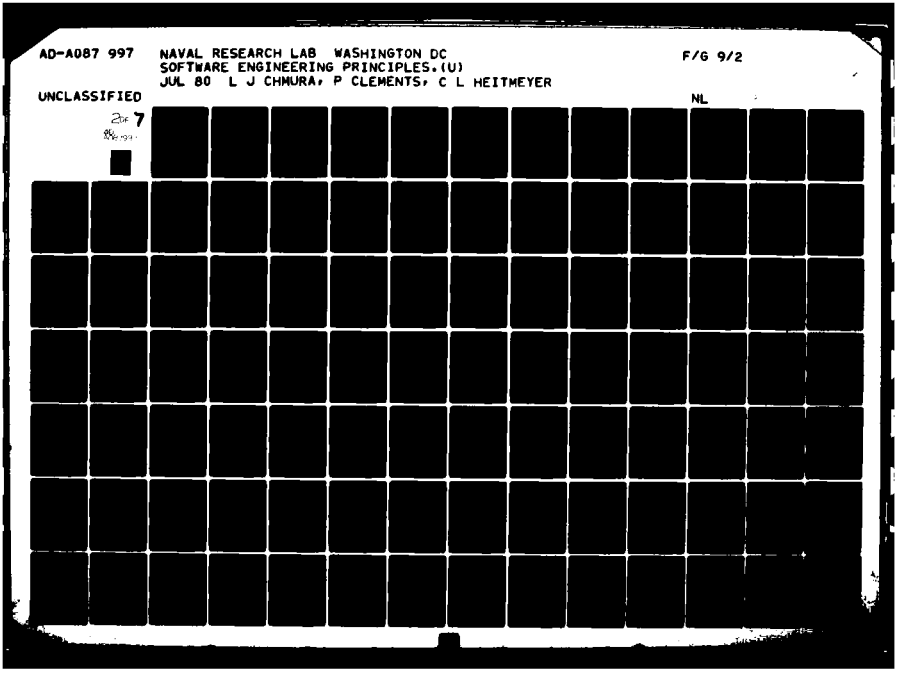
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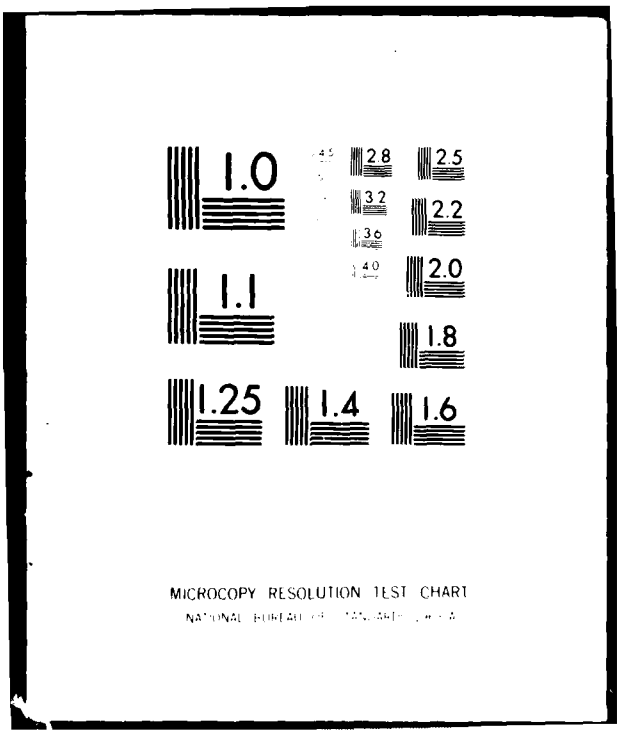
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MICROCOPY RESOLUTION TEST CHART

III. Wulf's KWIC Index Program*

A. Stage 1 PRINTKWIC

Design decisions:

B. Stage 2

```
PRINTKWIC:
     begin
        generate and save all interesting circular shifts;
        alphabetize the saved lines;
        print alphabetized lines;
     end;
```

Design decisions:

C. Stage 3

```
PRINTKWIC:
  begin
     comment generate and save all interesting circular shifts;
     for each line in the input do
       begin
       generate and save all interesting shifts of this line;
       end;
     end-for;
     alphabetize the saved lines;
     print alphabetized lines;
  end;
```

Design decisions:

* The original notation of this algorithm has been changed slightly in order to be consistent with the abstract programming language presented in GEN.5.

IV. Development of the Memory Allocator Family of Programs by Stepwise Refinement

A. Stage 1

```
begin

type1 BEST_YET, CANDIDATE;

type2 ACTUAL;

boolean NOT_ALL_SPACES_CONSIDERED, BETTER_SPACE_MIGHT_EXIST;

BEST_YET:= null;

while NOT_ALL_SPACES_CONSIDERED and BETTER_SPACE_MIGHT_EXIST do

   begin

      CANDIDATE:= FIND_NEXT_ITEM_FROM_FREE_SPACE_LIST;

      BEST_YET:= BEST_OF(BEST_YET,CANDIDATE);

   end;

end-while;

if (BEST_YET = null) then ERROR_ACTION end-if;

ACTUAL:= FRAGMENT(BEST_YET);

ADJUST(BEST_YET,ACTUAL);

ALLOCATE(ACTUAL);

end;
```

Note: type1 and type2 are ways of declaring variables without actually specifying the type. See section on design decisions not made in Stage 1.

1. Assumptions made to verify that the above is correct

   a. The memory is initially divided into frames of different sizes. A request is always for an amount of memory no greater than one frame. When memory areas are returned to the list of free spaces, adjacent sections of the same frame will be coalesced. The amount of space requested will be known to the program.

   b. BEST_YET is a variable that indicates an item from the list of free spaces. Null, a possible value of BEST_YET, indicates no item.

   c. BETTER_SPACE_MIGHT_EXIST is a boolean variable that is true as long as it is possible that a "better" space can still be found. The criteria for "better" have not yet been specified.

   d. NOT_ALL_SPACES_CONSIDERED is a boolean variable that is true until the loop has checked each free space once.

   e. CANDIDATE is a variable of the same type as BEST_YET.

   f. FIND_NEXT_ITEM_FROM_FREE_SPACE_LIST is a function that returns a value that indicates one of the items on the free space list. If there are n items on the list, a sequence of n function calls of the procedure will deliver each of the n items once.

   g. Adding new items during program execution will not occur.

h. BEST_OF is a procedure that takes two variables of the same type as BEST_YET (i.e., type1) and returns the better of the two according to some unspecified criterion. If neither is suitable, null is returned.

i. ERROR_ACTION is a procedure that performs the action that should be performed if no suitable space can be found. ERROR_ACTION does not return control to this program except at the beginning.

j. type2 is a class of variables that can describe a storage area.

k. FRAGMENT is a procedure that returns a variable of type2 after the procedure determines which part of the free space should be allocated. The free space is identified by the parameter.

l. ADJUST is a procedure that adjusts the list of free spaces to reflect the allocation. The parameter BEST_YET indicates which item is to be removed from the list. ACTUAL describes the amount of space to be allocated in case the unused fragment of the original space is to be left on the list.

m. ALLOCATE is a procedure that gives the storage area to the requesting program.

2. Stage 1 design decisions

   a. No items will be added to or removed from the free space during execution of the program until the final selection has been made.

   b. Once execution of the program begins, no other execution of it will begin until the executing program is completed (critical section).

   c. The only other program that might change the data structures involved is one that adds items to the free space list when space is returned.

   d. The program that adds free spaces to the list compacts two or more contiguous free spaces that are part of a frame into one space represented by a single item on the list.

   e. A candidate is not removed from the list while it is being considered.

   f. Before the search begins, there is no check to determine if allocation is possible (e.g., check for empty free space list, check for size of largest available space).

3. Design decisions not made in Stage 1

   a. The representation of the free space list.

b. The type of the variables BEST_YET, CANDIDATE and ACTUAL.

c. The order in which the free spaces are stored on the list.

d. The order in which the items on the free space list are searched.

e. The criteria used in BEST_OF.

f. The decision to allocate all of the space found or allocate only that part needed, (i.e., the action taken in FRAGMENT).

g. The ERROR_ACTION that will be taken.

B. Stage 2

```
begin
integer BEST_YET, CANDIDATE, N;
boolean BETTER_SPACE_MIGHT_EXIST;
type2 ACTUAL;
BEST_YET:= 0;
CANDIDATE:= 0;
while (CANDIDATE lt N) and BETTER_SPACE_MIGHT_EXIST do
   begin
      CANDIDATE:= CANDIDATE + 1;
      BEST_YET:= BEST_OF(BEST_YET,CANDIDATE);
   end;
end-while;
if BEST_YET = 0 then ERROR_ACTION end-if;
ACTUAL:= FRAGMENT(BEST_YET);
ADJUST(BEST_YET,ACTUAL);
ALLOCATE(ACTUAL);
end;
```

1. Stage 2 design decisions

   a. The list of free spaces is represented by a table with N entries. Each entry represents a valid free space. The first space searched is identified by entry 1 and the last space searched is identified by entry N.

b. The variables BEST_YET and CANDIDATE are integers (that will be used as array indices) so that the test for NOT_ALL SPACES_CONSIDERED can be an integer test on the value of CANDIDATE.

c. BETTER_SPACE_MIGHT_EXIST is a boolean variable that is true as long as it is possible that a "better" space can still be found. If it is set to false, that will be done by BEST_OF.

2. Design decisions not made in Stage 2

a. The characteristics that describe an item in the free space list (e.g., starting address and length, or starting address and end address).

b. The order in which the entries are stored on the list.

c. The relation of the variables CANDIDATE and BEST_YET to the items in the free space list.

d. The policy or selection criteria in BEST_OF.

e. The decision to allocate all of the space found, or allocate only that part needed and leave the rest on the free space list.

C. Stage 3

```
begin   integer BEST_YET, CANDIDATE,N, T, REQUIRED_LENGTH, OLD_T, I;
        integer array LAST[1:N], START[1:N];

BEST_YET:= 0;
CANDIDATE:= 0;
OLD_T:= infinite;  Comment infinite stands for the largest integer
                           that can be represented;
while (CANDIDATE lt N) do
  begin

    CANDIDATE:= CANDIDATE + 1;

    T:= LAST[CANDIDATE] - START[CANDIDATE] + 1;

    if (T ge REQUIRED_LENGTH) and (T lt OLD_T) then

      begin

        BEST_YET:= CANDIDATE;

        OLD_T:= T;

      end;
    end-if;
  end;
end-while;

if BEST_YET = 0 then ERROR_ACTION end-if;

ACTUAL:= (START[BEST_YET],OLD_T); comment the single variable ACTUAL
                                  is represented as two integers
                                  that are always used together;
N:= N - 1;

comment close up the gap caused by removing that element;

for I:= BEST_YET step 1 until N do

    begin

      LAST[I]:= LAST[I+1];

      START[I]:= START[I+1];

    end;
end-for;

ALLOCATE(ACTUAL);

end;
```

ADDITIONAL ASSUMPTION

The length of the requested space, REQUIRED_LENGTH, is input to the program. It must be known by BEST_OF.

1. Stage 3 design decisions

   a. Each item in the free-space table has the starting address (START[item]) and the ending address (LAST[item]) of the free space identified by the item in the arrays START and LAST.

   b. The entire free space that is selected will be allocated, not just the part of the space that is needed.

   c. The integer values of CANDIDATE and BEST_YET are indices into the table containing free space information.

   d. A policy of "best fit" is used to select the smallest free space whose length is greater than or equal to REQUIRED_LENGTH. Because the boolean variable BETTER_SPACE_MIGHT_EXIST is true until "all spaces considered" is false, so that it need no longer be included as one of the loop termination conditions. If the policy "first fit" were used, BETTER_SPACE_MIGHT_EXIST would become false as soon as the first suitable space were found.

2. Design decisions not made in Stage 3

   a. The order in which the entries are stored in the list.

   b. The ERROR_ACTION that will be taken.

c. Implementation of ALLOCATE.

V. Another Member of the Memory Allocator Family

A. Design decisions and assumptions

1. All the assumptions made for Stage 1.

2. There is a list of free spaces represented by two arrays. Each can be accessed by an index into the array identifying the free space. Each free space is represented by its starting address (START[item]) and its length (LENGTH[item]).

3. Both free space arrays have at least N entries and all entries between 1 and N represent valid free spaces. The first space searched is identified by the first entry, and the last space searched is identified by the Nth entry.

4. During execution of the memory allocator program, no items will be added to or removed from the free space list by other programs.

5. The only other program that might change the free space list is one that adds items to the list. This program compacts two or more contiguous free spaces into one space represented by a single entry on the list so that the list will never contain two contiguous areas.

6. Once execution of the program begins, no other execution of it will begin until the executing program is completed.

7. Before the search begins, there is no check to determine if allocation is possible (e.g., check for empy free space list). After the search is performed, if no suitable free space was found, a subroutine ERRORACTION is to be called.

8. The length of the requested space, an integer called REQUIRED_LENGTH, is input to the program.

9. A policy of "best fit" is used to select the smallest free space whose length is greater than or equal to REQUIRED_LENGTH.

10. While a candidate is being considered, it is not removed from the free space list.

11. The space that is allocated is equal in length to REQUIRED_LENGTH and is taken from the beginning of the free space selected by the "best fit" algorithm.

12. The free space list is adjusted to reflect the allocation of the necessary part of the selected free space.

13. A procedure named ALLOCATE is supplied with information about the space to be allocated and gives the space to the requesting program.

14. The variables BEST_YET and CANDIDATE are integers, so that the test for NOT_ALL_SPACES_CONSIDERED can be an integer test on the value of CANDIDATE.

    The value null indicates no item on the list.

B. Comparison of the two family members

   1. Same assumptions and design decisions as Stage 2.

   2. Differences in Stage 3 design decisions.

C. Alternative ways to develop the program

   1. Start from scratch.

   2. Start with Stage 3. Scan line by line and make required changes.

   3. Go back to Stage 2. Develop new program from there.

D. Abstract program for another member of the memory allocator family

```
begin   integer BEST_YET, CANDIDATE, N, T, REQUIRED_LENGTH, I;
        integer array LENGTH[1:N], START[1:N];

BEST_YET:= 0;
CANDIDATE:= 0;
T:= infinite;

while (CANDIDATE lt N) do
    begin
        CANDIDATE:= CANDIDATE + 1;

        if (LENGTH[CANDIDATE] ge REQUIRED_LENGTH) and
           (LENGTH[CANDIDATE] lt T)
        then
            begin
                BEST_YET:= CANDIDATE;
                T:= LENGTH[BEST_YET];
            end;
        end-if;
    end;
end-while;

if BEST_YET = 0 then ERROR_ACTION end-if;

ACTUAL:= (START[BEST_YET],REQUIRED_LENGTH);

if (REQUIRED_LENGTH lt T) then
    begin
        START[BEST_YET]:= START[BEST_YET] + REQUIRED_LENGTH;
        LENGTH[BEST_YET]:= T - REQUIRED_LENGTH;
    end;
else
    begin
        N:= N-1;

        for I:= BEST_YET step 1 until N do
            begin
                START[I]:= START[I+1];
                LENGTH[I]:= LENGTH[I+1];
            end;
        end-for;
    end;
end-if;

ALLOCATE(ACTUAL);
end;
```

PF.7 Applying the Program Family Principle

LECTURE

I. Steps of the Family Methodology

A. Identify the characteristics shared by family members

1. Example of feature common to all: capability of users to display a received message

2. We may need to identify a larger set of characteristics than that required by any single member

B. Identify and encapsulate the differences among family members

1. A software structure suitable for all family members is formulated

2. In that structure, the software is partitioned into modules that encapsulate the various distinguishing characteristics

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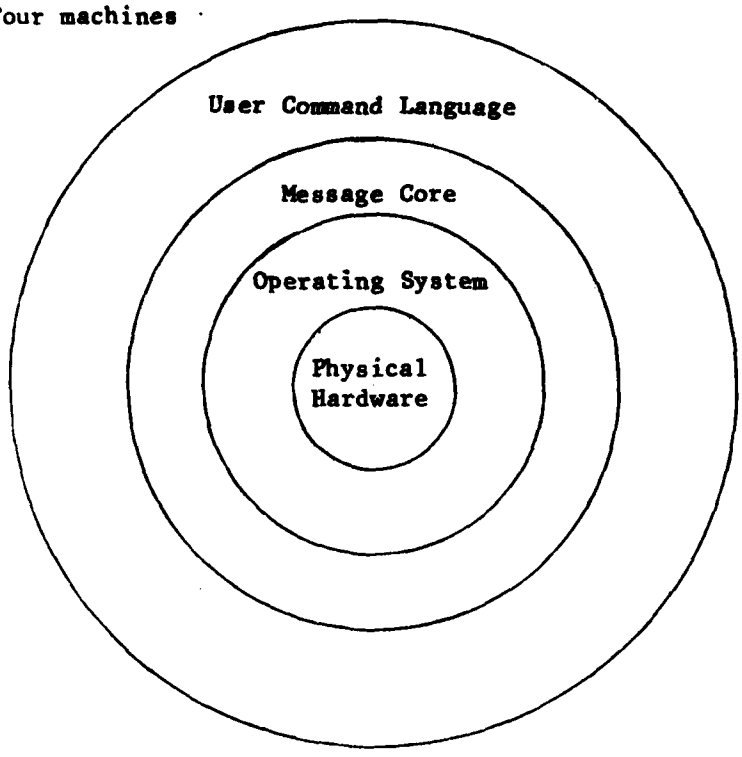
II. Application of the Family Methodology to Military Message Systems

A. To identify commonalities and differences among members, a model, based on a series of nested machines, was developed to represent each member of the family

1. Four machines



2. The data objects and operations of each extended machine are constructed from the data objects and operations of another machine

3. Examples of each machine's data objects and operations

Machine	Objects	Operations
Hardware	registers; memory words	load, store; move
Operating System	processes; segments	create_process, destroy_process; move_segment, copy_segment
Message Core	messages; message_files	create_message,setfield_message, getfield_message; create_msgfile,addmsg_msgfile, rmvmsg_msgfile, destroy_msgfile
User Command Lang.	messages; message_files	COMPOSE MESSAGE, DELETE MESSAGE, PRINT MESSAGE, SEND MESSAGE; CREATE FILE SECRET, PRINT FILE, DESTROY FILE

4. Difference between message core machine and user command language machine

   a. message core operations are typically less powerful than user command language statements

   b. to the extent feasible, all message core data types are specified independently of one another; i.e., an operation on a data object of a given type affects only that object and no others

5. Examples of user command language statements and the different data objects each affects

a. Command: CREATE MESSAGE AUTODIN SECRET CHINA
Message System: SIGMA
Operations: Create an AUTODIN message at Secret and insert it in a message_file named CHINA
Data Objects Affected: message, message_file

b. Command: CREATE FILE USSR CONFIDENTIAL
Message System: SIGMA
Operations: Create a message_file named USSR at Confidential and insert an entry for it in the user's directory of message_files
Data Objects Affected: message_file, message_file_directory

c. Command: PRINT SEQUENCE.S TEMPLATE.T
Message System: HERMES
Operations: Print every message in SEQUENCE.S using the display format defined by TEMPLATE.T
Data Types Affected: message, message_file, sequence, template

B. Step 1: Identify the characteristics shared by family members

1. Family members differ

a. user command languages

- different organizational procedures

- different habits and preferences

b. physical hardware

- special requirements aboard ships

- different processing speeds and/or memory requirements

c. operating systems

- different hardware has different operating system

- same hardware supports more than one operating system

2. The significant shared characteristics of military message systems are functional capabilities

a. create, coordinate, send, distribute, display, and delete messages

b. create, destroy, add messages to, and delete messages from message files

3. Shopping list of message core data types and operations

		SIGMA		HERMES	
message		X		X	
	create_message		X		X
	delete_message		X		X
	send_message		X		X
	setfield_message		X		X
	getfield_message		X		X
			.		.
			.		.
			.		.
message_file		X		X	
	create_messagefile		X		X
	destroy_messagefile		X		X
	addentry_messagefile		X		X
	rmventry_messagefile		X		X
			.		.
			.		.
			.		.
filter		X		X	
	create_filter		X		X
	destroy_filter		X		X
	modify_filter		___		X
			.		.
			.		.
			.		.
template		___		X	
	create_template		___		X
	destroy_template		___		X
	update_template		___		X
			.		.
			.		.
			.		.
user_profile		___		___	
	create_profile		___		___
	addterm_profile		___		___
			.		.
			.		.
			.		.

C. Step 2: Identify and encapsulate the differences

1. Every user command language statement can be expressed as a sequence of message core operations

2. Similarly, every message core operation can be translated into a sequence of operating system calls and/or machine instructions

3. The message core insulates the operating system/hardware from changes in the user command language

   a. when the user command language changes, the sequence of message core operations that implements each user command language statement will require change

   b. the lower level code that supports each message core operation will not require revision

4. The message core also insulates the user command language from changes in the operating system/hardware characteristics

   a. each message core operation must be reimplemented using the new operating system calls and/or new machine instructions

b. the translation of each user command language statement into a sequence of message core operations will remain unchanged

II. Lessons Learned

A. We developed sets of shared features. Each family member is associated with some subset of each set.

1. Shopping list of message core data types and operations

2. Shopping list of semantics of user command language statements: examples

a. CREATE TEMPLATE T

b. EDIT FILTER F

c. PRINT MESSAGE id [print-template]

d. CREATE MESSAGE [type] [security-level] [message-file] [compose-template]

B. We limited the range of family members

1. Examples

a. Number of message core machines

b. Semantics of user command language

2. These are examples of early design decisions. In making these decisions, we had to confirm that we didn't rule out any features that would be needed later on.

C. We studied specific family members in detail. It is helpful if some family members already exist, since it is easier to determine the requirements of existing systems than systems that will be built at some future date.

PF.8 Design Decisions in HAS Requirements

EXERCISE

Name: _____

In the HAS requirements summary (HAS.1), many decisions are already made that implicitly rule out family members that might be useful later. Because these are early decisions, they are likely to permeate the design and be very difficult to change later.

For example, the Navy may eventually require large, moored, repairable buoys to collect weather data in key locations. If HAS software designers consider the decisions "drifting buoy" and "disposable" absolutely fixed, the software may be designed so that it is not reusable in the new buoys, even though the functions are similar.

Study HAS.1, looking for four or five software-related design decisions that have already been made. List each decision, along with several reasonable, but rejected, alternatives. Indicate the alternative that was chosen for HAS. You may want to format your answers as multiple choice questions, as shown in the example below.

EXAMPLE

1. The HAS software transmits the following information: (the alternative chosen in HAS.1 is marked with "**".)

   a. No information,
   b. A summary at fixed intervals,
   c. A summary when requested,
   d. A small set of predefined reports on request,
** e. A summary at fixed intervals and a small set of predefined reports on request,
   f. Answers to specific queries.

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PF.9 Design Decisions in HAS Requirements

EXERCISE SOLUTION

Listed below are some of the software-related design decisions implicit in HAS.1, along with some reasonable alternatives.

1. The software will operate on the following hardware:

   ** a. BEEN computer
      b. NOVA computer
      c. a microprocessor
      d. PDP-11 computer
      e. any of the above

   NOTE: Choice of computer can profoundly affect software construction; for example, consider availability of support software.

2. The software designer should assume the sensor quality will be:

   ** a. poor, because HAS will use the cheapest sensors available
      b. variable, depending on accuracy required at a particular location
      c. consistently good

   NOTE: Assumptions about sensor quality affect decisions about frequency of reasonableness checks and the complexity of filtering algorithms.

3. The data retained in the system will be:

      a. none -- no data retained
      b. most recent data only
   ** c. most recent data with a limited history
      d. extensive history data

4. The various deployed buoys may or may not be connected as follows:

      a. master/slave mode where several buoys in predefined area collect data but only one transmits
   ** b. no connection
      c. sophisticated network with cooperation and comparison

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5. The communications system will consist of:

   a. wires with low data rate
   b. transmitter only, for regular broadcasts
   c. transmitter and receiver, for operating in broadcast burst mode on request
** d. transmitter and receiver, for broadcasting regularly and responding to requests
   e. multiple transmitters for broadcasting reports simultaneously on different channels

6. Geographic location will be determined:

   a. never -- geographic location information will not be available
   b. by initialization on deployment -- for moored buoys
** c. by Omega fix
   d. by NAVSAT fix

7. The message format is:

** a. RAINFORM
   b. determined by the HAS system designer
   c. flexible -- must change to meet varying user requirements

UE.1 Desired Responses to Undesired Events

LECTURE

I. Introduction

A. All previous discussions focus on specification of desired behavior

B. Experience tells us that we will not get all we desire all of the time

C. Behavior on the occurrences of undesired events (UEs) should not be decided implicitly during the implementation -- explicit decisions are needed

II. The Existence of Alternatives When Something Goes Wrong

A. Example: A garbled address is found on an input tape

1. Alternatives

a. Skip it

b. Print it with known errors -- no change

c. Print it with erroneous parts missing

d. Print it with erroneous parts replaced by "?"

e. Print it with erroneous parts marked

f. Use minimal correction methods to correct errors

g. Search for closest address in files

2. For each alternative, there is an appropriate situation

3. In practice, decision not made in specifications -- although it is visible behavior

B. Example: A memory bank in a multi-programming system fails -- no data lost -- insufficient memory available

1. Alternatives

a. Kill the job(s) that were currently using that memory bank allowing the others to continue normally

b. Use swapping to allow all of the jobs to continue more slowly

c. Pick the newest (most recently started) job and kill it, continuing with this procedure until those remaining function normally

2. All alternatives technically feasible if expected and planned for

3. Should and can be part of system specifications

C. Example: Message system operator types date of 1780 on message

1. Alternatives

a. System rejects the message because year is "out of range"

b. System files the message as the most recent message in its logs

c. System queries the operator, accepts message if he insists

d. System files the message as the oldest message in its logs

2. All easily achieved technically

3. All useful in some situations

III. The Existence of Alternatives When Designing the System

A. What, me worry?

B. Maintain redundant information necessary to discover inconsistencies

C. Maintain redundant information needed to recompute state

D. Maintain information necessary to restore state "immediately"

E. Spend the time in recovery actions if something occurs

IV. Factors in the Tradeoff

A. Cost of preparation for recovery whether or not an error occurs

B. Cost of no recovery and no recognition if an error occurs

C. Cost of recognition but no recovery if an error occurs

D. Cost of actual recovery in the event of an UE (Undesired Events)

E. Frequency of UEs must be a deciding factor

V. Incidents vs. Crashes

A. Concept from air and ground traffic control

B. Incident: something abnormal, undesired, against the rules

1. Recovery without significant long range cost

C. Crash: abnormal, undesired, forbidden -- results in significant costs

D. Traffic example

E. Computer system examples

1. Incident: most recent version of file lost; reconstructed from old copy and change list

2. Crash: file completely lost or real-time information too late

3. What is "successful" UE handling?

VI. Generalization to Degrees of UEs

A. Need for generalization -- the existence of intermediate possibilities, incidents with higher costs, crashes of little significance

B. The designer and implementor need guidance as to "preferred" outcome in the event of an incompletely correctable UE

C. There is no obvious ordering -- no single cost factor

D. The degrees must define a relation "less desirable than"

VII. Classes of UEs -- Guide to Error Anticipation

A. Resource failure

1. With information loss vs. without information loss

2. Temporary vs. long term

B. Incorrect input data

1. Detectable by examining input only

2. Detectable by comparison with internal data

3. Detected externally (after input)

4. Reported to user by means of incorrect output

C. Incorrect internal data

1. Detected by internal inconsistency

2. Detected by comparison with input data

3. Reported to system in terms of incorrect output data

4. Uncertain data (e.g., after reporting of hardware parity error)

VIII. Strategies (Conclusions)

A. Above list provides an approach to listing of classes of UEs, appropriate responses should become part of specification

B. External interfaces suggested by above list must be present

C. Tests on internal and external data, as well as resources, that are to be performed by the software must be specified. Both exits must be shown

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UE.2 MP and UEs

EXERCISE

Name: _____

Introduction

With one major exception, the descriptions of the MP system all fail to mention the behavior desired of the system in the event that something goes wrong. The exception is the frequently occurring undesired event -- noisy message data. There are, however, many other UEs that should be mentioned in a system specification.

Examples:

1. What services should be provided if the disk fails? Full service is obviously impossible, but partial service can be expected. What services have priority?

2. What services should be provided to assist in the event that messages that were thought to have been transmitted were not transmitted because of a failure beyond the scope of MP. MP's data structures now contain incorrect data.

3. How should the system react if an obviously incorrect date is inserted in a message being composed (e.g., 1780)?

Assignment

Think about the functions provided by MP and try to supplement the above list. The UE classification scheme in the lecture outline may provide some help in organizing your efforts.

UE.3 MP and UEs

EXERCISE SOLUTION

The following list of possible UEs is in no way complete. It merely illustrates the types of things that must be considered when defining the desired behavior of a system.

1. Resource failures

   a. What services can be provided if the operator's console fails?

   b. What should the system do if the UGHTRANS equipment fails to respond? Should the system detect this or wait for external notification?

   c. What services should be provided if a bank of memory goes down?

2. Incorrect input data

   a. What should the system do if the operator reports an incorrect destination during the time that the message is being transmitted?

   b. What should the system do if it does not receive a response within the required response time, for a message that requires a response (e.g., an emergency command precedence message)?

   c. What should the system do if the operator tells it that the date on all of the last 20 messages (Feb. 30) is incorrect?

3. Incorrect internal data.

   a. What should the system do if it discovers that there are parity errors in the Watch List?

   b. What should the system do if it discovers that its internal directory used to find log data contains an impossible disk address?

   c. What should the system do if two messages being composed have grown so large that deadlock prevents either from being finished before the other finishes?

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UE.4 Intermodule Interfaces and UEs

LECTURE

I. Introduction

A. UE handling can result in an order of magnitude decrease in the frequency of crashes

B. UE handling tends to introduce interprogram dependence

C. Preparation for UEs can avoid this

II. Probability Considerations and UE Handling

A. Need for redundant information -- information that would not be needed if no UE occurs

B. Detection vs. correction

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C. Number of simultaneous errors

1. Example: Warning lights in automobiles

2. Example: Archive files on <u>different</u> devices

D. No error-free system -- probability of error can be arbitrarily reduced

E. Extra complication -- situations in which multiple errors are highly probable

III. The Effect of Structure on UE Handling

A. Proper response to an error requires efforts from various modules

1. Example: Unreadable block on a tape file.
Detected by tape handler.
Attempt to correct by tape handler.
File system knows which file, location of other data.
Data system knows how to reconstruct data.

2. Example: Part of memory becomes error prone (no parity).
   User program detects inconsistent data.
   Memory allocator must not assign this area.
   Deadlock prevention must know of reduced resources.
   Background memory system must attempt to restore data.

B. Conventional response

1. Write a program that uses all relevant tables for common cases
   Introduce "connections between modules."

C. Conclusion -- interface must include UE communication possibilities

Examples:

1. Tape handler reports nature of error to file system in terms of block number and tape -- not: file system reads bits

2. File system reports to data system in terms of file/line

3. Data system knows file/line -- storage of redundant data

4. Memory user has "complaint box"

5. Banker can be informed of catastrophe, bad loans

6. Banker needs interface to "job killers"

7. Banker needs alternate entry to recompute deadlock danger

IV. Abstractions that Interface with Error Recovery

A. Useful information can be presented abstractly -- not likely to change

B. Hiding too much can prevent recovery

1. Example: "parallel changes" to a file

2. Example: indistinguishable error classes in hardware

V. Software Traps as an Error Reporting Mechanism

A. Reduce code complexity by separating normal behavior, detection, and response

B. Decrease likelihood of undetected errors

C. Ease the removal of detection code when not needed

D. Four possibilities for actions after UE detection

1. continue
2. retry
3. clean up
4. give up -- only if no higher level remains

VI. Classes of UEs to Report

1) Incorrect call
2) Incorrect results
3) Report earlier incorrect call
4) Resource failure
5) Unlikely actions

VII. "Impossible" vs. Possible States After a UE

VIII. Example of Abstract Reporting of Defects -- Tree Specification

IX. Summary -- To Make the Modular Concept Work, All Communication Must be Over the Predefined Interface -- UEs Included

UE.5 MP Intermodule Interfaces and UEs

EXERCISE

Name: _____

In the improved MP system (document MP.4), recovery from mishaps will often require the cooperation of several modules. One module may discover and handle the problem initially, but other modules must be informed to take appropriate action. Example: If a message is so badly garbled that the external interface module (EI) assigns a very low probability of its being correct, this should be noted in the logs by IR/LOG. The interface between the modules must provide for communication that will allow this. Examine the description of the improved MP. For each UE listed below, explain which modules are affected and describe the information that must be communicated between them.

1. Parity errors in output buffer.

2. High rate of errors in part of memory.

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3. Operator's console is no longer functioning.

4. An operator tries to use an UGHTRANS channel that does not exist.

5. All available disk space is allocated.

UE.6 MP Intermodule Interfaces and UEs

EXERCISE SOLUTION

1. Parity errors in output buffer.

The CM module requests the EI to rewrite the same information into other core locations.

2. High rate of errors in a part of memory.

The MH module requests the AL not to allocate the error-ridden area unless no alternative exists. It requests DS to report the problem to the operator.

3. Operator's console is no longer functioning.

TC detects that an operator's console is no longer functioning. The assignments for that console must be reassigned. (Resources allocated by AL to users of that console can be temporarily reassigned.) Partially processed messages must be either finished or removed from the system.

4. An operator tries to use an UGHTRANS channel that does not exist.

EC must inform MH to correct messages containing that channel number. EI informs the operator who has been using that channel.

5. All available disk storage space is allocated.

PS must inform the AL and the operator. Space must be freed by putting old logs or messages in archival storage off-line. Message archiving must be done by use of MH and log archiving by IR.

UE.7 The Uses Hierarchy and UEs

LECTURE

I. Introduction

A. UEs correspond to the violation of a specification

B. Uses hierarchy as the key to understanding UEs

II. The Problem of Designing for UEs

A. Characteristics of UEs

1. relatively infrequent

2. often caused by higher levels in uses hierarchy, detected by lower levels

3. recovery best performed at the higher levels

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B. UE detection and handling should not be afterthoughts in the design

C. How can we incorporate UE communication in such a way that appropriate (application dependent) recovery techniques can be added?

D. Problem -- UE handling requires efforts of several modules and levels

E. Result -- potential program interdependence that violates design principles

III. Criteria of Successful Design for UE's

A. UE communication doesn't violate information hiding

B. UE handling doesn't interfere with subsetability

C. Design permits change in UE handling without change in system structure

D. New levels in the uses hierarchy can be added (with UE handling) without changing the lower levels

IV. Review of the Uses Hierarchy

A. Given program A with specification S_a and program B, we say that A uses B if A cannot satisfy S_a unless B is present and satisfies some non-trivial specification S_b. The assumed specification S_b may differ for different users of B.

B. If A doesn't care about any S_b, a call on B is not a use of B

V. The Problem of UE Communications in a Uses Hierarchy

A. "Uses" provides a means for communicating downwards in the hierarchy

B. Since recovery possibilities are usually at higher levels, lower levels need to communicate UE detection upwards

C. Lower levels can make no assumptions about upper levels (i.e., they can call programs at higher levels, but they can't use programs at higher levels)

VI. Using "Traps" to Communicate Upwards in the Uses Hierarchy

A. The analogy with hardware

B. Consider each uses hierarchy level as a virtual machine with traps for the UEs detectable by the virtual machine

C. Hardware trap = branch to fixed trap location;
virtual machine trap = call (not use) of routine with reserved name

D. Actual trap routines (UE handlers) provided by users of virtual machine; can change dynamically

E. Virtual machine traps provide upwards UE communications without violating uses hierarchy, make no assumptions about who will receive information and what will be done with it

VII. Problems in Designing the Virtual Machine Traps

A. Can be advantageous to report on a class of UEs with a single trap

B. Further information about the UE can be passed by parameters

C. Information reported upwards must be in terms of appropriate abstraction -- must respect information hiding

1. No references to internal data structures or programs

2. No references to partially computed results

3. Information only in terms of specification of the virtual machine

4. Different versions of the same module must provide same UE reports

D. Trade-offs

1. Amount of information in UE handler name and parameters vs. ease of analysis at user level

2. Number and detail of virtual machine traps vs. diagnostic programs at the user level

E. UE information may also be reported "sideways" -- reports to the programmer

VIII. Classes of UEs to Consider

A. Parameter values

B. Capacity limits

C. Undefined information requests

D. Operations in certain order (e.g., open before read)

E. Detecting actions likely to be unintentional

IX. Sufficiency

X. Trap Priority -- Call Only One at a Time

XI. Detecting Errors -- Redundancy vs. Efficiency -- Early Development

XII. Summary in Terms of Criteria for Success (see outline item II)

A. Respect information hiding by communicating UEs in terms of suitable abstractions

B. Maintain Subsetability by using traps that don't violate uses hierarchy

C. Software traps allow changes in UE handling without changes in system structure

D. UE detection based on specifications permits addition of higher levels without change

MOD.1 Decomposition into Modules

LECTURE

I. Limitations of Stepwise Refinement

A. Level of detail (assumptions must be stated)

1. Intuitive understanding assumed

B. Sequencing decisions are implied

C. Postponement principle: postponement of sequencing decisions

D. Size of programs expands -- more people, work involved

II. What Else Can We Decide Besides the Order of Events?

A. The design of data structures

B. Interfaces

C. Work assignments -- modules

D. Parameters that characterize the program family

III. History of Modular Decomposition

A. Unit of measure = 3.27 square meters

B. Parts to be put together

IV. Modules of Hardware

A. How you put them together is obvious; there are well-known physical constraints. Hardware is a physical object

V. Modules of Software -- When Are Parts Put Together?

A. Write time

B. Assembly time

C. Memory load time

VI. The Three (or More) Meanings Must Not Be Confused

A. Constraints different

1. Write time -- intellectual coherence for programmer

2. Assembly time -- name conflicts

3. Memory load time -- fitting into core things needed at same time

B. Myth of overmodularization

1. Modules should be as small as possible

C. Inefficiency results from forcing coincidence

VII. In This Course, Modules Are Always Design-Time or Change-Time Entities

A. Units of change

B. Redesign = throw away

C. So small that changing does not help

VIII. The KWIC INDEX Example

A. Conventional structure

1. Input Module

2. Circular Shift Module

3. Alphabetizing Module

4. Output Module

5. Master Control Module

B. Decisions likely to change

1. Input format

2. How stored in memory

3. Output table sorted completely before output

C. Alternative structure

1. Line Holder Module -- special purpose memory to hold lines of KWIC index

GET_CHAR(lineno, wordno, charno)
SET_CHAR(lineno, wordno, charno, char)
CHARS(lineno, wordno)
LINES
WORDS(lineno)
DELETE_LINE(lineno)
DELETE_WORD(lineno, wordno)

2. Input Module -- reads from cards; calls line holder programs to store in memory

INPUT

3. Circular Shift Module -- uses line holder programs to get data from memory; may make table, may not

CS_SETUP
CS_CHAR(lineno, wordno, charno)

4. Alphabetizer Module

ALPH
ITH(lineno)

5. Output Module -- calls ITH and line holder programs

   OUTPUT

6. Master Control Module -- calls INPUT, CS_SETUP, ALPH, and OUTPUT

D. Claim

1. Not getting any really different program

2. Different way of cutting up -- so that change is confined in one person's work (recall module definition)

3. System organized into set of modules so that it is clearly seen what needs to be changed

4. Not necessarily better algorithms or data structures

5. Simplifies interfaces

IX. Terminology

A. Information-hiding modules

-- identify the design decisions that are likely to change

-- have a module for each changeable design decision

-- each changeable decision is a "secret" of a module

B. The secret of a module

Exactly the one design decision that might change -- only the implementor knows

1. Line holder -- how lines are represented in memory

2. Input -- input format

3. Circular shift -- how circular shifts are represented

4. Alphabetizer -- time in which alphabetization is done and sorting method used

5. Output -- output format

C. Structure redefined -- terms of modular structure

1. Connections between modules are assumptions that they make about each other (Interface)

2. Mistake -- flowchart boxes become modules

D. Frequency of switching from module to module

1. Steps-in-processing approach -- low frequency of switching

2. Information-hiding -- has many separate, callable routines

3. Macros -- after expanded may be same mess but to change the software, one looks at the information-hiding representation

X. Hiding information about the design at write-time and not information at run-time -- reduce the connectivity between the modules at write-time and not at run-time

A. Run-time information versus design-time information

XI. References

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MOD.2 Change and the Original MP Modular Structure

EXERCISE

Name: _____

1. (Hardware change) Suppose that a bulk core device were added to the optional hardware in the UGH 2PIE system. The device has roughly the capacity of the small disk used (but not that of the extended mass storage or large disk option); it is very fast (about 1/5 the speed of the primary memory, where the disk was 1/10000 for access); and code may be executed from bulk core. If MP is to make the best use of such a device, what modules must be changed? Explain why the change is not confined to one or two modules.

2. (Message format change) Suppose that a message format change is announced in which Format Line 5 may be entirely omitted from a message of the lowest security class. What modules will be affected by this change? Explain why the change is not limited to one or two modules.

MOD.3 Change and the Original MP Modular Structure

EXERCISE SOLUTION

1. The bulk core can replace small disks, but it cannot replace large disks. This means that logs, if kept, will still be on disk, but that all other data can now be in the bulk core. Unfortunately, this could change every module in the system, some substantially, others only slightly (but the slight changes might still be hard to make).

In practice, DK would probably be left in place, modified to use the core. This shouldn't really be considered a triumph for modularization, because it will multiply the overhead by perhaps a factor of ten. Any module that uses DK will now sacrifice a lot of the hardware performance available by not directly using the bulk core.

Changes to EX and DC and DK cannot be avoided, and they are substantial. EX and DC must now choose whether to use main memory or leave the data in bulk core, and they have no algorithms to do anything like this. The complex interaction between DK and EX is no longer required (indeed, since most executions might be done in bulk core, only the scheduling and interrupt service of EX will be required). DC now has little reason to allocate main memory at all and thus may acquire a third class of "disk" allocation for which it is unprepared.

Of course, if IR and LM are included in the system with bulk core, they will profit greatly by using it, and will require large changes to do so. The changed modules will be inappropriate to use on a system with only disk (the UGH-VAN and UGH-20 do not have the bulk core possibility).

Two mistakes in MP are shown here. The first is that disk addresses are used throughout the system, on the assumption that DK would always be present to handle reads/writes. The other was that the core/disk distinction was an early one, which was reflected in the module structure and hence hard to reverse.

2. Certainly CO, SC, and MA will be affected by this change. (SC, even though it doesn't use FL5, because it must skip over it to find the addressee list.) But there will be smaller changes in OP, IR, LM, and even DC and perhaps TO to deal with the changed messages.

The mistake is an obvious one: too many modules duplicate the process of pulling a message apart, using slightly different algorithms, but making a common set of assumptions about message format. Finding all the places where these assumptions enter into code is liable to be very difficult in the completed system.

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MOD.4 Modular Structure of Complex Systems

LECTURE

I. Review: Information Hiding as a Criteria

A. What is a secret?

B. What are some typical secrets?

(See Figures 1 and 2)

II. What is Different About Large Complex Systems?

A. How do we deal with unstructured lists of modules?

B. How can we tell when we have them all?

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C. How does everyone remember the names?

D. How do we avoid duplications?

III. Why Should We Group Modules Into Classes?

A. Put some structure in the list

B. Help to check for completeness

C. Leads to more helpful naming conventions

D. Makes duplications less likely

IV. What are Some Possible Classification Criteria for Modules?

A. By level in a hierarchy

B. By similarity of interface

C. By type of function served or service provided

D. By nature of the secret

E. Similar programming problems

V. What are the Classes of Modules in the A-7?

A. The Extended Computer Class of Modules

Secrets: Implementation of common data types, I/O, etc.

Characteristics of TC-2 computer such as registers, memory structure, etc.

B. The Device Interface Modules

Secrets: Device Characteristics

C. The Physical Model Modules

Secrets: Models of physical phenomena

D. The Data Banker Modules

Secrets: Source and updating policies for common data

E. The System Status Modules

Secrets: How the program keeps track of the status of the system and detects state changes of interest to the system.

F. The Function Driver Modules

Secrets: Algorithms for performing requirements functions

G. The System Generation Modules

Secrets: Implementation of the tools used to assemble the system from the library of components

VI. Concluding Dilemma:

How do you deal with the fact that large systems divided into modules that are small enough to be understood have confusingly many modules?

Figure 1*: Common Secrets in Data Processing Systems

Secret	Typical Reasons for Changes
Data base structure (logical)	- New fields needed in records - Field sizes changed - More records required - Faster access required for particular fields
Algorithms	- Different time-space tradeoffs required - More accurate or efficient algorithms invented
Data storage (physical)	- Size of available storage changed - Type of available storage changed (e.g., from one tape drive model to another, or from tape to disk) - Faster access required
Input	- Input medium changed (e.g., from cards to OCR) - Fields rearranged within records - More extensive error-checking required - Input sequence changed (e.g., from unsorted to sorted)
Output	- Change in output device (e.g., from printer to computer-output microform)
Operating system interface (e.g., JCL)	- Manufacturer issues new release
Software functions as seen by user	- New types of reports required - Client requires changes in report formats

* From Kathryn Heninger and John Shore, "Designing Modular Programs -- Methodology," Auerbach Portfolio i4-01-11, to be published.

Figure 2*: Common Secrets in Real-Time Systems

Secret	Typical Change
Computer characteristics	- Computer replaced by faster, larger, or cheaper model - Computer replaced by standard model (e.g., military standard)
Peripheral devices	- Sensors replaced by more accurate, more reliable, or faster models - Displays replaced by more flexible or more reliable models
Resource allocation (e.g., scheduling)	- Relative priorities of activities changed - Single computer replaced by set of micros - Capacity of resources changed, e.g., additional memory added
Algorithms	- More accurate or faster algorithms invented - More general algorithm invented that can replace several more specialized algorithms
Software functions	- User preferences changed, including New modes needed Transition between modes changed New responses required to user inputs New displays needed - Computer-driven devices used for different purposes

* From Kathryn Heninger and John Shore, "Designing Modular Programs -- Methodology," Auerbach Portfolio 14-01-11 to be published

MOD.5 MP Secrets

EXERCISE

Name:_____

The modular structure of a system should be based on the aspects of the system that are likely to change. Each changeable aspect should become the secret of a module. Thus it is important during requirements definition and during design to list the changeable aspects of a system. Referring to the MP documents MP.1, MP.2, and MP.3, make a list of the changeable aspects of the MP system. Hint: Some areas of possible change are algorithms, data structures, formats, strategies, and hardware characteristics.

Example:

1. The internal representation of a message.

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MOD.6 MP Secrets

EXERCISE SOLUTION

Listed below are some aspects of the MP system that are likely to change, and, therefore, are secrets to be hidden in modules.

1. The internal representation of messages.
2. The external message format(s).
3. The protocol(s) of the communication device(s).
4. The WATCH LIST of messages of interest.
5. The method of controlling UGHTRANS devices.
6. The format of terminal commands and displays.
7. The terminal characteristics.
8. The commands needed to compose and edit a message.
9. The organization of log data.
10. The paging and backup-store system.
11. The resource allocation strategy.
12. The interrupt handler.
13. The organization of WCB queues.
14. The format of the WCBs.
15. The search algorithm for the WATCH LIST.
16. The configuration of the system.
17. Message analysis.

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MOD.7 Change and the Improved MP Modular Structure

EXERCISE

Name: _____

1. (Hardware change) Suppose that a bulk core device were added to the optional hardware in the UGH 2PIE system. The device has roughly the capacity of the small disk used (but not that of the extended mass storage or large disk option); it is very fast (about 1/5 the speed of the primary memory, where the disk was 1/10000 for access); and code may be executed from bulk core. If MP is to make the best use of such a device, what modules must be changed? Explain why the change is not confined to one or two modules.

2. (Message format change) Suppose that a message format change is announced in which Format Line 5 may be entirely omitted from a message of the lowest security class. What modules will be affected by this change? Explain why the change is not limited to one or two modules.

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3. (Message format change) As a result of the Freedom of Information Act, every message must include a declassification date in both FL4 and FL12. Which modules will require a change?

4. (Hardware change) A microfilm printer has been added to produce hard copy. This device contains two rolls of film, one for unclassified messages, the other for classified. Which modules will require a change?

MOD.8 Change and the Improved MP Modular Structure

EXERCISE SOLUTION

1. This change can be confined to the paging module (PS) because it is the only one that "knows" the nature of the storage devices. Some performance improvement might be obtained by examining other parts of the system, which make a choice about when they request pages be removed or brought in. The optimum choice is a function of the speed of access. Nevertheless, it is possible to use the system initially without such improvements.

2. Only EI module is affected by this change.

3. This change requires a change in the information supplied by the MH module. The new format violates the assumptions that went into the design of the module (namely, that no such information was present or relevant). The danger exists that every function that uses the functions in MH may have to be changed. For example, the programs that display messages to the operator must be altered to include the new information in the display. Similarly, such information must be included in logs, so that the programs that store messages in logs may also be subject to change. The EI module will also have to change to accommodate the new format.

4. None of the modules requires a change. The control of the new device is done by a new program that can get all of the information that it needs from MH. If these microfilm files are considered "logs," the program can be considered part of the log module. The system must consider this new storage as "write only" memory.

MOD.9 Identifying HAS Modules

EXERCISE

Name: _____

The HAS modular structure given in HAS.2 is sensitive to specification changes such as adding a CPU and second transmitter, changing the time interval between sensor readings, or eliminating history report transmissions by storing them internally on a floppy disk (to be picked up by passing ships or by trained dolphins). Propose an improved modular structure for HAS based on the system description given in HAS.1. Use the information-hiding principle to organize the system into modules. Guide your design by using the table below, first filling in the secrets column, and then the module that hides each secret. Derive the secrets from consideration of possible changes described or implied in HAS.1. Give a short description of each module, including its functional capabilities. Recall that secrets include items such as algorithms, data structures, formats, and hardware characteristics. An example entry has been included.

PROPOSED HAS MODULES

Secret	Module Name	Module Capabilities
Sensor Characteristics	Sensor Control	Hidden in this module are the sensor characteristics that might change if we replaced one sensor with another that delivers the same information. The programs that take readings from sensors are in this module; they know the HAS-BEEN instruction sequences that perform sensor input and the hardware defined memory location corresponding to each device.

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Secret	Module Name	Module Capabilities

SPEC.1 What are Specifications?

LECTURE

I. What Are "Specifications"?

A. General definition of specification

1. Specific information about the object

B. Engineering definition

1. Specific information about the requirements the object must meet

2. We will use it in the engineering sense

II. Why Do We Need Specifications?

A. Multiperson projects

B. Multiversion projects

C. "Our inability to do much" (E. W. Dijkstra)

1. Each subtask should have a definition independent of the rest of the job

D. Making early decisions explicit and precise

1. Intramodule assumptions

2. Decision postponement

III. Why Must Specifications be Precise?

A. Early, distributed design decisions are hard to correct

B. Prevent incompatibility between parts

C. Remove the need for excessive information distribution

D. Minimize forbidden assumptions

IV. Why Must Specifications be Abstract?

A. Abstraction -- one model, many realizations

B. Must allow many versions

C. State only requirements

example: fictitious sort

D. Less information to comprehend

E. User only concerned about that which he could eventually discover for himself

V. What Do We Mean by Formal?

A. Not "superficial"

B. Based on forms and rules

1. No chance of misinterpretation

2. Conceivably mechanically interpretable

VI. Why Not English (German, French, Dutch,...?)

A. Interpretation may (often does) require an elaborate legal system

B. Examples of subtle ambiguities

1. Delivers the top of the stack

2. Delivers the address of the new PSW

3. Removes the top element from the stack

4. The date three months from today

VII. Stating the Visible Effects of Functions on Each Other

A. The basic technique of formal specifications

B. Refusal to mention internal or invisible effects

1. The way to abstract specifications

C. Leaving some externally visible values undefined

1. The way to restrict statements to requirements

VIII. Stating the "Syntactic" Properties of Functions

A. Does the function have a value? What is its type?

B. Input parameters -- how many? What type?

C. Output parameters -- how many? What type?

1. This information specifies the syntactically allowed calling combinations

2. More information can be added by defining more types

IX. Stating the Semantic Properties of Functions

A. The immediately visible effects

B. Relations among functions (F1 + F2 = 3)

C. Equivalent sequences -- enough to define all the effects

D. Effect after a sequence

E. References to "history"

X. Describing "Don't Cares"

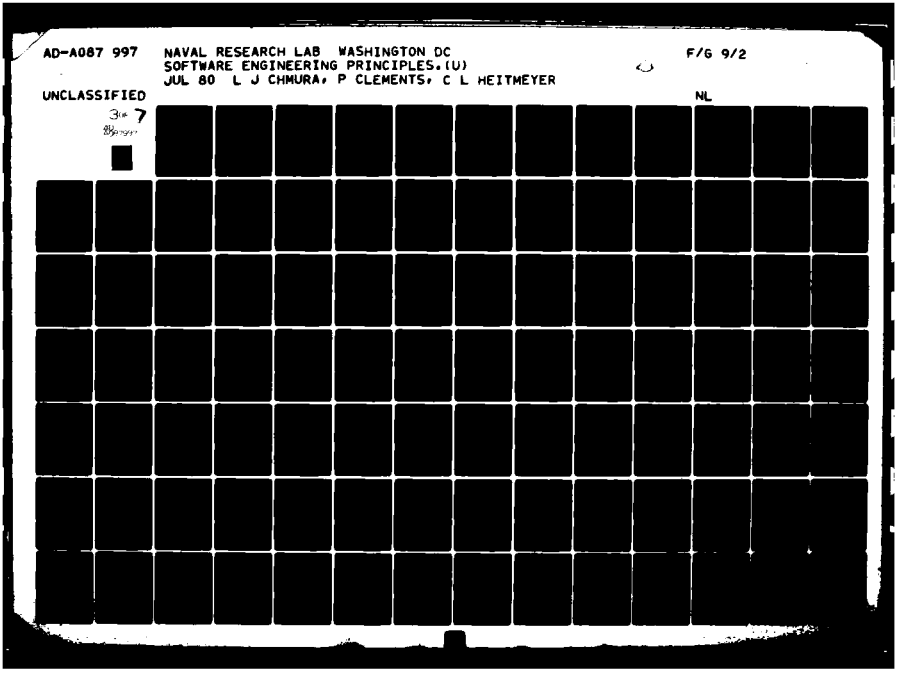
XI. Describing Forbidden or Undesired Actions

A. Stating the allowed actions

B. Stating the effects of restriction violations

C. Specifying conventions for reporting internal errors

XII. Example: Stack With Limitations


AD-A087 997
NAVAL RESEARCH LAB WASHINGTON DC
SOFTWARE ENGINEERING PRINCIPLES.(U)
JUL 80 L J CHMURA, P CLEMENTS, C L HEITMEYER
F/G 9/2
UNCLASSIFIED
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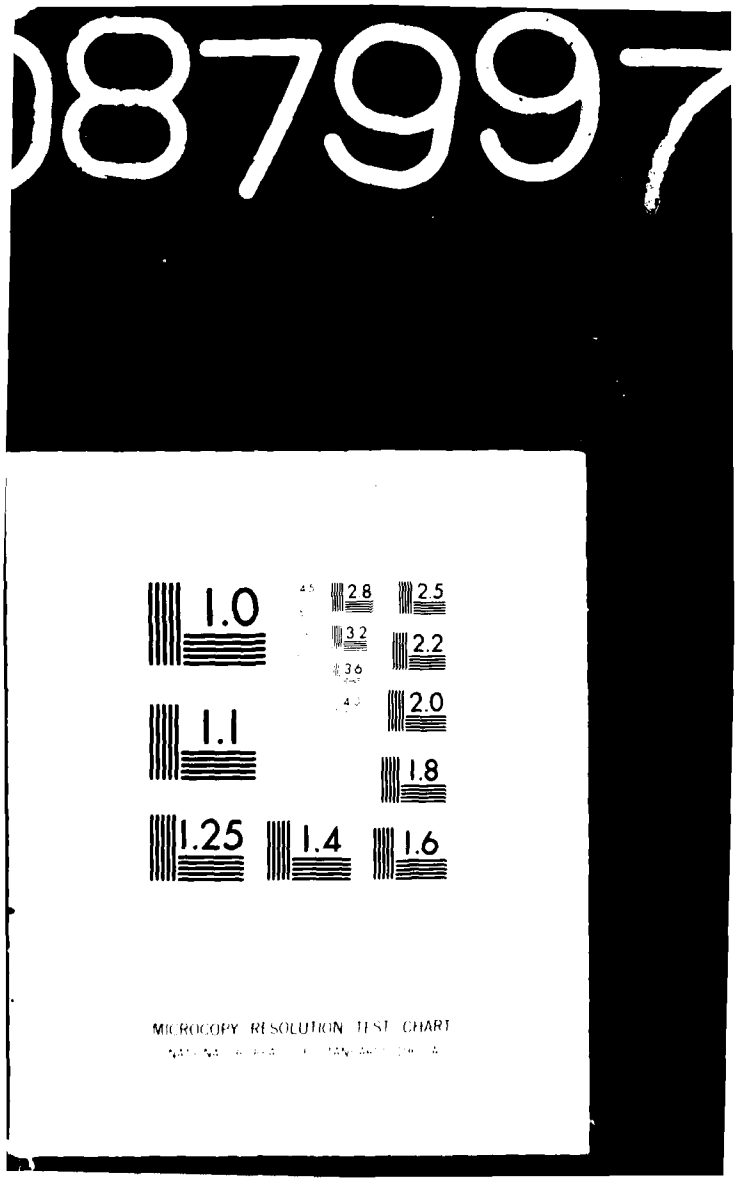
087997
1.0
2.8
2.5
3.2
2.2
3.6
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

XIII. Example: Stack Without Limitations

XIV. Example: Tree

XV. Example: Queue

XVI. Example: Sorting Queue

XVII. Completeness and Consistency

A. Derivation of value or "undefined" for all sequences

B. Only one value derivable

XVIII. Important vs. Notational Aspects

A. Rules about content important

B. Syntactic invention still needed

C. Don't let syntax control content

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SPEC.2 | Using an Informal Functional Specification

EXERCISE

Name:_____

Using the informal functional specification of the message holder module given in document MP.5, answer the following questions. Single quotes enclose a character string. Thus, 'RUSSIA' represents the six-character string RUSSIA.

1. What is the value of GET_ROUTING_INDICATOR after executing SET_ORIGINATOR_ROUTING_INDICATOR('RUSSIA')?

2. After executing SET_TEXT(25,30,'tricky'), what is the value of GET_TEXT(30,30)?

3. What is the effect of SET_TEXT(25,25,'tricky')?

4. The original text is HAPPY BIRTDAY; what command will correct it?

5. The original text is HAPPY BIRTHDAY; what is the text after executing BLANKIT(4)?

6. If the message already contains an addressee, what is the effect of SET_ADDEE('SECNAV')?

7. We have executed BIND(47), stored some text in the message, and then executed NEW_MESSAGE(47); what happens as a result?

8. What will happen if a program executes SET_SERIAL('serial')?

9. How long is the string GET_TEXT(30,30)?

10. If the text of a message currently contains 35 characters, what is the effect of SET_TEXT(50,71,'MP SOFTWARE')?

SPEC.3 Formal Functional Specifications

LECTURE

I. Purpose: Stating Requirements that an Implementation of an Information-Hiding Module Must Satisfy

A. State everything that is required

B. State nothing that is not required

C. Leave no room for doubt

II. Three Views About Showing Internals

A. Mention no internals

Why:

Why not:

B. Mention hypothetical "ridiculous internals"

Why:

Why not:

C. Mention hypothetical "suggested internals"

Why:

Why not:

III. Syntax in a Specification

A. What is a type?

B. "Presentation" presents type information

IV. What is a Trace?

A. Execution history of a module from creation

B. A subtrace is part of a trace

C. Notation for describing traces and subtraces

1. F(a, b, c)

2. F(a, b, c).Y(2, 3, 4)

3. $\sqcup$

4. V(T)

5. s^n

V. What Kinds of Assertions Can be Made About Traces?

A. Which traces must be legal?

B. When are two traces equivalent?

1. Equivalent traces must be indistinguishable from outside the module

2. Two traces are not equivalent unless shown to be equivalent

C. Values of traces in terms of previously defined types

VI. Specification of an Unbounded Stack

Syntax:

PUSH:	⟨integer⟩ x ⟨stack⟩	-> ⟨stack⟩
POP:	⟨stack⟩	-> ⟨stack⟩
TOP:	⟨stack⟩	-> ⟨integer⟩
DEPTH:	⟨stack⟩	-> ⟨integer⟩

Semantics:

A. Legality:

(1) $\lambda(T) \Rightarrow \lambda(T.PUSH(a))$
(2) $\lambda(T.TOP) = \lambda(T.POP)$

B. Equivalences:

(3) T.DEPTH ≡ T
(4) T.PUSH(a).POP ≡ T
(5) λ(T.TOP) => T.TOP ≡ T

C. Values:

(6) λ(T) => V(T.PUSH(a).TOP) = a
(7) λ(T) => V(T.PUSH(a).DEPTH) = 1 + V(T.DEPTH)
(8) V(DEPTH) = 0

The above specification assumes that only one stack exists and omits the stack parameter in the trace assertions.

VII. Specification of an Unbounded Queue

Syntax:

ADD: ⟨integer⟩ x ⟨queue⟩ -> ⟨queue⟩
REMOVE: ⟨queue⟩ -> ⟨queue⟩
FRONT: ⟨queue⟩ -> ⟨integer⟩

Semantics:

A. Legality:

(1) λ(T) => λ(T.ADD(a))
(2) λ(T) => λ(T.ADD(a).REMOVE)
(3) λ(T.REMOVE) = λ(T.FRONT)

B. Equivalences:

(4) λ(T.FRONT) => T.FRONT ≡ T
(5) λ(T.REMOVE) => T.ADD(a).REMOVE ≡ T.REMOVE.ADD(a)
(6) ADD(a).REMOVE ≡ |_|

C. Values:

(7) V(ADD(a).FRONT) = a
(8) λ(T.FRONT) => V(T.ADD(a).FRONT) = V(T.FRONT)

The above specification assumes that only one queue exists and omits the queue parameter in the calls on the access programs.

VIII. Specification of a Sorting Queue

Syntax:

INSERT: ⟨integer⟩ x ⟨squeue⟩ -> ⟨squeue⟩
REMOVE: ⟨squeue⟩ -> ⟨squeue⟩
FRONT: ⟨squeue⟩ -> ⟨integer⟩

Semantics:

A. Legality:

(1) $\lambda(T) \Rightarrow \lambda(T.INSERT(a))$
(2) $\lambda(T) \Rightarrow \lambda(T.INSERT(a).REMOVE)$
(3) $\lambda(T.FRONT) = \lambda(T.REMOVE)$

B. Equivalences:

(4) $\lambda(T.FRONT) \Rightarrow T.FRONT \equiv T$
(5) $T.INSERT(a).INSERT(b) \equiv T.INSERT(b).INSERT(a)$
(6) $INSERT(a).REMOVE \equiv \sqcup$
(7) $\lambda(T.FRONT)$ cand $(V(T.FRONT) \leq b) \Rightarrow T.INSERT(b).REMOVE \equiv T$

C. Values:

(8) $V(INSERT(a).FRONT) = a$
(9) $\lambda(T.FRONT)$ cand $V(T.FRONT) \leq b \Rightarrow V(T.INSERT(b).FRONT) = b$

NOTE: The value of X cand Y is false if X is false, and the value of X cand Y is the value of Y is X is true. Y need not have a defined value if X is false.

IX. Specification of a Stack that Overflows at the Bottom

Syntax:

PUSH: ⟨stac⟩ x ⟨integer⟩ - ⟨stac⟩
POP: ⟨stac⟩ -> ⟨stac⟩
VAL: ⟨stac⟩ -> ⟨integer⟩

Semantics:

A. Legality:

For all T, $\lambda(T)$

B. Equivalences:

$0 < N \leq 124 \Rightarrow PUSH^{N}(a_i).POP \equiv PUSH^{N-1}(a_i)$
$PUSH(a_0).PUSH^{124}(a_i) \equiv PUSH^{124}(a_i)$
$T.VAL \equiv T$
$N \geq 0 \Rightarrow POP^{N}.PUSH(a) \equiv PUSH(a)$

C. Values:

$V(T.PUSH(a).VAL) = a \bmod 255$

X. When is a Specification Complete? Do We Always Want Completeness?

XI. When is a Specification Consistent?

XII. Effect of Programming Languages

A. Lack of choices in some languages leads to simplification

B. Lack of "functions" leads to minor complication

C. User-defined types can simplify specifications

XIII. Dealing With Nonsequential Systems

XIV. Three Heuristics

A. Minimal subset approach

B. Looking for sequences that make the system "forget"

C. Canonical forms for showing completeness

XV. Open Problems

SPEC.4 Coding Specifications

LECTURE

I. Motivation

A. It is sometimes useful to have a level of documentation between module interface designs and module implementation code

1. Can ease maintenance (code is sometimes hard to read)

2. Can provide a useful form for reviewing module implementation design decisions

3. Can enable the design of module implementations valid for more than one language

B. Such documentation can ease problems that sometimes occur with programmers responsible for implementing modules or parts of modules

1. May not have "big picture"

2. Will (naturally) optimize locally

3. May not have much experience

4. May misinterpret requirements

II. What Are Coding Specifications?

A coding specification for a given program is a document in which pseudo-code or abstract programs are used to constrain the selection of algorithms and data structures or to specify them completely. Whatever the extent of the constraints imposed, the coding specification should contain all information (or references) required to write complete and correct code for the program.

III. Why Not Just Write Programs?

A. The programming language may not be well-suited to communicating algorithms to people

Examples: use of case, while, if ...then ...else.

```
if  flag                          IF (FLAG) GO TO 10
      then action_1;                 action_2
      else action_2;                 GO TO 20
end-if;                        10 action_1
                               20 CONTINUE
```

B. Since constraints imposed on different code may vary, we need a degree of informality

Example: "sort A"

vs.

"sort A using algorithm efficient for N less than 15"

vs.

"bubble sort A"

vs.

"for I:= 1 step 1 to N do ..."

C. Often desirable to introduce special notation to aid in specification, communication, or maintenance

1. Example: physical field references

R[5:9] or R["opfield"]

vs.

RSHIFT(LSHIFT(R,4), 28)

2. Example: names instead of values

if I gt SYSNUM then error(TOOBIG); end-if;

vs.

if I gt 796 then error(3); end-if;

IV. Selecting a Code Specification "Language"

A. The actual programming language might be a suitable base

B. It should be straightforward to translate to the programming language -- don't use a base like APL or LISP for coding specifications if the system will be written in FORTRAN

C. Balance formality and informality

1. Formality can facilitate automatic indexing, cross-referencing, and checking

2. Informality provides the advantages discussed in III

V. Using Coding Specifications

A. Have module designers write them and other designers review them

B. Have author and coder collaborate on necessary changes

C. Have author review resulting code

D. Use in designing and analyzing system tests

E. May be appropriate to keep them current and use as long-term documentation (depends on readability of code)

F. Keep on-line

G. Use utility programs

VI. Summary

CODING SPECIFICATION EXAMPLE

Interface Specification

)CLWTCT(

FUNCTION: Clears the contents of the write access counters (WCOUNT) for ATRTAB entries other than labels, procedures, or constants.

COMMENTS AND DESCRIPTION: Counters can be incremented or cleared but not set to a specific value.

CALLING SEQUENCE: CALL CLWTCT(ERRCODE)

PARAMETERS:

ERRCODE	INT;R	+ or - the function identifier of caller ⟨ERRINC⟩ Codes: ⟨OK⟩ ⟨NOBIND⟩ ≡ no ATRTAB entry bound ⟨ILLTYP⟩ ≡ label, procedure, or constant bound

Tables Referenced	Entry Types Referenced	Logical Components Referenced
ATRTAB	ARRAY	WCOUNT
	REG	WCOUNT
	TREG	WCOUNT
	TFLAG	WCOUNT

Interface Specification

)INWTCT(

FUNCTION: Conditionally increments the write access counter (WCOUNT) for ATRTAB entries other than labels, procedures or constants. If the STATUS field indicates that counting is enabled, counting is performed.

COMMENTS AND DESCRIPTION: Counters can be incremented or cleared but not set to a specific value.

CALLING SEQUENCE: CALL INWTCT(ERRCODE)

PARAMETERS:

ERRCODE	INT;R	+ or - the function identifier of caller ⟨ERRINC⟩ Codes: ⟨OK⟩ ⟨NOBIND⟩ ≡ no ATRTAB entry bound ⟨ILLTYP⟩ ≡ label, procedure or constant bound

Tables Referenced	Entry Types Referenced	Logical Components Referenced
ATRTAB	ARRAY	WCOUNT
	REG	WCOUNT
	TREG	WCOUNT
	TFLAG	WCOUNT

Coding Specification

Routines to clear access counters

ROUTINE	[PHYSICAL FIELD]
)CLRDCT(	[READ COUNT]
)CLWTCT(	[WRITE COUNT]
)CLMOCT(	[MONITOR COUNT]

Routines to increment access counters

ROUTINE	[PHYSICAL FIELD]
)INRDCT(	[READ COUNT]
)INWTCT(	[WRITE COUNT]
)INMOCT(	[MONITOR COUNT]

PARAMETER FILES:

ACERRI.REQ	⟨ERRINC⟩ Codes for calling)ERR(
ACNAM.REQ	Parameter definitions for routine name codes used for calling)ERR(function
ACATIP.REQ	ATRTAB entry type codes
ARFSIZ.REQ	Parameters for array size declarations and table entry size definition

COMMON BLOCK DEFINITION FILES:

ACSTOR.REQ	Primary data structure for support of table access routines

EXTERNAL REFERENCES:

ERR	for error reporting
(Byte and Halfword routines)	As required to extract table entries (See references (c), (d), and (e))

```
ALGORITHM:

    /* ⟨ROUTINE⟩ is the parameter containing the name of the routine being
       coded. */

    !if !DEBUG
       !then /* code the following with 'D' in column 1 */

          if ATRBD {ACSTOR} = -1
             then

                call ERR(ERRCODE, ⟨NOBIND⟩ + ⟨ERRCSZ⟩ * ⟨ROUTINE⟩)
                return

             end

          if ATRTP {ACSTOR} is not appropriate for the desired [PHYSICAL FIELD]
             then

                call  ERR(ERRCODE, ⟨ILLTYP⟩ + ⟨ERRCSZ⟩ * ⟨ROUTINE⟩)
                return

             end

          !end /* !DEBUG */

       !if routine being coded clears a counter
          !then

       [PHYSICAL FIELD]:= 0

          !else /* routine must increment a counter */

       if CTSTAT {ACSTOR}
          then /* counting will be effective */

             [PHYSICAL FIELD]:= [PHYSICAL FIELD] + 1

          end

          !end

       return
```

ABS.1 Abstract Interface Modules and Their Value

LECTURE

I. Introduction -- Review

A. The value of being explicit about design decisions and assumptions

1. Example -- the "fundamental assumptions" list for the A-7

2. Program families -- choosing the order of decisions

Difficulties:

3. Modules and information hiding

Difficulties:

B. What is an interface?

1. More than just syntax or format

2. An interface between two programs is defined by the set of explicit and implicit assumptions they make about each other

II. What's Special About DoD Software Interfaces?

A. Not just a question of size or real-time demands

B. Definition -- An embedded computer system is considered a module in some larger system

C. Some distinguishing characteristics of embedded computer systems

1. Designer not free to define interface

2. Interface constraints may be strict and arbitrary, but we can't ignore them

3. Several similar interfaces may be involved

4. Interface will change during development

5. Cost of changing computer system not considered seriously when changes in total system are made

6. Commercial contrasts

D. A contractual dilemma

1. Contract must constrain contractor by providing testable specifications

2. For above reasons, final interface must be considered unknown

3. System for "wrong" interface will be hard to change

4. Lack of competition makes changes afterward unreasonably expensive

E. Preponderance of embedded systems -- a partial explanation for the high cost of DoD software

1. Reason may not be functional complexity, programming tools, programmers' abilities

2. Technical advances can help

III. Examples of Embedded Systems

A. The address holder system (our programming problem)

Constraints that may change:

B. MP

Constraints:

C. Radar data analysis systems

Constraints:

D. Computers in weapons systems -- e.g., TC-2 computer in the A-7

Constraints:

IV. Examples of Implicit Assumptions in an Interface and Their Effects on Application Programs

A. Address holder

B. A-7

V. Applying "Information Hiding" to Solving the Interface Problem When Externals Will Change

A. Review of information hiding

B. Use an "abstract interface" to "hide" the actual interface

VI. Abstract Interface Modules

A. What do we mean by abstract?

1. Do not mean vague or highly mathematical; abstract means conceived apart from special cases

2. Abstract implies a many-to-one mapping that models some aspects but not all

3. Examples of abstractions

a. circuit diagrams

b. address holder assuptions

c. graphs

d. algorithms

e. data types

B. Why are abstractions useful?

1. If all properties of the abstract system correspond to properties of the real system -- we can learn about the real system by studying the abstraction

2. Abstraction is simpler (in principle, but abstract thinking may be unfamiliar)

3. Results about abstraction may be "reused"

C. What is an abstract interface?

1. Represents many possible actual interfaces

2. Models some properties of actual interface but not all

3. All things true of the abstract interface are true of actual interfaces

VII. How Can Abstract Interface Modules Help?

A. Define the abstract real-world interface

B. Procure applications programs based on abstract interface, preventing exploitation of facts that happen to be true of today's actual interface

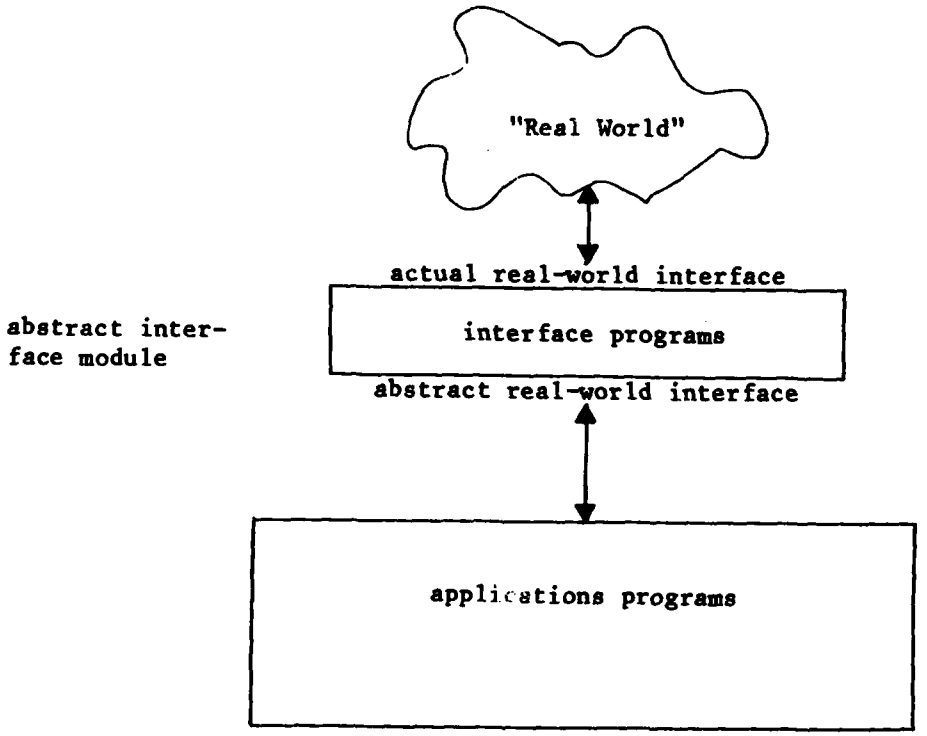

Figure 1. Abstract Interface Module.
The interface programs implement one instance of the many-to-one mapping between the actual real-world interface and the abstract real-world interface.

C. When actual interface is fixed, build interface programs

D. "Real-World" changes that affect actual interface should only affect the interface programs

E. Simple example -- a date interface. Possible formats in actual interfaces:

February 10, 1941	(month day-in-month, year),
10 February 1941	(day-in-month month year),
10 February 41	(day-in-month month last-two-digits-of-year),
10.2.1941	(day-in-month.integer-encoded-month.year),
2/10/1941	(integer-encoded-month/day-in-month/year),
41.2.10	(last-two-digits-of-year.integer-encoded-month.day-in-month),
41 February 10	(last-two-digits-of-year month day-in-month),
41,41	(day-in-year,last-two-digits-of-year).
15015	(days since the first day of 1900)

VIII. How to Design an Abstract Interface Module

A. Prepare a list of assumptions about properties of all the possible real-world interfaces to be encountered -- have this list reviewed

B. Express these assumptions by defining a set of "functions" representing possible system inputs and outputs and by stating relations between these functions

C. Perform consistency checks

1. Verify that any property of the function set is implied by the assumptions

2. It should be possible to write bulk of system in terms of these functions; if not, return to A

D. Contractor is required to write bulk of system in terms of the functions defined in B, and programs must be correct for any implementation of those functions that satisfies the description B

E. Illustration of this procedure for the address holder (programming example)

1. Initial assumptions

The following items of information will be contained in addresses and can be identified by analysis of the input data; this information is the only information that will be relevant for our computer programs:

Last name
First name
Organization
Street address
City, state and zip code (single line with a comma between city and state)

2. Objections

3. Refined assumptions

F. Another example -- abstract interfaces for the A-7 Device Interface Module

IX. Refining/Extending the Interface for a Subset of the Interfaces

A. Some useful applications programs may not be generally applicable

B. Confinement of the specialized program

C. Specialization (Refinement) by adding functions not generally implementable

D. Specialization (Refinement) by stating additional properties of functions

E. Deviant actual interfaces

F. The family tree again

X. When Won't It Work?

A. Success depends on our ability to predict change (oracle assumption)

B. Success depends on existence of commonality between actual interfaces (interface programs smaller than applications programs)

XI. Summary

A. An interface is equivalent to a set of assumptions

B. The abstract interface is a precise, formally specified interface

C. The abstract interface is a model of all "expected" actual interfaces

D. Contractor is more tightly constrained than in conventional procedure -- his program is not allowed to make assumptions that limit applicability

E. Actual interface is met by writing additional programs -- not by modifying programs that were written based on the abstract interface definitions

XII. Abstract Interface Module as an Application of Fundamental Principles

A. Being explicit about assumptions and design decisions

B. Encapsulation of likely changes

C. Abstract interface modules can solve the embedded computer system problem by hiding the embedding from the computer

D. Abstract interface modules are just a special case -- use same method for other information hiding modules

XIII. Reference

Parnas, D. L. 1977. Use of Abstract Interfaces in the Development of Software for Embedded Computer Systems. Naval Research Laboratory Report no. 8047.

ABS.2 Using the MP Abstract Interface

EXERCISE

Name:_____

The message on page 6-20 has been assembled according to the message format rules in the original MP design (MP.3). These rules are summarized on pages 6-18 and 6-19 of this exercise.

Your job is to use the abstract interface functions in MP.6 to assemble the same message. To do this, complete the list of function calls started below.

```
CREATE(bdaymsg)

SET_ORIGIN_ROUTE_PART(bdaymsg, DB)

SET_CHANNEL_ID(bdaymsg, 3)
```

MESSAGE FORMAT FROM ORIGINAL MP DESIGN

To summarize the original MP message format, we provide a few general rules, a message template, and a list of the fields in the template.

General rules

A message consists of a number of Format Lines numbered beginning with one. (These are abbreviated FL1, FL2, etc.) Capital letters represent themselves, and where given, must appear exactly. Where information is to be supplied, a lower-case name will appear, explained in the list below. Where items are optional, they are enclosed in square brackets; where a choice of items is permitted, these are shown one above the other. The spaces shown are nonrepresentative: the characters begin in the first column, and continue to the end of the format line without spacing unless explicit spaces are indicated by the symbol b. Each line ends with a sequence of two-carriage-returns-and-a-line-feed, not shown. When an item is superscripted, it is repeated that many times; superscript ^{n} means an indefinite repeat (but at least once).

Fields in the message template

The following list describes the form and content of the fields in the template, given on the next page.

"origin-route-part":	2-letter part of the originating routing code (the 3rd-last and 2nd-last letters of the code),
"channel":	3-digit number identifying the channel,
"precedence":	1-letter code from a standard list,
"origin-media":	1-letter language media code from a standard list,
"dest-media":	1-letter language media code from a standard list,
"classification":	1-letter security classification letter from a standard list,
"content-action":	4-letter identifier from a standard list,
"sender-orig-route":	7-letter routing indicator of the sender,
"serial":	4-digit number supplied by the sender,
"day-in-year":	3-digit Julian day-of-the-year, for date when message created,
"time":	4-digit GCT at which the message created,
"addressee-route"	7-letter routing indicator for the addressee,
"year":	2-digit year when message created, e.g., 76 for the bicentennial year,
"originator"	either "sender-orig-route" or plain text,
"addressee":	the plain text corresponding to the routing indicator it follows. (In the final addressee item the period replaces the comma, and similarly in FL8, 9.)
"subj-code":	6-character code composed of the letter N and 5 digits
"text":	the message text.
"null":	an empty line (but with the usual ending),
"lf":	line-feed.

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Message template

FL1: VZCZC origin-route-part channel

FL2:

precedence origin-media dest-media classification
content-action b sender-orig-route serial b date
time b classification[4] addressee-route

FL3: DE b sender-orig-route serial date time b year

FL4: ZNR b classification[5] T [addressee-route]

FL5:

precedence b day-in-year time Z b JAN ... DEC b year b

FL6: FM b originator

FL7: TO b [routing / addressee,][n].

FL8: [INFO b [routing / addressee,][n] .]

FL9: [XMT b [routing / addressee,][n] .]

FL11: BT

FL12: classification //subj-code// text

FL13: BT

FL15: # serial

FL16: null lf[7] NNNN

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MESSAGE TO BE REASSEMBLED

VZCZCDB003

RTTUZYUW RUCLDBA2355 1861200 UUUURUHHLFA

DE RUCLDBA23551861200 76

ZNR UUUUU

R 1861200Z JUL 76

FM COMNAVTELCOM WASHINGTON DC

TO RUHHLFA/ALCOM.

BT

U//N09999//

HAPPY BIRTHDAY

BT

#2355

(8 blank lines)

NNNN

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ABS.3 Using the MP Abstract Interface

EXERCISE SOLUTION

CONSTRUCTING MESSAGES WITH THE MP ABSTRACT INTERFACE

```
CREATE(BDAYMSG)

SET_ORIGIN_ROUTE_PART (bdaymsg, DB)

SET_CHANNEL_ID(bdaymsg, 3)

SET_PRECEDENCE(bdaymsg, R)

SET_ORIGIN_MEDIA(bdaymsg, T)

SET_DEST_MEDIA (bdaymsg, T)

SET_CLASSIFICATION (bdaymsg, U)

SET_CONTENT_ACTION(bdaymsg, ZYUW)

SET_SENDER_ORIG_ROUTE(bdaymsg, RUCLDBA)

SET_SERIAL(bdaymsg, 2355)

SET_DATE_CREATED (bdaymsg, JULIAN(76, 186))

SET_TIME_CREATED (bdaymsg, CLOCK24(12, 00))

SET_ADDRESSEE_ROUTE(bdaymsg, RUHHLFA)

SET_ORIGINATOR(bdaymsg, COMNAVTELCOM WASHINGTON DC)

SET_TO_LIST (bdaymsg, RUHHLFA, ALCOM)

SET_SUBJECT_CODE(bdaymsg, N09999)

SET_TEXT(bdaymsg, HAPPY BIRTHDAY)
```

COMMENTS

1. The 'SET' functions may be called in any order; the abstract interface programs arrange the information in the order required by the message format.

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2. No function calls are needed for control characters such as "VZCZC"; these are inserted by the abstract interface programs.

3. A given 'SET' function need be called only once, even if the information appears in the message several times. For example, even though "precedence" is inserted in both FL1 and FL5, 'SET_PRECEDENCE' need only be called once. The abstract interface programs take care of the repetition.

4. Even though the date appears in two forms (see FL3 and FL5), 'SET_DATE_CREATED' need only be called once. The abstract interface programs can compute the information required for both forms from the date variable it receives as the 'SET_DATE_CREATED' parameter.

HIE.1 Hierarchy Survey

LECTURE

I. Introduction

A. Much disagreement about benefits and disadvantages of hierarchical structures for computer software

B. Many different things meant by "hierarchical structure"

C. Nontrivial hierarchical structures always imply restrictions placed on the programmer

1. Restrictions may result in disciplined programming and a quality product

2. A given set of restrictions may not be appropriate for all situations

D. Purpose of lecture: survey of several well-known hierarchical structures

II. Definition of Structure

A. Division into parts

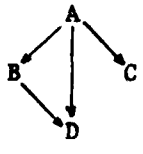
B. Relation between parts

C. Structure graphs

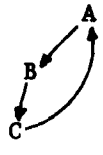
III. Definition of Hierarchical Structure

A. A structure with no loops in its relation

hierarchy



not hierarchies



B. Before you know what someone means by a hierarchical structure, you must know the <u>parts</u> and the <u>relation</u>

C. Hierarchies not necessarily trees

IV. The Uses Hierarchy

A. Parts: programs

Relation: uses

Time: late design time

B. Definition of uses:

Given program A with specification S_a and program B, we say that A uses B if A cannot satisfy S_a unless B is present and satisfies some nontrivial specification S_b. The assumed specification S_b may differ for different users of B

C. Differences between call and use

1. Calls that are not uses

2. Uses that are not calls

3. Example: hardware for division

uses power supply

but calls divide by 0 routine

D. Virtual-machine analogy

E. Found in T.H.E., also in many examples of structured programming

F. Advantages

1. Availability of tailored subsets

2. Fail-soft capabilities when UEs occur

3. Incremental development

counter example: Multics file system

4. Code duplication avoided

V. The Gives Work Hierarchy

A. Parts: processes

Relation: gives an assignment to

Time: run time

B. Found in T.H.E.

C. Useful in guaranteeing termination and preventing deadlock; neither necessary nor sufficient

D. In T.H.E. system uses and gives work hierarchies coincide

II. The Resource Allocation Hierarchy

A. Parts: processes

Relation: allocates a resource to, or owns the resources of

Time: run time

B. Applicable with dynamic resource administration only

C. "Allocates to" vs. "controls": the question of preemption

D. Advantages:

1. Interference reduced or eliminated

2. Deadlock possibilities reduced

E. Disadvantages

1. Poor utilization when load unbalanced

2. High overhead when resources are tight (especially with many levels)

VII. The Courtois Hierarchy

A. Parts: operations

Relation: takes more time and occurs less frequently than

Time: run time

B. Economics analogy

C. Approximately decomposable systems

D. T.H.E. comparison

VIII. The Module Decomposition Hierarchy

A. Parts: modules

Relation: part of

Time: early design time

B. All of a module's functions are not on the same level of the uses hierarchy. Not all functions need be offered in all system subsets

C. Never a loop in "part of" -- module decomposition always a hierarchy

IX. The Created Hierarchy

A. Parts: processes

Relation: created

Time: run time

B. Must be a hierarchy (father is older than son)

C. Why a tree? -- team work in creating progeny is accepted practice

D. Sometimes implies unnecessary restrictions

1. Father cannot die till all progeny die

2. Progeny die when father dies

X. The Protection Hierarchy (Multics)

A. Parts: system components

Relation: can access the data of

Time: design time and run time
(decisions made at design time, enforced at run time)

B. Disadvantage: Violate Need to Know principle

XI. Conclusions

A. When someone tells you "the software is hierarchically structured"

1. Find out what they mean (What are the parts? What is the relation?)

2. Evaluate appropriateness for particular application

B. Forcing different structures to coincide may lead to an unrealistic design.

XII. References

A. General:

Parnas, D. L. 1974. "On a 'Buzzword': Hierarchical Structure." Proceed. of IFIP Congress 74.

B. Uses:

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D. Owns Resources:

Brinch Hansen, P. 1970. "The Nucleus of a Multiprogramming System." Comm. ACM, vol. 13, no. 4, pp. 238-241, 250.

E. Shorter Duration -- Higher Frequency:

Courtois, P. J. 1975. "Decomposability, Instabilities and Saturation in Multiprogramming Systems." Comm. ACM, vol. 18, no. 7, pp. 371-377.

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Parnas, D. L. 1972. "On the Criteria to be Used in Decomposing Systems into Modules." Comm. ACM, vol. 15, no. 12, pp. 1053-1058.

G. Created:

Brinch Hansen, P. 1970. "The Nucleus of a Multiprogramming System." Comm. ACM, vol. 13, no. 4, pp. 238-241, 250.

HIE.2 Designing a Uses Hierarchy

LECTURE

I. Goals

A. Program families: different installations require different capabilities

1. Systems with different capacities

2. Systems with different degrees of flexibility

3. Spectrum: ONE to FIXED to VARYING

B. Adjustable systems: easy to extend or subset

1. Ability to remove functions to make room for other functions

PRECEDING PAGE BLANK-NOT FILMED

2. Fail-soft response to undesired events

II. Alternatives Available to the Software Procurer

A. The super system

1. Generality *costs!*

B. A system for the "average" user

C. A set of independently developed systems

** D. A subsettable super system -- each family member offers a subset of the services provided by the largest member

1. Individual installations only pay for what they need

2. Ability to extend by adding programs, not changing existing programs

3. Incremental implementation possible

III. Uses Hierarchy, Reviewed

A. Parts: programs, not modules

B. Relation: "requires correct operation of"

C. When defined: late design time

D. Purpose: additional specifications for programmers

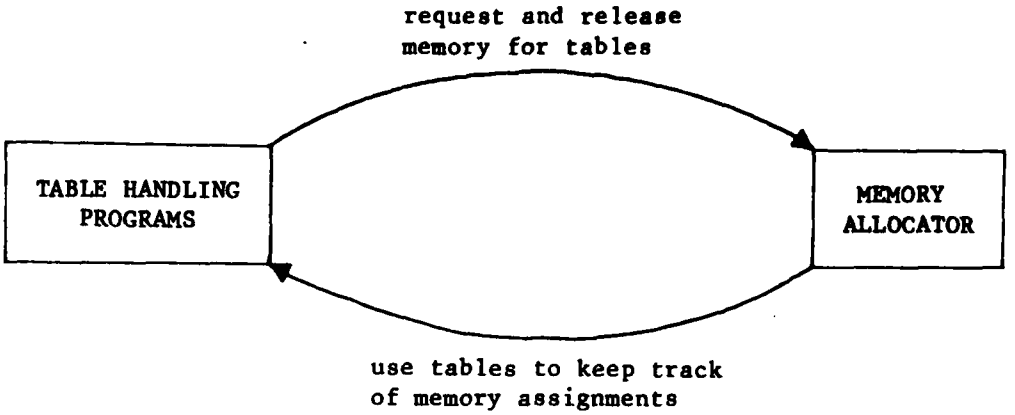
E. Why important

1. Determines possible subsets

2. Determines possible fail-soft modes

3. Affects order of program integration

F. Design error: loops in uses hierarchy



Two dangers:

1. Memory allocator and table generator use each other

   -- Neither works until both work

   -- If either is removed, system no longer works

2. Memory allocator builds own tables

   -- Code duplication

IV. Basic Steps in the Design of a Subsettable System

A. Requirements Definition: identify the subsets first

B. List programs belonging to each module

1. Access programs

2. Internal programs -- cannot be used by programs outside the module

3. Main programs -- cannot be used -- top level in uses hierarchy

C. For every pair of programs, three possibilities

A may use B

B may use A

Neither may use the other

D. List programs at level 0: programs that use no other programs

E. Work up from there

-- Level 1 programs use only level 0 programs

-- Level 2 programs use only level 0 or level 1 programs, etc.

F. Four conditions for allowing program A to use program B

1. A is simpler because it uses B

   -- Information retrieval programs in MP simpler because they use page storage programs: don't have to know details of memory handling

2. B is not much more complex because it is not allowed to use A

   -- Page storage programs: wouldn't be simpler if they used information retrieval programs

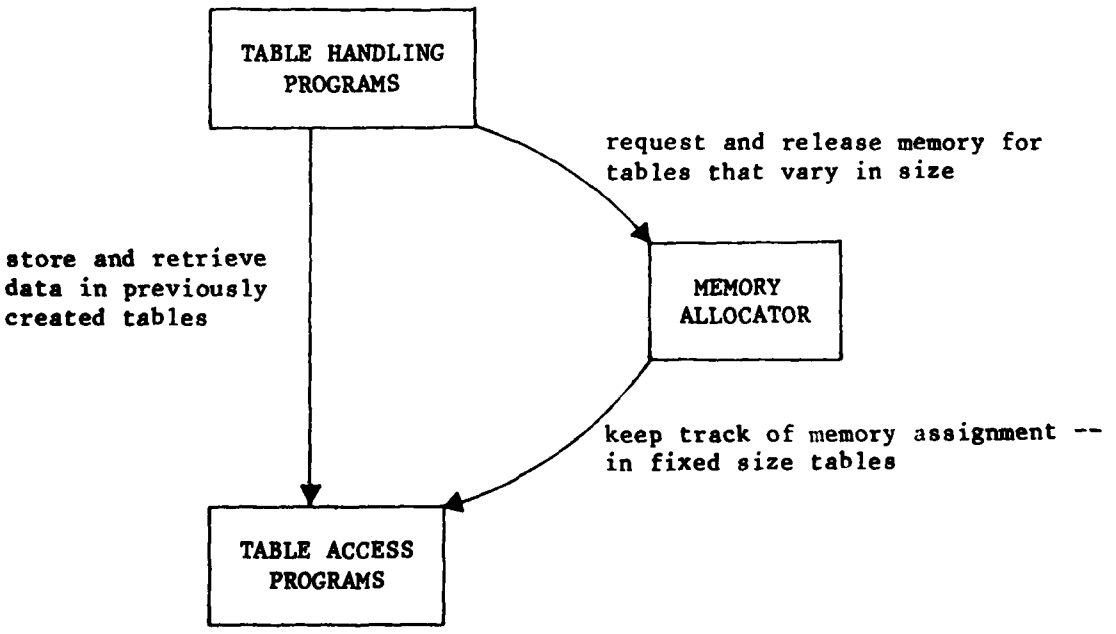
3. There is a useful subset containing B and not A

   -- Page storage programs useful for other purposes besides Information Retrieval, e.g., for implementing Message Holder programs

4. There are no useful subsets containing A and not B

   -- No reason to have Information Retrieval without memory (Page Storage)

G. Refinement through sandwiching - what to do if the four conditions don't hold



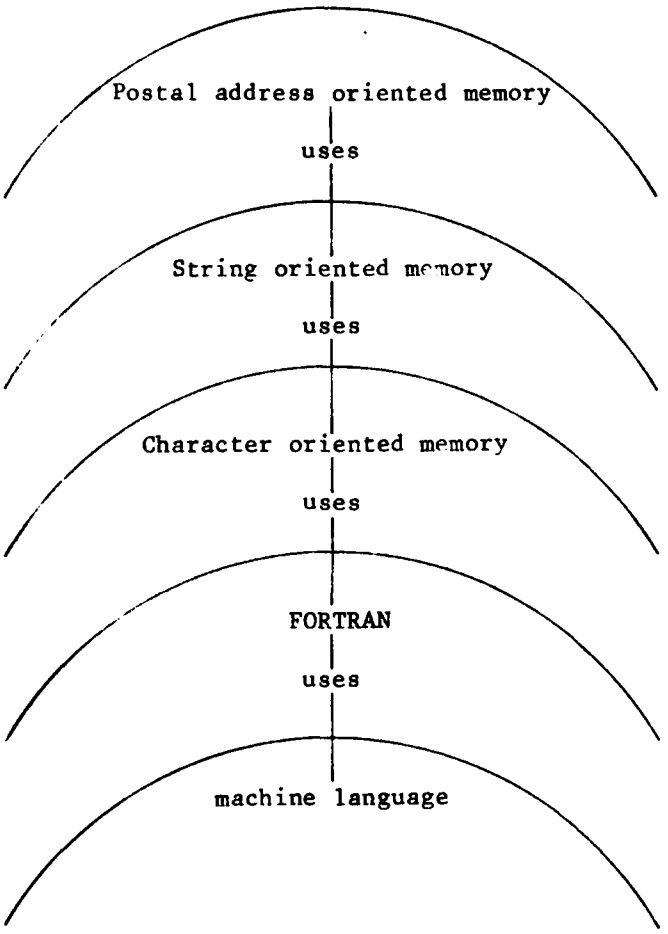
V. Result: Layers of Virtual Machines

A. Definition: A set of objects and operations, implemented in software, that could conceivably be provided by hardware

B. Applications programs are simpler because they use virtual machine programs

C. Resources used to implement a low-level program not available to a high-level program that uses it

D. Example from the MADDS example: Layered virtual machines



VI. Deriving Subsets From a Uses Hierarchy

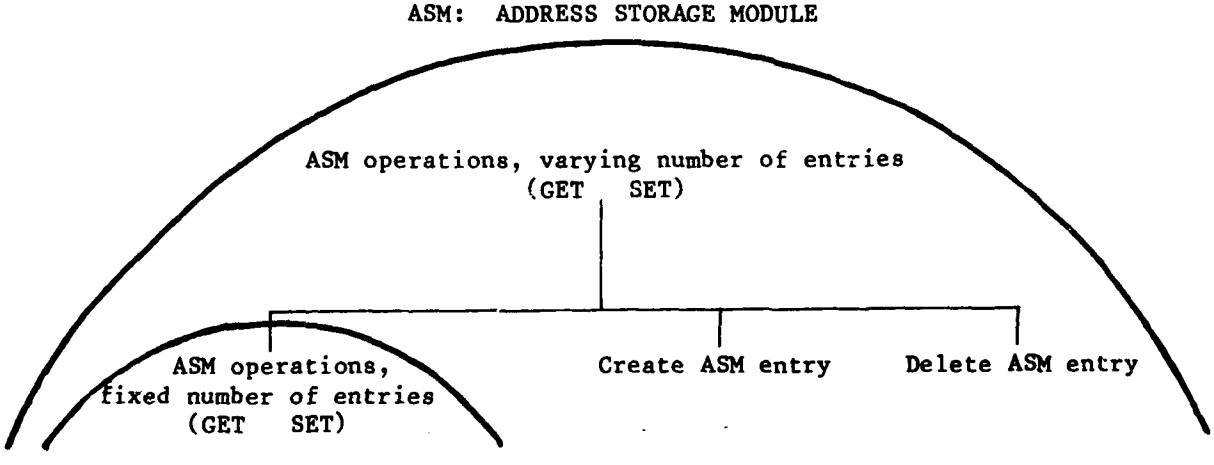
A. Rules

1. Can leave out upper levels

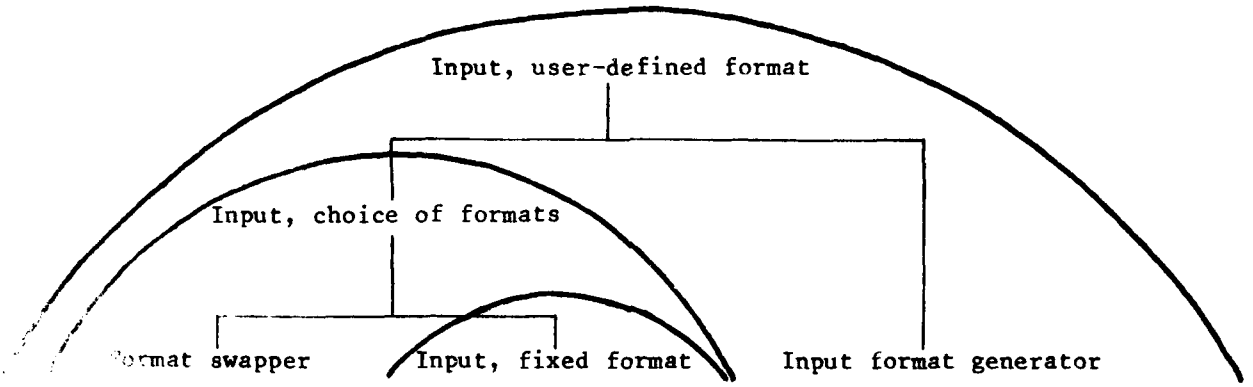
2. Can leave out parts of levels

3. If program A left out, must leave out all programs that use it

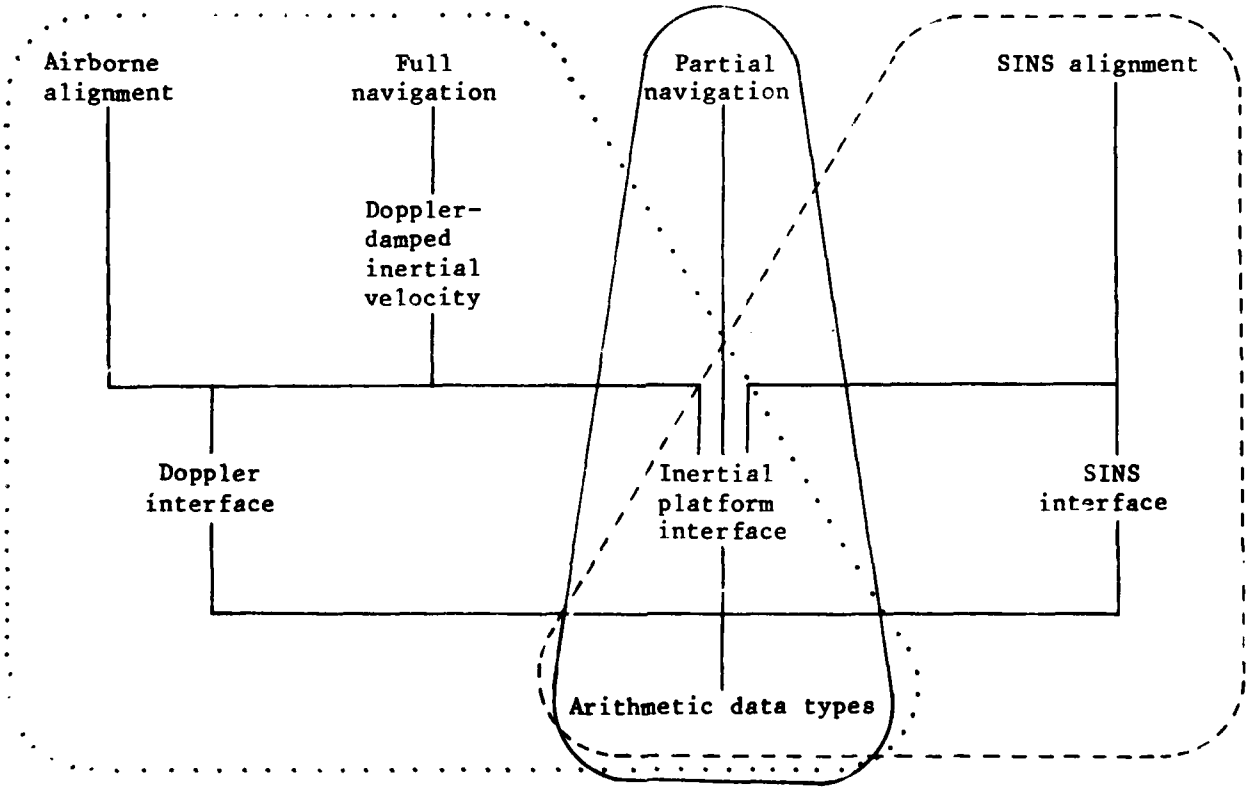
B. Example: Part of hierarchy for family of systems with different capacities



C. Example: Part of hierarchy for family of systems with different degrees of flexibility



D. Example: Part of hierarchy for single system that can be subsetted easily



VII. Evaluation Criteria for a Uses Hierarchy: What are the Goals?

A. Elegance and simplicity

B. Avoid duplication

C. The existence of an appropriate subset for each application situation ("Without consideration of subsets, anything goes")

VIII. Observations

A. Uses hierarchy as a compromise between

1. Letting any program use any other -- excessive dependencies

2. Not letting anything use anything -- duplication

IX. References

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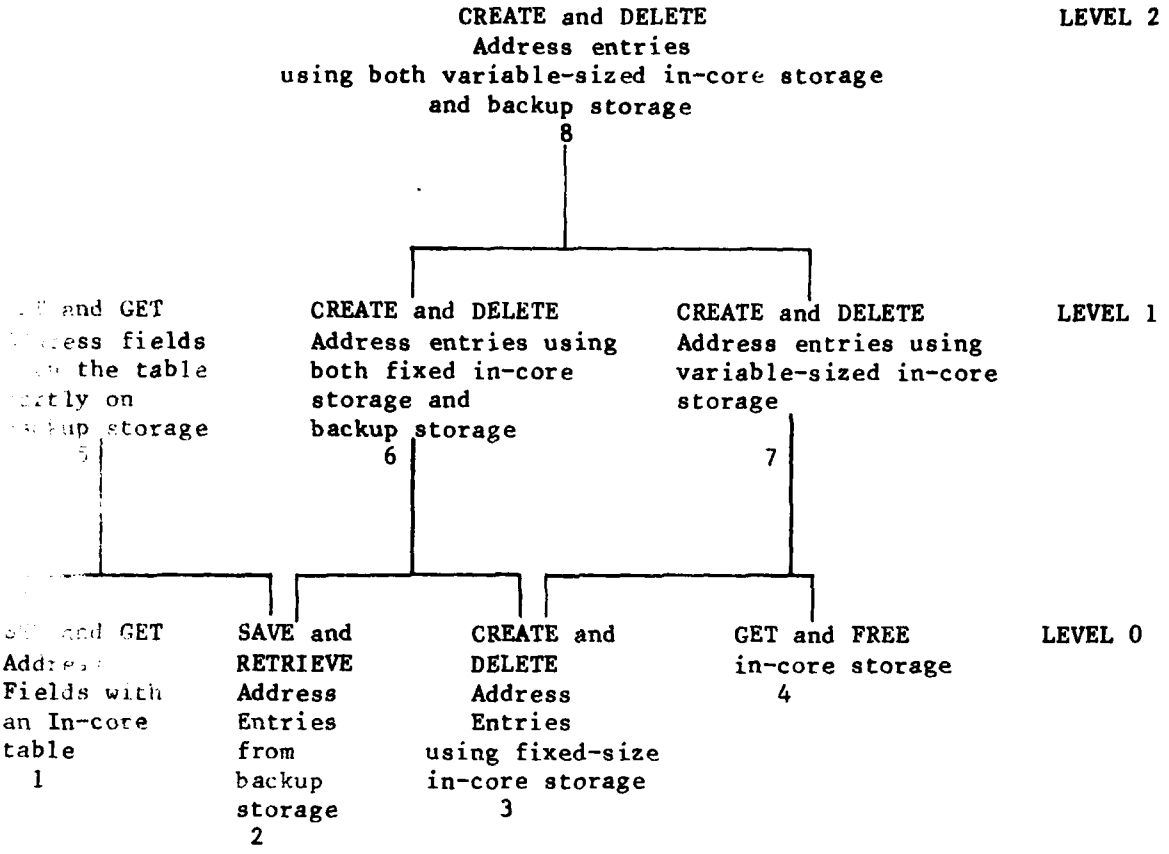
HIE.3 Uses Hierarchy for an Address System

EXERCISE

Name:_____

The diagram on the next page shows the uses hierarchy for a hypothetical address system. The same facilities are offered on several levels, with expanded resources on the upper levels.

Study the diagram and answer the questions that follow.



Remember that programs on the higher levels use, rather than duplicate, the code in the lower level programs. For example, component 3 assumes that it has a fixed memory space, but the size is a parameter. If higher levels are not available and the size is exceeded, an undesired event occurs. If the size is exceeded and component 7 is available, it uses component 4 to get additional space, then changes the parameter value. Then component 3 can be used to create the new entry.

Note: We have combined the pairs GET/SET, SAVE/RETRIEVE etc. into single components in order to make the example simpler. This is not necessary, since there may conceivably be systems in which only one member of the pair is needed. For example, if the address file is treated as a read-only data structure, GET functions will be needed but SET functions will not.

Part 1: Subsets with Different Capabilities

Each of the systems described below can be built with components in the uses hierarchy. Figure out which components are required for each system. Circle or underline the numbers below each description corresponding to all of the required components.

Example

An address system with a fixed number of entries, all in main storage.

1 2 3 4 5 6 7 8

1. System A: An address system with a varying number of entries, all in main storage. The maximum table size, and therefore maximum number of entries, is fixed at system initialization.

1 2 3 4 5 6 7 8

2. System B: An address system with a varying number of entries, all in main storage. Main storage space is dynamically allocated and freed as the number of entries changes.

1 2 3 4 5 6 7 8

3. System C: An address system with a varying number of entries. The main storage allotment is fixed, so that when it is full, overflow entries must be stored in backup storage.

1 2 3 4 5 6 7 8

4. System D: An address system with a large constant number of entries which do not all fit in the main storage allotment at once. The overflow entries are stored in backup storage.

1 2 3 4 5 6 7 8

5. System E: A very large capacity address system, with a varying number of entries. Main storage is dynamically allocated as the number of entries changes. When the number of entries exceeds a certain number, the overflow entries are stored in backup storage.

1 2 3 4 5 6 7 8

Part 2: Degraded Modes

1. Which of the above subsets would still operate fully if the backup device went down?

2. Which of the above subsets would still operate fully if a large area of core went down so that the program can no longer be allocated additional memory? (Assume the area occupied by the program has not gone down.)

3. Which subsets would still operate fully if both these UEs occurred?

HIE.4 Uses Hierarchy for an Address System

EXERCISE SOLUTION

In part 1, for each component that you decided to include, you should have also included all the components on lower levels used by that component. In the solutions on the next page, the components that should be included are underlined.

Part 1: Subsets with Different Capabilities

1. System A: An address system with a varying number of entries, all in main storage. The size of the in-core storage, and therefore the table size, is fixed at system initialization.

Answer:

1 2 3 4 5 6 7 8

2. System B: An address system with a varying number of entries, all in main storage. Main storage space is dynamically allocated and freed as the number of entries changes.

Answer

1 2 3 4 5 6 7 8

3. System C: An address system with a varying number of entries. The main storage allotment is fixed, so that when it is full, overflow entries must be stored in backup storage.

Answer:

1 2 3 4 5 6 7 8

4. System D: An address system with a large fixed number of entries which do not all fit in the main storage allotment at once. The overflow entries are stored in backup storage.

Answer:

1 2 3 4 5 6 7 8

5. System E: A very large capacity address system, with a varying number of entries. Main storage is dynamically allocated as the number of entries changes. When the number of entries exceeds a certain number, the overflow entries are stored in backup storage.

Answer:

1 2 3 4 5 6 7 8

Part 2: Degraded Modes

1. Which of the above subsets would still operate fully if the backup device went down?

None of the systems that use component 2 could be included. Therefore only system A and system B could continue to operate.

2. Which of the above subsets would still operate fully if a large area of core went down so that the program can no longer be allocated additional memory?

If a large area of core went down, the system is essentially restricted to a fixed area. Therefore only system A, system C, and system D would continue to work, since they do not use component 4.

3. Which subsets would still operate fully if both these UEs occurred?

Only systems using neither component 2 nor component 4 would continue to work -- system A.

Comment

In each of these UE situations, some capability is left, even though it may be very restricted. For example, if system E were in operation when the backup store went down, an appropriate UE response might be to continue operation using system B. System B could process the addresses that were in core when the UE occurred, and print a message whenever requested to access an address not in core.

Thus, this software allows for fail-soft operation when resources go down.

LANG.1 Language Selection

LECTURE

I. Introduction

A. Most of ideas discussed in this course are independent of language

B. But languages can help or hurt; the choice is significant

II. Four Views of a Programming Language

A. A notation for describing classes of computations

B. A convenient way to instruct computers

C. "VIGILANTE"; an enforcer of rules of good practice

D. An efficient mechanism for invoking special, previously written programs

III. Four Corresponding Language Evaluation Criteria

A. How easy is it to tell which computations are possible (verification)?

B. How well can you control the machine?

C. How "structured" (restrictive) is it? Does it allow bad practices?

D. How "rich" is it?

IV. The Four Views and Evaluation Criteria Conflict

A. Examples

B. Many choose one view and ignore all others

C. Choosing is reasonable for R&D (separation of concerns)

D. But system developers must resolve the conflicts

1. All views have some validity and should be weighed

2. Sometimes one can accomplish an objective with a non-language means

example: allow designers to determine coding restrictions

example: obtain an efficient library mechanism

example: put machine dependent "features" in library

System Designers and Developers Have Additional Evaluation Criteria

A. In what ways does the language help the designer?

1. Be free of surprises

2. Allow straightforward translation to efficient code

3. Help the designer enforce his information-access policies

4. Make it easy and efficient to use programs written by others

5. Make no assumptions about the desired response to runtime errors

6. Don't constrain implementation of parallel processes

7. Provide nonrestrictive looping structures

8. Help in confining assumptions and decisions

9. Facilitate user-defined data types and abstract data types

B. In what ways does the translator and related support help the designer/developer?

1. Give user-level diagnostics in terms of "write-time" structure

2. Debugging aids

3. Preprocessor systems

   a. Advantages

   b. Disadvantages

4. Library of useful programs

5. System management and integration tools

6. Manuals, texts, etc.

VI. What to do if No Supportive Language is Available?

   A. Use naming conventions in place of scope rules

B. Include runtime access-restriction code that can be removed later

C. Use the surprise-free subset

D. Use the efficient subset

E. Use the transportable subset

F. Postpone coding and debugging; spend more time on detailed design and evaluation

G. Use coding specifications

H. Write support software -- see Section V.B.

VII. General Remarks About the Selection Process

A. Look at all of the code that will be in the system

B. List the implied design decisions explicitly

C. Beware of productivity arguments

D. How well is the language supported?

VIII. Conclusions

A. "Right language" is not possible, necessary, or sufficient

B. Some help more than others

C. Some hurt more than others. Language designers make assumptions on how their language will be used. Check the implicit assumptions

D. Discipline in program design is what matters

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Liskov, B.; and Zilles, S. 1974. "Programming with Abstract Data Types." SIGPLAN Notices, vol. 9, no. 4, pp. 50-59.

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LANG.2 Ada

LECTURE

I. Ada History

A. Calendar of events

Strawman Requirements ..... June, 1975

Steelman Requirements ..... June, 1978

Preliminary Design Competition .... February, 1978

Selection of "Green" Language ..... April, 1979

Test & Evaluation of Design ..... November, 1979

Compiler Development Start ..... January, 1980

B. Pascal based (Jensen and Wirth 1974)

1. Many features added

a. separation of specification and implementation

b. multitasking

c. machine-dependent coding

d. representation specifications

e. generics

etc.

II. Ada Basics

A. Programs as collections of Ada modules

B. Module organization

1. Specification

2. Body

C. Packages and tasks

1. Package = information-hiding module

2. Task = process

D. Package specification = information-hiding module interface

```
package Chm is

    -- The specification contains all package entities that the user
    -- has access to, including procedures, functions, types,
    -- variables, and constants.

    function CharEq (Ch1, Ch2 : Character) return Boolean;

    function CharLt (Ch1, Ch2 : Character) return Boolean;

end  Chm;
```

E. Types

1. A type defines value space and operations

   a. numeric

      Integer, Real builtin

```
type I is range 0..100;

FieldLength: constant := 30;
```

b. enumeration

```
Boolean, Character builtin

type Field is (Boc, Cit, Coa, Gn, Gsl, Sop, St, Tit, Zip);

type MaddsModules is (Ssm, Asm, Apm, Ipm, Opm, Idm, Odm,
                      Chm, Mcm, Ueh);
```

c. array

```
type Table is array(1..10) of integer;

type Address is array(1..NumFields) of string(FieldLength);

type Module_Names is array(MaddsModules) of string(1..3) :=

    ("SSM", "ASM", "APM", "IPM", "OPM", "IDM", "ODM",
     "CHM", "MCM", "UEH");

Num_Errors: constant := 23;

type MsgLength is range 1..61;

type Msgs is array(1..Num_Errors) of string(MsgLength);
```

d. record

```
type StatusValue is (Undefined, Defined);
type StatusArray is array(1..NumFields) of StatusValue;
type Addr_Form is
    record
      Status: StatusArray;
      Value: array(1..NumFields) of string(FieldLength);
    end record;
```

2. Distinguishing among types

a. textual distinction

```
type Selector is (Boc, Cit, Zip);
type Field is (Boc, Cit, Zip);
```

b. Derived types

```
type Addr is new integer;
```

F. Variables and constants

```
MaxAds: constant integer := 100;
Addresses: array(1..MaxAds) of Addr_Form;
```

G. Procedures and functions

```
procedure SetBoc(A: Addr; S: string) is
    begin
        if A not in AddressNumber then Ueaida("ASM", "BOC");
        else
            Addresses(A).Status(1) := Defined;
            Addresses(A).Value(1) := S;
        end if;
end SetBoc;
function GetBoc(A: Addr) return string is
    if A not in AddressNumber then Ueaida("ASM", "BOC");
    else
        return Addresses(A).Value(1);
    end if;
end GetBoc;
```

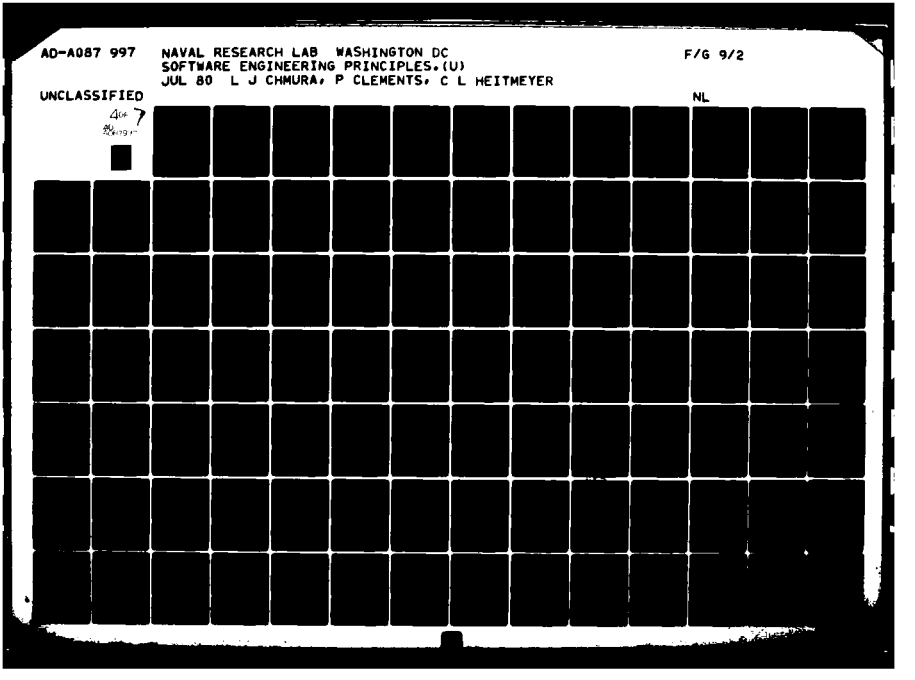
H. Example -- the address storage module as an Ada package

```
package ASM is

    -- Specifications for procedures, types, variables, constants,
    -- etc. needed by users.

end ASM;

separate package body ASM is

    -- Implementation of procedures, types, variables, constants,
    -- etc. declared in package specification.

end ASM;
```

I. Tasks

1. Task specification defines communication and synchronization operations

2. The rendezvous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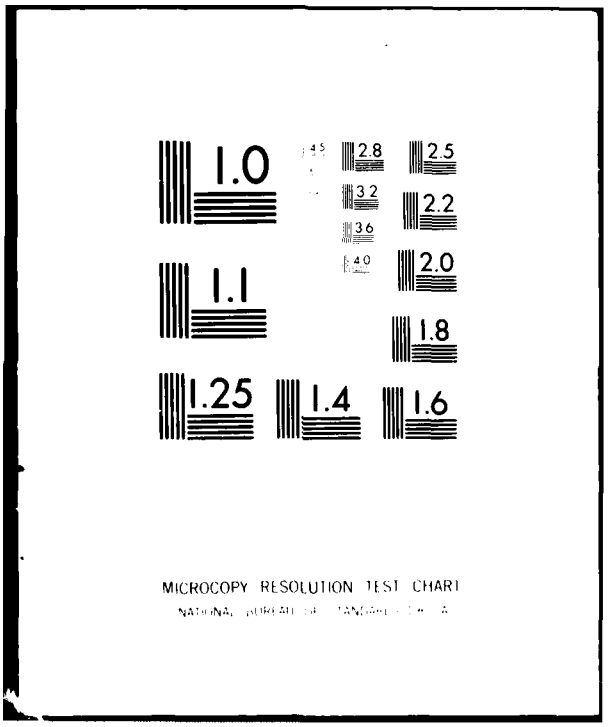
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MICROCOPY RESOLUTION TEST CHART

3. Specifying entry points

```
task semaphore is
    entry P;
    entry V;
end;
task body semaphore is
    begin
      loop
          accept P;
          accept V;
      end loop;
    end;
```

4. Entry calls and procedure calls

5. HAS location calculator as an Ada example

```
task buffer is
    entry withdraw(Data: out Item);
    entry deposit(Data: in Item);
end buffer;
task Location_Calculator;
task body Location_Calculator is
    -- Calculate location from an Omega reading
    temp, location: integer;
    procedure OmegaCalculation(Reading: in integer) is separate;
    begin
        loop
          -- Obtain Omega reading, calculate location, and
          -- deposit location in the location update buffer.
          Omobsbuf.withdraw(temp);
          location := OmegaCalculation(temp);
          Locupbuf.deposit(location);
        end loop;
end Location_Calculator;
```

6. Task proliferation

   a. one task per buffer monitor, one task per semaphore

b. cannot pass tasks as parameters when desired

III. Ada and Software Engineering

A. Information-hiding modules

1. Direct correspondence to packages

2. Peepholes into the interface

B Abstract interfaces

1. Can be represented as package

C. Processes

1. Process representable as task

2. Process synchronization based on semaphores, task synchronization based on rendezvous

D. Undesired events

1. Sufficient freedom to define and access appropriate procedures and packages when necessary

2. Situations not requiring parameter passing can make use of exceptions

IV. Ada Evaluation (LANG.1 Criteria)

A. Help the designer

1. Moderately surprise free

2. Probably will not allow very efficient translation

3. Information access enforceable

4. May allow ease and efficiency of use of programs by others

5. Some assumptions about desired response to runtime errors are builtin

6. Parallel process implementation is constrained

7. Nonrestrictive loops are provided

8. Facilities for confining assumptions and decisions are provided

9. Facilities for user-defined types and abstract types provided moderately well

B. Translator and related support

???????

V. The Address Storage Module (ASM) as an Ada Package

```
package ASM is

    -- The ASM consists of all address storage and retrieval routines.  It
    -- hides the representation used to store the addresses.  For each
    -- routine, the parameter A indicates the address whose field is being
    -- stored or retrieved.  GetNca returns the number of complete addresses.

    use SSM;                                -- need definition of strings

    MaxAds: constant integer := 100;        -- maximum allowable addresses

    type Addr is private;                   -- give users access to type Addr

    procedure InitAs;

    procedure VerAds;

    function GetNca return integer;

    function GetBoc(A: Addr) return string;

    procedure SetBoc(A: Addr; S: string);

    function GetCit(A: Addr) return string;

    procedure SetCit(A: Addr; S: string);

    function GetCoa(A: Addr) return string;

    procedure SetCoa(A: Addr; S: string);

    function GetGn(A: Addr) return string;

    procedure SetGn(A: Addr; S: string);

    function GetGsl(A: Addr) return string;

    procedure SetGsl(A: Addr; S: string);

    function GetLn(A: Addr) return string;

    procedure SetLn(A: Addr; S: string);

    function GetSer(A: Addr) return string;

    procedure SetSer(A: Addr; S: string);
```

```
        function GetSop(A: Addr) return string;

        procedure SetSop(A: Addr; S: string);

        function GetSt(A: Addr) return string;

        procedure SetSt(A: Addr; S: string);

        function GetTit(A: Addr) return string;

        procedure SetTit(A: Addr; S: string);

        function GetZip(A: Addr) return string;

        procedure SetZip(A: Addr; S: string);

        private
            type Addr is new integer;
end ASM;

package body ASM is separate;

restricted(Main, SSM);

separate package body ASM is

        use SSM, UEH;

        type Selector is (Boc, Cit, Coa, Gn, Gsl, Ln, Ser, Sop, St, Tit, Zip);

        -- Addresses are expected to have all fields either defined or undefined.
        -- The type StatusArray provides an easy way to mark fields of an address
        -- as either defined or undefined.

        type StatusArray is array(Boc .. Zip) of (Undefined, Defined);

        -- The type Addr_Form provides the storage representation for addresses.

        type Addr_Form is

            record
                Status: StatusArray;
                Value: array(Boc .. Zip) of string;
            end record;
```

```
-- The variables All_Undefined and All_Defined provide convenient arrays
-- for finding out if addresses are either all defined or all undefined.

All_Undefined: constant StatusArray := (Boc .. Zip => Undefined);

All_Defined: constant StatusArray := (Boc ..Zip => Defined);

type AddressNumber is range 1 .. MaxAds;

-- Variable Addresses is the array used to store addresses.

Addresses: array(AddressNumber'first .. AddressNumber'last);

Last: integer range 0 .. MaxAds;


procedure InitAs is

    begin
        Last := 0;
        for I in AddressNumber loop
            Addresses(I).Status := All_Undefined;
        end loop;

end InitAs;

procedure VerAds is

    begin
        Last := 0;
        for I in AddressNumber loop
            exit when Addresses(I).Status /= All_Defined;
            Last := I;
        end loop;
        for I in Last + 1 .. MaxAds loop
            if Addresses(I).Status /= All_Undefined then
                Ueasmi("ASM   ", "VERADS");
            end if;
        end loop;
end VerAds;
```

```
        function GetNca return integer is

            begin

                return Last;

        end GetNca;

        procedure SetBoc(A: Addr; S: string) is

            begin

                if A not in AddressNumber then Ueaida('ASM", "BOC");
                else
                    Addresses(A).Status(1) := Defined;
                    Addresses(A).Value(Boc) := S;
                end if

        end SetBoc;

        function GetBoc(A: Addr) return string is

            if A not in AddressNumber then Ueaida("ASM", "BOC");
            else
                return Addresses(A).Value(Boc);
            end if;

        end GetBoc;


    -- Other Set and Get function implementations are similar to SetBoc and
    -- GetBoc and are not included.

end ASM;
```

VI. References

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PROC.1 Process Structure of Software Systems

LECTURE

I. Imposing Structure on Run-Time Events

A. Examples of run-time events

1. Real-time

read value from angle of attack sensor
calculate new system velocities
output new heading value to display
aircraft becomes airborne
pilot keys in a number

2. Data processing

read new record from tape
extract key
print out a line
disk unit raises interrupt

B. Two ways to view events on a general-purpose computer

1. chaotic unrepeatable sequences

. . . read line typed on terminal by user A
fetch FORTRAN compiler into core for user B
compute value for user C
start compiling for user B
decode line typed by user A
output value computed for user C
respond to decoded command from user A . . .

2. Set of user jobs proceeding independently

A	B
. . . read line typed on terminal decode line respond to decoded command . . .	. . . fetch Fortran compiler into core start compiling . . .

C. Two ways to view a real-time system on a dedicated computer

1. First page from A-7 math flow

initialize navigation, if needed
calculate magnetic heading
calculate ground speed and total velocity from inertial north and east velocities
determine whether aircraft airborne, landbased, or seabased
determine if inertial platform ready and reliable
format horizontal velocity and total velocity for panel
output zero to ground track needle
if ground align just selected, zero panel clock and turn on light
compute true heading . . . .

2. Single train of thought

set scale for inertial platform accelerometer pulse	p. N-2
read in accelerometer pulses and calculate N and E vel	p. WD-2
calculate inertial groundspeed from N and E velocities	p. N-1
damp inertial groundspeed with system doppler groundspeed	p. N-12

D. Processes as subsets of events occurring in a system

1. In general purpose systems, each subset is a user's job

2. In real-time systems, determining best subsets is a major design problem

II. Two Aspects of Process Design

A. Deciding on the right subsets (processes), i.e., grouping the events into processes -- subject of this lecture

-- What are the parts of the structure?

B. How subsets cooperate and communicate -- subject of next lecture

-- What is the relation between parts?

III. Sequential Processes

A. Operational definition: a unit for processor allocation -- i.e., a unit competing for CPU time

B. Sequencing decisions made here

1. Sometimes order of events matters

   Example: read value
   smooth value

2. Sometimes order of events does not matter

   Example: compute magnetic heading
   decide whether aircraft airborne

3. When order matters, events belong in same process

4. Order of events in a process is always unambiguously determined

5. Order of events in different processes not well defined

   a. processes executed on one processor: interleaved execution

b. processes executed on several processors: depends on speed of processors, allocation strategy, etc.

c. Unpredictability of interrupts

C. Implications of definitions

1. Process executing on 0 or 1 processor at a time, never more

   -- cannot be worked on simultaneously by more than one CPU

2. Two events in same process can never occur simultaneously

   -- parallelism restricted

3. Speeds of processes unknown, i.e., time between events within a process unknown

   -- rate of one process affected by other processes

IV. Advantages of a Well-Designed Process Structure

A. Each process makes sense by itself

B. "What" a process does is separated from "when" it does it

1. "What" is simpler: can be done by less experienced programmers

2. "When" determined by scheduler: major timing problems are isolated

C. Easier to make configuration changes

1. Each process can be written as if it runs on its own machine

2. Scheduler takes care of interleaving them on the available machines

3. Can add or remove processors without changing anything but scheduler

V. Rules for Designing a Good Process Structure

A. Initially divide system into maximum number of processes

1. Two events in the same process if they could never overlap in time

2. Two events in different processes only if they could conceivably overlap or if the order is irrelevant

B. Decide on right granularity based on tradeoff between cost and benefit

1. Cost of smallest division
   -- maintaining process records
   -- creating and destroying short-lived processes
   -- communication between processes

2. Benefits of smallest division
   -- no potential parallelism ruled out
   -- no potential configuration ruled out
   -- programs extremely simple to understand

C. If granularity too fine, combine strongly related processes into one process

1. Still easy to understand

2. Arbitrary sequencing -- rules out some parallelism

3. Reduces cost of process switching and communication

D. Separate out extremely time-critical events

Example:

read Angle of attack
filter sensor value and stale value to produce new value

-- must read before filtering, but reading may get ahead
-- first step time-critical, second not
-- allow second step to get behind

VI. Critical Question: What Information Can One Use to Design Process Structure?

A. Nothing that depends on configuration

B. Only information that is unlikely to change

VII. Programs May Be Written As If They Would Control Separate Processes, Then Be Combined Into One Process By Macro Expansion

A. Retain ease of comprehension

B. Avoid overhead of separate processes

VIII. Examples of Poor Process Structure

A. Time cycle organization -- events organized by how often they must occur

1. extremely sensitive to small changes

2. hard to follow

B. Processes with internal scheduling

-- Sign of design error if every time a process runs it must spend several instructions figuring out what to do next

IX. Example of Process Definition From Good Process Structure

```
program control_Magheading_display;

begin
comment   this process executes periodically.  The desk clerk process signals
          the event "update time" whenever it is time for this process to run;
event update_time occurs freq times per second
while true do
begin
    wait(update_time);                    comment process suspended until it
                                          receives signal to run;

    it magnetic heading sensor turned off
          then output 0 ;
          else begin
              read value from magnetic heading sensor;
              calculate magnetic heading from sensor reading;
              output magnetic heading ;
              end;
    end-if;
end;
end-while;
end;
```

X. Reminder: A System Has Many Structures Which Do Not Have To Coincide With Each Other

A. Module structure (early design-time)

B. Uses structure (late design-time)

C. Process structure (run-time)

XI. Reference

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PROC.2 MP Process Structure

EXERCISE

Name:_____

The original and alternative MP systems have different process structures. In the original MP structure, most modules are also processes. Most MP modules described in MP.3 are the units of processor allocation, and the executive module is the scheduler. In the new MP structure, the modules only provide operations that are excuted by the processes at run-time; the modules themselves are not the units of processor allocation.

Pages 9-15 and 9-16 of this exercise illustrate the difference between the two process structures. Listed on page 9-15 are the events occurring in the message analysis module of the original MP structure. These events were taken from MP.2 and MP.3. Listed on page 9-16 are the events occurring in the incoming message process and outgoing message process in the new MP structure.

Evaluate the two different MP process structures, based on the considerations outlined in lecture PROC.1. In particular, consider the questions below. Be sure to give reasons or examples to support your opinions.

1. Which structure will have more inter-process communication overhead?

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2. Which structure could take better advantage of a multiprocessor configuration with shared memory?

3. Which structure causes processes to spend more time figuring out what to do next?

PROCESS FROM THE ORIGINAL MP PROCESS STRUCTURE

In the original MP structure described in MP.2 and MP.3, there is one process for each module. Thus there is a process to analyze messages (MA), another to screen messages (SC), another to assemble a message to be transmitted (CO), etc. To illustrate these processes, we list below the events occurring in the message analysis module.

Review the common characteristics of MP modules in document MP.2, page 1. There are interrupts, but the RUNNING module is always resumed as soon as the interrupt housekeeping is completed. Since the message analysis module requires long processing time, it releases control of the processor after analyzing every six lines of the message, in order to allow other modules to proceed. When it does this, it sends itself a WCB to tell itself where to pick up. Whenever a process releases control of the processor, the executive must determine which process runs next.

Step	Message Analysis Module
1	get next WCB out of message analysis WCB queue
2	analyze WCB to determine a) which message to work on, and b) what to do next (whether to branch to Step 3, 5, 7, or 9)
3	for lines 1 through 6, analyze line, subtracting points for errors and correcting errors where possible
4	queue WCB to self and give up processor
5	for lines 7 through 12, analyze line, subtacting points for errors and correcting errors where possible
6	queue WCB to self and give up processor
7	for lines 13 through 16, analyze line, subtracting points for errors and correcting errors where possible
8	queue WCB to self and give up processor
9	if remaining points 1t 80% of total points then message failed
10	prepare MDB for message
11	queue WCB to DC to store MDB
12	queue WCB to LM module to log message status
13	if message failed then a) queue WCB to DC to remove failed message from storage, and b) terminate process
14	queue WCB to DC to store message on disk
15	if incoming message then queue WCB to SC module, notifying it message is ready to be screened
16	if outgoing message and channel available queue WCB to TO module, notifying it message is ready to be transmitted
17	wait until WCB queue not empty; then start over with step 1

PROCESSES FROM THE NEW MP PROCESS STRUCTURE

In the new MP structure, there is one process for each active message that is being worked on at a time. A single process may use programs from many different modules, and different processes may all use programs from the same module. The following informal descriptions of two of these processes show the sequence of operations and the programs they use from the MP.4 modules.

Note that these processes can be suspended during any step, either because they request unavailable resources or because a hardware interrupt such as a clock interrupt occurs. Unlike the original MP structure, an interrupted process may not necessarily resume immediately after the interrupt housekeeping is completed. The scheduler may choose to start another process instead.

Since the programs provided by the modules are reentrant, they can be used by more than one process simultaneously.

INCOMING MESSAGE PROCESS

Step		Using programs in:
1	Input a string	Communications & Equipment Control
2	Analyze string, storing it in the message holder	External Interface & Message Holder
3	Register message in log	Information Retrieval/Log
4	Check message against the watch list	Screening Module & Message Holder
5	IF any addressees in the message are in watch list, notify operator on terminal ELSE delete message from storage	Terminal Control Paging Module
6	TERMINATE	

OUTGOING MESSAGE PROCESSES

Step		Using programs in:
1	Help the operator create a message, storing the data he types in the message holder	Text Editor & Message Holder
2	Register message in log	Information Retrieval/Log
3	Transform message into the AUTONOYS format getting data for fields from message holder	External Interface & Message Holder
4	Transmit the message	Communications & Equipment Control
5	TERMINATE	

There might be other processes to retrieve and display messages, edit old messages, etc.

PROC.3 MP Process Structure

EXERCISE SOLUTION

1. Which structure will have more inter-process communication overhead?

   The original MP structure (MP.2)

   The original structure uses control block queuing and scheduling to switch between the activities associated with a single message, where the new structure uses subroutine calls. Control block queuing is considerably more time-consuming than parameter passing. The inter-process overhead must be paid in the original structure even if only one message is processed at a time.

2. Which structure could take better advantage of a multiprocessor configuration?

   The new MP structure (MP.4)

   Consider a multiprocessor configuration, with several processes in the middle of message analysis and no other work to be done. In the original structure, only one processor would be used because there is only one MA process; the other messages would have to wait, and the other processor would be idle. Use of a single MA process introduces an artificial bottleneck into the system. With the new structure, each processor could be busy analyzing a different message, sharing the reentrant programs in the External Interface and Message Holder modules.

3. Which structure causes processes to spend more time figuring out what to do next?

   The original MP structure (MP.2)

   When a process in the original structure resumes running, it must analyze a Work Control Block (WCB) to determine what to do next. The decision can be arbitrarily complex: which message to work on, which step to do next, whether the message is in core, etc. In contrast, a process in the new MP structure can continue as if it had not been interrupted. What to do next is determined by the next instruction in the process.

   Note that the same work must be done in both structures to cause a process to resume running: the registers must be restored and the processor instruction counter must be loaded with the address of the next instruction in the process.

PROC.4 Process Synchronization

LECTURE

I. Introduction

A. System of cooperating sequential processes

B. Not totally independent

1. Different processes use same resources

Example: line printer

2. Production and use of information may be in different processes

Example: One process polls sensor and puts data in a buffer
Another process uses this data to control output device

3. Detection and response to an event may be in different processes

Example: One process detects the event target designation
Four other processes respond:
two displays turned on
ballistics calculations started
radar sampling started

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II. Three Classes of Synchronization Problems

A. Mutual exclusion problem

1. Example: airline reservation system

```
(A) local_1:= numseats;

(B) if local_1 lt total_seats
       then numseats:= local_1 + 1;
       else refuse reservation
    end-if;
```

```
(X) local_2:= numseats;

(Y) if local_2 lt total_seats
       then numseats:= local_2 + 1;
       else refuse reservation
    end-if;
```

2. Character of solution: explicitly prevent improper interleaving

Correct Interleaving

A	X
B	Y
X	A
Y	B

Incorrect Interleaving

A	A	X	X
X	X	A	A
B	Y	Y	B
Y	B	B	Y

B. Reader-writer problem

1. Example: Interactive data base
Readers do not interfere with each other
Writers must have exclusive access

2. Character of solution: less restrictive than mutual exclusion

C. Signalling problem

1. Example: the event "target designation"

```
wait (@T(!Desig!))              detect target designation
proceed                         signal (@T(!Desig!))
                                proceed
```

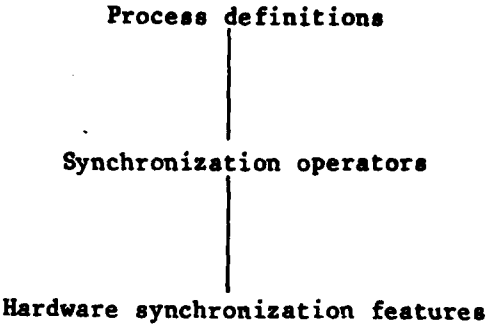
2. Character of solution: all processes that execute "wait" are suspended until another process executes "signal"

III. The Need for Special Synchronization Operators

A. Synchronization problems difficult to solve -- prone to subtle errors

B. Goal: to solve synchronization problems in a general way, rather than allow each programmer to solve them his own ad-hoc way

C. Uses hierarchy



1. Machine-dependent operations used for synchronization (e.g., disabling interrupts) -- confined to the implementation of synchronization routines

2. Synchronization routines: crucial code. Very carefully programmed and tested -- must be correct and fast

D. Choice of right synchronization operations: design problem

IV. The Rules of the Game

A. No assumptions about the relative speeds of processes

1. Cannot solve synchronization problems by assuming

"This takes longer than that"

2. Train analogy: why we need explicit synchronization

B. Minimize interrupt-disabled time

C. Avoid "busy form of waiting" -- waste of CPU and memory cycles

```
label:  if (busy = true) then go to label; end if;
        busy := true;
        . . .
        busy := false;
```

V. Synchronization Operators Change the Set of Processes Eligible for Scheduling

A. Process states:

Running -- currently allocated the processor

Ready -- eligible for scheduling

Waiting -- not eligible for scheduling

B. Synchronization operator may cause a process to change state

VI. Example: Classic Semaphore Variables, with P and V Operations -- Dijkstra

A. Semaphore variable

1. Only accessed by P and V operations

2. Usually implemented as a counter and a list of waiting processes

B. P(semaphore) -- "try" in Dutch

1. Process asks for permission to proceed

2. P-operation may affect state of process that calls it: change state from "running" to "waiting"

3. When process resumes, there is no record of interruption

4. Example implementation for P(semaphore)

```
begin
    semaphore.ctr:= semaphore.ctr - 1;
    if semaphore.ctr lt 0 then
       begin
       process status changed to "waiting";
       process put in the waiting list for the semaphore;
       end;
    end-if;
end;
```

C. V(semaphore) -- "increase" in Dutch:

1. Running process may change state of another process from "waiting" to "ready"

2. Example implementation for V(semaphore)

```
begin
    semaphore.ctr:= semaphore.ctr + 1;
    if semaphore.ctr le 0 then
       begin
       one process removed from waiting list;
       status of that process changed to ready;
       end;
    end-if;
end;
```

VII. Solving Synchronization Problems with P and V

A. Mutual exclusion problem (initial value of mutex.ctr = 1)

```
begin
   global semaphore mutex;
   P(mutex);
   local_1:= numseats;

   if local_1 lt total_seats then
      numseats:=local_1+1; end-if;
   V(mutex);
end;
```

```
begin
   global semaphore mutex;


   P(mutex);



   local_2:= numseats;
   if local_2 lt total_seats then
   numseats:=local_2+1; end-if;
   V(mutex);
end;
```

B. Signalling events (initial value of desig.ctr = 0)

```
begin
   global semaphore desig;
   P(desig);


   start radar sampling;
end;
```

```
begin
   global semaphore desig;

   detect target designation;
   V(desi
end;
```

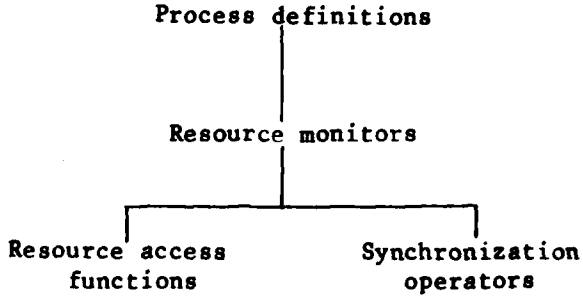
VIII. Coordinating Access to Resources Using P and V

A. Monitors

1. Set of functions assuring resources accessed correctly, according to a particular set of rules

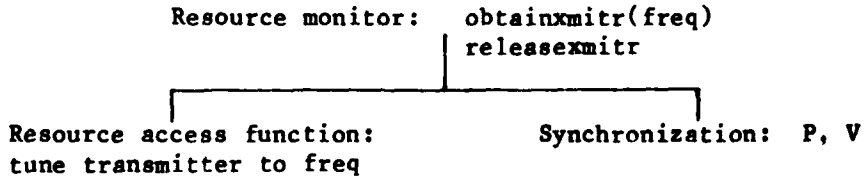
2. Resource can only be accessed through monitor functions

B. Uses hierarchy



C. Monitor for a transmitter (see HAS.4, p. 14-60)

1. Uses hierarchy



2. Rules: to avoid interleaved transmission, mutually exclusive access to a particular transmitter

3. Monitor: only program that knows how many transmitters

4. Processes: written as if each has own transmitter

D. Example: Monitor controlling access to a buffer

1. Initial condition -- buffer empty

   counter of semaphore "data" = 0 (no data available)

   counter of semaphore "space" = size-of-buffer
   (all spaces in buffer available)

2. No other access to buffer allowed

3. Rules implemented by monitor

   -- Only one deposit at a time on a particular buffer

   -- Only one accept at a time on a particular buffer

   -- accept and deposit may occur simultaneously, so long as they are not operating on same buffer slot

   -- deposit: process must wait if buffer full

   -- accept: process must wait if buffer empty

4. Deposit: function that puts an item in the buffer
   waits -- if another process putting an item in the buffer
   waits -- if buffer full

```
begin
    P(in);
    P(space);
    put item in buffer;          comment call buffer access fcn;
    V(data);
    V(in);
end;
```

5. Accept: function that takes an item out of a buffer
   waits -- if another process taking an item out of the buffer
   waits -- if buffer empty

```
begin
    P(out);
    P(data);
    take item out of buffer;     comment call buffer access fcn;
    V(space);
    V(out);
end:
```

VIII. References

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CORR.1 Introduction to Proofs of Correctness

LECTURE

I. Motivation -- Why Should "Practical People" be Interested in Verification?

A. Often regarded as a toy -- successful only with toy programs

B. State-of-the-art in program writing/testing

C. Cost of incorrect programs

D. Software engineering is in early stages of its development; verification likewise

E. It is important to understand the principles in order to be able to follow advances

F. Can be applied now in limited cases

G. Any alternative analysis of a program is valuable if "correctness" is important

II. Understanding the Word "Correct"

A. One can only verify that programs possess certain formally stated properties

B. Only actual use can verify that those properties correspond to "correctness"

III. What Constitutes an Acceptable Proof of Correctness?

A. Every producer of programs presents a program with an "explanation" that is intended to demonstrate its correctness. The explanation is often convincing even when the program is not correct

B. The property of the program being demonstrated must be precisely stated before the proof and not "refined" during the proof

C. A clear statement of the "rules of deduction" ("proof rules") must be provided

D. Each step should be a clearly correct application of one of those rules using previously verified properties

E. Complexity and Greek letters don't help

F. The proof reader should have to deal with one thing at a time

G. The proof reader should never have to "recall" or be reminded of sequences of events

H. At any given step only a small number of details should be relevant to following the proof

I. It is advantageous if the proof of a program is done by translating the question of correctness of the program to a mathematical theorem

IV. How Formal Should the Proof Be?

A. What do we mean by formal? -- not the same as logical or precise

B. Fully formal proofs are mechanically checkable

C. Such proofs are suited only to reading by machines

D. Informal does not necessarily mean less valid or less complete

V. Making Statements About Programs by Means of Predicates

A. Predicates make statements about the state at a given point

B. "Assertions" are statements that given predicates are true at given points

Example:
```
integer x, y, z;
   .
   .
   .

if y gt 0 and z gt 1

  then begin
         y:= y + z;
         x:= 3y + 7;
       end;

end-if;
```

VI. Proof by the Floyd-Hoare Method

A. Deriving "after" predicates (post conditions) from "before" predicates (pre conditions)

Example:
```
integer x, y, z;
   .
   .
   .

y:= x;

y:= y + z;
```

B. The meaning of assignment

C. A profound reversal -- letting the predicate transformation rules define the language

D. Reducing the proof to a mathematical theorem

E. Using abstraction in proofs

F. Major problems

1. combinatorial explosion

```
integer x, y, z;
   .
   .
   .
if y lt 0
    then x:= x + 1;
    else x:= x + 2;
end-if;
```

2. loops -- inductive assertions

3. termination -- partial correctness vs. total correctness

4. proof rules for non-trivial languages

5. dealing with time dependence and cooperating sequential processes

VII. When Can One Require a Proof and What Should One Demand?

A. Small critical programs

B. Highly advanced contractors (no blood from stones)

VIII. Applying our "Proof" Criteria to Less Formal and Less Complete Explanations

A. State requirements before showing that the program fulfills them

B. State the effects of each subprogram and statement type "abstractly"

C. Each step in the explanation should be a clear application of the statements provided under III

D. Programs with complex or unpredictable sequencing rules should be explained by means of invariants

E. Explanations of a program should never refer to internals of another program

IX. Concluding Remarks

A. Many useful mathematicians use theorems rather than proving new ones. Programmers should do the same

B. Applicability of the concepts

C. Understanding the motivation for recent developments in and attitudes about programming languages

X. References

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DOC.1 Documentation Guidelines

LECTURE

PART 1: GENERAL REMARKS

I. Why Documentation is so Important

A. Uses during development

1. Communication among designers, users, programmers, etc.

2. Training -- makes personnel turnover less disruptive

3. Prevents duplication of effort -- if reasons for design decisions recorded, reduces need to rethink them later

4. Basis for design reviews

5. Quality assurance -- standard against which software can be judged

B. Uses during maintenance

1. Training

2. Reduces labor of evaluating feasibility of changes

3. Guides programmers as they find and correct errors

4. Repository of design information, which even the original programmers often forget

5. Preservation of program conceptual integrity -- maintenance programmers have a way to check consistency of proposed change

II. Common Problems with Documentation -- Why is it Hard to Use?

A. Difficult to understand -- assumes reader knows more than he does

B. Difficult to find answers to specific questions

C. Difficult to maintain -- gets out-of-date all too soon

D. Wordy, repetitive, and boring

E. Confusing, inconsistent terminology

III. Remedy

A. View documentation as the important product of design, not as a by-product of coding

B. Design the documentation -- objectives, contents, organization, format

1. To be a convenient format for designers to record and exchange ideas

2. To serve as ready reference tools

3. To be maintained -- controlled and kept up-to-date

4. To explain reasons for decisions since reasons cannot be inferred from code

C. General principles for documentation design

1. Determine objectives

   - Who will need it?

   - What should they already know?

   - What should they be able to find out?

2. State questions before trying to answer them

3. Separate concerns

4. Documentation should consist of mutually supportive formal and informal parts

   - Informal -- easy for anyone to understand; useful for reviewers who are not programmers

   - Formal -- precise, concise, unambiguous

5. Involve maintainers early -- to find out what they need

D. Documentation design techniques

1. List questions to be answered

2. Organize questions into sections according to who needs to know answers, for what purpose

3. Design forms to be filled out

4. Plan to revise forms several times as documentation is written

5. Design tables, notation, templates

   - Use English only for overviews, narratives, and explanations

   - Use abstract Programs (otherwise known as PDL or coding specifications) for documenting algorithms

6. Define terms precisely; provide glossary

E. Design documentation reviews and configuration control procedures

1. Design reviews: What questions should reviewers ask themselves to determine if document meets its objectives?

2. Configuration control procedures

- How are changes reported?
- Who decides whether to make them?
- Who reviews them?
- How are updates distributed? To whom?
- What tools are needed? -- Word processing support invaluable

IV. Three Types of Documentation

A. Software requirements specification (e.g., Program Performance Specification)

1. Product of overall system design -- represents agreement among

- User representatives
- Builders of interfacing equipment or software
- Software builders

2. Questions answered

   - What role does the software play in the whole system?

   - What constraints are placed on the software?

3. Reference document for software designer and programmers, i.e., overall problem statement

4. Guidebook for maintenance programmers

   - Constraints on future improvements

   - Conceptual integrity of software

B. Overall design document (e.g., Program Design Specification)

1. Agreement between designer and programmers about system structure

2. Questions answered

   How is the software divided into modules?

   How do the modules work together to meet the overall requirements?

   Specifications for the module interfaces

   Overall system tradeoffs

3. Reference document for programmers, i.e., their individual problem statements

4. Guidebook for maintenance programmers -- where to make changes

C. Detailed design document (e.g., Program Description Document)

1. Program-by-program description

2. Questions answered

   What algorithms and data structures were selected? Why?

   What program implementation tradeoffs were made?

3. First product from programmers, i.e., the algorithms they choose and why

4. Guidebook for maintenance programmers -- how to make changes

5. Appropriate place for Abstract Programs or PDL

PART 2: AN EXAMPLE OF CAREFUL REQUIREMENTS SPECIFICATION

I. Background: A-7 Project

A. Purposes

1. To evaluate usefulness of modern software technology for real-time systems with tight constraints

2. To provide an engineering model

B. Basis: Existing flight software for Navy's A-7 aircraft

C. First step: document requirements of existing system

1. Implementation-independent description of current system

2. Problem statement for NRL A-7 project

II. Documentation Objectives

A. Specify external behavior only

1. Everything one needs to know to design and program the software

- If less, software may not fill purpose in larger system

- If more, software personnel constrained unnecessarily -- may not be able to use best approach

B. Specify constraints on implementation

- e.g., timing, accuracy, algorithms, and response time, etc.

C. Be easy to change

D. Serve as a reference tool for experienced designers and maintainers

E. Specify expected changes to software

F. Specify desired responses to undesired events

III. Does NOT Contain Programs, Data Structures, Flowcharts

IV. Table of Contents

CHAPTER 0 INTRODUCTION (DEFINITIONS, CONVENTIONS)

CHAPTER 1 COMPUTER CHARACTERISTICS

CHAPTER 2 HARDWARE INTERFACES

CHAPTER 3 SOFTWARE FUNCTIONS

CHAPTER 4 TIMING CONSTRAINTS

CHAPTER 5 ACCURACY CONSTRAINTS

CHAPTER 6 RESPONSE TO UNDESIRED EVENTS

CHAPTER 7 SUBSETS

CHAPTER 8 TYPES OF CHANGES

CHAPTER 9 GLOSSARY

CHAPTER 10 SOURCES OF INFORMATION

INDICES

V. Hardware Interface Documentation

A. Organize by data item

B. Design standard forms

C. Describe inputs as resources -- no mention of how used

D. Describe outputs in terms of effects on hardware -- no mention of purpose

E. Formal notation for data items

1. Bracketed names

inputs:	/RADALT/,	/IMSMODE/
outputs:	//STERROR//,	//HUDSCUE//
values:	On,	Off

2. Expressions

comparison	/RADALT/ lseq 3000 ft
change value	//HUDSCUE// := Off

F. Example of hardware interface description

Input Data Item: IMS Mode Switch

Acronym: /IMSMODE/

Hardware: Inertial Measurement Set

Description: /IMSMODE/ indicates the position of a six-position rotary switch on the IMS control panel.

Characteristics of Values

Value Encoding:		
	$Offnone$	(00000)
	$Gndal$	(10000)
	$Norm$	(01000)
	$Iner$	(00100)
	$Grid$	(00010)
	$Mags1$	(00001)

Instruction Sequence: READ 24 (Channel 0)

Data Representation: Bits 3-7

Comments: /IMSMODE/ = $Offnone$ when the switch is between two positions.

VI. Software Function Interface

A. Organize by function

B. Distinguish periodic and demand functions

1. Periodic functions: occur at regular time intervals

2. Demand functions: occur in response to specific events

C. Output values based on conditions, events, and modes

1. Conditions as predicates

2. Events as changes in condition values

3. Modes as classes of system states

D. Notation

1. Text macros: !Ground range to target!

2. Conditions: /IMSMODE/=$Gnda1$

3. Events: @T(/IMSMODE/=$Gnda1$)
@F(!Ground range to target! = 30 nmi)

4. Modes *DIG*

E. Example of a special table

Condition Table: Magnetic heading (//MAGHDGH//) output values

MODES	CONDITIONS	
DIG, *DI*, *I* *Mag sl*,*Grid*	Always	X
IMS fail	(NOT /IMSMODE/=$Offnone$)	/IMSMODE/=$Offnone$
//MAGHDGH// value	angle defined by /MAGHCOS/ and /MAGHSIN/	0 (North)

F. Example of function description

Periodic function name: Update Flight Path Marker coordinates

Modes in which function required:
DIG, *DI*, *I*, *Mag S1*, *Grid*, *IMS fail*

Output Data Items: //FPMAZ//, //FPMEL//

Initiation and Termination Events:
Start: @T(//HUDVEL// = On)
Stop: @T(//HUDVEL// = Off)

The flight path marker shows the direction of the aircraft velocity vector. The azimuth displacement from HUD center shows the lateral velocity component and elevation displacement shows vertical velocity component.

If the components are calculated from !System velocities!, !System velocities! are first resolved into forward, lateral and vertical components, that is, components along the aircraft Y, X, and Z axes. From these, the HUD coordinates are calculated in the following manner:

//FPMAZ// shows $\frac{\text{Lateral velocity}}{\text{Forward velocity}}$ //FPMEL// shows $\frac{\text{Vertical velocity}}{\text{Forward velocity}}$

Condition Table: Coordinates of the Flight Path Marker

MODES	CONDITIONS		
DIG, *DI*	X	Always	X
I	/ACAIRB/ = No	/ACAIRB/ = Yes	X
Mag s1, *Grid*	/ACAIRB/=No	!ADC Up! AND /ACAIRB/=Yes	!ADC Down! AND /ACAIRB/=Yes
IMS fail	/ACAIRB/=No	X	/ACAIRB/=Yes
FPM COORDINATES	//FPMAZ//:= 0 //FPMEL//:= 0	based on !System velocities!	//FPMAZ//:= 0 //FPMEL//:=/AOA/

VII. References

Heninger, K. L.; et al. 1978. Software Requirements for the A-7E Aircraft. Naval Research Laboratory Memorandum Report no. 3876. See readers' guide in preface.

Heninger, K. L. 1980. "Specifying Software Requirements for Complex Systems: New Techniques and their Application." Trans. on Software Engineering, vol. SE-6, no. 1, pp. 2-13.

MIL-STD-1679. 1978. Weapon System Software Development.

PROCESSING (MP)
SYSTEM

MP.1 The UGH Message Processing (MP) System

EXAMPLE DESCRIPTION

Fapsan Rat
Cognizant Engineer
UGH Corporation

Introduction

The UGH Message Processing System (MP) may use a variety of UGH computers from the large 2PIE to the small UGH-20 to provide an integrated support system for any organization requiring rapid and widespread distribution of messages to organizational units in geographically distributed locations. The UGH MP is designed to assist in every stage of message distribution beginning with the input of the draft message into the system, including automatic control of the communications equipment, the production of periodic reports about the status of the system and the messages that it has processed, and including (optional) an interactive information retrieval facility to allow managers to check on the status of the system or any message that has been submitted to it in the recent past. The UGH MP is highly modularly structured and can be tailored to meet the needs of any organization. As a result, its adaptability to changing needs is assured.

Interfaces and Functions

The UGH MP is designed to interface with and utilize the services of the world-wide AUTONOYS communications network. This network includes direct RF ship-to-shore communications, satellite relayed communications, and high capacity overland channels and is continually being expanded to include the most modern communications techniques. AUTONOYS is an existing communications network which has evolved over the years, starting from a fully manual system using very noisy (error-prone) communications channels, but has been adapted to take advantage of computer control as well as improved communications equipment. Because some of the low-traffic nodes on the AUTONOYS network are still manually controlled and some of the channels are still quite unreliable, all changes to the original AUTONOYS communications conventions have been made upwards compatible. This has resulted in a rather complex communications protocol. The MP is designed to produce messages in any of the AUTONOYS formats and is designed to be adaptable to the new formats which are expected to be introduced as AUTONOYS is improved.

It is expected that the organizations which UGH MP will serve will each have their own internal message conventions and guidelines. The MP adjustable user interface is designed to assist an operator with converting internal messages to external messages. MP can even assist with internal

message handling by producing the copies of outgoing messages to be sent to various "...house" addressees for information and retention. MP will automatically put addresses on these copies.

A special feature of MP is its ability to interface with UGHTRANS[R] computer-controlled communications equipment. This highly sophisticated equipment is designed to eliminate the need for a radio operator except for routine maintenance and emergency repairs. The "normal" functions of the operator such as antenna selection, tuning, connecting transmitter to antennae, etc., are all performed by electronically controlled switches and servomechanisms programmable in UGH hardware. The UGH MP software includes an option that will examine the "routing indicators" and select the appropriate communications setup.

An additional feature of MP is its ability to adjust to the security and privacy needs of its users and its ability to make use of the special AUTONOYS message security conventions. AUTONOYS offers a variety of communications channels ranging from "broadcast" (which is easily intercepted) to highly secure narrow beam communications. AUTONOYS communications conventions include highly redundant security codes designed to minimize the probability of a sensitive message being transmitted over an inappropriate channel. MP provides the necessary software and formatting to take advantage of these features. It also checks all input carefully to make sure that the security classifications are legitimate and consistent.

When used in connection with the broadcast channels of AUTONOYS, MP will receive many messages that are not intended for its user organizations. MP can "screen" these messages and select only those which its users are interested in. To prevent lost messages caused by incorrect screening, typing errors, or transmission errors, MP will (if requested) produce a list of rejected messages for operator review.

One of the special features of MP in this regard is its dynamic watch list. Every incoming message has a list of addressees. To screen these incoming messages, MP uses a list of "addressees of interest" or a "watch list." The message is selected if one of the addressees is on the watch list. MP allows the operator to alter this list so that messages for guests may also be received. This is also useful if one unit must temporarily support or replace another and must receive its messages.

The AUTONOYS system requires that each addressee be further identified by a routing designator which allows AUTONOYS to select the intermediate relay stations to be used. This has been a major source of costly errors and lost messages in manual systems. An error in one character of this routing indicator can cause a message to reach an unintended destination. In some organizations, where the addressees are "mobile" (e.g., ships or traveling salesmen), routing indicators must be updated frequently, which results in still more possibilities for making errors. MP automatically supplies the routing indicators for outgoing messages, using an internal routing indicator list. An optional feature is its ability to monitor incoming messages and

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It is expected that the organizations which UGH MP will serve will each have their own internal message conventions and guidelines. The MP adjustable user interface is designed to assist an operator with converting internal messages to external messages. MP can even assist with internal

report any inconsistencies between the routing indicators on these messages and its own list to the operator. This feature leads to greatly increased reliability if the routing designators change frequently.

Increased communications reliability is in fact one of the major advantages of using MP. Checking for errors and inconsistencies is performed at every stage of message processing. MP really "knows" the AUTONOYS communications conventions and checks more carefully than any human operator would. An incorrectly formatted message, a message with inconsistent descriptors, WILL NOT BE ISSUED. Many transmission errors on incoming channels will be detected. Such messages will be brought to the operator's attention so that the appropriate corrective measures may be taken. It is known to be mathematically impossible to detect all errors in messages over noisy channels, but checking is so widespread in the MP software that the probability of error is reduced to a lower point than with any alternative system.

Naturally MP supports a variety of input devices ranging from basic teletypes and paper tape readers to the most modern of character-oriented graphics consoles. An interactive option provides the most modern prompting and computer support of message input. With this option, the operator will be "prompted" for each item of format information which AUTONOYS requires. He can't forget anything and need not constantly refer to the AUTONOYS operator manuals. This can greatly increase the productivity of the operator and make him feel "supported."

Another option available is called the remote message drafting option (RMD). This allows the individual responsible for composing the text of the message to do so at a terminal with the aid of an advanced text editor. Individuals authorized to release a drafted message are given passwords and/or key controlled terminals so that they can authorize release without the existence of a hard copy which is transmitted to the operator with signature. As soon as release is obtained, the text is already in the system and can be composed and transmitted almost instantaneously. Possible errors in entering the text are eliminated by this option.

UGH MP FAMILIES

The UGH MP software is actually a "family" of systems, formed by the inclusion of optional features (some of which are mentioned above). The hardware support available is also a family, in two senses. First, the permanently located "base" versions of MP are designed to run on the UGH 2PIE computer family, which provides a wide range of upward compatible processors that share peripherals. MP requires a certain minimum hardware configuration depending on the supported options, but it will run on any of the 2PIE range, although larger processors are recommended for the base systems to realize the best MP performance. The 2PIE range was not designed for rugged mobile installations, and since MP is of extreme value in this setting, the system is also supported on the large UGH-7 (UGH-VAN) computer and on the smaller UGH-20 minicomputer. Although the full software system is available on UGH-7, the

incorporation of some features of the software family is of doubtful value. Only a subset of features is available on UGH-20. (Neither of these hardware systems is compatible with UGH 2PIE hardware.)

There is a complex interaction between the hardware required to support a given UGH MP feature, other features necessarily included with it, and the capabilities of the resulting system. Some examples will make this interaction clear.

UGH MP can be configured with optical character readers (OCR) for input text. Of course, the software support for this feature is useless without the OCR peripheral device itself. This device is available only on the 2PIE series as a standard option. (Although offered as a field-modification item for UGH-7, no such modifications exist at the present time.) Furthermore, the OCR is used by the system only in connection with the operator's console station. It is assumed that the operator will use the OCR for the input of authorized text which he receives in hard-copy form. This usage therefore alters the remote message drafting option, if it is selected. The hard-copy message is scanned only for comparison with the internal file copy that was created earlier with RMD, and the operator advised of any inconsistencies. Since some machine printing facility is required for OCR, it is likely that the remote message drafting options should be specified whenever OCR is specified.

The test generation and transmission option allows the complete hardware-software system, along with the crucial data stored within it, to be automatically given a real test and its performance evaluated. A message is generated, and addressed to the same unit which originates it. Using the complete facilities of the system with regard to the watch list, automatic routing of internal messages, etc., the message is sent and (if all is well) received. However, the message is flagged so that upon receipt, a complete description of the system performance is created and made available to the operator. In conjunction with another MP system, this testing can actually involve two or more distinct units, but the external system can also be tested by routing an internal message over an arbitrary route and checking it specially when it arrives in the specified way. MP creates such test messages on command without any operator control except the request to perform the test. The selection of this option evidently requires the complete UGHTRANS[R] hardware interface, and the additional features of automatic selection of communications setup from routing indicators, and monitoring of incoming routing for consistency. Although this enabling capability is available on UGH-20, the test option is not recommended for this small machine because it would degrade other functions.

Although the following table is not complete, it does include all MP options mentioned in this brief description, and gives an idea of the relationship between the hardware and software families according to the capabilities selected. As an example of the use of the table, capability "A", the information retrieval option, requires at least an UGH-VAN hardware system with extended mass storage ("Z") and memory ("Y"), and cannot be selected without also selecting the message retention capability ("B").

TABLE -- UGH MP Hardware and Software Families

	Capability	UGH-2PIE	UGH-VAN	UGH-20	Hardware and Other Capabilities
A	Information retrieval	*	*		ZYB
B	Message retention(1)	*	*	*	Z
C	Automatic selection of communications	*	*	*	X
D	Verify incoming routing indicators	*	*	*	
E	Operator prompting	*	*		
F	Remote message drafting	*	*		
G	OCR input	*	*(2)		WAF
H	Test generation and transmission	*	*	*	XABCD

Hardware codes:

Z Extended mass storage (large disk)
Y Extended memory
X UGHTRANS interface
W OCR peripherals

Notes:

(1) Retention period is 1, 3, or 6 months. Only the first is available for UGH-20, and the longer periods require further mass storage extensions.

(2) Requires a field modification to install OCR peripherals.

DELIVERY

UGH MP will be delivered 2-1/2 years after receipt of the first signed purchase contract. Later versions will be available with shorter delivery times.

MP.2 MP Basic Modular Structure

EXAMPLE DESCRIPTION

Introduction

The UGH MP is designed to be a highly modular piece of software that can be easily adapted to meet the needs of individual users as well as to changing AUTONOYS conventions.

To meet the needs for adaptability, the system is divided into a number of modules each of which has a precisely defined task. Communication between modules has been limited to well-defined data structures stored on disk and a sophisticated intermodule communication facility implemented as part of a system "kernel."

This document is designed to provide an overview of the basic system structure together with a brief introduction to the function of each module. Detailed functional specifications of each module as well as interface definitions will be provided in separate documents.

Common Characteristics of Modules and Intermodule Communication

Each module is designed to perform a given step in the processing of a message. Each one is designed to function independently of the others, starting its processing of a message and carrying this processing through to completion. Work is sent to a module through the system kernel in the form of a Work Control Block (WCB). Modules are called READY when they have one or more WCB's waiting for them. At any one time, at most one module is RUNNING. The RUNNING module is allowed to execute until it releases control because it has completed its work or for some other reason (see below). There may be brief periods of interruption of the RUNNING module to handle machine interrupts, but the RUNNING module is always resumed and is not cognizant of the pause. Some modules that require long processing times will relinquish the processor before finishing with a message in order to allow other messages to be processed. In such cases, the module sends itself a WCB before releasing the processor. This WCB contains the information necessary to allow the module to pick up where it left off.

The other form of communication between modules is through data kept on disk. For example, the text of the message being processed and a Message Description Block (MDB) containing the primary information about the message are stored on disk. The DC module will bring these data into core for processing when it receives a request (by means of a WCB).

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Overview of the System Modules

The following are the main software components of the system.

1. The System Executive (EX)

The EX controls the scheduling and communication between the remaining modules of the system. When one module wishes to communicate with another, it does so by preparing a WCB for the other module. It does this in a predefined core location. It then calls the EX routine Send Work Control Block (SWB), which queues the WCB against the recipient. If the recipient's queue was previously empty, it marks the recipient module READY and enters it in the queue of modules waiting for scheduling. EX is also called whenever a module signals completion. If the module still has WCBs in its input queue, it is placed in the list of waiting modules. If not, it is marked NOT READY. EX then determines which module will run next.

2. Message Analysis (MA)

The primary task of MA is to examine the raw message text (incoming and outgoing) identifying the principal message components and detecting format errors in the message. During this process, key information is extracted from the message and stored in the MDB. At the same time, a record of message received and channel is made. MA is also responsible for recording the status of channels and will not release a message to a channel that cannot handle it.

3. Screening Module (SC)

Primary purpose of SC is the detection of messages of interest. To this end, SC examines the list of message addressees and compares it with the WATCH LIST (made available by Data Control Module (DC)). SC also adds routing indicators to outgoing messages and can check incoming message routing indicators. Messages that are not of interest are sent by means of a WCP to the terminal control module (TC). Accepted messages result in a WCB being sent to the Log Maintenance Module (LM).

4. Message Composition Module (CO)

This module is responsible for assembly of the complete message as it is to be transmitted. Information is received from the other modules (e.g., routing indicators from screening) and the completed message is then sent to MA where it is checked as if it were an incoming message. The optional prompting package is part of this module if purchased. CO provides text editing facilities allowing modification of text previously input. These facilities keep control until the operator indicates that he is done editing and asks for composition of the final message.

5. Terminal Control (TC)

TC is responsible for all direct communication with consoles, including teletype, printers, and CRT devices. Terminal Control neither interprets the input nor decides what to output -- it is simply a standard interface between the other modules and the terminal.

6. Equipment Control (EC)

This module is responsible for control of the UGHTRANS devices. It receives its WCBs from OP.

7. Operator Control (OP)

This module implements the interfaces to the system control officer. It allows him, for example, to request reports, change circuit connections, verify connections, request tuning, and define available frequencies. This module implements a user-oriented interface with mnemonic commands, but relays all commands to other modules for execution.

8. Traffic Output (TO)

Traffic output is in control of a message during its actual transmission. It retrieves portions of the message from disk and causes them to be sent to the I/O devices. It verifies that no line contains more than 69 characters.

9. Data Control (DC)

This module is responsible for the maintenance of various lists of data used by other modules. For example, DC finds and allocates disk storage for the WATCH LIST, MDBs, and routing indicators. START and END addresses for the working disk storage areas of other modules are also kept by this module. DC does not issue control commands to the disk, but simply sends requests to DK (in terms of track and sector) where the actual I/O commands are generated.

10. Disk Control (DK)

All requests to use the disk are queued as WCBs for DK, thus making sure that the disk is not requested to carry out two access requests at once.

11. LOG Maintenance (LM)

This module is responsible for updating all lists used in the information retrieval and report generation functions. Space is allocated by DC and actual data transfers by call to DK. Among the logs kept are:

1. list of all messages received;
2. list per channel of all messages received;
3. list of messages originated;
4. list of messages sent; and
5. list of messages rejected (optional).

All entries in these logs are complete MDBs that include the address of the full text on disk.

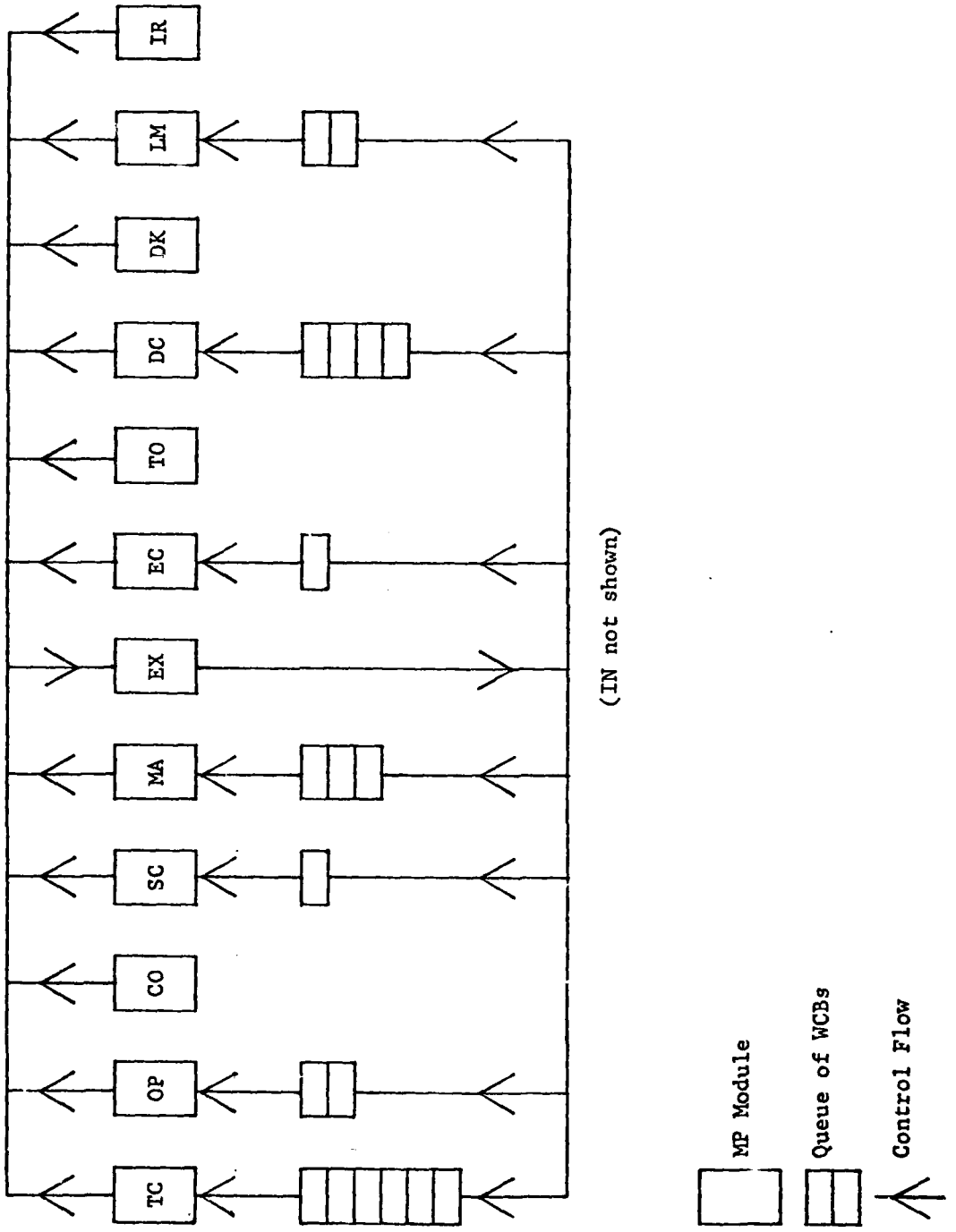
12. Initialization (IN)

This module performs all actions needed at system start. It is normally only called at that time.

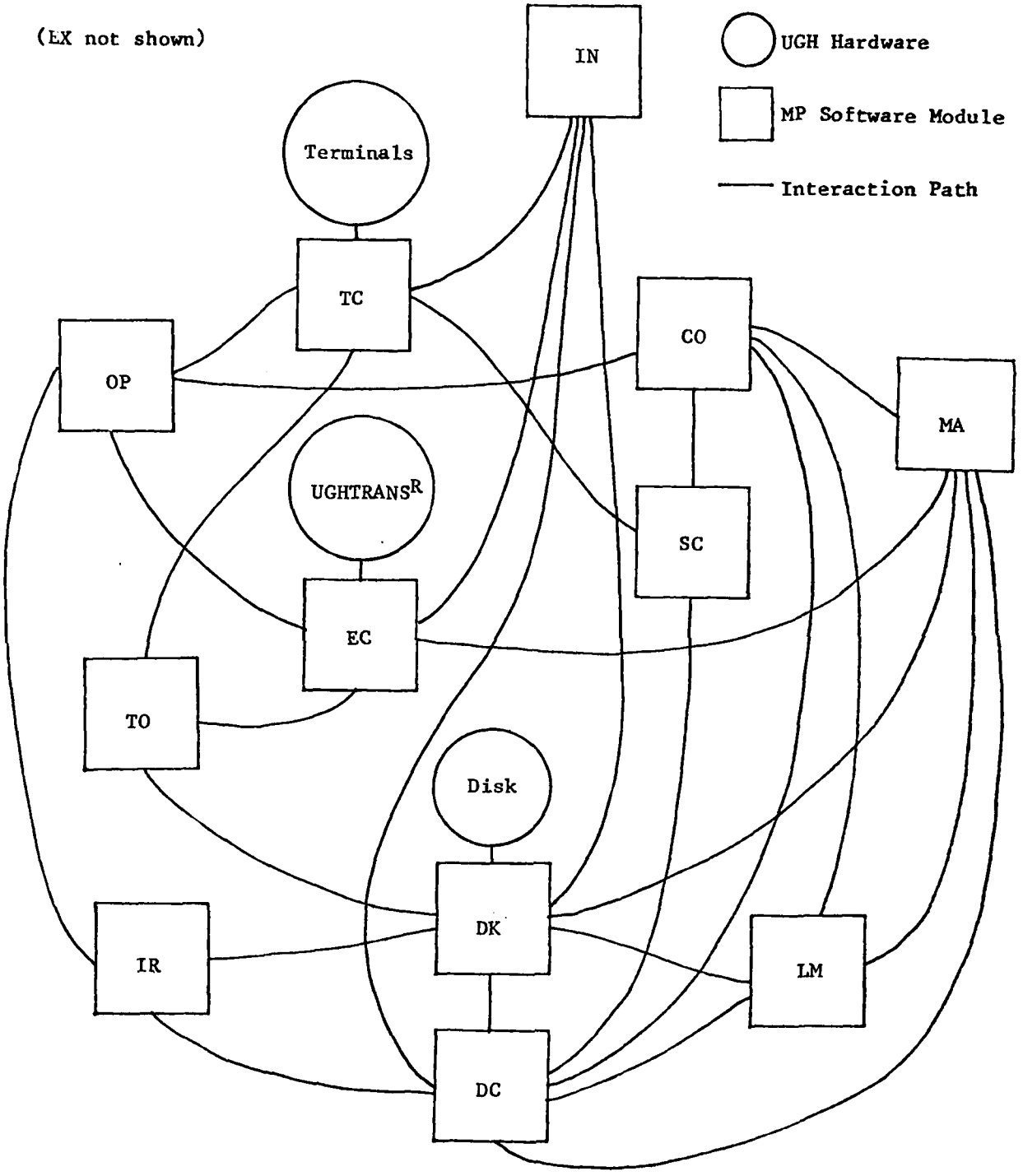
13. Information Retrieval Module (IR)

This module allows officials to obtain information such as:

"What message came in on channel 3 at 1500?"
"Was message _____ originated here?"
"Was message _____ transmitted?"



CONTROL PATHS IN UGS MP



BLOCK DIAGRAM OF UGH MP MODULES

MP.3 MP Detailed Modular Structure

EXAMPLE DESCRIPTION

Functional descriptions are attached for some of the primary modules of the UGH MP system. Only the "message-processing" group MA, SC, CO, and the "executive group" EX, DK, DC are included. For other modules the capsule descriptions of MP.2 are sufficient. Following the module descriptions are details of the Work Control Block by which modules communicate with each other. A useful summary of module functions is given below:

The Modules of MP: A Summary

CO: Message Composition -- Editing and assembly of messages to be transmitted.
DC: Data Control -- Storage allocation for data, both core and disk.
DK: Disk Control -- Controls disk access.
EC: Equipment Control -- Controls UGHTRANS devices.
EX: Executive -- Handles scheduling, intermodule communication, and interrupts.
IN: Initialization -- Initializes system at start.
IR: Information Retrieval -- Retrieves information of interest from logs.
LM: Log Maintenance -- Maintains logs of MDBs.
MA: Message Analysis -- Analyzes potential messages to see if they are real messages.
OP: Operator Control -- Handles operator interface.
SC: Screening -- Examines incoming traffic for messages of interest.
TC: Terminal Control -- Handles communication with system consoles.
TO: Traffic Output -- Controls transmission of messages.

MESSAGE FORMAT FOR MP

The description below supplies enough information to understand the actions of MP modules that deal with the headers of messages. It ignores some message features (such as multiple pages), and simplifies some others.

A message consists of a number of Format Lines numbered beginning with one. (These are abbreviated FL1, FL2, etc.) In specifying these, we will use a notation drawn from computer language and control-card manuals.

Uppercase letters represent themselves, and where given, must appear exactly as written. Where information is to be supplied, a lowercase name will appear, to be explained subsequently. Where items are optional, they are enclosed in square brackets; where a choice of items is permitted, these are shown one above the other. The spaces shown are nonrepresentative: the characters begin in the first column and continue to the end of the format line without spacing unless explicit spaces are indicated by the symbol b. Each line ends with a sequence of two-carriage-returns-and-a-line-feed, not

shown. When an item is superscripted, it is repeated that many times; superscript ^{n} means an indefinite repeat (but at least once).

FL1:

VZCZC origin-route-part channel

where "origin-route-part" is a two-letter part of the originating routing code (the 3rd-last and 2nd-last letters of the code), and "channel" is a three-digit channel number.

FL2:

precedence origin-media dest-media class content-action b
sender-orig-route serial b date time b class^{4} routing

where "precedence" is a single letter from a standard list, "origin-media" and "dest-media" each 1-letter language media codes from a standard list, "class" is the security classification letter from a standard list, "content-action" is a four-letter identifier from a standard list, "sender-orig-route" is the seven-letter routing indicator of the sender, "serial" is a four-digit number supplied by the sender, "date" is the three-digit Julian date and "time" the four-digit GCT at which the message was received for transmission, and "routing" is the seven-letter routing indicator for the addressee.

FL3:

DE b sender-orig-route serial date time b year

FL4:

ZNR b class^{5} T [routing]
ZNY

FL5:

precedence b date time Z b JAN ... DEC b year b

where "year" is a two-digit value, e.g., 76 for the bicentennial year.

FL6:

FM b origin

where "origin" may be a routing indicator "sender-orig-route" or may be in plain text.

FL7:

TO b [routing / addressee , n]n.

where "addressee" is the plain text corresponding to the routing indicator it follows. (In the final addressee item, the period replaces the comma, and similarly in FL8, 9.)

FL8:

[INFO b [routing / addressee,]n .]

FL9:

[XMT b [routing / addressee,]n .]

FL11:

BT

FL12:

class subj-code text

where "subj-code" is a six-character code composed of the letter N and five digits, surrounded by double slashes, and "text" is the message text.

FL13:

BT

FL15:

serial

FL16:

null $1f^7$ NNNN

where "null" is an empty line (but with the usual ending), "1f" is a line-feed.

A sample message in this format:

VZCZCDB003

RTTUZYUW RUCLDBA2355 1861200 UUUURUHHLFA

DE RUCLDBA23551861200 76

ZNR UUUUU

R 1861200Z JUL 76

FM COMNAVTELCOM WASHINGTON DC

TO RUHHLFA/ALCOM

BT

U//N09999//

HAPPY BIRTHDAY

BT

#2355

(8 blank lines)

NNNN

THE MESSAGE ANALYSIS MODULE (MA)

FUNCTION

The function of the MA module is to analyze a message to make sure that it is a message in the sense of the AUTONOYS standard message syntax rules. Before an incoming message is processed by the rest of the UGH MP system, MA is called upon to make certain that the string being processed is indeed a complete message and not a message fragment or some portion of more than one message. All of the remaining modules in UGH MP may proceed on the assumption that the text that they are processing is indeed a message and they need not perform error checking. To increase reliability, MA is also used to check outgoing messages. MA performs exactly the same analysis on an outgoing message that it performs on incoming messages. This provides an additional check that the other modules and the operator have done their work properly. If MA finds that a message does not conform to the AUTONOYS conventions, it does not release it for transmission.

Non-messages are rejected by MA and then discarded from the system, unless the message retention option with rejected-message log is included.

METHOD

The basic approach is to identify the components (format lines) of a message, thereby making sure that all required components are present and that each contains the information required. The possibility of transmission errors on AUTONOYS channels, together with the redundant nature of the AUTONOYS message conventions, makes it inadvisable and unnecessary to demand that a message be perfect. The MA module uses a sophisticated point system to determine the acceptability of messages. Every time that a message passes a certain requirement, it receives a certain number of points. Potential messages which receive at least 80% of the required points are considered to be messages and are passed on for further processing. MA may also improve a message by making certain obvious corrections.

The message is first checked to determine that it contains Format Line 1, which is required in all messages. In a perfect message, FL1 begins with "VZCZC". MA first checks for the first character being a "V". If the first character is not a "V", it checks to see that the second character is a "Z"; if so, the checking continues, but if the first character is not "V" and the second charcter is not "Z", MA checks to see if the second character is a "V" or the first character is a "Z", which would mean that either the first character of a message was lost or the second character of the message was the actual first character. If either of those conditions are met, the characters in the message are renumbered; otherwise, the checking proceeds as if the first character really was the first character but it is incorrect. In a similar way, MA then goes on to check for the presence of "C", "Z", and "C". Because these characters repeat themselves in this code, no check for misalignment is made. If all five characters are present where expected, the

message is given five points. If by renumbering the characters one can find at least four of the five characters on the proper positions, then four points are given. If only three of the characters can be found, two points are given; in all other cases zero points are computed.

The next component of FL1 should be the 5th and 6th letter of the originator's routing designator. There are only 42 possible combinations in the list of AUTONOYS routing designators, so a check is made to see if the two characters found are on that list of 42 combinations. If so, the message is given two points; if not, it is given no points for this test. The last three characters of FL1 are a three-digit channel designator. A check is performed to make certain that the three digits found here designate one of the channels being used by the system. If so, two points are given. If all the characters are digits but the number is not a possible channel designator, one point is given. If a non-digit is found, no points are given. The remainder of FL1 is spaces.

A search is next made for the beginning of FL2. This must be the message precedence. There are six possible AUTONOYS precedence codes. If the first non-blank character after the end of FL1 is one of these six characters, that position is assumed to be the start of FL2 and two points are given. If the first non-blank character is not a legal precedence code, a search is made for the next non-blank character. If that is a legal precedence code, then it is assumed that FL2 begins at that point (the message is corrected), and one point is credited. If not, FL2 is assumed to be missing and a search is made for the start of FL3. One point is subtracted from the score of the message if this occurs. The next two characters after the precedence are media indicators. These are not checked. The third character, however, is a security class indicator. If this indicates one of the five allowed security classes, three points are given. If not, the two neighboring positions are checked to see if they could be a security class. A match in either position results in one point for the message, and message correction. Four spaces after the security class, a routing indicator for the message originator is expected. This is seven characters long and begins with "R". If the "R" is not present in the expected position, a check is made for the previous or following character being an "R". If so, it is assumed that the routing indicator has been found. Seven points are given for the routing indicator being found where expected, five points if it is found one position off. A check is now made to make sure that characters five and six are on the list of 42 possible 5th and 6th characters for routing indicators. If so, three points accrue. If not, a check is made to see whether the 6th and 7th characters of FL1 passed the test. If so, they are substituted for the corresponding characters at this point. If these characters passed the test, but were not the same as those in FL1, one point is subtracted from the score and the FL1 characters are substituted. The next four characters are a serial number provided by the sending station. If these are all numeric, two points are given. The following three characters must be a Julian date. A possible Julian date receives two points, and today's date one more point. The next four characters represent "time filed"; if all are numeric and a possible time, two points are given. The following four characters must be the

security code repeated four times. If the same character is present four times, and it is the same as the security found on position four of FL2, 10 points are given. If the same character is present four times, but it is not a legitimate security code, then two points are given and the FL2 code is substituted. If it is present four times, is a legitimate code, but is not the same as that found earlier, then (a) seven points are given, and (b) the earlier security code is replaced. If the character is only present three times, but it is a legitimate code, then six points are given. If this character is not the same as that found earlier, the earlier one is replaced and one point is substracted from the score. The next seven characters are intended to be the addressee's routing indicator and must begin with "R". If it is correct, 10 points are given. If the "R" is incorrect, but the remainder is correct, then nine points are given. If the "R" is present, but the remaining code is incorrect in one or more positions, eight points minus the number of incorrect positions are accumulated.

Format Line three is identified by the string "DE", followed by a space, followed by the routing indicator of the originator. If this can be found, the message is given 10 points. If a routing indicator can be found, but it is not that which was found earlier, then seven points are given. If the routing indicator is found, but the "DE" is missing, then six points are given. The next four characters must be the sender's serial number again. If this is found and matches that found earlier, then five points are given. If four numeric characters are found but they do not match those found in FL2, then three points are given. If any non-numeric characters are found, then no points are given. The next characters must be a repeat of the Julian date. A legal date which matches that found earlier brings seven points. A legal date which does not match that found earlier brings four points. The following four characters must be a filing time. If they are all numeric, then three points are credited; if they are not numeric, no points are given.

Format Line four must begin with "ZNR" or "ZNY". If this is found, eight points are credited. If it is found with one or two errors, four points are credited. A search is then made for the classification repeated five times. If the previously determined classification is found five times, 10 points are credited. If it can be found three or four times, five points are credited. If a legitimate code is found five times, but it is not the same as that determined earlier, then five points are credited and the higher classification is used. The other occurrences of the security code are replaced by this higher classification.

MA continues in this fashion until the entire message has been processed.

After determining whether or not the message passes the tests (by obtaining at least 80% of the possible points), WCBs are prepared and sent to other modules. A WCB is sent to the screening module. If this is an outgoing message, a WCB is sent to the TO module. If the message has failed, WCBs are sent to DC to remove the message from the system. In all cases, WCBs are sent to the LM module to record the disposition of the message. A WCB is then sent to the DC module requesting that it allocate disk space to store the corrected

message text. (DC will eventually do so and by a WCB will cause the DK module to transfer the message to disk. DK will, on completion of this transfer, send a WCB to DC which can then release the core space for the storage of an incoming future message.) Before terminating itself, MA prepares an MDB for the message. This is allocated space by DC and stored by DK. The disk address of the MDB for a message is always given in fields 15-17 of a WCB.

THE SCREENING MODULE (SC)

FUNCTION

Once a string of characters, whether incoming or outgoing, has been accepted by MA as an acceptable message, it must be screened to see if it is intended for a recipient served by the installation. Outgoing messages must be screened as well as incoming messages because messages may have multiple addressees and some of those addressees may be at a location served by the installation. The message text, as stored on the disk, is searched for the addressees, and when they are found, a list is prepared in core. This is then compared with the WATCH LIST obtained from the DC module. SC produces an internal routing list, which is the intersection of the two lists (addressees and WATCH). If this intersection is empty, and the message is incoming, SC takes no action. Otherwise, WCBs causing further processing of the message are prepared.

METHOD

Since the addressees are to be found in Format Line seven and Format Line eight, the first step is to find the starting location of Format Line seven. This is done by proceeding stepwise through the message. The start of FL1 is identified by the string "VZCZC". If this string cannot be found anywhere in the first 20 characters, it is assumed to have been destroyed by noise. To assist future modules in their processing, SC corrects the start of the message by inserting VZCZC. The end of FL1 is identified by the three digit channel number. The start of FL2 is identified by searching for the precedence code. The precedence code can be found in field 9 (Byte 27) of the WCB. As a further check that FL2 has been found, the classification code is checked for two characters after the supposed precedence code. The end of FL2 is identified by searching for the four occurrences of the classification code and then the routing indicator. When these are found, it is assumed that we are at the end of FL2 and the search for "DE" which indicates the start of FL3, is begun. Having found this "DE", the end of FL2 is signaled by the occurrence of seven digits in a row. FL4 is identified as the string "ZBR" or "ZNY", followed by five occurrences of the security class. Because FL5 is so short, we search for the end of it as indicated by the clear-text month and date. FL6 must be clearly and certainly identified since the information that we are looking for begins in FL7. FL6 contains "FM" followed by a seven letter routing indicator beginning with "R", or the originator in plain text. The next non-blank character is assumed to be the start of FL7.

The start of FL7 is marked by a "TO", followed by a list of addressees separated by commas. Each addressee consists of a routing code, followed by a "/", followed by the identifier of the addressee. The program searches for the "/", then writes in its working list all characters until it finds a ",". It then searches for the occurrence of either a "/" or a ".". A "." indicates the end of the TO list and FL7. The start of FL8 is indicated by the string "INFO". The addressees which are listed after this are listed in the same

format. Hence, the same algorithm is applied, search for the "/", copy the addressee until "," or "." . The SC module handles information and action (to) addressees identically.

After composing the list of addressees, SC sends a WCB requesting that DC bring the WATCH LIST into its core area. It then terminates until it receives a WCB, which informs it that the WATCH LIST is now in core. It then proceeds to search for each of the addressees in the WATCH LIST. Each one that is found is copied into a list. If this list is empty, then processing of incoming messages stops, unless rejected message retention or the routing indicator check option has been selected. For outgoing messages (and for incoming messages, if one of these options has been chosen), the module next requests that the routing indicator directory be brought into core. This is done by means of a WCB to DC. The routing indicator directory contains a routing indicator for all addressees of interest to the installation. Each addressee is looked up in this directory, and the routing indicator is compared with that found in the message. If it is different, the discrepancy is reported to the operator who is given the opportunity to correct either the message or the directory. An additional option allows the SC module to simply add the routing indicator found in the directory to an outgoing message on the assumption that the routing indicator in the directory is the correct one.

THE MESSAGE COMPOSITION MODULE (CO)

FUNCTION

The Message Composition Module (CO) is one of the most significant new features and innovations of MP. It is designed to take most of the drudgery out of AUTONOYS communication. The characters in an AUTONOYS message can be divided into three categories:

(1) Format characters: (e.g., "VZCZC", "TO") which are present in every message and serve primarily to clearly identify message components.

(2) Redundant characters (e.g., nine repetitions of classification code, second insertion of station serial number, etc.)

(3) Information characters: characters such as the message text, the addressees, etc., which could not be deduced from the remaining text.

The purpose of the CO module is to spare the operator the work of typing in anything but "real" information characters. The format characters are automatically supplied by the CO module; the redundant characters are inserted in the proper portions of the text as soon as the first piece of information has been supplied. For example, once the message classification has been input to the system, it can be inserted in the text automatically wherever the AUTONOYS conventions require it. Even the routing indicators are redundant information; CO requests the routing indicator directory and adds this information to the message as soon as the addressee has been named.

METHOD

OP sends CO a WCB indicating that the operator is ready to input a message. CO's first action is to send a WCB to DC requesting that core space for message composition be supplied. Upon receipt of the WCB from DC, which indicates where this core area is, CO initializes the message by writing the characters "VZCZC" at the start of the core area. It also writes the 5th and 6th characters of the installation's own routing designator in core. It then sends a WCB to the OP module requesting that the operator be prompted to state the channel designator. The response WCB from OP should contain the three-digit channel. If this is not on the list of possible channels, the operator is prompted again (through OP, of course). A proper channel completes Format Line 1 (FL1).

Next, a WCB is sent to OP which requests OP to prompt the operator for message precedence. When this information is received, it is stored in the MDB as well as inserted in the message being composed. Next, the operator is prompted for a media code and this one byte code (either 'T', 'C', 'P', or 'Q') is inserted twice in the message. Similarly, the operator supplies the content-action code and the classification code. A direct request to EX obtains a four-digit station serial number, which is then inserted in the

message text as well as the MDB. The next step is to prompt the operator to supply Julian date and filing time. This information is also checked to make certain that it is feasible (possible date, time less than 2400, etc.), and then inserted in the message text as well as the MDB. CO then goes on to insert the message classification code four times in the text. The operator is then prompted for the name of the first addressee. When this is received, a WCB is sent to DC to bring the routing directory into a specified core area. The addressee is looked up in the routing directory, and the routing indicator (seven characters) is inserted in the text as well as stored in the MDB.

CO now is able to supply FL3 completely automatically, since it consists of format information (DE), the originator's routing indicator (constant for the system and already inserted in FL2), the station Serial Number, filing date and time, which can be obtained from the MDB, having been supplied earlier, and year. To obtain FL4, the operator is prompted for a three-alphabetic-character transmission (which must be "ZNR"), and then the classification is inserted five times. FL5 is composed of the precedence, date, and time once more, and then the month and year in clear text together following a "Z". This is all supplied on the basis of previously stored information (once a month the system must be reloaded with a new month and year). FL6 is also supplied without bothering the operator since it consists of the format information "FM" together with the name of the originating station and/or its routing indicator.

CO continues in a similar way using information stored inside the system together with a knowledge of the format to produce the message with the minimum amount of operator intervention. Text editing facilities are provided for the message text itself, but not for the fixed format information.

When the message has been completely composed, the operator is prompted for a release number. When this is supplied and verified, a WCB is sent to MA to check the message. Release by MA will result in a WCB to TO which will control the actual transmission. WCBs are also sent to DC (to release storage areas no longer needed), to LM (to make the appropriate journal entries), and to SC, which checks the message to see if there are internal addressees.

EXECUTIVE GROUP (EX, DK, DC)

These modules (along with TC and EC, not described here) are responsible for control of UGH hardware devices. The primary device is the UGH processor, which EX schedules; DK and DC manage disk operations and allocation of disk and core.

THE SYSTEM EXECUTIVE (EX)

FUNCTION

The System Executive Module (EX) is central to the UGH MP system, yet itself takes only a supporting role in that system. EX arranges for the proper functioning of the modules that actually carry out the MP tasks. Several MP resources are controlled by EX and dispensed as needed. Among the EX resources, the UGH memory and logical and arithmetic processing units are primary, and all others are of secondary importance. Examples of secondary resources are the system clock and other centrally stored values such as the date, and unique sequence numbers. In controlling the UGH processors, EX also has control of hardware interrupts, and may itself perform a small amount of processing as the initial part of interrupt service. An important special class of interrupt service is response to software-initiated interrupts from other modules requesting service.

METHOD

Nothing happens within the UGH MP system until an interrupt occurs. Then EX takes control, and deals with the situation directly, or arranges that it will be handled by another module, which EX schedules with a proper Work Control Block (WCB).

The simplest kind of interrupt is a request from a running module. In each such case, a code is provided to describe the necessary action. Simple requests (such as for the time, or a unique sequence number) are handled and dismissed immediately. The requesting module resumes as if it had merely called a subroutine. Of course, the effect of the request often extends beyond the requesting module; for example, the sequence number is updated. More complex requests result in EX passing work to another module (not EX itself). This is accomplished by generating an appropriate WCB, queuing it against the necessary module, and returning to the requesting module. If the requestor must await the completion of the other module's work, it must request termination (an immediate EX service) following return from sending the WCB; when the other module is done, it must send another WCB to restart the original requestor.

The MP modules operate as independent processes, but they differ from arbitrary processes in a general-purpose operating system in that EX has full information on each one and can predict the resource needs of each. This information makes many of EX's tasks easier to perform. Further, preemption of the processor is usually difficult, but EX never preempts a running process.

EX uses a first-come-first-served (FCFS) queuing scheme, with emergency override. The queue order is determined by the list of pending WCB's, which are kept in the order of request. When one module requests work from another, a new WCB is appended to the end of this list. When a module terminates, the first WCB in the list is examined, and if the needed module is in core, it

assumes control. If not, the queues of pending WCBs are examined, and the core resident module which will be invoked last is removed from core. There is one exception to FCFS queueing. A module may request "priority" service, and have a WCB placed at the very head of the queue.

THE DISK CONTROL MODULE (DK)

FUNCTION

Whenever a module requires the use of UGH mass storage (typically disk packs, although this is dependent on the configuration), it sends a WCB to the disk control module (DK), specifying the track and sector, the length (in sectors), and read/write. DK does not check the address for validity for the requesting module because addresses are obtained from the data control module which verifies them (DC is the primary source of work for DK in any case). Two modes of DK operation are available. First, the request can be an I/O and wait. The operation is started, and EX terminates the requesting module. When the completion is signaled to DK, it sends a WCB to the requestor to continue. Second, the request can merely start the disk operation by sending a WCB to DK, but the requesting module continues to be READY. Later, the module may ask EX if the request is yet finished and itself take appropriate action. Use of the second kind of operation realizes a considerable saving when a module can start its requests ahead of time or has other work to do while the request is honored.

METHOD

DK uses the "scan" technique to manage multiple requests and minimize positioning contention. While one request is in progress on the disk, a number more may be queued. DK accepts their WCBs and forms a list of the needed addresses in order of arm position. It then freezes this list (additional arriving requests start a new one) and makes a "scan" across the disk servicing the requests as their addresses pass under the heads. This operation may reorder the requests slightly, but DK takes care to treat multiple requests from the same module in the order they arrive.

THE DATA CONTROL MODULE (DC)

FUNCTION

The Data Control Module (DC) has two related functions. First, it allocates space on the disk for all modules. In this, it is something like part of a general-purpose file system, although the spaces are not named permanently. To obtain space, a module requests the size needed, and DC returns the address of such a block. Deallocation of the space requires another request. Similarly, DC allocates core memory for data. (EX allocates core for module code.)

The second DC function is also similar to part of a file system: DC knows about certain data sets which are important to all phases of MP operations, and aids modules in accessing these data sets. For example, the WATCH LIST is a permanent part of any MP installation, and DC allocates the space for it. But DC also allows modules to use the WATCH LIST without knowing its format or disk address, as if it were a sort of "file" with variable blocking. A module can thus simply "read" WATCH by sending a WCB to DC, and receive a buffer of data in response. In a sense, each message within the system is a "file" of this kind, since DC will access it for a module from its MDB.

METHOD

Space allocation on disk is done in variable-size segments that are a multiple of a minimum unit. DC controls the available space by keeping a list of addresses of the beginning and size of all in-use space. When a request is made for space DC returns the first block (or part thereof) which is large enough to meet the request. Although this operation can cause disk "checker-boarding," the transient requests for space are not a significant fraction of the total space in use and are of short duration. The space allocated to longer-lasting items like the WATCH LIST, message texts, and logs is allocated contiguously to avoid "holes." The two kinds of space work towards each other from opposite ends of the address space -- temporary allocations from the low end, permanent allocations from the high end.

DC may also be called upon to allocate core memory for purposes that are not clearly connected with a particular module (otherwise the core is part of the module itself, allocated by EX). The primary such usage is the memory for messages themselves, allocated from main memory in a manner similar to that of temporary disk allocation. For the "permanent" data sets such as the WATCH LIST, DC does not allocate the memory into which they are read. That is the function of the module requesting the data, and DC merely calls upon DK to perform the transfer. The requesting module must verify that the memory area provided is adequate.

No actual disk operations are performed by DC, but rather by DK upon receipt of a WCB containing a description of the operation. However, DC does call itself to obtain memory space for buffers, and to allocate temporary disk space (in particular to hold the available space list itself).

WORK CONTROL BLOCKS (WCB's)

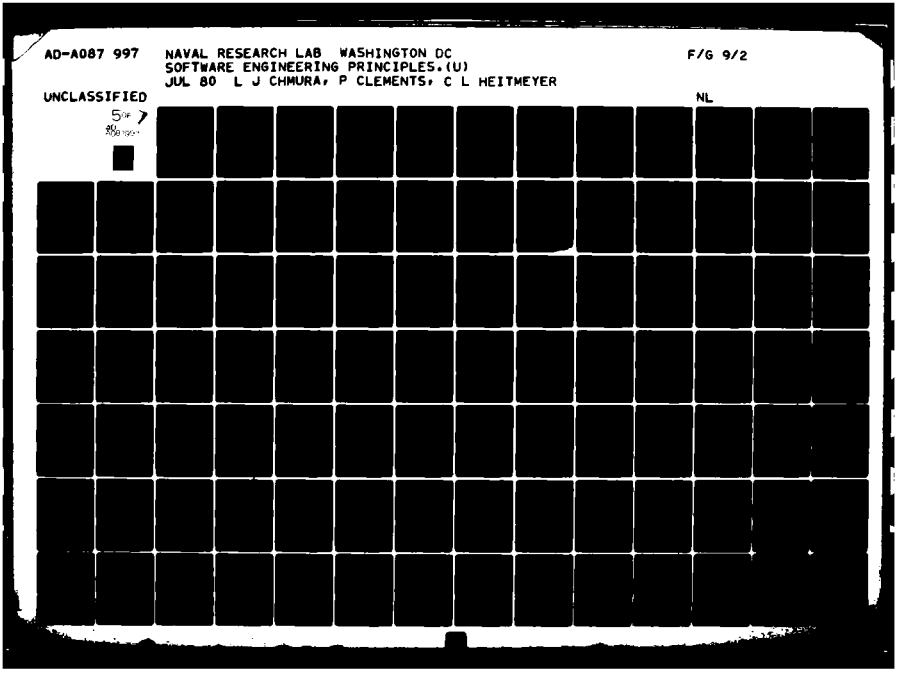
The communication mechanism between modules is the Work Control Block, which any module can pass to any other (including itself) by means of an EX request.

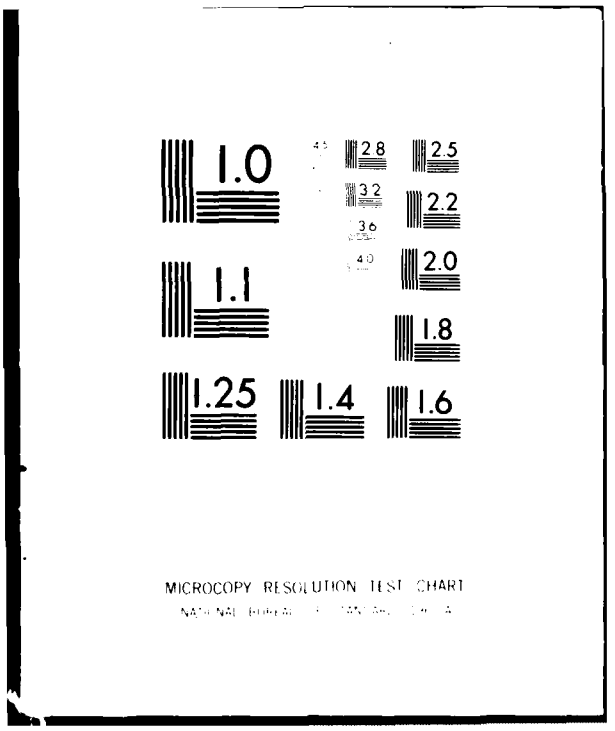
FORMAT OF A WCB (WORK CONTROL BLOCK)

WCBs are the primary means of communication between the modules of MP. All requests from one module to another are made by composing a WCB in a predetermined core area, then calling EX to send it to the recipient. Each WCB concerns a specific message, and the WCB identifies the message of concern both by means of the message identifier and by means of the disk address of the message text.

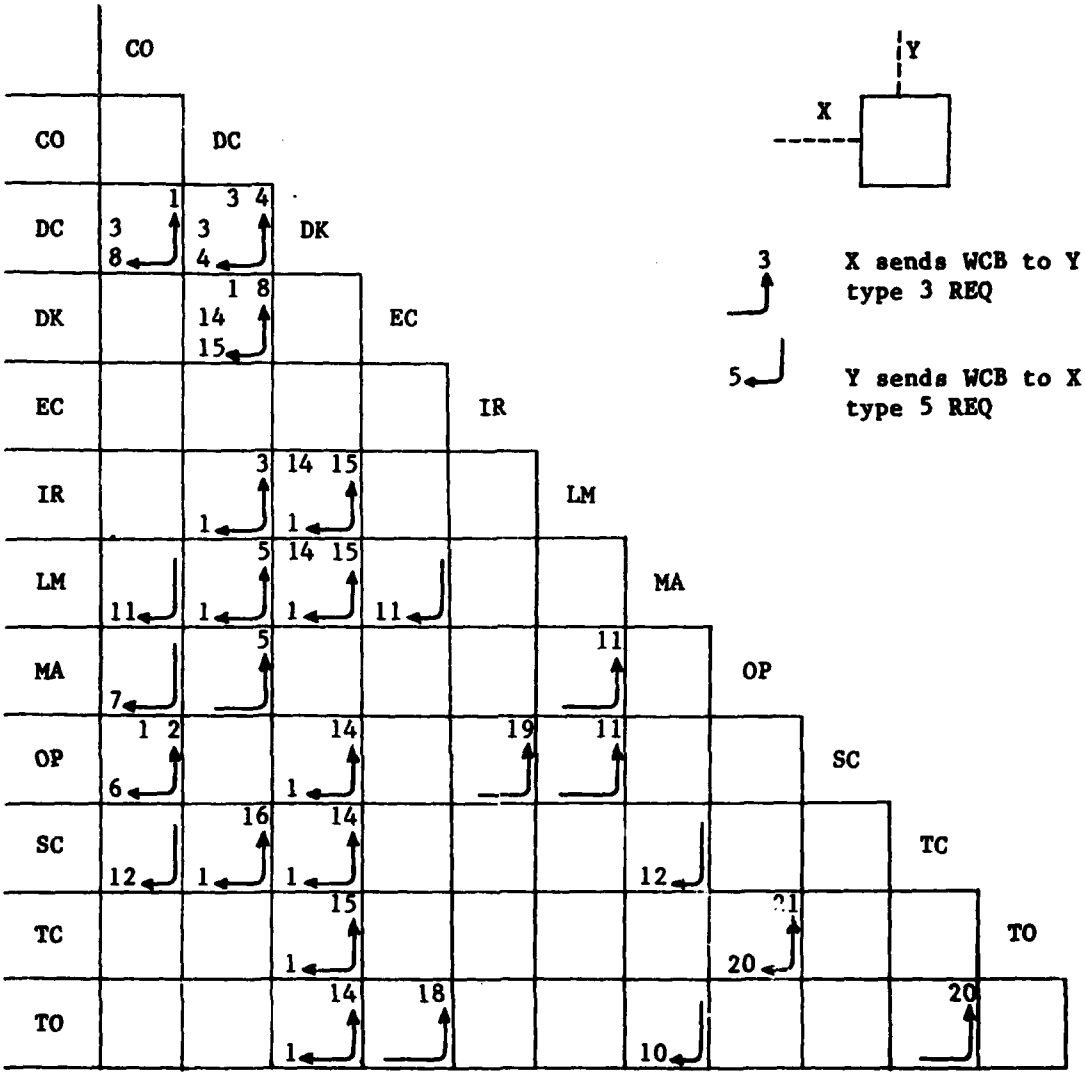
In the following, the length of each WCB field is given in bytes.

FIELD #	NAME	LENGTH	PURPOSE
0	SIZE	2	Size in bytes of this WCB
1	SENDER	2	Identifies the sending module
2	RECIP	2	Identifies the intended recipient
3	REQ	3	Identifies the function requested of recipient
4	DSKTR	4	Determines the track # on disk where message is
5	DSKST	2	Determines position on track where message starts
6	DSKLN	3	Length of message text in sectors on disk
7	INNO	4	Serial number of message
8	CLASS	6	Classification # of message
9	PREC	1	Message precedence
10	AROUT	7	Routing indicator of originator
11	SEC	1	Security code of message
12	DIRECT	1	1 = incoming, 0 = outgoing
13	IRDSUTC	4	Starting position of internal routing list on disk
14	DSULN	2	Length of internal routing list in sectors
15	MDBTR	4	Disk address of MDB (track)
16	MDBST	2	Track position of MDB
17	MDBLN	1	Length of MDB in disk sectors
18	PRIO	1	Queue priority of WCB
19	SEQ	4	Sequence number of WCB
20	REQDAT	0-10	Request-dependent data


AD-A087 997
NAVAL RESEARCH LAB WASHINGTON DC
SOFTWARE ENGINEERING PRINCIPLES.(U)
JUL 80 L J CHMURA, P CLEMENTS, C L HEITMEYER
F/G 9/2
UNCLASSIFIED
NL
5 OF 7


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

REQ #	Description	REQDAT Contents
1	Response to a previous WCB request	SEQ of request and response data
2	Create new message	None
3	Request core	Size
4	Request temporary disk space	Size
5	Request permanent disk space	Size
6	Prompt operator	Prompt query
7	Test and verify message	None
8	Release core	Address
9	Release disk	Address
10	Transmit message	None
11	Log data	Log identification and data to logged
12	Screen message	None
13	Direct EX request	Desired information
14	Disk operation (wait)	Description of operation
15	Disk operation (proceed)	Description of operation
16	"Read" permanent data set	Data set identification and buffer to use
17	"Write" permanent data set	Data set identification and buffer to use
18	Drive UGHTRANS	UGHTRANS function
19	Retrieval request	None
20	Terminal read/write	Data or pointer to it on temporary disk
21	Terminal attention request	None



The REQ functions are listed below by number.

MP WCB ROUTING DIAGRAM

MP.4 MP Improved Modular Structure

EXAMPLE DESCRIPTION

Introduction

The original modular structure of the MP demonstrates a number of serious and fundamental violations of the information-hiding criterion for dividing systems into modules. This results in the excessive complexity of the system, as well as the fact that changes tend to involve many modules. Among the most significant errors are:

1. Far too many modules are sensitive to changes in the external message format. The descriptions of CO, MA, SC and TO all show a dependence on the AUTONOYS conventions; these conventions are both complex and subject to change.

2. Several modules have direct knowledge of disk characteristics and use disk addresses. This makes it difficult to use another type of storage device, should a better one become available.

3. Two different modules must know the data organization used in the logs. Changes in the queries possible can have major effects on the log maintenance required, and changes in the log organization will in turn have major effects on the IR module.

4. The fact that resources are allocated by several modules without communication will make deadlock recognition and prevention quite difficult.

5. The fact that the incoming data is modified by several modules during their attempts to analyze it may result in subtle, hard-to-find errors.

The following is a proposal for an improved structure.

Modules

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MH: Message Holder

This module is responsible for storage and retrieval of all messages. All direct accesses to the internal representation of a message are serviced by functions belonging to this module. The original storage of the message and any subsequent modifications are performed by the functions belonging to this module. The interface to this module is a set of functions allowing other programs to store and access elements of a message, e.g., SET_CHANNEL and GET_CHANNEL to store and read the channel number in the message. The special character sequences at the start of various format lines are no longer considered part of the message and are not made available. Additionally, from

the set of functions available on the interface, one can no longer recognize the order in which the various components appeared in the original text. Further, one cannot test to see if a given item was present several times to provide redundancy.

If messages must be stored on backup-store devices, the data is organized in "pages" that are then stored and retrieved by PS.

EI: External Interface Module(s)

This module is responsible for conversions between the actual message format and the abstract format. If there are several external message formats in use, there will be separate versions or submodules for each one.

Programs in this module analyze the incoming text, which they find stored in buffers, identify the components of the message and call programs in the message holder module to store the information, making it available to other modules.

When a message is being output, programs in this module call the functions of the message holder module to get the contents of the message fields and then arrange the information in the proper order with the appropriate delimiters, storing the completed message in an output buffer.

If the transmission is noise free, the input programs and the output programs are essentially complementary and have the same "secret". If the input data is noisy, then the input programs require additional information that is not needed by the output programs. The input programs must know the expected frequency and nature of errors, in order to detect and correct errors on the basis of redundancy.

CM: Communication Modules

These modules know the communication protocols, including handshaking and timing. Although they control transmission of messages on devices, they know neither the structure of messages nor the details of device control. Incoming messages go to, and outgoing messages come from, the external interface (EI) module. Programs in the equipment control (EC) module are called to tune the device, change the frequency, etc.

SC: Screening

This module fulfills the same function as the SC module in the old MP structure, but it no longer requires detailed knowledge of the format, since it uses the message holder to get the contents of the addressee lists of incoming messages.

The "watch list" is a secret of a submodule of this module. The submodule contains programs to insert and delete watch list entries and to search the watch list for a specific entry.

EC: Equipment Control

Controls UGHTRANS devices.

TC: Terminal Control

This module controls the terminal devices. It knows how to read and write characters, how to generate line feeds, etc. The module includes separate submodules for each terminal type.

DS: Display Module

This module displays messages for the operators. A message can be either received over the UGHTRANS device or created with the text editor module. The module knows how the fields of a message should be arranged in the display, and it uses the message holder interface to get the contents of the fields. It uses a terminal control module to write the characters to the device.

The module includes a separate submodule for each different display format. The display formats will probably be quite different from the format known by the external interface module.

TE: Text Editor

This module implements the command language the operator uses to create messages. It recognizes commands and generates prompts. When the operator inputs a message field, the text editor stores the contents using the message holder interface.

IR/LOG: Information Retrieval and Log Storage

We have combined the information retrieval and log modules into a single module that understands the organization of the data that has been stored about incoming and outgoing messages. This module does not deal directly with background memory but uses pages that are stored and retrieved by PS.

PS: Page Storage

All memory and backup-store access is centralized in this module. It keeps files in terms of pages.

*IC: Intermodule Communication

This module is responsible for keeping the queues of WCBs between components as they are needed. It was formerly a part of EX.

---

* These modules will be discussed in more detail later in the course.

*AL: Allocator and Scheduling

This module is the central allocator of all resources including core and processors. It includes a "banker" to help prevent deadlocks.

*IH: Interrupt Handler

This module translates interrupts into signals for the various system components.

Relation between the "old" modules and the new

1. The work of EX has been divided among IC, AL and IH.
2. MA work is now done by EI, using MH SET functions to store the resulting information.
3. SC work is still done by SC, but the new SC is considerably simpler because it uses the MH GET functions.
4. CO work is now done in the output submodules of EI, which use the GET functions of MH to get the information to put in the messages. The text editor is now separate (TE).
5. TC's duties are carried out by the DS module, which uses the new TC module to write the characters. Thus, the display format is separated from the device characteristics. DS is simpler than the old TC because it gets information for the display using the GET functions of MH.
6. EC now receives commands from the CM module. The new EC is simpler than the old because it knows nothing about when and why things are done, only how they are done.
7. The duties of OP are divided among several modules, including DS, CM, and TE.
8. The work of TO is now performed by parts of MH, EI and CM.
9. DC has been subsumed in PS and AL.
10. DK is now in PS.
11. LM and IR are now the single module IR/LOG, which uses PS.
12. Initialization is not a separate module, but is performed by the initialization routines for the individual modules.

---

* These modules will be discussed in more detail later in the course.

MP.5 MP Message Holder Module

EXAMPLE DESCRIPTION

The following is an informal functional specification of the message holder module.

Index of Function Descriptions

Function	Page
BIND(mn)	12-38
BLANKIT(i)	12-38
GET_ACTION_OR_INFO	12-39
GET_ADDEE	12-39
GET_CHANNEL	12-39
GET_CLASSIFICATION	12-40
GET_DAY	12-40
GET_ORIGINATOR	12-40
GET_ORIGINATOR_ROUTING_INDICATOR	12-41
GET_PRECEDENCE	12-41
GET_ROUTING_INDICATOR	12-41
GET_SERIAL	12-42
GET_TEXT(i,j)	12-42
GET_TIME	12-42
NEW_MESSAGE(mn)	12-43
SET_ACTION_OR_INFO(bit)	12-43
SET_ADDEE(ade)	12-43
SET_CHANNEL(c)	12-44
SET_CLASSIFICATION(c)	12-44
SET_DAY(d)	12-44
SET_ORIGINATOR(c)	12-45
SET_ORIGINATOR_ROUTING_INDICATOR(r)	12-45
SET_PRECEDENCE(p)	12-45
SET_ROUTING_INDICATOR(s)	12-46
SET_SERIAL(n)	12-46
SET_TEXT(i,j,s)	12-46
SET_TIME(t)	12-47

FUNCTION CALLING FORM: BIND(mn)

INPUT PARAMETERS:

Name	Type	Description
mn	message identification	message to be accessed next

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: message designated by mn is bound. Future calls of message information functions refer to this message

---

FUNCTION CALLING FORM: BLANKIT(i)

INPUT PARAMETERS:

Name	Type	Description
i	integer	position to be blank

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: the i^{th} character is removed

FUNCTION CALLING FORM: GET_ACTION_OR_INFO

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: 0 = action required
1 = information only

EFFECTS: none

FUNCTION CALLING FORM: GET_ADDEE

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: string -- 6 characters

FUNCTION VALUE: message addressee

EFFECTS: none

FUNCTION CALLING FORM: GET_CHANNEL

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: channel on which message was received will be sent

EFFECTS: none

FUNCTION CALLING FORM: GET_CLASSIFICATION

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: character

FUNCTION VALUE: classification of message (T = TOP SEC, S = SEC, etc.)

EFFECTS: none

FUNCTION CALLING FORM: GET_DAY

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: date

FUNCTION VALUE: day message was received for transmission as indicated in message text

EFFECTS: none

FUNCTION CALLING FORM: GET_ORIGINATOR

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: string

FUNCTION VALUE: code of originating organization in message

EFFECTS: none

FUNCTION CALLING FORM: GET_ORIGINATOR_ROUTING_INDICATOR

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: string -- 7 characters

FUNCTION VALUE: routing indicator for originating organization in message

EFFECTS: none

FUNCTION CALLING FORM: GET_PRECEDENCE

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: precedence of message

EFFECTS: none

FUNCTION CALLING FORM: GET_ROUTING_INDICATOR

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: string -- 7 characters

FUNCTION VALUE: routing indicator in message

EFFECTS: none

FUNCTION CALLING FORM: GET_SERIAL

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: serial number in message

EFFECTS: none

FUNCTION CALLING FORM: GET_TEXT(i,j)

INPUT PARAMETERS:

Name	Type	Description
i	integer	starting location
j	integer	ending location

FUNCTION VALUE TYPE: string

FUNCTION VALUE: the string of characters between positions i and j in text

EFFECTS: error call if no such characters in text

FUNCTION CALLING FORM: GET_TIME

INPUT PARAMETERS:

Name	Type	Description
none		

FUNCTION VALUE TYPE: time of day

FUNCTION VALUE: time at which message was received and filed according to message

EFFECTS: none

FUNCTION CALLING FORM: NEW_MESSAGE(mn)

INPUT PARAMETERS:

Name	Type	Description
mn	integer	unused integer identifier to be associated with new message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: bound message is now "mn" -- all functions are reset

---

FUNCTION CALLING FORM: SET_ACTION_OR_INFO(bit)

INPUT PARAMETERS:

Name	Type	Description
bit	boolean	type of addressee to be stored in message 0 = ACTION 1 = INFORMATION

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: AI = bit

FUNCTION CALLING FORM: SET_ADDEE(ade)

INPUT PARAMETERS:

Name	Type	Description
ade	string	addressee to be stored in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: addressee is added to message stored

FUNCTION CALLING FORM: SET_CHANNEL(c)

INPUT PARMETERS:

Name	Type	Description
c	integer	channel # to be stored in the message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: channel stored in the message

FUNCTION CALLING FORM: SET_CLASSIFICATION(c)

INPUT PARAMETERS:

Name	Type	Description
c	character	security classification to be assigned to message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: security classification "c" is stored in message text

---

FUNCTION CALLING FORM: SET_DAY(d)

INPUT PARAMETERS:

Name	Type	Description
d	date	date to be stored in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: day of filing is stored in the message

FUNCTION CALLING FORM: SET_ORIGINATOR(c)

INPUT PARAMETERS:

Name	Type	Description
c	string	originator to be stored in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: originator "c" is stored in message

FUNCTION CALLING FORM: SET_ORIGINATOR_ROUTING_INDICATOR(r)

INPUT PARAMETERS:

Name	Type	Description
r	string	routing indicator of originator to be stored in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: the routing indicator is stored in the message

FUNCTION CALLING FORM: SET_PRECEDENCE(p)

INPUT PARAMETERS:

Name	Type	Description
p	integer	precedence to be assigned to message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: message precedence is set

FUNCTION CALLING FORM: SET_ROUTING_INDICATOR(s)

INPUT PARAMETERS:

Name	Type	Description
s	string -- 7 characters	routing indicator to be in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: routing indicator is inserted in message

FUNCTION CALLING FORM: SET_SERIAL(n)

INPUT PARAMETERS:

Name	Type	Description
n	integer	serial number to be set in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: serial number is inserted in message

FUNCTION CALLING FORM: SET_TEXT(i,j,s)

INPUT PARAMETERS:

Name	Type	Description
i	integer	starting point for insertion of new text
j	integer	end point of new text
s	string	text to be inserted in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: s will be inserted between the i^{th} and j^{th} character of TEXT

FUNCTION CALLING FORM: SET_TIME(t)

INPUT PARAMETERS:

Name	Type	Description
t	time of day	time to be stored in message

FUNCTION VALUE TYPE: none

FUNCTION VALUE: none

EFFECTS: time of filing is stored in message

MP.6 MP Abstract Interface Module

EXAMPLE DESCRIPTION

Introduction

This paper describes the design of an abstract interface module for the MP system. The format of messages transmitted over the AUTONOYS communications network is defined by the AUTONOYS designers; the MP implementors will probably not be consulted about future format changes. The abstract interface module is intended to insulate the MP system from format changes: if the message format changes, only the code in the abstract interface module should need to change.

Designing an abstract interface module consists of two phases:

(1) compiling the list of assumptions about the information that will be transmitted through the interface, and

(2) designing the functions provided by the abstract interface module.

Phase (2) is a syntax for communication based on phase (1). Since the two are closely related, a change in phase (1) will require a corresponding change in phase (2).

The abstract interface module for MP should be based on assumptions that are not likely to change. Consequently it should not be based on specific characteristics of AUTONOYS, such as the order of message fields, the control characters separating fields, or redundancy included for error checking. The interface should be sufficiently general to apply to any message transmission protocol that might reasonably be used to transmit messages to and from the MP system. Care must also be taken that each assumption on the list is both a necessary requirement for the interface and not unduly restrictive.

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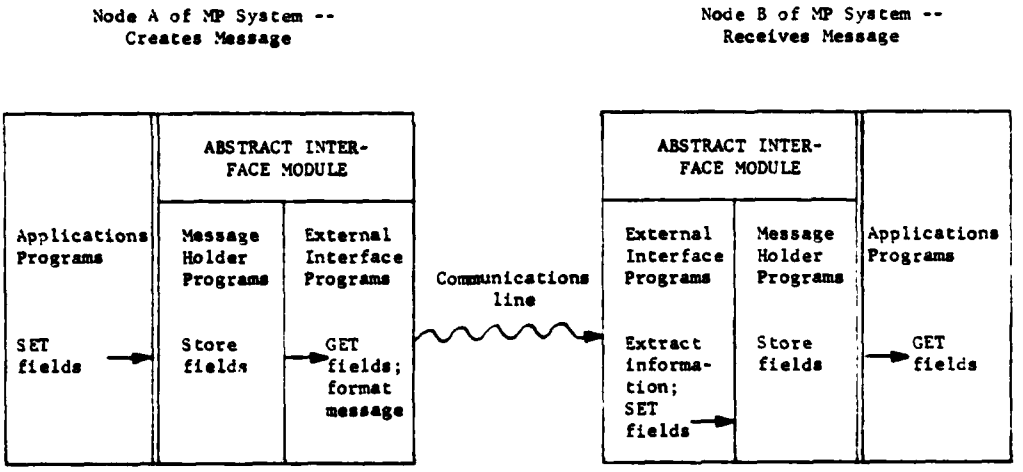
Description of the MP Abstract Interface Module

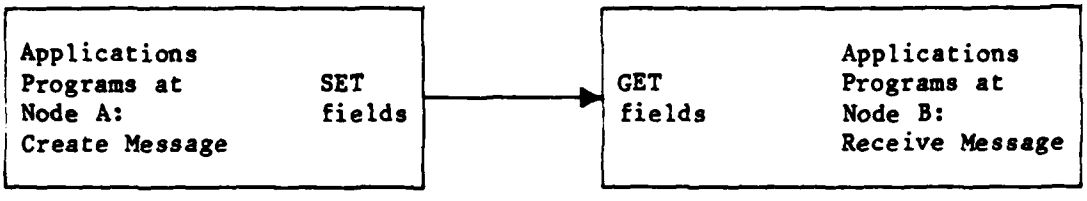
Figure 1 shows how an abstract interface module is used in the MP system. The applications programs in node A construct a message by calling SET functions provided by the MP abstract interface module. The abstract interface programs in node A arrange the fields in the correct order, duplicate fields that appear more than once in the message, insert control characters, etc. After the message has been transmitted to node B, the abstract interface programs in node B extract the fields from the stream of characters received over the communications line. Node B applications programs can read fields in the message by calling GET functions provided by the abstract interface module.

Figure 1: Flow of Information Between MP Modes



As shown in figure 2, the two applications programs can be written as if they could exchange information directly; the fact that the information must be formatted into AUTONOYS messages, sent over a communications line, and extracted from the message is hidden from them.

Figure 2: Message Communication as it Appears to Applications Programs



The same abstract interface module is used to format and extract information, since both activities need the same secret; i.e., the message format. This module contains two submodules: the message holder (MH) and external interface (EI). Both submodules are described in the paper about the improved MP module structure (MP.4).

Semantic Information in the Assumption List

Semantic knowledge about messages should be an agreement between the applications programs that put information into the message and the applications programs that take information out of the message. However, the semantics of the message are of no concern to the implementor of the abstract interface module; he should not infer any additional assumptions by believing he understands message semantics. Therefore there should be two assumption lists, a semantic list for the applications programs, and a syntactic list for both the abstract interface module and the applications programs. For example, the following assumption is not a proper assumption for the implementor to make, even though it must appear in the semantic list: "Messages may contain declassification information that indicates when the message should be downgraded." The fact that the declassification information states when the message should be downgraded is not a concern of the abstract interface module implementor; he need only know whether his module needs to enforce any restrictions on the declassification values. Leaving the semantics out of the assumption list for implementors will discourage them from inferring such assumptions as:

> declassification information is represented as dates
> and all such dates will be future dates.

However, if it is a requirement that the interface module verify that all declassification dates are in the future, then the above assumption should be explicitly included in the assumption list for the implementor.

Semantic information should be included in a separate assumption list meant only for the applications programs; this list defines terms, relates the assumptions to the environment of the applications programs, and shows how each field should be interpreted. The semantic assumption list is omitted from this document.

Use of Data Types to Simplify Specifications

To specify functions provided by a module, it is often necessary to place restrictions on the variables that are passed as parameters or returned by functions. We define a set of data types in order to express these restrictions concisely and precisely. By associating each value function and function parameter with a data type, we can define the set of legal and meaningful function calls in a simple and compact manner. For example, the MP abstract interface specifications refer to variables that have the data type time. Restrictions on variables of type time are defined in one place; all variables of type time that are passed as parameters or returned by functions must conform to these restrictions.

If the module is implemented in a modern programming language with user-defined data types, data types used in the specifications can also be used in programs so that the programmer can take advantage of type-checking capabilities in the compiler. If we use a more conventional language such as FORTRAN, we can rely on the programmers or we can provide type-checking by means of preprocessing and/or run-time checking with calls to error routines. The use of data type references in specifications does not imply an implementation requirement.

The data type definitions must provide a way for the applications programs to create and refer to variables of specific types. These are simple for conventional data types: character strings are represented by strings of characters and integers by integers. For more novel data types like date and time, we provide functions that convert integers or character strings into variables of these types.

The three functions in figure 3 are provided to create date and time variables from integers and strings. Note that two date conversion functions are provided; if the parameters represent the same date, the two date functions produce variables with the same value. Thus a date variable representing July 4, 1976 can be produced by either calling JULIAN (76, 186) or by calling DAYMOYR (4, July, 76).

Figure 3: Data Type Function Specifications

FUNCTION CALLING FORM: JULIAN (year, day)

INPUT PARAMETERS:

Name	Type	Description
year	integer	year in the 20th century
day	integer	day in year

FUNCTION VALUE TYPE: date

FUNCTION VALUE: date represented by the two input parameters

FUNCTION CALLING FORM: DAYMOYR (day, month, year)

INPUT PARAMETERS:

Name	Type	Description
day	integer	day in month
month	string	name of month
year	integer	year in 20th century

FUNCTION VALUE TYPE: date

FUNCTION VALUE: date represented by the three input parameters

---

FUNCTION CALLING FORM: CLOCK24 (hour, min)

INPUT PARAMETERS:

Name	Type	Description
hour	integer	hour of day in 24-hour clock
min	integer	minutes after the hour

FUNCTION VALUE TYPE: time

FUNCTION VALUE: time represented by the two input parameters

The table below lists the data types used in the abstract interface specifications that follow.

Type	Meaning	Example
integer	a conventional integer	3
boolean	variable which can take two values: TRUE and FALSE	TRUE, FALSE
character	an alphanumeric character	c, x, z, 1, p
time	variable from which hour, minute can be determined	CLOCK24(13,15)
date	variable from which day, month and year can be determined	JULIAN(76,186) DAYMOYR(4,JULY,76)
string	string of characters	birthday_message, congratulations, please send money
ARchar	single character, two legal values: A and R	A, R

MP ABSTRACT INTERFACE MODULE: ASSUMPTION LIST

In the assumption list that follows, various parameters are used in order to defer decisions that are better made during implementation or at system generation time. These parameters characterize the message holder in a particular node of the MP system; the parameters may take different values in different nodes. These parameters are:

MAX_{msg}	=	the maximum possible number of messages in the message holder
MAX_{line}	=	the maximum number of lines in a message
MAX_{char}	=	the maximum number of characters in one line of a message
$MAX_{addressee}$	=	the maximum number of addressees in a message
MAX_{to_list}	=	the maximum number of addressees that the message may contain in a TO line
MAX_{info_list}	=	the maximum number of addressees that the message may contain in an INFO line
MAX_{xmt_list}	=	the maximum number of addressees that the message may contain in an XMT line

ASSUMPTIONS

1. The message holder can contain both received messages and created messages. Received messages arrived over the communications line; created messages are being contructed at this node. It will be possible to distinguish between them. (A node may transmit a message to itself; the message will be treated as if it were received. The created version of the message will also be accessible until it is destroyed (see assumption 5).)

2. After starting to create a message and before the message is destroyed, other messages may be created or received. There will be a maximum of MAX_{msg} messages in the message holder at a time.

3. Information in received messages cannot be altered (only GET functions are permitted).

4. Information in created messages may be read or written (both GET and SET functions are permitted).

5. Message information is accessible until the message holder module is given a command to destroy the message. (The message holder makes no assumptions about how long to retain messages or whether to delete messages when they are transmitted.)

6. Received message information is not accessible from the message holder until the message holder is given a name to associate with the message. The message holder indicates whether or not there are any received messages waiting to be named.

7. Each message contains at most MAX_{line} number of lines.

8. Each message line has at most MAX_{char} items of type character.

9. The following information may be found or placed in a message.

Item name	Number in completed message	Type
addressee	at least one at most $MAX_{addressee}$	string
origin_route_part	exactly one	string
channel_id	exactly one	integer
precedence	exactly one	string
origin_media	exactly one	string
dest_media	exactly one	string
classification	exactly one	string
content_action	exactly one	string
sender_orig_route	exactly one	string
serial	exactly one	integer
date_received	exactly one	date
time_received	exactly one	time
addressee_route	exactly one	string
to_list	at least one at most MAX_{to_list}	string
info_list	at most MAX_{info_list}	string
xmt_list	at most MAX_{xmt_list}	string
subject_code	exactly one	string
text	exactly one	string
originator	exactly one	string

MP ABSTRACT INTERFACE MODULE: FUNCTION SPECIFICATIONS

This section specifies the functions provided by the MP abstract interface module. The function specifications will require alteration if the assumption list is changed.

Undesired events are handled in the following specifications via function calls to user-supplied trap routines. The function names suggest the nature of the undesired event that occurred. This mechanism allows us to delay specifying the action that should be taken in exceptional circumstances.

FUNCTION CALLING FORM: GET_NUMBEROF_MESSAGES MODULE: MH

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: Number of messages currently in the message holder. This number is at most MAX_{msg}.

INITIAL VALUE: 0

EFFECTS: None

FUNCTION CALLING FORM: IS_CREATED_STATUS(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	an identifier associated with a message

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: TRUE if msg is a created message; FALSE if msg is a received message

EFFECTS: If msg is not associated with a message in the message holder then UE_NO_MSG is called.

FUNCTION CALLING FORM: CREATE(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	an identifier to be associated with the newly created message

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: If GET_NUMBEROF_MESSAGES = MAX_{msg} then UE_TOO_MANY_MSG is called.

Otherwise, a new message is created and associated with the string msg. GET_NUMBEROF_MESSAGES is incremented by 1. IS_CREATED_STATUS(msg)=TRUE

FUNCTION CALLING FORM: IS_WAITING_MESSAGE MODULE: MH

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: TRUE if any messages have been received but not named.
FALSE if no messages are waiting to be named.

EFFECTS: None

FUNCTION CALLING FORM: NAME_MESSAGE(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	an identifier to be associated with the newly received message

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: If GET_NUMBEROF_MESSAGES = MAX_{msg} then UE_TOO_MANY_MSG is called. If IS_WAITING_MESSAGE = FALSE then UE_NO_WAITING_MESSAGE is called

Otherwise, a received message is associated with the name msg. GET_NUMBEROF_MESSAGES is incremented by 1. IS_CREATED_STATUS(msg)=FALSE

FUNCTION CALLING FORM: DESTROY(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the message holder

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: If msg is not associated with a message in the message holder then UE_NO_MSG is called.

Otherwise, msg is no longer associated with a message in the message holder. GET_NUMBEROF_MESSAGES is decremented by 1.

The notation GET_@ and SET_@ denotes a set of functions where each string in the following list may be substituted for @ to obtain a particular function. Additionally, the parameter type for each function may differ depending on the value of @. These differences are indicated in the #-type list below.

In the following function specifications substitute the following values for @ and #. Whenever @ is used and a # symbol appears in the specification, substitute the corresponding type. For example, in SET_@(msg,parm) if @ is SERIAL then # is integer; the resulting function is SET_SERIAL(msg,parm) and parm must be an integer.

@	#-type
ORIGIN_ROUTE_PART	string
CHANNEL_ID	integer
PRECEDENCE	string
ORIGIN_MEDIA	string
DEST_MEDIA	string
CLASSIFICATION	string
CONTENT_ACTION	string
SENDER_ORIG_ROUTE	string
SERIAL	integer
DATE_CREATED	date
TIME_CREATED	time
ADDRESSEE_ROUTE	string
SUBJECT_CODE	string
TEXT	string
ORIGINATOR	string

FUNCTION CALLING FORM: SET_@(msg,parm) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the message holder
parm	#	the item to be stored in the @-field of msg

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: If msg is not associated with any message in the message holder, then UE_NO_MSG is called. If IS_CREATED_STATUS(msg) = false, then UE_GET_ACCESS_ONLY is called.

Otherwise, the @-field of msg is set to parm. If the @-field has previously been set then the @-field is overwritten with the new value.

FUNCTION CALLING FORM: GET_@(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the message holder

FUNCTION VALUE TYPE: #

FUNCTION VALUE: the @-field of the message associated with msg

EFFECTS: If msg is not associated with a message in the message holder then UE_NO_MSG is called. If this field has not been set in the message associated with msg then UE_NO_@ is called.

In the following function specifications substitute the following values for $. Each list contains up to MAX$ pairs of variables; one variable is the routing indicator, the other an addressee identifier.

$
INFO_LIST
XMT_LIST
TO_LIST

FUNCTION CALLING FORM: GET_NUMBEROF_$(msg) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the message holder

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: the number of $-list pairs in msg. This number is at most MAX$.

EFFECTS: If msg is not associated with a message in the message holder, then UE_NO_MSG is called

---

FUNCTION CALLING FORM: SET_$(msg,route,addressee) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the mesage holder
route	string	the routing indicator to be stored in the next $ pair of the message
addressee	string	the addressee identifier to be stored in the next $ pair of the message

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: If msg is not associated with any message in the message holder, then UE_NO_MSG is called. If IS_CREATED_STATUS(msg)=FALSE, then UE_GET_ACCESS_ONLY is called. If GET_NUMBEROF_$(msg) = MAX$, then UE_TOO_MANY_$ is called.

Otherwise, route and addressee are set in a pair appended to the contents of the $-field of msg and GET_NUMBEROF_$(msg) is incremented. If there were no previous items in the $-field, then this pair is the first.

FUNCTION CALLING FORM: GET_$(msg,infotype,i) MODULE: MH

INPUT PARAMETERS:

Name	Type	Description
msg	string	the identifier of a message in the message holder
infotype	ARchar	whether addressee or route component of the pair
i	integer	the number of the pair in $-list

FUNCTION VALUE TYPE: string

FUNCTION VALUE: if infotype = A then the ith addressee in the $-list
if infotype = R then the ith route in the $-list

EFFECTS: If msg is not associated with any message in the message holder, then UE_NO_MSG is called. If i lt 0 or i gt GET_NUMBEROF_$(msg), then UE_BAD_$_NO is called.

MADDS.1 The Military Address System (MADDS)

EXAMPLE DESCRIPTION

Motivation

Many organizations maintain lists of names and postal addresses in a computer. In simple applications, the whole list is used to generate a set of mailing labels or "personalized" letters. In other applications, a subset of the list is selected according to criteria believed to identify individuals most likely to be interested in the contents of the mailing. For example, a publisher who wished to offer a new magazine called Tax Loopholes might want to select addresses for people with medical degrees. Others might want to select all persons within a particular geographic area (consider a magazine like Southern Living, for example), while still others might be interested in persons with specific first or last names.

The address lists can be obtained from various sources, such as magazine subscription departments, and are generally delivered on a medium such as magnetic tape. Data from different sources are likely to appear in different record formats.

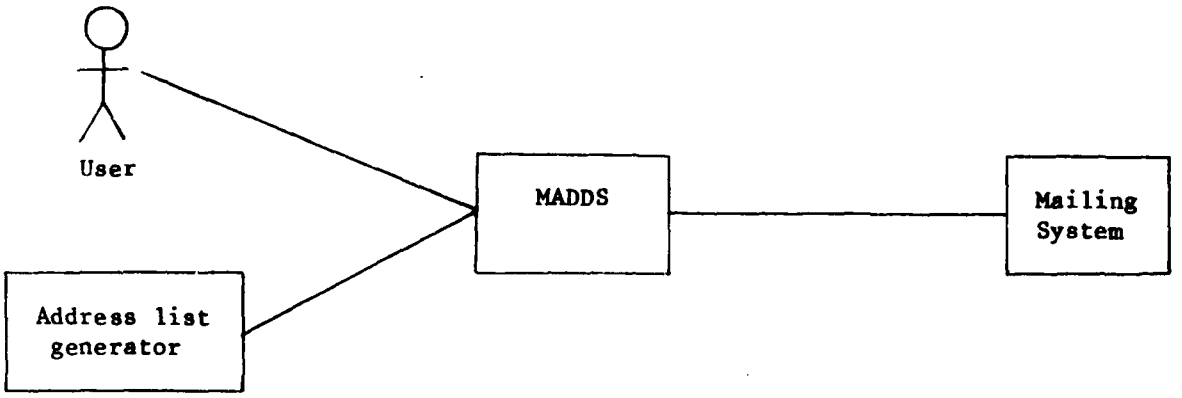
The task for any software system that processes such a list is to read the input data (in a specified, but likely-to-change, format), extract the desired subset of the list according to certain criteria (which are specified, but likely to change), and print that subset (also in a specified, but likely-to-change, format).

A general mailing-list-processing system is an example of am embedded system; that is, one which is subject to arbitrarily changing constraints, outside the designer's control. The input format is determined by the designers of the system that produced the tape, and the output format is considerably constrained by the requirements of the postal system in which the mail will be deposited.

The Assignment

You will each be constructing parts of a simplified version of such an address processing system. The system will be able to search for and print the addresses within a certain ZIP-code area, and to do the same for the addresses with a certain O-grade. (An O-grade is a numerical representation of an officer's rank; it is further explained in MADDS.5.) Even though the resulting system will be simple by comparison with its real-world counterparts, it is important to understand that the principles outlined in this course still apply. There are four steps to the assignment.

1. The first step is an exercise for you to identify the modules of the Military Address System (MADDS). MADDS has the three external interfaces pictured below:



The following table lists the inputs to MADDS and outputs from MADDS for each MADDS interface:

Interface	Inputs	Outputs
Human user	Request to run rank and area applications	UE message
Address list generator	Address list	
Mailing system		ress labels

The request to run the application does not specify the order in which to create the output. That is, it does not request that the O-grade application be run first, and then the ZIP code application, or vice versa. Nor does it imply that the two applications are in fact separate tasks. That is an implementation detail that is subject to change. The format of the input address list is also an implementation specific that varies between family members, as is the format of the output addresses.

2. After the exercise, you will be given a set of informal interface specifications for the MADDS modules identified by us. You will study these specifications and satisfy yourself that they are complete. All questions should be resolved before you continue.

3. The class will be divided into two-person teams (although you may work alone if you wish). Each team will be assigned the responsibility of implementing one of the modules of the system, as defined in its interface specifications. Implementation information and documentation concerning the local programming environment will be distributed.

4. Finished modules will be chosen in various combinations to create a running MADDS system, demonstrating the value of carefully chosen and properly specified modules. In addition, two different input formats and two different output formats will be specified, and different MADDS family members will be constructed using the different input and output modules. This will demonstrate the value of using information-hiding modules to isolate change.

MADDS.2 MADDS Modular Structure

EXERCISE

Name: _____

Consider the Military Address System described in MADDS.1. Identify the main modules of the system and describe the information that each module hides.

Module Name	Secret

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MADDS.3 MADDS Modular Structure

EXERCISE SOLUTION

The system consists of nine modules. In addition, there is an undesired event handler.

Module Name	Secret
Applications Program Module (APM)	The APM consists of all applications programs, that is, all programs that perform end-user specified operations on a database of addresses. There are at least two applications programs. One finds and outputs addresses with a specific ZIP-code area. Another outputs addresses with O-grade level less than or equal to a specific value. The APM hides selection algorithms and the order of address entries output.
Address Storage Module (ASM)	The ASM consists of all address storage and retrieval routines. It hides the structure used to store addresses.
Character Module (CHM)	The CHM consists of all character manipulation routines. It hides the internal representation of characters.
Input Device Module (IDM)	The IDM consists of all routines that communicate directly with the physical input device. It hides knowledge of the type of device, the device's representation of characters, the length of input lines, and the protocol used to read input from the device.
Input Module (IPM)	The IPM analyzes the input data and stores the addresses for the ASM. It hides the format (e.g., number, order, and length of the fields) of the input.

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Output Device Module (ODM)	The ODM consist of all routines that communicate directly with the physical output device. It hides knowledge of the type of device, the device's representation of characters, the length of output lines, and the protocol used to write output to the device.
Output Module (OPM)	The OPM determines the format in which the address entries are to be output. It hides, for example, order of fields as well as number and content of output lines.
String Storage Module (SSM)	The SSM consists of all string manipulation routines. It hides the internal representation of strings.
Master Control Module (MCM)	The MCM determines the sequence in which applications programs and other programs will be called. Its secret is the way that the functions of other modules are put together to perform useful tasks.
Undesired Event Handler (UEH)	The UEH is a collection of UE handling functions that any module can use to report a UE.

MADDS.4 Using the Computer System

LECTURE

1. INTRODUCTION

During the MADDS exercise, you will be using the Academic Computing Center (ACC) of the United States Naval Academy. The ACC uses the Dartmouth Time Sharing System (DTSS) operating on a Honeywell 6000 computer. DTSS is tailored to support time sharing and to provide a single user interface that facilitates easy on-line program development and testing. The purpose of this MADDS document is to provide you with sufficient information to use DTSS in the MADDS assignment. As such, it does not describe all of the capabilities available to you on DTSS. If you feel that additional capabilities would help you in the exercise, or if you have sufficient time and an interest in experimenting with the system, refer to your ACC Computer Primer.

2. LOGGING ON/AND OFF

The first step in using DTSS is to "log on." Your instructor will give each of you a user number and a password. To connect to the computer, turn your terminal on and press the RETURN key (R) twice. The system will respond with a greeting message such as:

```
USNA/DTSS TIME-SHARING
LINE 0/0013 ON AT 14:21 23 JUN 80
USER NUMBER - -
```

In response to the user number prompt, you must enter your six-character user number. If you enter the wrong number, the system will repeat the prompt until you get it right.

Once an acceptable user number has been entered, the system will prompt for a password. You must then enter your password. The password will not be displayed.

When a valid password is entered the system will respond with

```
• READY
```

To "log off," just type

```
BYE (R)
```

You will now be disconnected from the system.

3. CREATING FILES

If you want to create and save your own files, you need only learn a few commands. It is very easy to create an empty new file. Whenever the system is ready to listen to a command (e.g., it has just said READY), you may type NEW, a space, and then a name for the file. The name may be from one to eight characters long and contain letters, digits, periods [.], or hyphens [-]. A space may not be part of the file name. For example, to create a file named WRITERS, type:

NEW WRITERS (R)

Now that you have a file, you probably would like to put something in it. You may do this in several different ways. The easiest way is to start typing lines that begin with numbers. These numbers are called line numbers and are used to keep your file in order. If you want to put a list of newspaper columnists into the empty file, you can type:

100 JACK ANDERSEN (R)
110 JAMES KILPATRICK (R)
120 ABIGAIL VAN BUREN (R)

Suppose that you had intended to put the name ART BUCHWALD between the first and second lines. To do this, you just have to type a line beginning with a number between 100 and 110. For instance:

104 ART BUCHWALD (R)

To see what you have in your file, type:

LIST (R)

The following will be printed on your terminal:

100 JACK ANDERSEN
104 ART BUCHWALD
110 JAMES KILPATRICK
120 ABIGAIL VAN BUREN

You will note that the computer automatically sorts your file by line number. In this example, line numbers were not entered consecutively. Therefore, it will be easy to insert new lines in the future. Any integer increment between line numbers may be used, and the numbers may start anywhere. It is good not to use line numbers with more than five digits, since they are not allowed by many programming language translators.

If you have been trying out the examples on a terminal, you now have a "temporary" file with the name WRITERS. If you signed off from the computer now and signed on again just an instant later, there would be no trace of what

was in the file, or even that it ever existed. Likewise, if you typed another NEW command or an OLD command, the file which you created then would disappear. To keep the file available for future use, you must make a "permanent" copy of it by using the SAVE command:

SAVE ®

To retrieve a copy of a file you have saved, type OLD, a space, the name of the file, and then press RETURN. For example, if you work with another file after you finish with WRITERS, and you wish to retrieve WRITERS, type:

OLD WRITERS ®

WRITERS now becomes the "current" file. Since few of us type without ever making a mistake, there are several ways of correcting errors on USNA/DTSS. You can make the computer "forget" the previous character on the line you are typing by pressing the CONTROL and Z keys simultaneously, and the whole line you are typing can be "forgotten" by pressing CONTROL and X simultaneously. Once you push the RETURN key, however, these methods are useless for the line you just entered, since they operate only on the line which you are currently entering. One easy way to correct a line in the file is simply to retype it, using the same line number. In the example above, the name JACK ANDERSON is misspelled. If you have been working with the examples at a terminal, you can correct that line by typing:

100 JACK ANDERSON ®

Sometimes, you may wish to delete a line from your file. You can do so by typing the line number immediately followed by RETURN. For example, to delete the line with the name JAMES KILPATRICK, you type:

110 ®

A word of caution is due here. If you wish to insert a "blank" line in your file, do not type a line number immediately followed by RETURN. Instead, type a space after the line number and then RETURN.

The changes you have typed since you told the computer to SAVE your file are only made to a temporary copy of your file. In order to preserve the corrected copy, use the REPLACE command:

REPLACE ®

The SAVE command is only used the first time a file is saved. Any later additions or changes to the file are preserved with the REPLACE command. If you type SAVE, and there is already a file saved with the name you have given your file (via NEW or OLD), the computer will tell you that the file is already saved. This precautionary message protects you from accidentally destroying a different file with the same name. If you receive this message, you should either type REPLACE or RENAME your file and SAVE it. If you type

REPLACE without previously having SAVED your file, the computer will tell you that the file is not saved. If this happens, use the SAVE command.

4. LINE NUMBERING YOUR FILE AFTER EDITING

If you make any changes (insertions, deletions, etc.) to your file, you should re-line-number the new file by typing:

EDI RES ®

It is advisable to resequence your file every time you edit it. This will ensure that a properly numbered program is used when you compile and run.

5. MODIFYING AN EXISTING FILE

5.1 General Conventions

If you wish to make changes to a permanent file stored on the system you may do so by using the QED editor available under USNA/DTSS. Each of QED's editing commands will be explained later. There are, however, a few conventions that will hold for all commands.

First, the file to be edited should be made the current file by typing OLD ⟨filename⟩. Type QED to use the QED editor. QED responds with its prompt character, a left parenthesis [(], which is your cue that QED is ready to accept commands from the terminal. Commands and text lines are stored temporarily in an input buffer until an empty line (two carriage returns in immediate succession) is received; only then does QED begin processing the commands. Thus, to signal QED to process a group of lines, press the RETURN key twice. Lines are then processed, and QED requests more input by typing (.

Commands operate on a copy of the current file. When editing has been completed, type the exit command [E] to terminate QED and press the RETURN key twice. The edited version becomes the current file, and you can make modifications permanent by typing SAVE or REPLACE. If QED is aborted, the current file is not changed.

The following example demonstrates the QED entrance and exit procedure. In the example, and throughout this guide, information printed by the system will be denoted with an underscore. Information that you must enter will not be underscored. Also throughout the guide, the angle brackets signify a variable quantity that you must fill in with an actual value; hence, angle brackets should never be actually typed.

```
old ⟨filename⟩ ®
READY
qed
( ⟨qed commands⟩ ®
( e ®  ®
READY
replace ®
READY
```

5.2 Command Format; A Simple Command

The general form of a QED command is as follows:

⟨line specification⟩ ⟨command⟩

where ⟨line specification⟩ specifies a line or group of lines which is to be operated upon. ⟨Command⟩ denotes the operation to be performed. All QED commands are specified by a single letter, which may be typed in upper- or lowercase.

In this first section we will use the print command [P], in addition to the exit command [E], to facilitate our discussion of QED conventions. The P prints at the terminal the line(s) specified in the command. The user may specify particular lines in two different ways, which we will now discuss.

5.3 Line Addressing

A line is identified by its position in the file, not by any line number that may appear in the line. The position of a line is determined by counting lines. (QED counts a new line after each line feed, even if the line feed is not part of a normal carriage return-line feed sequence.)

⟨line specification⟩ may be of the form ⟨line #1⟩, ⟨line #2⟩, which denotes the first and last lines of the group to be operated on. For example, the command 3,5P prints the third through the fifth lines of the file. (⟨Line #1⟩ should precede ⟨line #2⟩ in the file; if this is not the case, the error message "Address wraparound" is printed.)

If the command is to operate on a single line rather than a group of lines, omit the comma and ⟨line #2⟩. Typing 3P prints the third line of the file.

If no address is given, the current line is acted upon; after each command, one line, generally the last line processed, becomes the current line. The current line may be represented by a period [.]. For example, if the second line has just been printed (and is therefore the new current line), then .,4P prints the second, third, and fourth lines. Subsequently, the fourth line is the new current line. The last line of the file is represented by the dollar sign [$]. Thus, 1,$P prints the entire file and causes the last line to become the current line.

A numerical line offset may be used in an address so that a line can be specified by counting backward or forward from the current line. A minus sign [-] signifies lines which precede the current line; a plus sign [+] denotes lines which follow the current line. Typing .,.+3P prints the current line and three lines immediately following that line. (Note that the "fourth" line becomes the new current line.) Typing .-3,.P prints the preceding three lines and the current line.

You may also use a numerical line offset to count backward from the last line in the file. Typing $-1P prints the next to the last line in the file.

Examples of the use of line addressing follow. These examples, as do other examples in this manual, assume the following ten-line file (called COUNT). (Note that each set of examples starts with this original file; changes made in previous examples are ignored.) In this example the command 1,$P is used to list the entire file. Remember that you enter an empty line to signal QED to process any commands which have been entered.

```
qed ®
( 1,$p ® ®
one
two
three
four
five
six
seven
eight
nine
ten
( e ®  ®
READY
```

Line addressing examples:

```
qed ®
( 3p ® ®
three
( 3,4p ® ®
three
four
( $p ® ®
ten
( 1+2p ® ®
three
( .p ® ®
three
( .+1p ® ®
four
( .-1p ® ®
three
( .-1,.+1p ® ®
two
three
four
( $-2p ® ®
eight
( $-2,$p ® ®
eight
nine
ten
( e ® ®
READY
```

5.4 Content Addressing

A string is a sequence of characters. You can address a line in a QED command by specifying a unique string of characters that is contained in the desired line, commonly called a search string. QED locates a line which contains the string, thus establishing the address for the command, which is then executed. The string may be up to 256 characters long. Upper- and lowercase letters are distinct characters.

It is important that the beginning and end of the search string be identified, so that it is kept separate from the rest of the command. Slashes [/] should be used as delimiters and should immediately precede and follow the search string. For example /STA/ would search for the first occurrence of a line containing the string STA.

QED searches for the string in a circular fashion, beginning with the line after the current line, continuing to the end of the file, returning to the first line, and continuing back to the current line. When QED is entered, the current line is the first line of the file; thus a search would start with

the second line, go through the file to the last line (if the desired string has not been found), and then return to the first line. Thus the first line would be the last line to be searched.

Using Search Strings: Typing /STA/P causes QED to print the next line from the current line containing the string STA. Several search strings may be included in one address. QED searches for each string in succession while forming the complete address. The command line /LDA//STA/P causes QED to print from the next line containing the string LDA, through the next line containing the string STA.

You can use your file's line numbers as search strings, for example /110/P would print the line of your file that you have numbered 110.

5.5 QED Commands

The following seven commands are the most commonly used commands for manipulating files with the QED editor. Except for %K, each command is a single upper- or lowercase character.

Command	Function
P	Print line(s)
S	Substitute one string for another
D	Delete line(s)
A	Append line(s) after a specified line
E	Exit QED
=	Print the ordinal position number for the current line
%K	Kill this command sequence
I	Insert ...

5.5.1 Print [P]. The command ⟨line specification⟩ P displays the line(s) defined by ⟨line specification⟩. If ⟨line specification⟩ is omitted, the current line is printed. The new current line is the last line printed.

5.5.2 Substitute [S]. To alter parts of lines, the substitute command is used. Its format is:

⟨line specification⟩ S/ ⟨first string⟩ / ⟨second string⟩ /

Note that only one delimiter separates the two strings. String delimiters for the substitute command follow the same rules as for search strings used in content addressing (see "Content Addressing").

All occurrences of the search string ⟨first string⟩ in line group defined by ⟨line specification⟩ are replaced by ⟨second string⟩. After each substitution the search continues with the first unchanged character. If ⟨first string⟩ is empty (i.e., //), the previously typed search string is used. If ⟨second string⟩ is null, ⟨first string⟩ is removed from the specified lines, and the current search string remains ⟨first string⟩.

With the substitute command, ampersands [&] may be used within the second string to represent the first string. All ampersands in ⟨second string⟩ signify that ⟨first string⟩ is to be inserted at that point. For example, the command /LDA/S//&Q/ changes each LDA in the next line containing that string to LDAQ.

Examples of the substitute command follow:

```
qed ®
( 2s/two/2/p ® ®
2
( .+5s/e/E/p ® ®
sEvEn
( /2/s//two/p ® ®
two
( 1,$s/E/e/7p ® ®
seven
( /six/s//&teen/p ® ®
sixteen
( s/teen//p ® ®
six
( e ® ®
READY
```

5.5.3 Delete [D]. Lines to be deleted are specified in the same way as lines to be printed: ⟨line specification⟩ D. After a deletion has been performed, the first line not deleted (following the lines addressed) becomes the current line. If the last line [$] is deleted, then the new last line becomes the current line. In the following example, the original file COUNT is modified:

```
qed ®
( 2,5p ® ®
two
three
four
five
( 3,4d ® ®
( .p ® ®
five
( 2,3p ® ®
two
five
( e ® ®
READY
```

The current file now contains:

```
one
two
five
six
seven
eight
nine
ten
```

5.5.4 Append [A]. To add lines after a specified line, type:

```
⟨line specification⟩ A
⟨new lines⟩
%E
```

The characters which appear between the command A and %E are placed after the line line specification in the file. If the first characters after the A are a carriage return-line feed pair, then they are ignored. Any number of lines may be appended. The last line appended becomes the current line. If the line address is omitted, then the current line is assumed.

Warning: The %E must be typed in order to terminate QED's input mode. If it is omitted, all information (including command lines) typed thereafter will be appended until receipt of a %E; no further commands will be processed until the %E has been typed.

If you push RETURN twice without typing %E, QED will type) as a prompt, instead of the usual (. This is to remind you that you are still entering lines of text.

The file COUNT is modified in the following example:

```
qed (R)
( 2A (R)
two.five (R)
two.six (R)
%e2,5p (R) (R)
two
two.five
two.six
three
( e (R) (R)
READY
```

The resulting current file is:

```
one
two
two.five
two.six
three
four
five
six
seven
eight
nine
ten
```

5.5.5 Exit [E]. When the exit command is processed, QED replaces the current file with the edited version and terminates. (Remember to type SAVE or REPLACE after you exit from QED in order to keep the edited version.)

The exit command must be the last character on a line.

5.5.6 Equal [=]. The command ⟨line specification⟩ = prints the line number of ⟨line specification⟩. This line number is the number corresponding to the ordinal position of the line in the file, not a program-related line number. The line number of the first line in a file, for example, is 1. QED counts a new line after each line feed or carriage return (with associated line feed) that occurs in the file. Note that the number will change if lines are added or deleted before ⟨line specification⟩.

Following are examples of the equal command:

```
qed ®
( /five/= ® ®
5
( $ ® ®
10
( 2d/five/= ® ®
4
( 2p ® ®
three
( e ®  ®
READY
```

5.5.7 Kill [%K]. If %K is the last thing typed to QED before the double carriage return which tells QED to start processing commands, then all input since the last double carriage return is ignored. This lets you delete erroneous command lines which you have discovered before requesting execution.

5.5.8 Insert [I]. The insert command has the following format:

```
⟨line specification⟩ I
⟨new lines⟩
%E
```

Insert is the same as append, except that the lines between the command I and %E are placed before ⟨line specification⟩. If the line address is omitted, then the lines are inserted before the current line. The last line inserted becomes the current line. 1I inserts lines at the beginning of the file, while $A adds lines to the end. (See "Append" and the note on the importance of %E.) Examples of the insert command follow, using the ten-line file COUNT.

```
qed ®
( 1i ®
zero ®
%e  R  ®
( 1,2p ®  ®
zero
one
( /five/i ®
four.five
%e  ®  ®
( .,.+1p  ®  ®
four.five
five
( e ®  ®
READY
```

5.5.9 Change [C]. The format of the change command is:

```
⟨line specification⟩ C
⟨new lines⟩
%E
```

Change is the same as append and insert, except that it replaces the line group given with the lines between the command C and %E.

Following are examples of the change command:

```
old COUNT (R)
READY
qed (R)
( /two/,/four/c (R)
two.three.four (R)
%e1,3p (R) (R)
one
two.three.four
five
( 2c (R)
two (R)
three (R)
four (R)
%e (R) (R)
( .p (R) (R)
four
( 1,5pe (R)  (R)
one
two
three
four
five
READY
```

6. DEBUGGING YOUR MODULE

The first step in debugging your module should be to attempt to run the module without linking to other modules of MADDS. To do this you need only retrieve your current file and type COMPILE F78. The scenario for doing this is as follows:

```
OLD ⟨filename⟩ (R)
READY
COMPILE F78  (R)
```

The results of this attempt to run will be stored in a file named ".OBJECT.". If your compilation was successful you will receive the message

COMPILATION SUCCESSFUL

If not, errors detected in the compilation attempt will be listed at your terminal. Each error message will specify the error type and the line number of your source code at which the error was detected.

When you have successfully compiled your module, you should store the object code for later use. The object code will be stored in a file named ".OBJECT.". You should rename that file and save it for future execution by entering the following commands:

```
OLD .OBJECT. (R)
READY
RENAME MODULE.OBJ (R)
READY
SAVE MODULE.OBJ (R)
```

Where the term MODULE.OBJ should contain the three-character abbreviation for your module concatenated with .OBJ (e.g., IPM.OBJ, OPM.OBJ, etc.).

6.1 Linking to the Rest of MADDS

To run your module with the rest of MADDS you need to use the INCLUDE command, as follows:

```
INCLUDE *⟨MADDS object file⟩
INCLUDE *⟨MADDS data file⟩
```

These two lines should be the last two line of your source program. The names of the data files and object files that you should use are shown in the implementation notes.

7. SAMPLE DTSS SESSION

```
**************************************************
*  A typical session on the DARTMOUTH TIMESHARING  *
*  SYSTEM (DTSS) is illustrated below.  LINES      *
*  PRINTED (DISPLAYED) by the system are under-    *
*  lined. (R) indicates a carriage return.         *
**************************************************
```

USNA/DTSS TIME-SHARING

LINE 010013 ON AT 1421 12 JULY 1980

```
                                  ***************************
USER NUMBER --  12345 (R)         *  LOGIN AND ENTER YOUR   *
*********   --  PASSWORD (R)      *        PASSWORD         *
                                  ***************************
```

READY

```
**************************************
* CREATE A NEW PROGRAM CALLED CHAREQ *
**************************************

NEW CHAREQ (R)
```

READY

```
 10  *CHARACTER EQUALITY TEST (R)
 20  * (R)
 30  LOGICAL FUNCTION CHAREQ(CH1,CH2) (R)
 40  CHARACTER*1  CH1, CH2 (R)
 50  INTEGER MASK, INTCHR,INT1,INT2,ICHAR (R)
 60  COMMON/CHMBLK/INTCHR(128) (R)
 70  INT1] ICHAR (CH1) (R)
 80  INT2; ICHAR (CH2) (R)
 90  CHAREQ = INTCHR(INT1+1).EQ.INTCHR(INT2+1) (R)
100  RETURN (R)
110  END (R)

********************
* SAVE THE PROGRAM *
********************

SAVE (R)
```

READY

```
************************
* COMPILE THE PROGRAM *
************************

COMPILE F78

*************************
* THE COMPILER DETECTED *
* THE FOLLOWING ERRORS  *
*************************

LINE 70, CH3:  UNKNOWN STATEMENT
LINE 80, CH3:  UNKNOWN STATEMENT
INTEGER VARIABLE (INT1) NEVER ASSIGNED A VALUE, LINE 90
INTEGER VARIABLE (INT2) NEVER ASSIGNED A VALUE, LINE 90

STOP

READY

*****************************
* PRINT THE LINES IN ERROR *
*****************************

QED  ®

( /70/p  ®

/80/p  ®

/90/p  ® ®

70   INT1] ICHAR (CH1)
80   INT2; ICHAR (CH2)
90   CHAREQ = INTCHR (INT1 + 1).EQ.INTCHR(INT2+1)

***********************************
* CORRECT LINES 70 AND 80         *
* USING QED's SUBSTITUTE COMMAND *
***********************************

QED ®

( S/INT1]/INT1=/P ® ®

70 INT1 = ICHAR(CH1)

( .+1S/INT2;/INT2=/P ® ®

80 INT2 = ICHAR(CH2)
```

```
**************************
* INSERT SOME COMMENTS   *
* AT THE TOP OF THE FILE *
**************************

( 1I ®

  C   THIS PROGRAM COMPARES CHARACTERS; ®
  C   UPPER AND LOWER CASE CHARACTERS ®
  C   WILL BE CONSIDERED EQUAL ®

% E ® ®

(E ® ®

READY

*******************************
* R□-LINE-NUMBER YOUR PROGRAM *
*******************************

EDI RES ®

READY

*******************************
* REPLACE YOUR OLD FILE WITH *
* THE NEW ONE THEN LIST IT   *
*******************************

REPLACE ®

READY

LIST ®

100  C  THIS PROGRAM COMPARES CHARACTERS;
110  C  UPPER AND LOWER CASE CHARACTERS
120  C  WILL BE CONSIDERED EQUAL
130  *CHARACTER EQUALITY TEST
140  *
150  LOGICAL FUNCTION CHAREQ (CH1, CH2)
160  CHARACTER*1  CH1, CH2
170  INTEGER MASK, INTCHR, INT1, INT2, ICHAR
180  COMMON/CHMBLK/INTCHR (128)
190  INT1= ICHAR (CH1)
200  INT2= ICHAR (CH2)
210  CHAREQ = INTCHR (INT1+1).EQ.INTCHR (INT2+1)
220  RETURN
230  END

READY
```

```
**************************
* COMPILE THE NEW PROGRAM *
**************************

COMPILE  F78 (R)

LINE 110 CH3 UNKNOWN STATEMENT
LINE 120 CH3 UNKNOWN STATEMENT
LINE 130 CH3 UNKNOWN STATEMENT

READY

************************ **************
* THE ERRORS OCCURRED BECAUSE YOU    *
* USED A 'C' INSTEAD OF AN ASTERISK *
* '*' ON YOUR COMMENT LINES          *
************************ ************

************************************
* CHANGE 'C' TO AN ASTERISK ON THE *
* FIRST COMMENT LINE, THEN DELETE  *
* THE SECOND TWO LINES             *
************************************

QED (R)

( S/C   /*   /P (R) (R)

*  THIS PROGRAM COMPARES CHARACTERS
C  UPPER AND LOWER CASE CHARACTERS
C  WILL BE CONSIDERED EQUAL

(  2, 3  D (R) (R)

(  E (R) (R)

READY

************************
* RESEQUENCE YOUR FILE *
* ONCE AGAIN           *
************************

EDI  RES (R)

READY
```

```
*************************
* REPLACE YOUR OLD FILE *
* WITH THE NEW ONE      *
*************************

REPLACE (R)

READY

************************
* TRY TO COMPILE AGAIN *
************************

COMPILE  F78 (R)

COMPILATION SUCCESSFUL

YOUR CURRENT FILE IS NOW CALLED ".OBJECT."

READY

***************************************
* LINK YOUR SOURCE PROGRAM TO A MADDS *
* FILE CALLED 'U07008:MADEMO' AND A   *
* DATA FILE CALLED 'U07008:DATUE'     *
***************************************

OLD CHAREQ (R)

READY

************************************
* FIND OUT THE LINE NUMBER OF YOUR *
* LAST LINE OF SOURCE CODE         *
************************************

QED (R)

( $P (R) (R)

230 END
```

```
************************************************
* USE THE INCLUDE STATEMENT TO LINK TO A MADDS *
* OBJECT FILE AND A MADDS DATA FILE            *
************************************************

( $ A ®

240 INCLUDE *U07008:MADEMO ®

250 INCLUDE *U07008:DATUE ®

%E ® ®

( E ® ®

READY

****************************
* RESEQUENCE YOUR PROGRAM *
****************************

EDI RES ®

READY

**************************************
* REPLACE THE OLD VERSION OF CHAREQ *
* WITH THE NEW ONE.                  *
**************************************

REPLACE ®

READY

*********************
* RUN YOUR PROGRAM *
*********************

RUN F78 ®
```

```
************************************
* DURING EXECUTION, MADDS DETECTED *
* AN UNDESIRED EVENT (UE).  THE    *
* FOLLOWING MESSAGE WAS GENERATED. *
************************************

**THE UE:  NO CHARS AVAILABLE ON INPUT DEVICE
     DETECTED IN FUNCTION RDCHAR OF MODULE IDM.
     EXECUTION TERMINATED.
  AT LINE 15210
IN SUBPROGRAM UENOCH CALLED AT LINE 9420
IN SUBPROGRAM RDCHAR CALLED AT LINE 9930
IN SUBPROGRAM RDFLD CALLED AT LINE 9680
IN SUBPROGRAM RDADS CALLED AT LINE 10140

READY

****************************************
* UE's WILL BE EXPLAINED LATER IN THE  *
* COURSE.  TRY TO RUN YOUR PROGRAM     *
* AGAIN USING A DIFFERENT DATA FILE.   *
* USE DAT26ADR.                        *
****************************************

OLD CHAREQ (R)

READY

QED (R)

( $ S /DATUE/DAT1ADR/P (R) (R)

250 INCLUDE *U07008:DAT1ADR

( E  (R) (R)

READY

************************************
* REPLACE THE OLD VERSION OF CHAREQ *
************************************

REPLACE (R)

READY
```

```
**********************
* RERUN YOUR PROGRAM *
**********************

RUN F78 (R)

**************************************
* YOUR RESULTS WILL BE PRINTED AT    *
* THE TERMINAL AS FOLLOWS:           *
**************************************

MAD-APM  25 JUN 70 14:43

STARTING ADDRESS INPUT

ADDRESS READING COMPLETE

OUTPUT OF AREA IS:
MR. STEPHEN ALONZO WILEY
AIR 53424E
NAVAIRSYSCOM
WASHINGTON, DC  20331
```

MADDS.5 Informal Functional Specifications for MADDS Modules

EXAMPLE DESCRIPTION

Introduction

Each module may be completely defined in terms of its interface with the outside world. This interface consists of those operations, or functions, which can be invoked from outside the module. A description of this interface must, therefore, be from the point of view of the user. This document is a set of informal specifications for the functions of the MADDS modules. These functions may be used in programs of other modules. Other information about the modules, such as implementation considerations (involving specific machine, operating system, and programming language characteristics), is given elsewhere.

The following are some remarks that aid in the use of the informal specifications.

1. The informal specifications of functions given below are independent of any specific programming language (e.g., FORTRAN, ALGOL, PL/I, COBOL). If the specifications indicate that a function returns a value, then the function is normally used in a programming language as a function reference. For example, in FORTRAN typical references (using functions defined below) are:

```
I  = GETNCA( )
CH = GETCHR(STRNG,POSIT)
```

   If in the specifications a function does not return a value, then it is a pure procedure (e.g., a subroutine in FORTRAN) and is used by means of an explicit call. Some example FORTRAN calls are:

```
CALL  INITAS
CALL  SETCHR(STRNG,POSIT,CHR)
```

2. The character set for type char is the ASCII character set. It is possible to use single-character alphanumeric literals in place of any type char identifiers. For example, we might have:

```
CALL  SETCHR(STRNG,POSIT,'A')
F =   CHAREQ('!',CH)
```

The following character operations must be done using the access functions of the Character Module:

a) Comparing two characters for equality;

b) Comparing two characters to see if one has the relation "less than" to the other.

3. A string is a sequence of type char characters and has a fixed positive length. The following string operations must be done using the access functions of the String Storage Module:

a) Setting a position in a string to a given character;

b) Retrieving a character from a given position in a string;

c) Retrieving a substring of a string, given a starting position and desired length;

d) Comparing two strings for equality.

4. An address is simply a set of strings. If one, but not all, of the fields is undefined (i.e., has not been assigned a string value), then the address is partially defined, and if all fields are undefined, then the address is undefined. If all fields of an address are defined, then the address is complete. An address identifier is a positive integer no larger than maximum address storage capacity MAXADS and is "absurd" if not in this range. Once the number of complete addresses n: $0 \leq n \leq$ MAXADS has been determined (by VERADS of the ASM), subsequently giving GETNCA = n, we may say that an address identifier adr is assigned if and only if $1 \leq adr \leq$ GETNCA, and unassigned otherwise. There are no operations on addresses as such; only the setting of and retrieving from their fields is allowed. Multiple ownership of addresses (e.g., several instances of the same identifier value occurring in the system) is permitted; however, caution must be exercised because changes to an address by one owner, of course, affects the other owners -- possibly adversely.

5. The user of a function need be concerned only with what a function does and how to call or reference it; he is not concerned with how a function does its task. The EFFECTS part of an informal function specification contains most of this task description. For example, the EFFECTS part for most functions mentions tests for undesired events (UEs) and the corresponding UE handler calls. The user of the function does not set up these tests for these calls; this is the job of the implementor. The user may refer to the informal specifications for the modules or the UE handler mentioned in the EFFECTS part for further information (e.g., the action of the UE handling functions in the UEH).

TABLE OF CONTENTS

Module and Function Names	Page
Applications Program Module (APM)	13-34
AREA	
RANK	
Address Storage Module (ASM)	13-36
INITAS	
MAXADS	
VERADS	
GETNCA	
SET@	
GET@	
Character Module (CHM)	13-40
CHAREQ	
CHARLT	
Input Device Module (IDM)	13-41
OPENID	
CLOSID	
RDCHAR	
Input Module (IPM)	13-42
RDADS	
Master Control Module (MCM)	13-43
MAIN	
Output Device Module (ODM)	13-44
OPENOD	
CLOSOD	
WRCHAR	
NEWLIN	
Output Module (OPM)	13-46
WRADR	
String Storage Module (SSM)	13-47
SETCHR	
GETCHR	
SUBSTR	
STREQ	
Undesired Event Handler (UEH)	13-49
UE$	

Informal Function Specifications

1. Applications Program Module

FUNCTION CALLING FORM: AREA(prezip) MODULE: APM

INPUT PARAMETERS:

Name	Type	Description
prezip	string	a string whose first three characters are digits $d_1d_2d_3$, giving the area part (first three digits) of a set of ZIP-codes, and whose remaining characters are blanks

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: AREA selects and writes out all complete addresses with $d_1d_2d_3$ as the area part of their ZIP-code fields. If no addresses are selected, then no output occurs. A set of complete addresses (for searching and selection) exists after RDADS of the IPM has been called; hence, AREA assumes that RDADS has been called since the last INITAS. AREA also assumes that the output device is open for output.
If $d_1d_2d_3$ is not a three-digit sequence representing an integer $i : 0 \leq i \leq 999$,
then UEZIP is called.

FUNCTION CALLING FORM: RANK(oglim) MODULE: APM

INPUT PARAMETERS:

Name	Type	Description
oglim	string	a string whose first two characters are digits d_1d_2 giving an O-grade level, and whose remaining characters are blanks

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: RANK selects and writes out all complete addresses with O-grade $\leq d_1d_2$. The O-grade is determined by the following table. A set of complete addresses (for searching and selection) exists after RDADS of the IPM has been called; hence, RANK assumes that RDADS has been called since the last INITAS. RANK assumes the output device is open for output.
If d_1d_2 is not a two-digit sequence representing an integer i: $1 \leq i \leq 10$,
then UEOGL is called.

Table: O-grade Levels

Service:	USA USAF USMC	USN	blank
O-grade	Title	Title	GS Level
01	2LT	ENS	07
02	1LT	LTJG	08, 09
03	CAPT	LT	10, 11
04	MAJ	LCDR	12
05	LCOL	CDR	13, 14
06	COL	CAPT	15
07	BG	RADM	16
08	MG	RADM	16
09	LG	VADM	17
10	GEN	ADM	18

2. Address Storage Module

FUNCTION CALLING FORM: INITAS MODULE: ASM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: INITAS initializes the ASM for the storage of addresses. That is, it sets up the data structures and places the ASM in the initial state (i.e., capable of address storage but with no addresses presently existing and all fields undefined). It must be called prior to any calls to other ASM functions to assure that the ASM operates correctly in all cases. A call to INITAS automatically destroys any currently existing addresses and returns the ASM to maximum address storage capacity available.

FUNCTION CALLING FORM: MAXADS MODULE: ASM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: maximum address storage capacity

EFFECTS: None

FUNCTION CALLING FORM: VERADS MODULE: ASM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: VERADS determines the largest integer n: $0 \leq n \leq$ MAXADS, for which all address identifiers adr: $1 \leq adr \leq n$ have all fields defined, and sets an internal counter in the ASM to n. The value of this counter is considered to be the number of complete addresses stored and is returned as the value of GETNCA of the ASM. The ASM is in a correct state only if all fields of all address identifiers adr are undefined, for $n < adr \leq$ MAXADS.
If there is a defined field for an adr: $n < adr \leq$ MAXADS (i.e., an incorrect state for the ASM),
then UEASMI is called.

FUNCTION CALLING FORM: GETNCA MODULE: ASM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: integer

FUNCTION VALUE: The number of complete addresses stored

EFFECTS: GETNCA returns the value of an internal counter in the ASM giving the number of complete addresses stored.
If VERADS hasn't been called since the last INITAS,
then UENCAU is called.

Below is a table of field mnemonics @, their corresponding descriptive phrases #, and the lengths of their string parameters $. For each, there is a field setting (i.e., insertion) and a field getting (i.e., extraction) function in the ASM.

Table: Field Mnemonics for Addresses

@	#	$
BOC	Branch-Or-Code	20
CIT	City	25
COA	Command-Or-Activity	30
GN	Given Names	20
GSL	GS Level	2
LN	Last Name	25
SER	Service	5
SOP	Street-Or-Post-Office-Box	30
ST	State Abbreviation	2
TIT	Title	10
ZIP	ZIP-Code	9

For the field insertion functions, a single informal specification schema suffices, which is identical for each field except for the field mnemonic @, its descriptive phrase #, and its string parameter length $. The same is true for field extraction. Below are given the field insertion and extraction schemas, each followed by an example obtained in this case by substituting 'BOC' for @, 'Branch-Or-Code' for #, and '20' for $.

Field Insertion Function Schema

FUNCTION CALLING FORM: SET@(adr,str) MODULE: ASM

INPUT PARAMETERS:

Name	Type	Description
adr	integer	identifier of an address
str	string	a string

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: The first $ characters of the string str are stored as the new value of the # field of the address adr. If the length of str is less than $, then the # field is set to str followed by blanks. In either case, the previous value is lost.
If adr is < 1 or > MAXADS,
then UEAIDA is called.

Sample Field Insertion Function

FUNCTION CALLING FORM: SETBOC(adr,str) MODULE: ASM

INPUT PARAMETERS:

Name	Type	Description
adr	integer	identifier of an address
str	string	a string

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: The first 20 characters of the string str are stored as the new value of the Branch-or-Code field of the address adr. If the length of str is less than 20, then the Branch-or-Code field is set to str followed by blanks. In either case, the previous value is lost.
If adr is < 1 or > MAXADS,
then UEAIDA is called.

Field Extraction Function Schema

FUNCTION CALLING FORM: GET@(adr) MODULE: ASM

INPUT PARAMETERS:

Name	Type	Description
adr	integer	identifier of an address

FUNCTION VALUE TYPE: string with length $

FUNCTION VALUE: the string stored in the # field of address adr.

EFFECTS: If adr is < 1 or > MAXADS,
then UEAIDA is called.
If the # field of address identifier adr is undefined but adr has a defined field (i.e., partial address),
then UEADRP is called.
If all fields of address adr are undefined,
then UEADRU is called.

Sample Field Extraction Function

FUNCTION CALLING FORM: GETBOC(adr) MODULE: ASM

INPUT PARAMETERS:

Name	Type	Description
adr	integer	identifier of an address

FUNCTION VALUE TYPE: string with length 20

FUNCTION VALUE: the string stored in the Branch-Or-Code field of address adr.

EFFECTS: If adr is < 1 or > MAXADS,
then UEAIDA is called.
If the Branch-Or-Code field of address identifier adr is undefined but adr has a defined field (i.e., partial address),
then UEADRP is called.
If all fields of address identifier adr are undefined,
then UEADRU is called.

---

3. Character Module

FUNCTION CALLING FORM: CHAREQ(ch1, ch2) MODULE: CHM

INPUT PARAMETERS:

Name	Type	Description
ch1	char	first character to be compared
ch2	char	second character to be compared

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: if ch1 = ch2 then true else false

EFFECTS: Equality (=) is defined as equality of the internal integer character codes, except in the following cases: upper and lower case alphabetic characters are considered equal (e.g., "a" = "A", "b" = "B", ..., "z" = "Z").

FUNCTION CALLING FORM: CHARLT(ch1, ch2) MODULE: CHM

INPUT PARAMETERS:

Name	Type	Description
ch1	char	first character to be compared
ch2	char	second character to be compared

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: if ch1 < ch2 then true else false

EFFECTS: The relation is-less-than (<) is defined by the following:

(a) SPACE (blank) $< \begin{Bmatrix} A \\ a \end{Bmatrix} < \begin{Bmatrix} B \\ b \end{Bmatrix} < \ldots < \begin{Bmatrix} Z \\ z \end{Bmatrix} < 0 < 1 < \ldots < 9$

(b) is restricted to this subset of characters and hence is a partial function.

If ch1 or ch2 is not a blank, a digit, or a letter, then UECHLT is called.

---

4. Input Device Module

FUNCTION CALLING FORM: OPENID MODULE: IDM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: OPENID "opens", or initializes, the input device and the buffers, etc., to enable reading. The input device is initially in the closed state. Whenever it is in the closed state, it must be opened by OPENID, prior to reading characters via RDCHAR.
If the input device is open and OPENID is called,
then UEROPN is called.

FUNCTION CALLING FORM: CLOSID MODULE: IDM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: CLOSID "closes" the input device to reading. For each OPENID there must be a corresponding CLOSID.
If the input device is closed and CLOSID is called,
then UERCLS is called.

FUNCTION CALLING FORM: RDCHAR MODULE: IDM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: char

FUNCTION VALUE: the next character from the input device

EFFECTS: If the input device is closed,
then UEWRCL is called.
If no characters are available on the input device,
then UENOCH is called.
If a device error occurs during the read,
then UEDVER is called.

---

5. Input Module

FUNCTION CALLING FORM: RDADS MODULE: IPM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: The input addresses are read from an external storage medium or device accessed by the IDM. These addresses are in external form as sequences of characters, which are partitioned into strings according to an input format known to the IPM. RDADS by means of the IDM causes these strings to be read in character-by-character and stored as the fields of a set of addresses. The reading of this set of addresses is terminated at the first "address" whose first field consists of all end-of-file marker characters; this "address" is not stored. No input validation is performed on the input field values. After all input has been read, RDADS calls VERADS of the ASM to verify the addresses as complete and to set the number-of-complete-addresses counter in the ASM. RDADS uses functions of the IDM to open and close the input device (file). If the number of addresses read exceeds MAXADS of the ASM, then UEADOV is called.

6. Master Control Module

FUNCTION CALLNG FORM: MAIN MODULE: MCM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: MAIN is the main driver program. It initiates all module initializations by invoking functions in the modules requiring this action. The central task of MAIN is to specify a particular sequence of input, output, and computation actions for which MADDS is designed. Thus, it will typically use the IPM, the APM and possibly the ODM; however, the capabilities of all the modules are available to MAIN, subject only to use rules stated in their interface specifications.

---

7. Output Device Module

FUNCTION CALLING FORM: OPENOD MODULE: ODM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: OPENOD "opens", or initializes, the output device and buffers, etc., to enable writing. The output device is initially in the closed state. Whenever it is in the closed state, it must be opened by OPENOD, prior to writing characters via WRCHAR.
If the output device is open and OPENOD is called,
then UEROPN is called.

FUNCTION CALLING FORM: CLOSOD MODULE: ODM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: CLOSOD "closes" the output device to writing. For each OPENOD there must be a corresponding CLOSOD. The output device is initially in the closed state.
If the output device is closed and CLOSOD is called,
then UERCLS is called.

FUNCTION CALLING FORM: WRCHAR(chr) MODULE: ODM

INPUT PARAMETERS:

Name	Type	Description
chr	char	a character to be written

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: The character chr is written on the output device.
If the output device is closed,
then UEWRCL is called.
If a device error occurs during the write,
then UEDVER is called.

FUNCTION CALLING FORM: NEWLIN MODULE: ODM

INPUT PARAMETERS: None

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: NEWLIN undertakes device-dependent actions which have the effect of writing an end-of-line character for the device (via WRCHAR). No printable character is actually written on the device. Subsequent writes by WRCHAR start on the next line, unless the current line has not had any printable characters written to it, in which case subsequent writes are to the current line.
If the output device is closed,
then UEWRCL is called.
If a device error occurs during the write,
then UEDVER is called.

---

8. Output Module

FUNCTION CALLING FORM: WRADR(adr) MODULE: OPM

INPUT PARAMETERS:

Name	Type	Description
adr	integer	identifier of an address

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: The address adr is written out to an external device used by the ODM. Certain fields of the address are written character-by-character according to an output format known to the OPM. This format specifies at least the order and identity of fields, spacing, and line contents. It is assumed that RDADS of the IPM has been called since the last INITAS.
If adr < 1 or > MAXADS,
then UEAIDA is called.
If GETNCA < adr ≤ MAXADS,
then UEAIDU is called.

---

9. String Storage Module

FUNCTION CALLING FORM: SETCHR(str, pos, chr) MODULE: SSM

INPUT PARAMETERS:

Name	Type	Description
str	string	a string
pos	integer	a character position in str
chr	char	a character to be inserted

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: SETCHR replaces the character at position pos of string str by the character chr.
If pos < 1 or pos > length of str,
then UESPOS is called.

FUNCTION CALLING FORM: GETCHR(str, pos) MODULE: SSM

INPUT PARAMETERS:

Name	Type	Description
str	string	a string
pos	integer	a character position in str

FUNCTION VALUE TYPE: char

FUNCTION VALUE: the character at position pos of string str

EFFECTS: If pos < 1 or pos > length of str,
then UESPOS is called.

FUNCTION CALLING FORM: SUBSTR(str, pos, len) MODULE: SSM

INPUT PARAMETERS:

Name	Type	Description
str	string	a string
pos	integer	a character position in str
len	integer	the length of the substring to be extracted

FUNCTION VALUE TYPE: string

FUNCTION VALUE: a string whose first len characters are the len characters of the string str, beginning with position pos, and whose remaining characters are blanks

EFFECTS: If pos < 1 or pos > length of str,
then UESPOS is called.
If len < 0 or pos + len - 1 > length of str,
then UESLEN is called.

FUNCTION CALLING FORM: STREQ(str1, str2) MODULE: SSM

INPUT PARAMETERS:

Name	Type	Description
str1	string	a string
str2	string	a string

FUNCTION VALUE TYPE: boolean

FUNCTION VALUE: if str1 = str2 then true else false

EFFECTS: Let c_i and c'_i denote the characters at position i of strings str1 and str2, respectively. Let L be the length of the shorter of the two strings. Then str1 and str2 are equal (=) if and only if.

a) for $1 \leq i \leq L$, CHAREQ(c_i, c'_i), and

b) all remaining characters of the longer string are blanks.

If both str1 and str2 are the same length, then the second condition is, of course, unnecessary.

---

10. Undesired Event Handler

The UEH consists of the UE handling functions, one for each UE. The list of UEs that can occur are summarized in the following table, where $ is the UE mnemonic and ¢ is the corresponding UE description.

Table: Undesired Events (UEs)

$	¢
ADOV	Address storage capacity overflow
ADRP	Partially defined address (at least one field undefined)
ADRU	Undefined address (no fields defined)
AIDA	Absurd address identifier (i.e., < 1 or > max capacity)
AIDU	Unassigned address identifier (i.e., > GETNCA and ≤ MAXADS)
ASMI	State of the ASM incorrect (i.e., defined fields beyond GETNCA)
CHLT	Undefined character comparison
DVER	Device error
MIDU	Non-existent module identifier
NCAU	Undefined number of complete addresses
NOCH	No characters available on input device
OGL	O-grade level is < 1 or > 10
RCLS	Redundant device closing
ROPN	Redundant device opening
SLEN	Substring length is < 0 or too large
SPOS	Character position in string is < 1 or > string length
WRCL	Writing or reading on closed device
ZIP	ZIP-code area part not three decimal digits

All of the UE handling functions can be represented by a single function schema. This is given below, using UE mnemonic $ and description ¢, and is followed by a sample UE function. Note that there is a UE handler for UEs in the UE handlers (i.e., MIDU; see next page).

The module identifiers used as arguments in the UE handler calls are simply the module abbreviations given in the informal specifications.

UE Function Schema

FUNCTION CALLING FORM: UE$(mdid,fnid) MODULE: UEH

INPUT PARAMETERS:

Name	Type	Description
mdid	string	module identifier
fnid	string	function identifier

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: A message is written out to the effect that the UE: "ç" has been detected in function fnid of module mdid and the run is aborted. Then execution is terminated.
If mdid is not the identifier of a known module,
then UEMIDU is called (except when $ is MIDU; that is, UEMIDU will not call itself).

Sample UE Function

FUNCTION CALLING FORM: UEAIDU(mdid,fnid) MODULE: UEH

INPUT PARAMETERS:

Name	Type	Description
mdid	string	module identifier
fnid	string	function identifier

FUNCTION VALUE TYPE: None

FUNCTION VALUE: None

EFFECTS: A message is written out to the effect that the UE: "Unassigned address identifier" has been detected in function fnid of module mdid and the run is aborted. Then execution is terminated.
If mdid is not the identifier of a module,
then UEMIDU is called.

MADDS.6 MADDS Input Formats

EXAMPLE DESCRIPTION

The list of addresses input to MADDS can be read in character by character. Addresses follow directly after one another without intervening characters. Each address consists of 11 fields. The fields follow directly after one another as specified in the following table.

Field	Name	Field Size (Number of Characters)	Content[1]
1	Title	4	E.g., "Mr.", "Ms.", "Dr.", "CAPT", "Capt"[2]
2	Last Name	15	
3	Given Names	20	Two strings separated by at least one blank; First string is first name, second is middle
4	Branch or Code	20	
5	Command or Activity	20	
6	Street or P.O. Box	20	E.g., "P.O. Box 208"
7	City	20	
8	State Abbreviation	2	
9	Zip Code, APO code, or FPO code	7	Contiguous decimal digits
10	GS Level	2	"01", "02", ... , "18"[3]
11	Branch of Service	4	"USA", "USMC", "USN", "USAF" or an upper-lowercase variant

---

1. The value of any field can be an all-blank string. If the value of a field is not an all-blank string, then its first character will be non-blank (i.e., values are left justified). Any example field value shorter than the field size should be considered to be padded on the right with blanks.
2. An officer rank appears when the Branch of Service field is non-blank.
3. Value is all blanks when Branch of Service field is non-blank and is non-blank only when Branch of Service is all blanks.

The last address of the file is fake, having only a title field consisting completely of asterisks. It is an end-of-file marker.

As mentioned in MADDS.1, it is possible that the format of the address file might change. One imminent change is that the 11 fields will follow one another as specified in the following table. The last address of the file is still fake, having only a command or activity field consisting of asterisks.

Field	Name
1	Command or Activity
2	Street or P.O. Box
3	City
4	State Abbreviation
5	Zip Code, APO code, or FPO code
6	Title
7	Given Names
8	Last Name
9	Branch or Code
10	GS Level
11	Branch of Service

MADDS.7 MADDS Output Formats

EXAMPLE DESCRIPTION

Each address produced by MADDS should adhere to the following format:

Line 1: Title
single blank
Given Names
single blank
Last Name

Line 2: Branch or Code (BOC)

Line 3: Command or Activity (COA)

Line 4: City
comma
single blank
State Abbreviation
single blank
Zipcode

Trailing blanks in a field should not be printed. Addresses are separated from one another by five blank lines. Each output line is to begin in the first column.

As mentioned in MADDS.1, the output format is likely to change. The new format could be the following:

Line 1: Command or Activity (COA)

Line 2: City
comma
single blank
State Abbreviation

Line 3. Street or Post Office Box

Line 4: Last Name

Trailing blanks in a field should not be printed. Addresses are separated from one another by three blank lines. Each output line is to begin in the first column.

MADDS.8 MADDS Implementation Notes

General

Everyone should read the informal specifications for all of the modules whose interface functions he or she will be using. The Master Control Module (MCM) performs all initializations for the modules. No other module initializations should be done.

The Undesired Event Handler

In this implementation of MADDS, character constants are used for module and function identifiers in calls to the UE handling functions.

A call to a UE handling function should be such that, if control returns to the calling program, normal processing can continue. The return implies that corrective action has taken place.

FORTRAN 78 Compilation

To compile an F78 program, type

```
OLD <program name>®
READY
COMPILE F78 ®
```

If compilation is successful, the resulting machine-language file is named .OBJECT. and becomes the new current file. Rename the file by typing

```
RENAME <module name>.OBJ ®
```

then save it.

The name of your object module should be one of the following:

- ASM.OBJ
- IPM.OBJ
- OPM.OBJ
- APM.OBJ

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Linking

To run your module, you will have to link first with the other MADDS modules. These modules are stored in library files. The name of each of the files indicates which module of MADDS is missing. For example, MAD-ASM will contain all modules except ASM. If you are writing ASM you should link with that file. If you are writing OPM, link with MAD-OPM; if you are writing APM, link with MAD-APM; if you are writing IPM, link with MAD-IPM.

File name	Contents of file
U07008:MAD-APM	All modules except APM
U07008:MAD-ASM	All modules except ASM
U07008:MAD-IPM	All modules except IPM
U07008:MAD-OPM	All modules except OPM
U07008:DAT1ADR	Test data file with 1 address
U07008:DAT3ADR	Test data file with 3 addresses
U07008:DAT7ADR	Test data file with 7 addresses
U07008:DATUE	Test data file that will cause a UE
U07008:DAT26ADR	Test data file with 26 addresses

To link with the MADDS modules you require, the last two lines of your source program should be:

```
INCLUDE *⟨one of the MAD files⟩

INCLUDE *⟨one of the DAT files⟩
```

To run your program, you then make the file containing the object code for your module your current file and type:

```
RUN F78 (R)
```

For your final production run, use DAT26ADR as your test data file.

MADDS.9 MADDS Program Listings

EXAMPLE DESCRIPTION

Table of Contents

Module	Page
APM	13-58
ASM	13-60
CHM	13-85
IDM	13-86
IPM	13-88
MCM	13-89
ODM	13-90
OPM	13-92
SSM	13-94
UEH	13-96

```
100 *
110 *  apm
120 *
130 *  output addresses with zip area part prezip
140 *
150 subroutine area(prezip)
160 implicit
170 character*1 digit(10),getchr,chr
180 character*3 prezip,zarea,substr
190 character*9 getzip
200 integer adr, getnca, i, j, n
210 logical chareq,streq
220 data digit/'1','2','3','4','5','6','7','8','9','0'/
230
240 do 20 j=1,3
250   chr=getchr(prezip,j)
260   do 10 i=1,10
270     if (chareq(chr,digit(i))) go to 20
280   10     continue
290   call uezip('apm','area')
300 20     continue
310 n=getnca()
320 if (n.eq.0) return
330 do 30 adr=1,n
340   zarea = substr(getzip(adr),1,3)
350   if (streq(zarea,prezip)) call wradr(adr)
360 30     continue
370 return
380 end
390 *
400 *  apm
410 *
420 *  output addresses with 0-grade at most oglim
430 *
440 subroutine rank(oglim)
450 implicit
460 character*1 ch1,ch2,ch3,ch4,getchr,digit(10)
470 character*2 oglim,gslev(10),gsl,getgsl
480 character*4 serv,usatit(10),usntit(10)
490 character*5 getser
500 character*10 title, gettit
510 integer lim,nca,getnca,adr,j
520 logical chareq,charlt,streq
530 data usatit/'2lt','1lt','capt','maj','lcol','col','bg','mg',
540           &'lg','gen'/
550 data usntit/'ens','ltjg','lt','lcdr','cdr','capt','radm',
560           &'radm','vadm','adm'/
570 data gslev/'07','09','11','12','14','15','16','16','17','18'/
580 data digit/'1','2','3','4','5','6','7','8','9','0'/
590
```

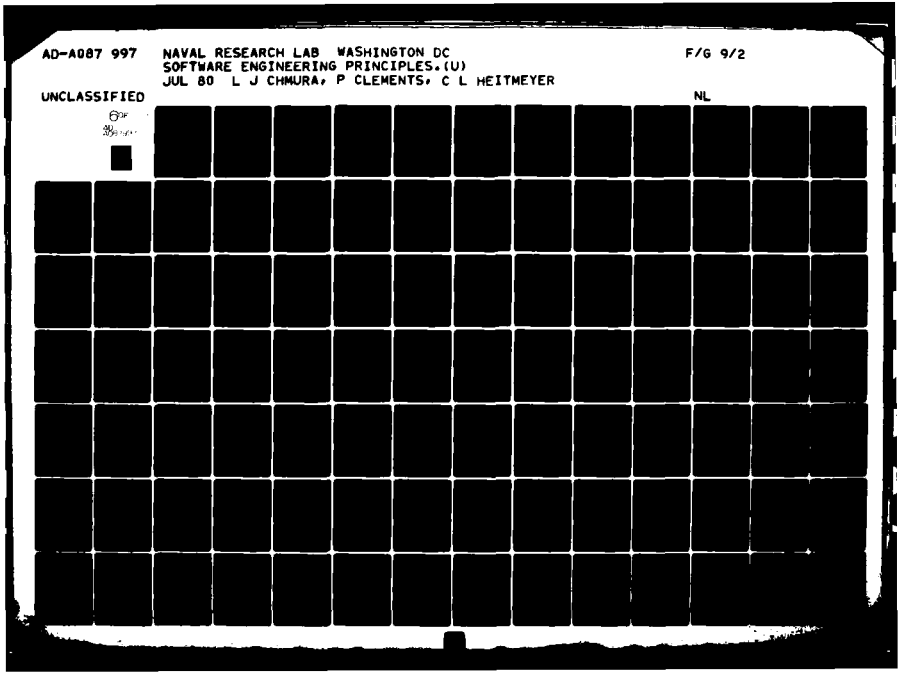
```
600 ch1=getchr(oglim,1)
610 ch2=getchr(oglim,2)
620 if (chareq(ch1,'0')) go to 10
630 if (.not.chareq(ch1,'1')) go to 30
640 if (.not.chareq(ch2,'0')) go to 30
650 lim = 10
660 go to 40
670 10 do 20 lim=1,9
680      if (chareq(ch2,digit(lim))) go to 40
690 20 continue
700 30 call ueogl('apm','rank')
710 40 nca=getnca()
720 if (nca.eq.0) return
730 do 80 adr=1,nca
740   serv=getser(adr)
750   title=gettit(adr)
760   if (streq(serv,' ')) go to 70
770   ch1=getchr(serv,1)
780   ch2=getchr(serv,2)
790   ch3=getchr(serv,3)
800   ch4=getchr(serv,4)
810   if (.not.chareq(ch1,'u') .or. .not.chareq(ch2,'s')) go to 80
820   if (chareq(ch3,'n')) go to 60
830   if (chareq(ch3,'a')) go to 45
840   if (.not.chareq(ch3,'m')) go to 80
850   if (chareq(ch4,'c')) go to 50
860   go to 80
870   45 if (.not.(chareq(ch4,' ').or.chareq(ch4,'f'))) go to 80
880   50 do 57 j=1,lim
890        if (.not.streq(title,usatit(j)))go to 57
900        call wradr(adr)
910        go to 80
920   57 continue
930   go to 80
940   60 do 67 j=1,lim
950        if (.not.streq(title,usntit(j)))go to 67
960        call wradr(adr)
970        go to 80
980   67 continue
990   go to 80
1000  70 gsl=getgsl(adr)
1010   ch1=getchr(gsl,1)
1020   ch2=getchr(gsl,2)
1030   if(charlt(getchr(gslev(lim),1),ch1)) go to 80
1040   if(charlt(ch1,getchr(gslev(lim),1))) go to 75
1050   if (charlt(getchr(gslev(lim),2),ch2)) go to 80
1060   75 call wradr(adr)
1070 80 continue
1080 return
1090 end
```

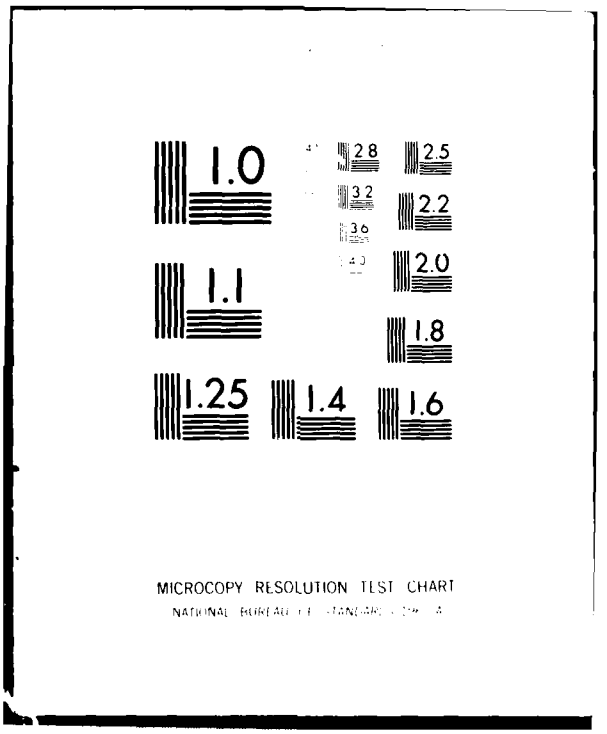
```
1100 *
1110 *  asm
1120 *
1130 *  initialize the asm
1140 *
1150 subroutine initas
1160 implicit
1170 character*30 sop,coa
1180 character*25 cit,ln
1190 character*20 boc,gn
1200 character*10 tit
1210 character*9  zip
1220 character*5  ser
1230 character*2  gsl,st
1240 integer  nca,mad,nflds,adr,i,j
1250 logical adflag
1260 parameter (mad=26,nflds=11)
1270 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
1280 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
1290 &                adflag(mad,nflds)
1300
1310 nca=-1
1320 do 10 j=1,nflds
1330   do 10 i=1,mad
1340     adflag(i,j)=.false.
1350 10     continue
1360 return
1370 end
1380 *
1390 *  asm
1400 *
1410 *  maximum number of addresses
1420 *
1430 integer function maxads
1440 implicit
1450 integer mad,nflds
1460 parameter (mad=26,nflds=11)
1470 maxads=mad
1480 return
1490 end
```

```
1500 *
1510 *  asm
1520 *
1530 *  determine number of consecutive complete addresses
1540 *
1550 subroutine verads
1560 implicit
1570 character*30 sop,coa
1580 character*25 cit,ln
1590 character*20 boc,gn
1600 character*10 tit
1610 character*9  zip
1620 character*5  ser
1630 character*2  gsl,st
1640 integer  nca,mad,nflds,adr,i,j,n
1650 logical adflag
1660 parameter (mad=26,nflds=11)
1670 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
1680 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
1690 &                adflag(mad,nflds)
1700
1710 do 20 n=1,mad
1720   do 10 j=1,nflds
1730     if (.not.adflag(n,j)) go to 30
1740   10 continue
1750 20 continue
1760 nca=mad
1770 return
1780 30  nca=n-1
1790 do 50 i=n,mad
1800   do 40 j=1,nflds
1810     if (adflag(i,j)) call ueasmi('asm','verads')
1820   40 continue
1830 50 continue
1840 return
1850 end
```

```
1860 *
1870 *
1880 *  asm
1890 *
1900 *  get number of consecutive addresses
1910 *
1920 integer function getnca
1930 implicit
1940 character*30 sop,coa
1950 character*25 cit,ln
1960 character*20 boc,gn
1970 character*10 tit
1980 character*9  zip
1990 character*5  ser
2000 character*2  gsl,st
2010 integer  nca,mad,nflds
2020 logical adflag
2030 parameter (mad=26,nflds=11)
2040 common  /asmblk/nca, sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
2050 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
2060 &                adflag(mad,nflds)
2070
2080 if (nca.lt.0) call uencau('asm','getnca')
2090 getnca=nca
2100 return
2110 end
```

```
2120 *
2130 *  asm
2140 *
2150 *  set branch-or-code field of adr to str
2160 *
2170 subroutine setboc(adr,str)
2180 implicit
2190 character*30 sop,coa
2200 character*25 cit,ln
2210 character*20 boc,gn
2220 character*10 tit
2230 character*9  zip
2240 character*5  ser
2250 character*2  gsl,st
2260 character*(*) str
2270 integer  nca,mad,nflds,adr
2280 logical adflag
2290 parameter (mad=26,nflds=11)
2300 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
2310 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
2320 &                adflag(mad,nflds)
2330
2340 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setboc')
2350 boc(adr)=str
2360 adflag(adr,1)=.true.
2370 return
2380 end
```


AD-A087 997
NAVAL RESEARCH LAB WASHINGTON DC
SOFTWARE ENGINEERING PRINCIPLES.(U)
JUL 80 L J CHMURA, P CLEMENTS, C L HEITMEYER
F/G 9/2
UNCLASSIFIED
NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

```
2390 *
2400 *  asm
2410 *
2420 *  set city field of adr to str
2430 *
2440 subroutine setcit(adr,str)
2450 implicit
2460 character*30 sop,coa
2470 character*25 cit,ln
2480 character*20 boc,gn
2490 character*10 tit
2500 character*9  zip
2510 character*5  ser
2520 character*2  gsl,st
2530 character*(*) str
2540 integer  nca,mad,nflds,adr
2550 logical adflag
2560 parameter (mad=26,nflds=11)
2570 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
2580 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
2590 &                adflag(mad,nflds)
2600
2610 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setcit')
2620 cit(adr)=str
2630 adflag(adr,2)=.true.
2640 return
2650 end
```

```
2660 *
2670 *  asm
2680 *
2690 *  set command-or-activity field of adr to sir
2700 *
2710 subroutine setcoa(adr,str)
2720 implicit
2730 character*30 sop,coa
2740 character*25 cit,ln
2750 character*20 boc,gn
2760 character*10 tit
2770 character*9  zip
2780 character*5  ser
2790 character*2  gsl,st
2800 character*(*) str
2810 integer  nca,mad,nflds,adr
2820 logical adflag
2830 parameter (mad=26,nflds=11)
2840 common   /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
2850 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
2860 &                adflag(mad,nflds)
2870
2880 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setcoa')
2890 coa(adr)=str
2900 adflag(adr,3)=.true.
2910 return
2920 end
```

```
2930 *
2940 *  asm
2950 *
2960 *  set given-names field of adr to str
2970 *
2980 subroutine setgn (adr,str)
2990 implicit
3000 character*30 sop,coa
3010 character*25 cit,ln
3020 character*20 boc,gn
3030 character*10 tit
3040 character*9  zip
3050 character*5  ser
3060 character*2  gsl,st
3070 character*(*) str
3080 integer  nca,mad,nflds,adr
3090 logical adflag
3100 parameter (mad=26,nflds=11)
3110 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
3120 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
3130 &                adflag(mad,nflds)
3140
3150 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setgn')
3160 gn(adr)=str
3170 adflag(adr,4)=.true.
3180 return
3190 end
```

```
3200 *
3210 *  asm
3220 *
3230 *  set gs-level field of adr to str
3240 *
3250 subroutine setgsl(adr,str)
3260 implicit
3270 character*30 sop,coa
3280 character*25 cit,ln
3290 character*20 boc,gn
3300 character*10 tit
3310 character*9  zip
3320 character*5  ser
3330 character*2  gsl,st
3340 character*(*) str
3350 integer  nca,mad,nflds,adr
3360 logical adflag
3370 parameter (mad=26,nflds=11)
3380 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
3390 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
3400 &                adflag(mad,nflds)
3410
3420 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setgsl')
3430 gsl(adr)=str
3440 adflag(adr,5)=.true.
3450 return
3460 end
```

```
3470 *
3480 *  asm
3490 *
3500 *  set last-name field of adr to str
3510 subroutine setln (adr,str)
3520 implicit
3530 character*30 sop,coa
3540 character*25 cit,ln
3550 character*20 boc,gn
3560 character*10 tit
3570 character*9  zip
3580 character*5  ser
3590 character*2  gsl,st
3600 character*(*) str
3610 integer  nca,mad,nflds,adr
3620 logical adflag
3630 parameter (mad=26,nflds=11)
3640 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
3650 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
3660 &                adflag(mad,nflds)
3670
3680 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setln')
3690 ln(adr)=str
3700 adflag(adr,6)=.true.
3710 return
3720 end
```

```
3730 *
3740 *  asm
3750 *
3760 *  set service field of adr to str
3770 *
3780 subroutine setser(adr,str)
3790 implicit
3800 character*30 sop,coa
3810 character*25 cit,ln
3820 character*20 boc,gn
3830 character*10 tit
3840 character*9  zip
3850 character*5  ser
3860 character*2  gsl,st
3870 character*(*) str
3880 integer  nca,mad,nflds,adr
3890 logical adflag
3900 parameter (mad=26,nflds=11)
3910 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
3920 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
3930 &                adflag(mad,nflds)
3940
3950 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setser')
3960 ser(adr)=str
3970 adflag(adr,7)=.true.
3980 return
3990 end
```

```
4000 *
4010 *  asm
4020 *
4030 *  set street-or-post-office-box field of adr to str
4040 *
4050 subroutine setsop(adr,str)
4060 implicit
4070 character*30 sop,coa
4080 character*25 cit,ln
4090 character*20 boc,gn
4100 character*10 tit
4110 character*9  zip
4120 character*5  ser
4130 character*2  gsl,st
4140 character*(*) str
4150 integer  nca,mad,nflds,adr
4160 logical adflag
4170 parameter (mad=26,nflds=11)
4180 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
4190 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
4200 &                adflag(mad,nflds)
4210
4220 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setsop')
4230 sop(adr)=str
4240 adflag(adr,8)=.true.
4250 return
4260 end
```

```
4270 *
4280 *  asm
4290 *
4300 *  set state field of adr to str
4310 *
4320 subroutine setst (adr,str)
4330 implicit
4340 character*30 sop,coa
4350 character*25 cit,ln
4360 character*20 boc,gn
4370 character*10 tit
4380 character*9  zip
4390 character*5  ser
4400 character*2  gsl,st
4410 character*(*) str
4420 integer  nca,mad,nflds,adr
4430 logical adflag
4440 parameter (mad=26,nflds=11)
4450 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
4460 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
4470 &                adflag(mad,nflds)
4480
4490  if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setst')
4500 st(adr)=str
4510 adflag(adr,9)=.true.
4520 return
4530 end
```

```
4540 *
4550 *  asm
4560 *
4570 *  set title field of adr to str
4580 *
4590 subroutine settit(adr,str)
4600 implicit
4610 character*30 sop,coa
4620 character*25 cit,ln
4630 character*20 boc,gn
4640 character*10 tit
4650 character*9  zip
4660 character*5  ser
4670 character*2  gsl,st
4680 character*(*) str
4690 integer  nca,mad,nflds,adr
4700 logical adflag
4710 parameter (mad=26,nflds=11)
4720 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
4730 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
4740 &                adflag(mad,nflds)
4750
4760 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','settit')
4770 tit(adr)=str
4780 adflag(adr,10)=.true.
4790 return
4800 end
```

```
4810 *
4820 *  asm
4830 *
4840 *  set zip-code field of adr to str
4850 *
4860 subroutine setzip(adr,str)
4870 implicit
4880 character*30 sop,coa
4890 character*25 cit,ln
4900 character*20 boc,gn
4910 character*10 tit
4920 character*9  zip
4930 character*5  ser
4940 character*2  gsl,st
4950 character*(*) str
4960 integer  nca,mad,nflds,adr
4970 logical adflag
4980 parameter (mad=26,nflds=11)
4990 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
5000 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
5010 &                adflag(mad,nflds)
5020
5030 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','setzip')
5040 zip(adr)=str
5050 adflag(adr,11)=.true.
5060 return
5070 end
```

```
5080 *
5090 *  asm
5100 *
5110 *  get branch-or-code field from adr
5120 *
5130 character*(20) function getboc(adr)
5140 implicit
5150 character*30 sop,coa
5160 character*25 cit,ln
5170 character*20 boc,gn
5180 character*10 tit
5190 character*9  zip
5200 character*5  ser
5210 character*2  gsl,st
5220 integer  nca,mad,nflds,adr,j
5230 logical adflag
5240 parameter (mad=26,nflds=11)
5250 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
5260 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
5270 &                adflag(mad,nflds)
5280
5290 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getboc')
5300 if (adflag(adr,1)) go to 20
5310 do 10 j=1,nflds
5320   if (adflag(adr,j)) call ueadrp('asm','getboc')
5330 10     continue
5340 call ueadru('asm','getboc')
5350 20     continue
5360 getboc=boc(adr)
5370 return
5380 end
```

```
5390 *
5400 *  asm
5410 *
5420 *  get city field from adr
5430 *
5440 character*(25) function getcit(adr)
5450 implicit
5460 character*30 sop,coa
5470 character*25 cit,ln
5480 character*20 boc,gn
5490 character*10 tit
5500 character*9  zip
5510 character*5  ser
5520 character*2  gsl,st
5530 integer  nca,mad,nflds,adr,j
5540 logical adflag
5550 parameter (mad=26,nflds=11)
5560 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
5570 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
5580 &                adflag(mad,nflds)
5590
5600 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getcit')
5610 if (adflag(adr,2)) go to 20
5620 do 10 j=1,nflds
5630   if (adflag(adr,j)) call ueadrp('asm','getcit')
5640 10     continue
5650 call ueadru('asm','getcit')
5660 20     continue
5670 getcit=cit(adr)
5680 return
5690 end
```

```
5700 *
5710 *  asm
5720 *
5730 *  get command-or-activity field from adr
5740 *
5750 character*(30) function getcoa(adr)
5760 implicit
5770 character*30 sop,coa
5780 character*25 cit,ln
5790 character*20 boc,gn
5800 character*10 tit
5810 character*9  zip
5820 character*5  ser
5830 character*2  gsl,st
5840 integer  nca,mad,nflds,adr,j
5850 logical adflag
5860 parameter (mad=26,nflds=11)
5870 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
5880 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
5890 &                adflag(mad,nflds)
5900
5910 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getcoa')
5920 if (adflag(adr,3)) go to 20
5930 do 10 j=1,nflds
5940   if (adflag(adr,j)) call ueadrp('asm','getcoa')
5950 10     continue
5960 call ueadru('asm','getcoa')
5970 20     continue
5980 getcoa=coa(adr)
5990 return
6000 end
```

```
6010 *
6020 *  asm
6030 *
6040 *  get given-names field from adr
6050 character*(20) function getgn(adr)
6060 implicit
6070 character*30 sop,coa
6080 character*25 cit,ln
6090 character*20 boc,gn
6100 character*10 tit
6110 character*9  zip
6120 character*5  ser
6130 character*2  gsl,st
6140 integer  nca,mad,nflds,adr,j
6150 logical adflag
6160 parameter (mad=26,nflds=11)
6170 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
6180 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
6190 &                adflag(mad,nflds)
6200
6210 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getgn')
6220 if (adflag(adr,4)) go to 20
6230 do 10 j=1,nflds
6240   if (adflag(adr,j)) call ueadrp('asm','getgn')
6250 10     continue
6260 call ueadru('asm','getgn')
6270 20     continue
6280 getgn=gn(adr)
6290 return
6300 end
```

```
6310 *
6320 *  asm
6330 *
6340 *  get gs-level field from adr
6350 *
6360 character*(2) function getgsl(adr)
6370 implicit
6380 character*30 sop,coa
6390 character*25 cit,ln
6400 character*20 boc,gn
6410 character*10 tit
6420 character*9  zip
6430 character*5  ser
6440 character*2  gsl,st
6450 integer  nca,mad,nflds,adr,j
6460 logical adflag
6470 parameter (mad=26,nflds=11)
6480 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
6490 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
6500 &                adflag(mad,nflds)
6510
6520 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getgsl')
6530 if (adflag(adr,5)) go to 20
6540 do 10 j=1,nflds
6550   if (adflag(adr,j)) call ueadrp('asm','getgsl')
6560 10     continue
6570 call ueadru('asm','getgsl')
6580 20     continue
6590 getgsl=gsl(adr)
6600 return
6610 end
```

```
6620 *
6630 *  asm
6640 *
6650 *  get last-name field from adr
6660 *
6670 character*(25) function getln(adr)
6680 implicit
6690 character*30 sop,coa
6700 character*25 cit,ln
6710 character*20 boc,gn
6720 character*10 tit
6730 character*9  zip
6740 character*5  ser
6750 character*2  gsl,st
6760 integer  nca,mad,nflds,adr,j
6770 logical adflag
6780 parameter (mad=26,nflds=11)
6790 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
6800 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
6810 &                adflag(mad,nflds)
6820
6830 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getln')
6840 if (adflag(adr,6)) go to 20
6850 do 10 j=1,nflds
6860   if (adflag(adr,j)) call ueadrp('asm','getln')
6870 10     continue
6880 call ueadru('asm','getln')
6890 20     continue
6900 getln=ln(adr)
6910 return
6920 end
```

```
6930 *
6940 *  asm
6950 *
6960 *  get service field from adr
6970 *
6980 character*(5) function getser(adr)
6990 implicit
7000 character*30 sop,coa
7010 character*25 cit,ln
7020 character*20 boc,gn
7030 character*10 tit
7040 character*9  zip
7050 character*5  ser
7060 character*2  gsl,st
7070 integer  nca,mad,nflds,adr,j
7080 logical adflag
7090 parameter (mad=26,nflds=11)
7100 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
7110 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
7120 &                adflag(mad,nflds)
7130
7140 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getser')
7150 if (adflag(adr,7)) go to 20
7160 do 10 j=1,nflds
7170   if (adflag(adr,j)) call ueadrp('asm','getser')
7180 10     continue
7190 call ueadru('asm','getser')
7200 20     continue
7210 getser=ser(adr)
7220 return
7230 end
```

```
7240 *
7250 *  asm
7260 *
7270 *  get street-or-post-office-box field from adr
7280 *
7290 character*(30) function getsop(adr)
7300 implicit
7310 character*30 sop,coa
7320 character*25 cit,ln
7330 character*20 boc,gn
7340 character*10 tit
7350 character*9  zip
7360 character*5  ser
7370 character*2  gsl,st
7380 integer  nca,mad,nflds,adr,j
7390 logical adflag
7400 parameter (mad=26,nflds=11)
7410 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
7420 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
7430 &                adflag(mad,nflds)
7440
7450 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getsop')
7460 if (adflag(adr,8)) go to 20
7470 do 10 j=1,nflds
7480   if (adflag(adr,j)) call ueadrp('asm','getsop')
7490 10     continue
7500 call ueadru('asm','getsop')
7510 20     continue
7520 getsop=sop(adr)
7530 return
7540 end
```

```
7550 *
7560 *  asm
7570 *
7580 *  get state field from adr
7590 *
7600 character*(2) function getst(adr)
7610 implicit
7620 character*30 sop,coa
7630 character*25 cit,ln
7640 character*20 boc,gn
7650 character*10 tit
7660 character*9  zip
7670 character*5  ser
7680 character*2  gsl,st
7690 integer  nca,mad,nflds,adr,j
7700 logical adflag
7710 parameter (mad=26,nflds=11)
7720 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
7730 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
7740 &                adflag(mad,nflds)
7750
7760 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getst')
7770 if (adflag(adr,9)) go to 20
7780 do 10 j=1,nflds
7790   if (adflag(adr,j)) call ueadrp('asm','getst')
7800 10     continue
7810 call ueadru('asm','getst')
7820 20     continue
7830 getst=st(adr)
7840 return
7850 end
```

```
7860 *
7870 *  asm
7880 *
7890 *  get title field from adr
7900 *
7910 character*(10) function gettit(adr)
7920 implicit
7930 character*30 sop,coa
7940 character*25 cit,ln
7950 character*20 boc,gn
7960 character*10 tit
7970 character*9  zip
7980 character*5  ser
7990 character*2  gsl,st
8000 integer  nca,mad,nflds,adr,j
8010 logical adflag
8020 parameter (mad=26,nflds=11)
8030 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
8040 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
8050 &                adflag(mad,nflds)
8060
8070 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','gettit')
8080 if (adflag(adr,10)) go to 20
8090 do 10 j=1,nflds
8100   if (adflag(adr,j)) call ueadrp('asm','gettit')
8110 10     continue
8120 call ueadru('asm','gettit')
8130 20     continue
8140 gettit=tit(adr)
8150 return
8160 end
```

```
8170 *
8180 *  asm
8190 *
8200 *  get zip-code field from adr
8210 *
8220 character*(9) function getzip(adr)
8230 implicit
8240 character*30 sop,coa
8250 character*25 cit,ln
8260 character*20 boc,gn
8270 character*10 tit
8280 character*9  zip
8290 character*5  ser
8300 character*2  gsl,st
8310 integer  nca,mad,nflds,adr,j
8320 logical adflag
8330 parameter (mad=26,nflds=11)
8340 common  /asmblk/nca,sop(mad),coa(mad),cit(mad),ln(mad),boc(mad),
8350 &            gn(mad),tit(mad),zip(mad),ser(mad),gsl(mad),st(mad),
8360 &                adflag(mad,nflds)
8370
8380 if (adr.lt.1.or.adr.gt.mad) call ueaida('asm','getzip')
8390 if (adflag(adr,11)) go to 20
8400 do 10 j=1,nflds
8410   if (adflag(adr,j)) call ueadrp('asm','getzip')
8420 10     continue
8430 call ueadru('asm','getzip')
8440 20     continue
8450 getzip=zip(adr)
8460 return
8470 end
```

```
8480 *
8490 *  chm
8500 *
8510 *  define internal character comparison code
8520 *
8530 block data
8540 integer mask,intchr
8550 common /chmblk/intchr(128)
8560 data intchr/0,-1,-2,-3,-4,-5,-6,-7,-8,-9,-10,-11,
8570 &-12,-13,-14,-15,-16,-17,-18,-19,-20,-21,-22,-23,-24,
8580 &-25,-26,-27,-28,-29,-30,-31,1,-32,-33,-34,-35,-36,
8590 &-37,-38,-39,-40,-41,-42,-43,-44,-45,-46,28,29,30,31,
8600 &32,33,34,35,36,37,-47,-48,-49,-50,-51,-52,-53,2,3,
8610 &4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,
8620 &23,24,25,26,27,-54,-55,-56,-57,-58,-59,2,3,4,5,6,7,
8630 &8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,
8640 &26,27,-60,-61,-62,-63,-64/
8650 end
8660 *
8670 *  chm
8680 *
8690 *  character equality test
8700 *
8710 logical function chareq(ch1,ch2)
8720 character*1 ch1,ch2
8730 integer mask,intchr,int1,int2,ichar
8740 common /chmblk/intchr(128)
8760
8770 int1=ichar(ch1)
8780 int2=ichar(ch2)
8790 chareq=intchr(int1+1).eq.intchr(int2+1)
8800 return
8810 end
8820 *
8830 *  chm
8840 *
8850 *  character less-than comparison
8860 *
8870 logical function charlt(ch1,ch2)
8880 character*1 ch1,ch2
8890 integer mask,intchr,int1,int2,ichar
8900 common /chmblk/intchr(128)
8910
8930 int1=ichar(ch1)
8940 int2=ichar(ch2)
8950 if (intchr(int1+1).le.0) call uechlt('chm','charlt')
8960 if (intchr(int2+1).le.0) call uechlt('chm','charlt')
8970 charlt=intchr(int1+1).lt.intchr(int2+1)
8980 return
8990 end
```

```
9000 *
9010 *  idm
9020 *
9030 *  initialize
9040 *
9050 block data
9060 implicit
9070 character*60 buffer
9080 integer bufpos,bufsiz,unit
9090 logical idop
9100 common /idmblk/bufpos,idop,buffer
9110 data bufpos/60/idop/.false./
9120 end
9130 *
9140 *  idm
9150 *
9160 *  open input device
9170 *
9180 subroutine openid
9190 implicit
9200 character*60 buffer
9210 integer bufpos,bufsiz,unit
9220 logical idop
9230 parameter(unit=5)
9240 common /idmblk/bufpos,idop,buffer
9250
9260 if (idop)call ueropn('idm','openid')
9270 open(unit,"tdata26")
9280 idop=.true.
9290 return
9300 end
9310 *
9320 *  idm
9330 *
9340 *  close input file
9350 *
9360 subroutine closid
9370 implicit
9380 character*60 buffer
9390 integer bufpos,bufsiz,unit
9400 logical idop
9410 parameter (unit=5)
9420 common /idmblk/bufpos,idop,buffer
9430
9440 if (.not.idop) call uercls('idm','closid')
9450 close (unit)
9460 idop=.false.
9470 return
9480 end
```

```
9490 *
9500 *  idm
9510 *
9520 *  read character from input stream
9530 *
9540 *  this f4p compiler treats an end-of-file condition as an
9550 *  device error condition. so there is no implementation
9560 *  of the device error ue.
9570 *
9580 character*1 function rdchar
9590 implicit
9600 character*1 getchr
9610 character*60 buffer
9620 integer bufpos,bufsiz,unit
9630 logical idop
9640 parameter (unit=5)
9650 common /idmblk/bufpos,idop,buffer
9660
9670 if (.not.idop) call uewrcl('idm','rdchar')
9680 if (bufpos.lt.60) go to 10
9690 read (unit,100,err=30,end=20) buffer
9700 bufpos=0
9710 10     bufpos=bufpos+1
9720 rdchar=getchr(buffer,bufpos)
9730 return
9740 20     call uenoch('idm','rdchar')
9750 return
9760 30     call uedver('idm','rdchar')
9770 return
9780 100 format (a60)
9790 end
```

```
9800 *
9810 *  ipm
9820 *
9830 *  read and store input addresses
9840 *
9850 subroutine rdads
9860 implicit
9870 character*20 coa,rdfld,endstr
9880 integer nads,maxads,mads
9890 logical streq
9900 data endstr /'********************'/
9910
9920 call openid
9930 mads=maxads()
9940 nads=0
9950 1 coa=rdfld(20)
9960 if (streq(coa,endstr)) go to 20
9970 nads=nads+1
9980 if (nads.gt.mads) call ueadov('ipm','rdads')
9990 call setcoa (nads,coa)
10000 call setsop (nads,rdfld(20))
10010 call setcit (nads,rdfld(20))
10020 call setst (nads,rdfld(2))
10030 call setzip (nads,rdfld(7))
10040 call settit (nads,rdfld(4))
10050 call setgn (nads,rdfld(20))
10060 call setln (nads,rdfld(15))
10070 call setboc (nads,rdfld(20))
10080 call setgsl (nads,rdfld(2))
10090 call setser (nads,rdfld(4))
10100 go to 1
10110 20 call verads
10120 call closid
10130 return
10140 end
10150 *
10160 *  ipm
10170 *
10180 *  read and create an address field string
10190 *
10200 character *(*) function rdfld(length)
10210 implicit
10220 character*1 chr, rdchar
10230 integer length,i
10240
10250 rdfld=" "
10260 do 10 i=1,length
10270   call setchr(rdfld,i,rdchar())
10280 10 continue
10290 return
10300 end
```

```
10310 *
10320 * mcm
10330 *
10340 program mcm
10350 implicit
10360 integer i
10370 character *1 getchr
10380 character *2 oglim
10390 character *3 prezip
10400
10410 call initas
10420 call openod
10430 call newlin
10440 call wrchar (' ')
10450 call newlin
10460 do 106 i=1,23
10470   call wrchar(getchr('starting address input.',i))
10480 106 continue
10490 call rdads
10500 call newlin
10510 call wrchar(' ')
10520 call newlin
10530 do 107 i=1,25
10540   call wrchar(getchr('address reading complete.',i))
10550 107 continue
10560 prezip = '203'
10570 call newlin
10580 call wrchar(' ')
10590 call newlin
10600 do 108 i=1,18
10610   call wrchar(getchr('output of area is:',i))
10620 108 continue
10630 call area(prezip)
10640 oglim = '10'
10650 call newlin
10660 call wrchar(' ')
10670 call newlin
10680 do 109 i=1,18
10690   call wrchar(getchr('output of rank is:',i))
10700 109 continue
10710 call rank(oglim)
10720 call newlin
10730 call wrchar(' ')
10740 call newlin
10750 do 110 i=1,17
10760   call wrchar(getchr('end of madds run.',i))
10770 110 continue
10780 call newlin
10790 call closod
10800 stop
10810 end
```

```
10820 *  odm
10830 *
10840 *  initialize output device
10850 *
10860 block data
10870 implicit
10880 character*60 line
10890 integer linlen, linpos
10900 logical odop
10910 common /odmblk/linpos,odop,line
10920 data linpos/1/,odop/.false./
10930 end
10940 *
10950 *  odm
10960 *
10970 *  open output device
10980 *
10990 subroutine openod
11000 implicit
11010 character*60  line
11020 integer linlen,linpos
11030 logical odop
11040 common /odmblk/linpos,odop,line
11050
11060 if (odop) call ueropn('odm','openod')
11070 odop=.true.
11080 return
11090 end
11100 *
11110 *  odm
11120 *
11130 *  close output file
11140 *
11150 subroutine closod
11160 implicit
11170 character*60  line
11180 integer linpos,linlen
11190 logical odop
11200 common /odmblk/linpos,odop,line
11210
11220 if (.not.odop) call uercls('odm','closod')
11230 odop=.false.
11240 return
11250 end
```

```
11260 *
11270 *  odm
11280 *
11290 *  write character to output stream
11300 *
11310 subroutine wrchar(chr)
11320 implicit
11330 character*1 chr
11340 character*60  line
11350 integer linpos, linlen
11360 logical odop
11370 common /odmblk/linpos,odop,line
11380
11390 if (.not.odop) call uewrcl('odm','wrchar')
11400 call setchr(line,linpos,chr)
11410 linpos=linpos+1
11420 if (linpos.le.60)return
11430 write(0,100,err=20)line
11440 linpos=1
11450 return
11460 20     call uedver('odm','wrchar')
11470 return
11480 100 format (1x,a60)
11490 end
11500 *
11510 *  odm
11520 *
11530 *  write current line unless empty and get new line
11540 *
11550 subroutine newlin
11560 implicit
11570 character*60 line,getchr
11580 integer linpos,linlen,i
11590 logical odop
11600 common /odmblk/linpos,odop,line
11610
11620 if (.not.odop) call uewrcl('odm','wrchar')
11630 if (linpos.eq.1) return
11640 write (0,100,err=20) (getchr(line,i),i=1,linpos-1)
11650 linpos=1
11660 return
11670 20 call uedver('odm','newlin')
11680 return
11690 100 format (1x,60a)
11700 end
```

```
11710 *
11720 * opm
11730 *
11740 *  write address adr
11750 *
11760 subroutine wradr(adr)
11770 implicit
11780 character*30 getcoa
11790 character*20 getcit,getln
11800 character*20 getgn,getboc
11810 character*10 gettit
11820 character*9 getzip
11830 character*2 getst
11840 integer maxads,getnca,mads,adr,i
11850
11860 mads=maxads()
11870 if (adr.lt.1.or.adr.gt.mads)
11880 &   call ueaida('opm','wrads')
11890 if (getnca().lt.adr.and.adr.le.mads)
11900 &call ueaidu('opm','wradr')
11910 call newlin
11920 call wrfld(gettit(adr))
11930 call wrchar(' ')
11940 call wrfld(getgn(adr))
11950 call wrchar(' ')
11960 call wrfld(getln(adr))
11970 call newlin
11980 call wrfld(getboc(adr))
11990 call newlin
12000 call wrfld(getcoa(adr))
12010 call newlin
12020 call wrfld(getcit(adr))
12030 call wrchar(',')
12040 call wrchar(' ')
12050 call wrfld(getst(adr))
12060 call wrchar(' ')
12070 call wrfld(getzip(adr))
12080 call newlin
12090 do 10 i=1,5
12100   call wrchar(' ')
12110   call newlin
12120 10 continue
12130 return
12140 end
```

```
12150 *
12160 *  opm
12170 *
12180 *  write a field
12190 *
12200 subroutine wrfld(str)
12210 implicit
12220 character *(*) str
12230 character*1 getchr
12240 integer nblank,i,n
12250 n=nblank(str)
12260 if (n.gt.0) go to 5
12270 do 4 i=1,5
12280 4 call wrchar('*')
12290 return
12300 5 do 10 i=1,n
12310   call wrchar(getchr(str,i))
12320 10 continue
12330 return
12340 end
```

```
12350 *  ssm
12360 *
12370 *  replace character at position pos of str by chr
12380 *
12390 subroutine setchr(str,pos,chr)
12400 implicit
12410 character *1 chr
12420 character *(*) str
12430 integer pos,len
12440 if (pos.lt.1.or.pos.gt.len(str)) call uespos('ssm','setchr')
12450 str(pos:pos)=chr
12460 return
12470 end
12480 *
12490 *  ssm
12500 *
12510 *  get character at position pos of str
12520 *
12530 character *1 function getchr(str,pos)
12540 implicit
12550 character *(*) str
12560 integer len,pos
12570 if (pos.lt.1.or.pos.gt.len(str)) call uespos('ssm','getchr')
12580 getchr=str(pos:pos)
12590 return
12600 end
12610 *
12620 *  ssm
12630 *
12640 *  create substring of sir
12650 *
12660 character *(*) function substr(str,pos,length)
12670 implicit
12680 character *(*) str
12690 integer  pos,length, len, strlen, uppos
12700 strlen = len(str)
12710 uppos = pos+length-1
12720 if (pos.lt.1.or.pos.gt.strlen) call uespos('ssm','substr')
12730 if (length.lt.0.or.uppos.gt.strlen)
12740 &call ueslen('ssm','substr')
12750 substr = " "
12760 if (length.eq.0) return
12770 substr=str(pos:uppos)
12780 return
12790 end
```

```
12800 *
12810 *  ssm
12820 *
12830 *  string equality test
12840 *
12850 logical function streq(str1,str2)
12860 implicit
12870 character*(*) str1,str2
12880 integer 1,len,l1,l2,min,i
12890 logical chareq
12900 l1=len(str1)
12910 l2=len(str2)
12920 l=min(l1,l2)
12930 streq=.false.
12940 do 10 i=1,l
12950   if (.not. chareq(str1(i:i),str2(i:i)))return
12960 10  continue
12970 if (l1-l2) 100,200,300
12980 100  do 110 i=l1+1,l2
12990        if (.not.chareq(str2(i:i)," "))return
13000 110  continue
13010 streq=.true.
13020 return
13030 200 streq=.true.
13040 return
13050 300 do 310 i=l2+1,l1
13060       if (.not.chareq(str1(i:i)," "))return
13070 310  continue
13080 streq= .true.
13090 return
13100 end
```

```
13110 *
13120 *  ueh
13130 *
13140 *  data definitions for ue handlers
13150 *
13160 block data
13170 implicit
13180 character*3 mids
13190 integer nmods
13200 parameter (nmods=9)
13210 common /uehblk/mids(nmods)
13220 data mids/'apm','asm','chm','idm','ipm','mcm','odm','opm',
13230         &'ssm'/
13240 end
13250 *
13260 *  ueh
13270 *
13280 *  handler of ue: address storage capacity overflow
13290 *
13300 subroutine ueadov(mdid,fnid)
13310 implicit
13320 character*3 mids
13330 character*(*) mdid,fnid
13340 integer nmods,j
13350 parameter (nmods=9)
13360 common /uehblk/mids(nmods)
13370
13380 do 20 j=1,nmods
13390   if (mdid.eq.mids(j)) go to 30
13400 20     continue
13410 call uemidu('ueh','adcv')
13420 30     write(0,100) fnid,mdid
13430 100 format (/' *** the ue:  addresss storage capacity overflow '/
13440 &'     detected in function ',a,' of module ',a,'.'/
13450 &'     execution terminated.')
13460 call error (" ")
13470 stop
13480 end
```

```
13490 *
13500 *  ueh
13510 *
13520 *  handler for ue: partially defined address
13530 *
13540 subroutine ueadrp(mdid,fnid)
13550 implicit
13560 character*3 mids
13570 character*(*) mdid,fnid
13580 integer nmods,j
13590 parameter (nmods=9)
13600 common /uehblk/mids(nmods)
13610
13620 do 20 j=1,nmods
13630   if (mdid.eq.mids(j)) go to 30
13640 20     continue
13650 call uemidu('ueh','adrp')
13660 30     write(0,100) fnid,mdid
13670 100 format (/' *** the ue:  partially defined address '/
13680 &'     detected in function ',a,' of module ',a,'.'/
13690 &'     execution terminated.')
13700 call error (" ")
13710 stop
13720 end
13730 *
13740 *  ueh
13750 *
13760 *  handler for ue: undefined address
13770 *
13780 subroutine ueadru(mdid,fnid)
13790 implicit
13800 character*3 mids
13810 character*(*) mdid,fnid
13820 integer nmods,j
13830 parameter (nmods=9)
13840 common /uehblk/mids(nmods)
13850
13860 do 20 j=1,nmods
13870   if (mdid.eq.mids(j)) go to 30
13880 20     continue
13890 call uemidu('ueh','adru')
13900 30     write (0,100) fnid,mdid
13910 100 format (/' *** the ue:  undefined address '/
13920 &'     detected in function 'a,' of module ',a,'.'/
13930 &'     execution terminated.')
13940 call error (" ")
13950 stop
13960 end
```

```
13970 *
13980 *  ueh
13990 *
14000 *  handler for ue:  absurd address identifier
14010 *
14020 subroutine ueaida(mdid,fnid)
14030 implicit
14040 character*3 mids
14050 character*(*) mdid,fnid
14060 integer nmods,j
14070 parameter (nmods=9)
14080 common /uehblk/mids(nmods)
14090
14100 do 20 j=1,nmods
14110   if (mdid.eq.mids(j)) go to 30
14120 20     continue
14130 call uemidu('ueh','aida')
14140 30     write (0,100) fnid,mdid
14150 100 format (/' *** the ue:  absurd address identifier '/
14160 &'     detected in function ',a,' of module ',a,'.'/
14170 &'     execution terminated.')
14180 call error (" ")
14190 stop
14200 end
14210 *
14220 *  ueh
14230 *
14240 *  handler for ue:  unassigned address identifier
14250 *
14260 subroutine ueaidu(mdid,fnid)
14270 implicit
14280 character*3 mids
14290 character*(*) mdid,fnid
14300 integer nmods,j
14310 parameter (nmods=9)
14320 common /uehblk/mids(nmods)
14330
14340 do 20 j=1,nmods
14350   if (mdid.eq.mids(j)) go to 30
14360 20     continue
14370 call uemidu('ueh','aidu')
14380 30     write (0,100) fnid,mdid
14390 100 format (/' *** the ue:  unassigned address identifier '/
14400 &'     detected in function ',a,' of module ',a,'.'/
14410 &'     execution terminated.')
14420 call error (" ")
14430 stop
14440 end
```

```
14450 *
14460 *  ueh
14470 *
14480 *  handler for ue:  state of asm incorrect
14490 *
14500 subroutine ueasmi(mdid,fnid)
14510 implicit
14520 character*3 mids
14530 character*(*) mdid,fnid
14540 integer nmods,j
14550 parameter (nmods=9)
14560 common /uehblk/mids(nmods)
14570
14580 do 20 j=1,nmods
14590   if (mdid.eq.mids(j)) go to 30
14600 20     continue
14610 call uemidu('ueh','asmi')
14620 30     write (0,100) fnid,mdid
14630 100 format (/' *** ue:  state of asm incorrect '/
14640 &'     detected in function ',a,' of module ',a,'.'/
14650 &'     execution terminated.')
14660 call error (" ")
14670 stop
14680 end
14690 *
14700 *  ueh
14710 *
14720 *  handler for ue:  undefined character comparison
14730 *
14740 subroutine uechlt(mdid,fnid)
14750 implicit
14760 character*3 mids
14770 character*(*) mdid,fnid
14780 integer nmods,j
14790 parameter (nmods=9)
14800 common /uehblk/mids(nmods)
14810
14820 do 20 j=1,nmods
14830   if (mdid.eq.mids(j)) go to 30
14840 20     continue
14850 call uemidu('ueh','chlt')
14860 30     write (0,100)  fnid,mdid
14870 100 format (/' *** the ue:  undefined character comparison '/
14880 &'     detected in function ',a,' of module ',a,'.'/
14890 &'     execution terminated.')
14900 call error (" ")
14910 stop
14920 end
```

```
14930 *
14940 *  ueh
14950 *
14960 *  handler for ue: device error
14970 *
14980 subroutine uedver(mdid,fnid)
14990 implicit
15000 character*3 mids
15010 character*(*) mdid,fnid
15020 integer nmods,j
15030 parameter (nmods=9)
15040 common /uehblk/ mids(nmods)
15050
15060 do 20 j=1,nmods
15070   if (mdid.eq.mids(j)) go to 30
15080 20     continue
15090 call uemidu('ueh','dver')
15100 30     write (0,100) fnid,mdid
15110 100 format (/' *** the ue:  device error '/
15120 &'     detected in function ',a,' of module 'a,'.'/
15130 &'     execution terminated.')
15140 call error (" ")
15150 stop
15160 end
15170 *
15180 *  ueh
15190 *
15200 *  handler for ue: non-existent module identifier
15210 *
15220 subroutine uemidu(mdid,fnid)
15230 implicit
15240 character*(*) mdid,fnid
15250 30 write (0,100)fnid,mdid
15260 100 format (/' *** the ue:  non-existent module identifier '/
15270 &'     detected in function ',a,' of module 'a,'.'/
15280 &'     execution terminated.')
15290 call error (" ")
15300 stop
15310 end
```

```
15320 *
15330 *  ueh
15340 *
15350 *  handler for ue: number of complete addresses undefined
15360 *
15370 subroutine uencau(mdid,fnid)
15380 implicit
15390 character*3 mids
15400 character*(*) mdid,fnid
15410 integer nmods,j
15420 parameter (nmods=9)
15430 common /uehblk/mids(nmods)
15440
15450 do 20 j=1,nmods
15460   if (mdid.eq.mids(j)) go to 30
15470 20     continue
15480 call uemidu('ueh','ncau')
15490 30     write (0,100) fnid,mdid
15500 100 format (/' *** the ue:  number of complete addresses undefined '/
15510 &'     detected in function ',a,' of module ',a,'.'/
15520 &'     execution terminated.')
15530 call error (" ")
15540 stop
15550 end
15560 *
15570 *  ueh
15580 *
15590 *  handler for ue: no chars available on input device
15600 *
15610 subroutine uenoch(mdid,fnid)
15620 implicit
15630 character*3 mids
15640 character*(*) mdid,fnid
15650 integer nmods,j
15660 parameter (nmods=9)
15670 common /uehblk/mids(nmods)
15680
15690 do 20 j=1,nmods
15700   if (mdid.eq.mids(j)) go to 30
15710 20     continue
15720 call uemidu('ueh','noch')
15730 30     write (0,100) fnid,mdid
15740 100 format (/' *** the ue:  no chars available on input device '/
15750 &'     detected in function ',a,' of module ',a,'.'/
15760 &'     execution terminated.')
15770 call error (" ")
15780 stop
15790 end
```

```
15800 *
15810 *  ueh
15820 *
15830 *  handler for ue: 0-grade level < 1 or > 10
15840 *
15850 subroutine ueogl(mdid,fnid)
15860 implicit
15870 character*3 mids
15880 character*(*) mdid,fnid
15890 integer nmods,j
15900 parameter (nmods=9)
15910 common /uehblk/mids(nmods)
15920
15930 do 20 j=1,nmods
15940   if (mdid.eq.mids(j)) go to 30
15950 20     continue
15960 call uemidu('ueh','ogl')
15970 30     write (0,100) fnid,mdid
15980 100 format (/' *** the ue: 0-grade level < 1 or > 10 '/
15990 &'     detected in function ',a,' of module ',a,'.'/
16000 &'     execution terminated.')
16010 call error (" ")
16020 stop
16030 end
16040 *
16050 *  ueh
16060 *
16070 *  handler for ue: redundant device closing
16080 *
16090 subroutine uercls(mdid,fnid)
16100 implicit
16110 character*3 mids
16120 character*(*) mdid,fnid
16130 integer nmods,j
16140 parameter (nmods=9)
16150 common /uehblk/mids(nmods)
16160
16170 do 20 j=1,nmods
16180   if (mdid.eq.mids(j)) go to 30
16190 20     continue
16200 call uemidu('ueh','rcls')
16210 30     write (0,100) fnid,mdid
16220 100 format (/' *** the ue:  redundant device closing '/
16230 &'     detected in function ',a,' of module ',a,'.'/
16240 &'     execution terminated.')
16250 call error (" ")
16260 stop
16270 end
```

```
16280 *
16290 *  ueh
16300 *
16310 *  handler for ue: redundant devi*e opening
16320 subroutine ueropn(mdid,fnid)
16330 implicit
16340 character*3 mids
16350 character*(*) mdid,fnid
16360 integer nmods,j
16370 parameter (nmods=9)
16380 common /uehblk/mids(nmods)
16390
16400 do 20 j=1,nmods
16410   if (mdid.eq.mids(j)) go to 30
16420 20     continue
16430 call uemidu('ueh','ropn')
16440 30     write (0,100) fnid,mdid
16450 100 format (/' *** the ue: redundant device opening '/
16460 &'     detected in function ',a,' of module ',a,'.'/
16470 &'     execution terminated.')
16480 call error (" ")
16490 stop
16500 end
16510 *
16520 *  ueh
16530 *
16540 *  handler for ue:  substring length illegal
16550 *
16560 subroutine ueslen(mdid,fnid)
16570 implicit
16580 character*3 mids
16590 character*(*) mdid,fnid
16600 integer nmods,j
16610 parameter (nmods=9)
16620 common /uehblk/mids(nmods)
16630
16640 do 20 j=1,nmods
16650   if (mdid.eq.mids(j)) go to 30
16660 20     continue
16670 call uemidu('ueh','slen')
16680 30     write (0,100) fnid,mdid
16690 100 format (/' *** the ue: substring length illegal '/
16700 &'     detected in function ',a,' of module ',a,'.'/
16710 &'     execution terminated.')
16720 call error (" ")
16730 stop
16740 end
```

```
16750 *
16760 *  ueh
16770 *
16780 *  handler for ue: string character position illegal
16790 *
16800 subroutine uespos(mdid,fnid)
16810 implicit
16820 character*3 mids
16830 character*(*) mdid,fnid
16840 integer nmods,j
16850 parameter (nmods=9)
16860 common /uehblk/mids(nmods)
16870
16880 do 20 j=1,nmods
16890   if (mdid.eq.mids(j)) go to 30
16900 20     continue
16910 call uemidu('ueh','spos')
16920 30     write (0,100) fnid,mdid
16930 100 format (/' *** the ue:  string character position illegal '/
16940 &'     detected in function ',a,' of module ',a,'.'/
16950 &'     execution terminated.')
16960 call error (" ")
16970 stop
16980 end
16990 *
17000 *  ueh
17010 *
17020 *  handler for ue: write/read on closed device
17030 *
17040 subroutine uewrcl(mdid,fnid)
17050 implicit
17060 character*3 mids
17070 character*(*) mdid,fnid
17080 integer nmods,j
17090 parameter (nmods=9)
17100 common /uehblk/mids(nmods)
17110
17120 do 20 j=1,nmods
17130   if (mdid.eq.mids(j)) go to 30
17140 20     continue
17150 call uemidu('ueh','wrcl')
17160 30     write (0,100) fnid,mdid
17170 100 format (/' *** the ue:  write/read on closed device '/
17180 &'     detected in function ',a,' of module ',a,'.'/
17190 &'     execution terminated.')
17200 call error (" ")
17210 stop
17220 end
```

```
17230 *
17240 *  ueh
17250 *
17260 *  handler for ue:  zip area part not 3 de* digs
17270 *
17280 subroutine uezip(mdid,fnid)
17290 implicit
17300 character*3 mids
17310 character*(*) mdid,fnid
17320 integer nmods,j
17330 parameter (nmods=9)
17340 common /uehblk/mids(nmods)
17350
17360 do 20 j=1,nmods
17370   if (mdid.eq.mids(j)) go to 30
17380 20     continue
17390 call uemidu('ueh','zip')
17400 30     write (0,100) fnid,mdid
17410 100 format (/' *** the ue:  zip area part not 3 dec digs '/
17420 &'     detected in function ',a,' of module ',a,'.'/
17430 &'     execution terminated.')
17440 call error (" ")
17450 stop
17460 end
```

HAS.1 The Host-at-Sea (HAS) Buoy System

EXAMPLE DESCRIPTION

Introduction

The Navy intends to deploy HAS buoys to provide navigation and weather data to air and ship traffic at sea The buoys will collect wind, temperature, and location data, and will broadcast summaries periodically. Passing vessels will be able to request more detailed information. In addition, HAS buoys will be deployed in the event of accidents at sea to aid sea search operations.

Rapid deployment and the use of disposable equipment are novel features of HAS. HAS buoys will be relatively inexpensive, lightweight systems that may be deployed by being dropped from low-flying aircraft. It is expected that many of the HAS buoys will disappear because of equipment deterioration, bad weather conditions, accidents, or hostile action. The ability to redeploy rather than to attempt to prevent such loss is the key to success in the HAS program. In this sense, HAS buoys will be disposable equipment. To keep costs down, government surplus components will be used as much as possible.

Hardware

Each HAS buoy will contain a small computer, a set of wind and temperature sensors, and a radio receiver and transmitter. Eventually, a variety of special purpose HAS buoys may be configured with different types of sensors, such as wave spectra sensors. Although these will not be covered by the initial procurement, provision for future expansion is required.

The HAS-BEEN computer has been chosen for the HAS buoy program. There are more than 3000 of these available as government-surplus equipment. They were originally developed as the standard computer for a balloon force (High Altitude Surveying, or HAS), which is now defunct. Known as the Balloon Internal Navigator, they were originally called HAS-BIN computers; the spelling was corrected in 1976 as part of a presidential program to remove "redneckisms" from government documents.

The HAS-BEEN computer has been found suitable for the new HAS program by virtue of its low weight, low cost, low power consumption, and nomenclature. A preliminary study shows that the capacity of a single BEEN computer will be insufficient for some HAS configurations, but it has been decided to use two or more BEEN computers in these cases. Therefore, provision for multi-processing is required in the software.

The HAS-BEEN computer has a typical complement of full-word integer instructions. Input is performed by a SNS (SENSE) instruction that selects a device and stores the contents of its control register at a designated core

location. Up to 256 different sensors may be connected, and the first 256 core locations are available for depositing the results. The device and corresponding core location are addressed by an 8-bit field in the SNS instruction.

The temperature sensors take air and water temperature (Centigrade). On some HAS buoys, an array of sensors on a cable will be used to take water temperature at various depths.

Because the surplus temperature sensors selected for HAS are not designed for sea-surface conditions, the error range on individual readings may be large. Preliminary experiments indicate that the temperature can be measured within an acceptable tolerance by averaging several readings from the same device. To improve the accuracy further and to guard against sensor failure, most HAS buoys will have multiple temperature sensors.

Each buoy will have one or more wind sensors to observe wind magnitude in knots and wind direction. Surplus propellor-type sensors have been selected because they meet power restrictions.

Buoy geographic position is determined by use of a radio receiver link with the Omega navigation system.

Some HAS buoys are also equipped with a red light and an emergency switch. The red light may be made to flash by a request radioed from a vessel during a sea-search operation. If the sailors are able to reach the buoy, they may flip the emergency switch to initiate SOS broadcasts from the buoy.

Software Functions

The software for the HAS buoy must carry out the following functions:

1. Maintain current wind and temperature information by monitoring sensors regularly and averaging readings.

2. Calculate location via the Omega navigation system.

3. Broadcast wind and temperature information every 60 seconds.

4. Broadcast more detailed reports in response to requests from passing vessels. The information broadcast and the data rate will depend on the type of vessel making the request (ship or airplane). All requests and reports will be transmitted in the RAINFORM format.

5. Broadcast weather history information in response to requests from ships or satellites. The history report consists of the periodic 60-second reports from the last 48 hours.

6. Broadcast an SOS signal in place of the ordinary 60-second message after a sailor flips the emergency switch. This should continue until a vessel sends a reset signal.

7. Accept external update data. Although HAS buoys calculate their own position, they must also accept correction information from passing vessels. The software must use the information to update its internal database. Major discrepancies must cause it to invoke elaborate self diagnostics to attempt to eliminate the errors in future calculations.

8. Perform periodic built-in test (BIT) checks. The software should be able to detect and compensate for memory or computer-function failures. Also, the many sensors of a HAS host are relatively easily damaged and may be providing erroneous data. There should be sufficient sensors to provide reasonableness checks and to allow compensation for those found to be inconsistent or biased. Those found to be nonfunctioning can be ignored in future calculations.

Specifically, the following BIT checks are deemed necessary:

(a) Basic computer function test.

This test is designed to check the most frequently used functions of the computer. It checks arithmetic and control operations and all fast registers. It should be repeated every 350 ms.

(b) Extended computer function test.

This program makes more extensive tests on the basic computer, plus checking less central functions such as I/O and shifts. It should be completed at least once every 5000 ms.

(c) Computer memory function test.

Each word in the memory must be checked by storing and reading all zero, all one, and alternating zero-one bit patterns. A complete check of a 10000 word memory should be completed every 15 minutes.

(d) Sensor consistency tests.

Although each of the sensors provides data independently, there are known constraints on the reasonable relationships that they can have to each other. For example, the many temperature readings can be expected to remain within a few degrees of each other and not to change by more than 20 degrees in 30 minutes. Other sensors such as wind sensors, contain provision for calibration readings. Checks of all wind sensors should be made every 10 minutes. Consistency checks of temperature sensors should be completed every 5 minutes.

Response to Detected Failures

The software is expected to function without noticeable degradation with damage to up to 20% of the sensors. If more than 20% of the sensors are improperly functioning, both periodic and request reports should be marked

"suspect." In the event that the data are considered unusable (e.g., more than 50% of the sensors found malfunctioning), a "defective" report should be sent in place of the suspect data.

In the event that BIT detects malfunctioning of a few specific commands, their simulation by means of sequences of other commands (e.g., simulation of subtraction using addition and negation) should be attempted.

Where areas of memory are found defective, functioning with reduced memory should be attempted. If no more than 10% of memory is defective, relocation without loss of function can be attempted. If more memory is defective, deletion of air temperature calculations should be the first step. Relocation should then allow the performance of the remaining functions.

Software Timing Requirements

In order to maintain accurate information, readings must be taken from the sensing devices at the following fixed intervals:

temperature sensors:	every 10 seconds
wind sensors:	every 30 seconds
Omega signals:	every 10 seconds.

Since the buoy can only transmit one report at a time, conflicts will arise.

If the transmitter is free and more than one report is ready, the next report will be chosen according to the following priority ranking:

SOS	1	highest
Airplane Request	2	
Ship/Satellite Request	3	
Periodic	4	
History	5	lowest

Program Generation

HAS host programs will be generated at the HAS Program Generation Center (NAVHASPGC) located at Chesapeake Beach, Maryland. A NAVHASPGCPAC is also planned for eventual location in Monterey, California. Since different HAS buoys may carry different sets of sensors, HAS-BEEN programs may be different. The software to be procured must include a system generator. To generate a specific program, a configuration (number of sensors of each type) will be described and generation of the program should then be automatic.

HAS.2 HAS Data Acquisition and Transmission Software: Program Design Specification

EXAMPLE DESCRIPTION

COMPUTER SYSTEMS DISTRIBUTORS, INC.

O. U. De Zeeman
Cognizant Software Engineer

R. E. Tired
Contract Liaison Officer

Scope

This document is a detailed description of CSD's proposed design for the HAS system software. The reader is assumed to be familiar with the HAS system functions as described in The Host-At-Sea System (HAS) Buoy System (Document HAS.1).

For a variety of reasons, the document does not assume detailed knowledge of the HAS-BEEN computer, which is GFE for this project. CSD has already expressed its opinion that the HAS-BEEN computer is not ideal for the job. Working together with one of our sister firms, CHIP Corporation, we have proposed a specially designed microprocessor that is ideal for the job. In order to allow the Navy more time for a decision, we have prepared our design in a machine-independent form. However, it has been necessary to recognize two limitations of the HAS-BEEN computer at this early stage of the design process.

(1) HAS BEEN has no interrupt system. Our design calls for periodic polling of sensors.

(2) HAS BEEN has no instructions that are particularly useful in subroutine calls. For that reason, we have avoided subroutine calls in many places where we might have used them.

In spite of the effects of these two limitations, we believe that our design is also applicable to the CHIP computer.

Documentation Approach

"Show me your flowcharts and conceal your tables, and I shall continue to be mystified. Show me your tables, and I won't usually need your flowcharts; they'll be obvious." (Brooks 1975, p. 102)

Believing that data structure dictates program structure, we frequently reference a description of the Common Data Base (CDB), the data structure that keeps track of the state of HAS. A complete description of all of the data items in the system appears in Appendix I (p. 14-10) of this document. We find reference to the CDB description to be of great value in understanding the algorithms used in the system. A representative sample of the algorithms are documented in Appendix II (p. 14-23), using a self-evident, ALGOL-like pseudo code that we believe everyone can readily understand.

The proposed design divides the HAS software into functional modules, each to be constructed by a separate group of programmers. The remainder of this document describes each module separately and then discusses intermodule cooperation.

Module Overview

For the moment, we will ignore the time constraints on the HAS software and instead will describe only the system functions performed by each module. The modules are described below:

Sensor Reading

Each sensor attached to the HAS system is controlled by one sensor-reading module. Whenever the module polls the sensor, the value obtained is converted to engineering units and stored in a location in the CDB.

Averaging

Unweighted time averages are computed for all sensors that are prone to large errors. One averaging module exists for each of these sensors. The averages are stored in the CDB.

Multisensor Averaging

These modules compute averages of readings from more than one sensor. Depending on the type of the sensors being averaged, the readings used are either raw sensor readings (after conversion to engineering units) or time averages. In either case, the readings are obtained from the CDB and the computed averages are stored in the CDB.

Omega Location Calculator

This module obtains Omega data from the CDB, uses the data to compute the current location, and stores the location into the CDB for use by other modules.

Record Updating

This module maintains the 48-hour history in the CDB. Each time it is started, sensor, location, and time values are copied from their locations in the CDB into the appropriate history locations in the CDB.

Receiving Module

This module controls the radio receiving equipment. It scans assigned frequencies for indication of a message transmission, receives the message, and stores it into the CDB for later interpretation.

Message Interpretation

Messages stored in the CDB are parsed, and the module responsible for responding to the message is initiated.

Report Generator

One report generator module exists for each of the five types of reports. Each module is aware of the priority of its type of report with respect to the other types and uses this information to ensure that reports are broadcast according to the prescribed priority ranking. Additionally, each module is able to access the readings it needs in the CDB and to control the transmitting equipment used to broadcast the report.

Location Verification

This module is initiated by the Message Interpretation module when a passing vessel supplies location information. The location information is used to validate Omega location calculations stored in the CDB. Error recovery is attempted if any discrepancy is larger than a specified tolerance.

Buoy Device Control

This module reads any external switch settings on the buoy and controls the operational emergency beacon.

Intermodule Cooperation

Owing to the limitations of the HAS-BEEN computer, we have designed the HAS software as a set of cooperative modules. All intermodule communication is through the CDB. Each of the modules keeps track of real time and is aware of the deadlines of the other modules. They transfer control to each other according to the urgency of the situation. Where several modules are able to process data, and none has an urgent deadline, a fair round-robin scheduling strategy is used. Each module performs this task itself because the HAS-BEEN computer does not contain the preemption circuitry that the more desirable CHIP computer would contain.

When a module needs data produced by another module (a sequencing requirement) or the use of some resource, the requesting module tests a variable in the CDB to determine the status of the resource (data). If the resource is not available, the requesting module sets the variable to indicate that it needs the associated resource and transfers control to another module.

The transfer of control is effected by using Module Control Blocks (MCBs) that are linked into a set of FIFO queues. The MCB, contained in the CDB, serves two purposes: (1) it holds state information such as register contents and the PC, and (2) it contains queue pointers. The module relinquishing control inserts its MCB into a FIFO queue associated with the resource it needs, saves its state into its MCB, selects a module to start, and loads the machine state from the selected module's MCB.

At any given time, it is likely that many modules will be selectable, i.e., all of the resources they require will be available. One of these modules must be selected on the basis of the urgency of the task it performs. Urgency is represented by a dynamically changing module priority; the more urgent the task, the higher is the priority. A FIFO queue of MCBs is associated with each priority level; the selection process is simply to select the first MCB from the highest priority nonempty queue.

The alert reader now has two questions: (1) how do the MCBs get into the selection queues in the first place, and (2) what enforces polling and other real-time deadlines? In order to answer these questions, let us consider a "snapshot" of the system in action. There is one currently executing module, a number of modules waiting for a resource to become available, and some modules that are ready to use the CPU. The MCBs for the resource-blocked modules are in the queue associated with the resource (as described above); the MCBs for the modules needing only the CPU are in selection queues. When the currently executing module makes a resource available (by creating data or no longer needing an actual resource), it moves the first MCB on the resource queue to the selection queue for the priority level stored in the MCB and adjusts the variable associated with the resource to indicate that the resource is available.

We now consider the enforcement of real-time deadlines. Since the HAS BEEN computer has no hardware interrupts with which to signal that an event needs to occur, the code in each module must frequently read the real-time clock and determine whether any modules need to be run at that time. If there are any, those modules' MCBs are moved to the appropriate selection queues. In any case, the MCB for the currently executing module is moved to the end of the selection queue that it currently resides in, and the module transfers control as described above. The movement (deletion and reinsertion) of the MCB for the currently executing module assures a round-robin scheduling strategy for equal priority modules since all queues are FIFO.

The CDB includes a Time Control Table (TCT) containing a list of time deadlines. A queue of MCBs is associated with each deadline. Using these data structures, each module need only compare the clock time with the TCT

deadlines, put the associated MCBs on the proper selection queue, select a module, and transfer control to the selected module.

Reentrant procedures are used to save space by avoiding duplicate code. Therefore, a mechanism is needed for providing a separate copy of all private variables for each invocation of a reentrant procedure. The maximum number of invocations of each procedure is determined when the system is constructed. Therefore, we will use an array for each private variable; one array element corresponds to one invocation of the procedure. The invocation number is assigned by the reentrant procedure call mechanism (by use of a bit string for each procedure), and is stored in the INV# field of the module's MCB. The previous value of INV# is saved in the CINV# array in the Private Variable Area (PVA) for the procedure; it is restored when the procedure returns.

The modules performing background tasks are given a low priority, and therefore never execute unless there is extra CPU time. The report priorities described in the module functional descriptions are enforced by the modules themselves.

Conclusion

We believe the design presented in this document to be the best possible design given the constraints imposed by the limitations of the HAS-BEEN computer. It is also applicable to the more suitable CHIP computer. The CDB provides a clean, precisely specified intermodule interface that is system wide.

APPENDIX I Common Data Base

Contents

Table	Page
Module Control Block Area (MCBA)	14-11
Time Control Table (TCT)	14-14
Average Calculator PVA	14-14
Time Control Table (TCT)	14-15
Intermediate Averager PVA	14-16
Sensor Reader PVA	14-16
Global Area	14-17
Receiver PVA	14-22

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CDB - MODULE CONTROL BLOCK AREA (MCBA)

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CDB - TIME CONTROL TABLE (TCT)

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CDB - AVERAGE CALCULATOR 'A

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NOTES:
1. THE STORAGE OCCUPIED BY THE VARIABLES ON THIS PAGE IS IDENTICAL TO THAT OCCUPIED BY THE TCT.

CDB - TIME CONTROL TABLE (TCT)

NEXTOBS (1) = 0	NEXTOBS (2) = 0	NEXTOBS (3) = 0	NEXTOBS (4) = 0	NEXTOBS (5) = 0	NEXTOBS (6) = 0	NEXTOBS (7) = 0	NEXTOBS (8) = 0	
NEXTOBS (9) = 0	NEXTOBS (10) = 0	NEXTOBS (11) = 0	NEXTOBS (12) = 0	NEXTOBS (13) = 0	SUM (1) = 0	SUM (2) = 0	SUM (3) = 0	
SUM (4) = 0	SUM (5) = 0	SUM (6) = 0	SUM (7) = 0	SUM (8) = 0	SUM (9) = 0	SUM (10) = 0	SUM (11) = 0	
SUM (12) = 0	SUM (13) = 0	TEMP (1) = 0	TEMP (2) = 0	TEMP (3) = 0	TEMP (4) = 0	TEMP (5) = 0	TEMP (6) = 0	
TEMP (7) = 0	TEMP (8) = 0	TEMP (9) = 0	TEMP (10) = 0	TEMP (11) = 0	TEMP (12) = 0	TEMP (13) = 0	CINV# (1) = 0	
CINV# (2) = 0	CINV# (3) = 0	CINV# (4) = 0	CINV# (5) = 0	CINV# (6) = 0	CINV# (7) = 0	CINV# (8) = 0	CINV# (9) = 0	
CINV# (10) = 0	CINV# (11) = 0	CINV# (12) = 0	CINV# (13) = 0					

CDB - INTERMEDIATE AVERAGER PVA

OBS (1) = 0	OBS (2) = 0	OBS (3) = 0	OBS (4) = 0	OBS (5) = 0	OBS (6) = 0	OBS (7) = 0	OBS (8) = 0	
OBS (9) = 0	OBS (10) = 0	OBS (11) = 0	OBS (12) = 0	OBS (13) = 0	OBS (14) = 0	OBS (15) = 0	OBS (16) = 0	
OBS (17) = 0	CINV# (1) = 0	CINV# (2) = 0	CINV# (3) = 0	CINV# (4) = 0	CINV# (5) = 0	CINV# (6) = 0	CINV# (7) = 0	
CINV# (8) = 0	CINV# (9) = 0	CINV# (10) = 0	CINV# (11) = 0	CINV# (12) = 0	CINV# (13) = 0	CINV# (14) = 0	CINV# (15) = 0	
CINV# (16) = 0	CINV# (17) = 0							

CDB - SENSOR READER PVA

IEBP = 0	HEBP = 0	TEBP = 0	IRBS = 0	HRBS = 0	TRBS = 0	IEMOFF = 0	HEMOFF = 0	
TEMOFF = 0	ISOSREPT = 0	HSOSREPT = 0	TSOSREPT = 0	IELON = 0	HELON = 0	TELON = 0	IELOFF = 0	
HELOFF = 0	TELOFF = 0	IREPTSCHED = 0	HREPTSCHED = 0	TREPTSCHED = 0	IAIRREPT = 0	HAIRREPT = 0	TAIRREPT = 0	
IHISTREPT = 0	HHISTREPT = 0	THISTREPT = 0	IPERIODICREPT = 0	HPERIODICREPT = 0	TPERIODICREPT = 0	ISHIPREPT = 0	HSHIPREPT = 0	
TSHIPREPT = 0	IBCAST = 1	HBCAST = 0	TBCAST = 0	IRCVRTABL = 1	HRCVRTABL = 0	TRCVRTABL = 0	IRTABLCHNG = 1	
HRTABLCHNG = 0	TRTABLCHNG = 0	IXMITRTABL = 1	HXMITRTABL = 0	TXMITRTABL = 0	ITTABLCHNG = 1	HTTABLCHNG = 0	TTTABLCHNG = 0	
IOEMRPTBUF = 1	HOEMRPTBUF = 0	TOEMRPTBUF = 0	IREMRPTBUF = 0	HREMRPTBUF = 0	TREMRPTBUF = 0	IIEMRPTBUF = 1	HIEMRPTBUF = 0	
TIEMRPTBUF = 0	IFEMRPTBUF = 3	HFEMRPTBUF = 0	TFEMRPTBUF = 0	SEMRPTBUF = 3	FNTEMRPTBUF = 1	RREMRPTBUF = 3	EMRPTBUF (1) =	
EMRPTBUF (2) =	EMRPTBUF (3) =	IOATOBSBUF (1) = 1	HOATOBSBUF (1) = 0	TOATOBSBUF (1) = 0	IRATOBSBUF (1) = 0	HRATOBSBUF (1) = 0	TRATOBSBUF (1) = 0	
IIATOBSBUF (1) = 1	HIATOBSBUF (1) = 0	TIATOBSBUF (1) = 0	IFATOBSBUF (1) = 3	HFATOBSBUF (1) = 0	TFATOBSBUF (1) = 0	SATOBSBUF (1) = 3	FNTATOBSBUF (1) = 1	
RRATOBSBUF (1) = 3	IOATOBSBUF (2) = 1	HOATOBSBUF (2) = 0	TOATOBSBUF (2) = 0	IRATOBSBUF (2) = 0	HRATOBSBUF (2) = 0	TRATOBSBUF (2) = 0	IIATOBSBUF (2) = 1	
HIATOBSBUF (2) = 0	TIATOBSBUF (2) = 0	IFATOBSBUF (2) = 3	HFATOBSBUF (2) = 0	TFATOBSBUF (2) = 0	SATOBSBUF (2) = 3	FNTATOBSBUF (2) = 1	RRATOBSBUF (2) = 3	
IOATOBSBUF (3) = 1	HOATOBSBUF (3) = 0	TOATOBSBUF (3) = 0	IRATOBSBUF (3) = 0	HRATOBSBUF (3) = 0	TRATOBSBUF (3) = 0	IIATOBSBUF (3) = 1	HIATOBSBUF (3) = 0	
TIATOBSBUF (3) = 0	IFATOBSBUF (3) = 3	HFATOBSBUF (3) = 0	TFATOBSBUF (3) = 0	SATOBSBUF (3) = 3	FNTATOBSBUF (3) = 1	RRATOBSBUF (3) = 3	IOWSOBSBUF (1) = 1	
HOWSOBSBUF (1) = 0	TOWSOBSBUF (1) = 0	IRWSOBSBUF (1) = 0	HRWSOBSBUF (1) = 0	TRWSOBSBUF (1) = 0	IIWSOBSBUF (1) = 1	HIWSOBSBUF (1) = 0	TIWSOBSBUF (1) = 0	
IFWSOBSBUF (1) = 3	HFWSOBSBUF (1) = 0	TFWSOBSBUF (1) = 0	SWSOBSBUF (1) = 3	FNTWSOBSBUF (1) = 1	RRWSOBSBUF (1) = 3	IOWSOBSBUF (2) = 1	HOWSOBSBUF (2) = 0	
TOWSOBSBUF (2) = 0	IRWSOBSBUF (2) = 0	HRWSOBSBUF (2) = 0	TRWSOBSBUF (2) = 0	IIWSOBSBUF (2) = 1	HIWSOBSBUF (2) = 0	TIWSOBSBUF (2) = 0	IFWSOBSBUF (2) = 3	
HFWSOBSBUF (2) = 0	TFWSOBSBUF (2) = 0	SWSOBSBUF (2) = 3	FNTWSOBSBUF (2) = 1	RRWSOBSBUF (2) = 3	IOWSOBSBUF (3) = 1	HOWSOBSBUF (3) = 0	IOWSOBSBUF (3) = 0	
IRWSOBSBUF (3) = 0	HRWSOBSBUF (3) = 0	TRWSOBSBUF (3) = 0	IIWSOBSBUF (3) = 1	HIWSOBSBUF (3) = 0	TIWSOBSBUF (3) = 0	IFWSOBSBUF (3) = 3	HFWSOBSBUF (3) = 0	
TFWSOBSBUF (3) = 0	SWSOBSBUF (3) = 3	FNTWSOBSBUF (3) = 1	RRWSOBSBUF (3) = 3	IOWSOBSBUF (4) = 1	HOWSOBSBUF (4) = 0	TOWSOBSBUF (4) = 0	IRWSOBSBUF (4) = 0	

RRWSOBSBUF (4) = 0	TRWSOBSBUF (4) = 0	IIWSOBSBUF (4) = 1	HIWSOBSBUF (4) = 0	TIWSOBSBUF (4) = 0	IFWSOBSBUF (4) = 3	HFWSOBSBUF (4) = 0	TFWSOBSBUF (4) = 0
SWSOBSBUF (4) = 3	FNTWSOBSBUF (4) = 1	RRWSOBSBUF (4) = 3	IOWSOBSBUF (5) = 1	HOWSOBSBUF (5) = 0	TOWSOBSBUF (5) = 0	IRWSOBSBUF (5) = 0	HRWSOBSBUF (5) = 0
TRWSOBSBUF (5) = 0	IIWSOBSBUF (5) = 1	HIWSOBSBUF (5) = 0	TIWSOBSBUF (5) = 0	IFWSOBSBUF (5) = 3	HFWSOBSBUF (5) = 0	TFWSOBSBUF (5) = 0	SWSOBSBUF (5) = 3
FNTWSOBSBUF (5) = 1	RRWSOBSBUF (5) = 3	IOWDOBSBUF (1) = 1	HOWDOBSBUF (1) = 0	TOWDOBSBUF (1) = 0	IRWDOBSBUF (1) = 0	HRWDOBSBUF (1) = 0	TRWDOBSBUF (1) = 0
IIWDOBSBUF (1) = 1	HIWDOBSBUF (1) = 0	TIWDOBSBUF (1) = 0	IFWDOBSBUF (1) = 3	HFWDOBSBUF (1) = 0	TFWDOBSBUF (1) = 0	SWDOBSBUF (1) = 3	FNTWDOBSBUF (1) = 1
RRWDOBSBUF (1) = 3	IOWDOBSBUF (2) = 1	HOWDOBSBUF (2) = 0	TOWDOBSBUF (2) = 0	IRWDOBSBUF (2) = 0	HRWDOBSBUF (2) = 0	TRWDOBSBUF (2) = 0	IIWDOBSBUF (2) = 1
HIWDOBSBUF (2) = 0	TIWDOBSBUF (2) = 0	IFWDOBSBUF (2) = 3	HFWDOBSBUF (2) = 0	TFWDOBSBUF (2) = 0	SWDOBSBUF (2) = 3	FNTWDOBSBUF (2) = 1	IRWDOBSBUF (2) = 3
IOWDOBSBUF (3) = 1	HOWDOBSBUF (3) = 0	TOWDOBSBUF (3) = 0	IRWDOBSBUF (3) = 0	HRWDOBSBUF (3) = 0	TRWDOBSBUF (3) = 0	IIWDOBSBUF (3) = 1	HIWDOBSBUF (3) = 0
TIWDOBSBUF (3) = 0	IFWDOBSBUF (3) = 3	HFWDOBSBUF (3) = 0	TFWDOBSBUF (3) = 0	SWDOBSBUF (3) = 3	FNTWDOBSBUF (3) = 1	RRWDOBSBUF (3) = 3	IOWDOBSBUF (4) = 1
HOWDOBSBUF (4) = 0	TOWDOBSBUF (4) = 0	IRWDOBSBUF (4) = 0	HRWDOBSBUF (4) = 0	TRWDOBSBUF (4) = 0	IIWDOBSBUF (4) = 1	HIWDOBSBUF (4) = 0	TIWDOBSBUF (4) = 0
IFWDOBSBUF (4) = 3	HFWDOBSBUF (4) = 0	TFWDOBSBUF (4) = 0	SWDOBSBUF (4) = 3	FNTWDOBSBUF (4) = 1	RRWDOBSBUF (4) = 3	IOWDOBSBUF (5) = 1	HOWDOBSBUF (5) = 0
TOWDOBSBUF (5) = 0	IRWDOBSBUF (5) = 0	HRWDOBSBUF (5) = 0	TRWDOBSBUF (5) = 0	IIWDOBSBUF (5) = 1	HIWDOBSBUF (5) = 0	TIWDOBSBUF (5) = 0	IFWDOBSBUF (5) = 3
HFWDOBSBUF (5) = 0	TFWDOBSBUF (5) = 0	SWDOBSBUF (5) = 3	FNTWDOBSBUF (5) = 1	BRWDOBSBUF (5) = 3	IOATAVBUF (1) = 1	HOATAVBUF (1) = 0	IOATAVEUF (1) = 0
IRATAVBUF (1) = 0	HRATAVBUF (1) = 0	IRATAVBUF (1) = 1	HIATAVBUF (1) = 0	TIATAVBUF (1) = 0	IFATAVBUF (1) = 3	IPATAVBUF (1) = 3	HFATAVBUF (1) = 0
TFATAVBUF (1) = 0	SATAVBUF (1) = 3	FNTATAVBUF (1) = 1	HRATAVBUF (1) = 3	IOATAVBUF (2) = 1	HOATAVBUF (2) = 0	TOATAVBUF (2) = 0	IRATAVEUF (2) = 0
HRATAVBUF (2) = 0	TRATAVBUF (2) = 0	IIATAVBUF (2) = 1	HIATAVBUF (2) = 0	TIATAVBUF (2) = 0	IFATAVBUF (2) = 3	HFATAVBUF (2) = 0	IFATAVEUF (2) = 0
IATAVBUF (2) = 3	FNTATAVBUF (2) = 1	HRATAVBUF (2) = 3	IOATAVBUF (3) = 1	HOATAVBUF (3) = 0	TOATAVBUF (3) = 0	IRATAVBUF (3) = 0	HRATAVEUF (3) = 0
TIATAVBUF (3) = 0	IIATAVBUF (3) = 1	HIATAVBUF (3) = 0	TIATAVBUF (3) = 0	IFATAVBUF (3) = 3	HFATAVBUF (3) = 0	TFATAVBUF (3) = 0	SATAVEUF (3) = 3
FNTATAVBUF (3) = 1	RRATAVBUF (3) = 3	IOWSAVBUF (1) = 1	HOWSAVBUF (1) = 0	IRWSAVBUF (1) = 0	TOWSAVBUF (1) = 0	IRWSAVBUF (1) = 0	HRWSAVBUF (1) = 0
IIWSAVBUF (1) = 1	HIWSAVBUF (1) = 0	TIWSAVBUF (1) = 0	IFWSAVBUF (1) = 3	HFWSAVBUF (1) = 0	TFWSAVBUF (1) = 0	SWSAVBUF (1) = 3	FRWSAVBUF (1) = 1

RRWSAVBUF (1) = 3	IOWSAVBUF (2) = 1	HOWSAVBUF (2) = 0	TOWSAVBUF (2) = 0	IRWSAVBUF (2) = 0	HRWSAVBUF (2) = 0	TRWSAVBUF (2) = 0	IIWSAVBUF (2) = 1
HIWSAVBUF (2) = 0	TIWSAVBUF (2) = 0	IFWSAVBUF (2) = 3	HFWSAVBUF (2) = 0	TFWSAVBUF (2) = 0	SWSAVBUF (2) = 3	FNTWSAVBUF (2) = 1	ERWSAVBUF (2) = 3
IOWSAVBUF (3) = 1	HOWSAVBUF (3) = 0	TOWSAVBUF (3) = 0	IRWSAVBUF (3) = 0	HRWSAVBUF (3) = 0	TRWSAVBUF (3) = 0	IIWSAVBUF (3) = 1	HIWSAVBUF (3) = 0
TIWSAVBUF (3) = 0	IFWSAVBUF (3) = 3	HFWSAVBUF (3) = 0	TFWSAVBUF (3) = 0	SWSAVBUF (3) = 3	FNTWSAVBUF (3) = 1	RRWSAVBUF (3) = 3	IOWSAVBUF (4) = 1
HOWSAVBUF (4) = 0	TOWSAVBUF (4) = 0	IRWSAVBUF (4) = 0	HRWSAVBUF (4) = 0	TRWSAVBUF (4) = 0	IIWSAVBUF (4) = 1	HIWSAVBUF (4) = 0	TIWSAVBUF (4) = 0
IFWSAVBUF (4) = 3	HFWSAVBUF (4) = 0	TFWSAVBUF (4) = 0	SWSAVBUF (4) = 3	FNTWSAVBUF (4) = 1	RRWSAVBUF (4) = 3	IOWSAVBUF (5) = 1	HOWSAVBUF (5) = 0
TOWSAVBUF (5) = 0	IRWSAVBUF (5) = 0	HRWSAVBUF (5) = 0	TRWSAVBUF (5) = 0	IIWSAVBUF (5) = 1	HIWSAVBUF (5) = 0	TIWSAVBUF (5) = 0	IFWSAVBUF (5) = 3
HFWSAVBUF (5) = 0	TFWSAVBUF (5) = 0	SWSAVBUF (5) = 3	FNTWSAVBUF (5) = 1	RRWSAVBUF (5) = 3	IOWDAVBUF (1) = 1	HOWDAVBUF (1) = 0	TOWDAVBUF (1) = 0
IRWDAVBUF (1) = 0	HRWDAVBUF (1) = 0	TRWDAVBUF (1) = 0	IIWDAVBUF (1) = 1	HIWDAVBUF (1) = 0	TIWDAVBUF (1) = 0	IFWDAVBUF (1) = 3	HFWDAVBUF (1) = 0
TFWDAVBUF (1) = 0	SWDAVBUF (1) = 3	FNTWDAVBUF (1) = 1	RRWDAVBUF (1) = 3	IOWDAVBUF (2) = 1	HOWDAVBUF (2) = 0	TOWDAVBUF (2) = 0	IRWDAVBUF (2) = 0
HRWDAVBUF (2) = 0	TRWDAVBUF (2) = 0	IIWDAVBUF (2) = 1	HIWDAVBUF (2) = 0	TIWDAVBUF (2) = 0	IFWDAVBUF (2) = 3	HFWDAVBUF (2) = 0	TFWDAVBUF (2) = 0
SWDAVBUF (2) = 3	FNTWDAVBUF (2) = 1	RRWDAVBUF (2) = 3	IOWDAVBUF (3) = 1	HOWDAVBUF (3) = 0	TOWDAVBUF (3) = 0	IRWDAVBUF (3) = 0	HRWDAVBUF (3) = 0
TRWDAVBUF (3) = 0	IIWDAVBUF (3) = 1	HIWDAVBUF (3) = 0	TIWDAVBUF (3) = 0	IFWDAVBUF (3) = 3	HFWDAVBUF (3) = 0	TFWDAVBUF (3) = 0	SWDAVBUF (3) = 3
FNTWDAVBUF (3) = 1	RRWDAVBUF (3) = 3	IOWDAVBUF (4) = 1	HOWDAVBUF (4) = 0	TOWDAVBUF (4) = 0	IRWDAVBUF (4) = 0	HRWDAVBUF (4) = 0	TRWDAVBUF (4) = 0
IIWDAVBUF (4) = 1	HIWDAVBUF (4) = 0	TIWDAVBUF (4) = 0	IFWDAVBUF (4) = 3	HFWDAVBUF (4) = 0	TFWDAVBUF (4) = 0	SWDAVBUF (4) = 3	FNTWDAVBUF (4) = 1
RRWDAVBUF (4) = 3	IOWDAVBUF (5) = 1	HOWDAVBUF (5) = 0	TOWDAVBUF (5) = 0	IRWDAVBUF (5) = 0	HRWDAVBUF (5) = 0	TRWDAVBUF (5) = 0	IIWDAVBUF (5) = 1
HIWDAVBUF (5) = 0	TIWDAVBUF (5) = 0	IFWDAVBUF (5) = 3	HFWDAVBUF (5) = 0	TFWDAVBUF (5) = 0	SWDAVBUF (5) = 3	FNTWDAVBUF (5) = 1	ERWDAVBUF (5) = 3
IOWT1OBSBUF = 1	HOWT1OBSBUF = 0	TOWT1OBSBUF = 0	IRWT1OBSBUF = 0	HRWT1OBSBUF = 0	TRWT1OBSBUF = 0	IIWT1OBSBUF = 1	HIWT1OBSBUF = 0
TIWT1OBSBUF = 0	IFWT1OBSBUF = 3	HFWT1OBSBUF = 0	TFWT1OBSBUF = 0	SWT1OBSBUF = 3	FNTWT1OBSBUF = 1	RRWT1OBSBUF = 3	WT1OBSBUF (1) =
WT1OBSBUF (2) =	WT1OBSBUF (3) =	IOWT2OBSBUF = 1	HOWT2OBSBUF = 0	TOWT2OBSBUF = 0	IRWT2OBSBUF = 0	HRWT2OBSBUF = 0	TRWT2OBSBUF = 0

IIWT2OBSBUF = 1	HIWT2OBSBUF = 0	TIWT2OBSBUF = 0	IFWT2OBSBUF = 3	HFWT2OBSBUF = 0	TFWT2OBSBUF = 0	SWT2OBS3OF = 3	FNTWT2OESBUF = 1
RRWT2OBSBUF = 3	WT2OBSBUF (1) =	WT2OBSBUF (2) =	WT2OBSBUF (3) =	IOWT3OBSBUF = 1	HOWT3OBSBUF = 0	TOWT3OBSBUF = 0	IRWT3OBSBUF = 0
HRWT3OBSBUF = 0	TRWT3OBSBUF = 0	IIWT3OBSBUF = 1	HIWT3OBSBUF = 0	TIWT3OBSBUF = 0	IFWT3OBSBUF = 3	HFWT3OBSBUF = 0	TFWT3OBSBUF = 0
SWT3OBSBUF = 3	FNTWT3OBSBUF = 1	RRWT3OBSBUF = 3	WT3OBSBUF (1) =	WT3OBSBUF (2) =	WT3OBSBUF (3) =	IOATUPBUF = 1	HOATUPEUF = 0
TOATUPBUF = 0	IRATUPBUF = 0	HRATUPBUF = 0	TRATUPBUF = 0	IIATUPBUF = 1	HIATUPBUF = 0	TIATUPBUF = 0	IFATUPBUF = 3
HFATUPBUF = 0	TFATUPBUF = 0	SATUPBUF = 3	FNTATUPBUF = 1	RRATUPBUF = 3	ATUPBUF (1) =	ATUPBUF (2) =	ATUPBUF (3) =
IOWSUPBUF = 1	HOWSUPBUF = 0	TOWSUPBUF = 0	IRWSUPBUF = 0	HRWSUPBUF = 0	TRWSUPBUF = 0	IIWSUPBUF = 1	HIWSUPEUF = 0
TIWSUPBUF = 0	IFWSUPBUF = 3	HFWSUPBUF = 0	TFWSUPBUF = 0	SWSUPBUF = 3	FNTWSUPBUF = 1	RRWSUPBUF = 3	WSUPBUF (1) =
WSUPBUF (2) =	WSUPBUF (3) =	IOWDUPBUF = 1	HOWDUPBUF = 0	TOWDUPBUF = 0	IRWDUPBUF = 0	HRWDUPBUF = 0	TRWDUPEUF = 0
IIWDUPBUF = 1	HIWDUPBUF = 0	TIWDUPBUF = 0	IFWDUPBUF = 3	HFWDUPBUF = 0	TFWDUPBUF = 0	SWDUPBUF = 3	FNTWDUPEUF = 1
RRWDUPEUF = 3	WDUPBUF (1) =	WDUPBUF (2) =	WDUPBUF (3) =	IOWT1UPBUF = 1	HOWT1UPBUF = 0	TOWT1UPBUF = 0	IRWT1UPBUF = 0
HRWT1UPBUF = 0	TRWT1UPBUF = 0	IIWT1UPBUF = 1	HIWT1UPBUF = 0	TIWT1UPBUF = 0	IFWT1UPBUF = 3	HFWT1UPBUF = 0	TFWT1UPEUF = 0
SWT1UPBUF = 3	FNTWT1UPBUF = 1	RRWT1UPBUF = 3	WT1UPBUF (1) =	WT1UPBUF (2) =	WT1UPBUF (3) =	IOWT2UPBUF = 1	HOWT2UPBUF = 0
TOWT2UPBUF = 0	IRWT2UPBUF = 0	HRWT2UPBUF = 0	TRWT2UPBUF = 0	IIWT2UPBUF = 1	HIWT2UPBUF = 0	TIWT2UPBUF = 0	IFWT2UFBUF = 3
HFWT2UPBUF = 0	TFWT2UPBUF = 0	SWT2UPBUF = 3	FNTWT2UPBUF = 1	RRWT2UPBUF = 3	WT2UPBUF (1) =	WT2UPBUF (2) =	WT2UPEUF (3) =
IOWT3UPBUF = 1	HOWT3UPBUF = 0	TOWT3UPBUF = 0	IRWT3UPBUF = 0	HRWT3UPBUF = 0	TRWT3UPBUF = 0	IIWT3UPBUF = 1	HIWT3UPBUF = 0
TIWT3UPBUF = 0	IFWT3UPBUF = 3	HFWT3UPBUF = 0	TFWT3UPBUF = 0	SWT3UPBUF = 3	FNTWT3UPBUF = 1	RRWT3UPBUF = 3	WT3UPBUF (1) =
WT3UPBUF (2) =	WT3UPBUF (3) =	IOOMOBSBUF = 1	HOOMOBSBUF = 0	TOOMOBSBUF = 0	IROMOBSBUF = 0	HROMOBSBUF = 0	TROMOBSBUF = 0
IIOMOBSBUF = 1	HICMOBSBUF = 0	TIOMOBSBUF = 0	IFOMOBSBUF = 3	HFOMOBSBUF = 0	TFOMOBSBUF = 0	SOMOBSBUF = 3	FNTOMOBSBUF = 1
RROMOBSBUF = 3	OMOBSBUF (1) =	OMOBSBUF (2) =	OMOBSBUF (3) =	IOLOCUPBUF = 1	HOLOCUPBUF = 0	TOLOCUPBUF = 0	IRLOCUFBUF = 0

HRLOCUPBUF = 0	TRLOCUPBUF = 0	IILOCUPBUF = 1	HILOCUPBUF = 0	TILOCUPBUF = 0	IFLOCUPBUF = 3	HFLOCUPBUF = 0	TFLOCUPBUF = 0
SLOCUPBUF = 3	FNTLOCUPBUF = 1	RRLOCUPBUF = 3	LOCUPBUF (1) =	LOCUPBUF (2) =	LOCUPBUF (3) =	IOLOCUPBUF = 1	HOLOCUPBUF = 0
TOLOCUPBUF = 0	IRLOCUPBUF = 0	HRLOCUPBUF = 0	TRLOCUPBUF = 0	IILOCUPBUF = 1	HILOCUPBUF = 0	TILOCUPBUF = 0	IFLOCUPBUF = 3
HFLOCUPBUF = 0	TFLOCUPBUF = 0	SLOCUPBUF = 3	FNTLOCUPBUF = 1	RRLOCUPBUF = 3	LOCUPBUF (1) =	LOCUPBUF (2) =	LOCUPBUF (3) =
IOLOCORBUF = 1	HOLOCORBUF = 0	TOLOCORBUF = 0	IRLOCORBUF = 0	HRLOCORBUF = 0	TRLOCORBUF = 0	IILOCORBUF = 1	HILOCORBUF = 0
TILOCORBUF = 0	IFLOCORBUF = 3	HFLOCORBUF = 0	TFLOCORBUF = 0	SLOCORBUF = 3	FNTLOCORBUF = 1	RRLOCORBUF = 3	LOCORBUF (1) =
LOCORBUF (2) =	LOCORBUF (3) =	IOMSGBUF = 1	HOMSGBUF = 0	TOMSGBUF = 0	IRMSGBUF = 0	HRMSGBUF = 0	TRMSGBUF = 0
IIMSGBUF = 1	HIMSGBUF = 0	TIMSGBUF = 0	IFMSGBUF = 5	HFMSGBUF = 0	TFMSGBUF = 0	SMSGBUF = 5	FNTMSGBUF = 1
RRMSGBUF = 5	MSGBUF (1) =	MSGBUF (2) =	MSGBUF (3) =	MSGBUF (4) =	MSGBUF (5) =	IOARPTBUF = 1	HOARPTBUF = 0
TOARPTBUF = 0	IRARPTBUF = 0	HRARPTBUF = 0	TRARPTBUF = 0	IIARPTBUF = 1	HIARPTBUF = 0	TIARPTBUF = 0	IFARPTBUF = 2
HFARPTBUF = 0	TFARPTBUF = 0	SARPTBUF = 2	FNTARPTBUF = 1	RRARPTBUF = 2	ARPTBUF (1) =	ARPTBUF (2) =	IOHRPTBUF = 1
HOHRPTBUF = 0	TOHRPTBUF = 0	IRHRPTBUF = 0	HRHRPTBUF = 0	TRHRPTBUF = 0	IIHRPTBUF = 1	HIHRPTBUF = 0	TIHRPTBUF = 0
IFHRPTBUF = 2	HFHRPTBUF = 0	TFHRPTBUF = 0	SHRPTBUF = 2	FNTHRPTBUF = 1	RRHRPTBUF = 2	HRPTBUF (1) =	HRPTBUF (2) =
IOPRPTBUF = 1	HOPRPTBUF = 0	TOPRPTBUF = 0	IRPRPTBUF = 0	HRPRPTBUF = 0	TRPRPTBUF = 0	IIPRPTBUF = 1	HIPRPTBUF = 0
TIPRPTBUF = 0	IFPRPTBUF = 2	HFPRPTBUF = 0	TFPRPTBUF = 0	SPRPTBUF = 2	FNTPRPTBUF = 1	RRPRPTBUF = 2	PRPTBUF (1) =
PRPTBUF (2) =	IOSRPTBUF = 1	HOSRPTBUF = 0	TOSRPTBUF = 0	IRSRPTBUF = 0	HRSRPTBUF = 0	TRSRPTBUF = 0	IISRPTBUF = 1
HISRPTBUF = 0	TISRPTBUF = 0	IFSRPTBUF = 2	HFSRPTBUF = 0	TFSRPTBUF = 0	SSRPTBUF = 2	FNTSRPTBUF = 1	RRSRPTBUF = 2
SRPTBUF (1) =	SRPTBUF (2) =	HEADRDYLIST (1) = 0	HEADRDYLIST (2) = 0	HEADRDYLIST (3) = 0	HEADRDYLIST (4) = 0	HEADRDYLIST (5) = 0	TAILRDYLIST (1) = 0
TAILRDYLIST (2) = 0	TAILRDYLIST (3) = 0	TAILRDYLIST (4) = 0	TAILRDYLIST (5) = 0	SOSREPTREQ = 0	PERIODICREPTREQ = 0	SHIPREPTREQ = 0	AIRREPTREQ = 0
HISTREPTREQ = 0	CHN = 0						

CDB - GLOBAL AREA

MSG (1) = 0	MSG (2) = 0	MSG (3) = 0	MSGDETECTED (1) = 0	MSGDETECTED (2) = 0	MSGDETECTED (3) = 0	ENDOFMESSAGE (1) = 0	ENDOFMESSAGE (2) = 0
ENDOFMESSAGE (3) = 0	RCHAR (1) = 0	RCHAR (2) = 0	RCHAR (3) = 0	CINV# (1) = 0	CINV# (2) = 0	CINV# (3) = 0	

CDB - *RECEIVER PVA*

APPENDIX II Sample Algorithms

Contents

Program	Page
sensor_reader	14-24
emergency_report_generator	14-27
transmitter	14-29

```
sensor-reader:
reentrant program srdr(sensnum,okfcn,fetfcn,buffer,sem);
comment This program reads a sensor and stores the result
        in an observation buffer.

        sensnum: sensor number
        okfcn: function to test operation of the sensor
        fetfcn: function to retrieve a sample from the sensor
        buffer: observation buffer to insert sample into
        sem: semaphore to wait on for scheduling

     Typical parameter values:
        sensnum  okfcn   fetfcn   buffer     sem
        1 to 3   okat    fetat    atobsbuf   ats
        1 to 5   okws    fetws    wsobsbuf   wss
        1 to 5   okwd    fetwd    wdobsbuf   wds
        1        okom    fetom    omobsbuf   oms
        1        okwt1   fetwt1   wt1obsbuf  wt1s
        1        okwt2   fetwt2   wt2obsbuf  wt2s
        1        okwt3   fetwt3   wt3obsbuf  wt3s;

parameter integer sensnum;
parameter procedure okfcn, fetfcn;
parameter structure buffer of integer(fnt,rr,size)
  of structure o of integer(i, h, t)
  of structure r of integer(i, h, t)
  of structure i of integer(i, h, t)
  of structure f of integer(i, h, t)
  of integer b (s.buffer);
parameter structure sem of integer(i, h, t);
begin private integer obs;
  while true do
  begin
    begin global structure sem(sensnum) of integer(i, h, t);
      i.sem(sensnum) := i.sem(sensnum) - 1;
      if i.sem(sensnum) < 0 then
        begin global integer cmn;
          begin private integer pri; global integer head_ready_list,
                tail_ready_list;
            pri := priority(cmn);
            removep(cmn,head_ready_list(pri),tail_ready_list(pri));
          end;
          insertp(cmn,h.sem(sensnum),t.sem(sensnum));
          processor_allocate;
        end;
      end-if;
    end;
```

```
begin global integer tct, dlist, dtime;
  if dtime(tct(dlist(1)+1)) > "clock time" then
    quick;
  end-if;
end;
if okfcn then
  begin
    obs := fetfcn(sensnum);
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) > "clock time" then
        quick;
      end-if;
    end;
    begin global integer fnt.buffer(sensnum), s.buffer(sensnum);
      global integer buffer(sensnum) (s.buffer(sensnum));
      begin global structure i.buffer(sensnum) of integer(i, h, t);
        i.i.buffer(sensnum) := i.i.buffer(sensnum) - 1;
        if i.i.buffer(sensnum) < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.i.buffer(sensnum),t.i.buffer(sensnum));
            processor_allocate;
          end;
        end-if;
      end;
      begin global structure f.buffer(sensnum) of integer(i, h, t);
        i.f.buffer(sensnum) := i.f.buffer(sensnum) - 1;
        if i.f.buffer(sensnum) < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.f.buffer(sensnum),t.f.buffer(sensnum));
            processor_allocate;
          end;
        end-if;
      end;
```

```
            buffer(sensnum)(fnt.buffer(sensnum)) := obs;
            fnt.buffer(sensnum) := mod(fnt.buffer(sensnum),s.buffer(sensnum))+1;
            begin global structure r.buffer(sensnum) of integer(i, h, t);
              i.r.buffer(sensnum) := i.r.buffer(sensnum) + 1;
              if i.r.buffer(sensnum) < 1 then
                begin
                  removep(h.r.buffer(sensnum),h.r.buffer(sensnum),
                         t.r.buffer(sensnum));
                  begin private integer pri; global integer head_ready_list,
                        tail_ready_list, priority;
                    pri := priority(h.r.buffer(sensnum));
                    insertp(h.r.buffer(sensnum),head_ready_list(pri),
                          tail_ready_list(pri));
                  end;
                end;
              end-if;
            end;
            begin global structure i.buffer(sensnum) of integer(i, h, t);
              i.i.buffer(sensnum) := i.i.buffer(sensnum) + 1;
              if i.i.buffer(sensnum) < 1 then
                begin
                  removep(h.i.buffer(sensnum),h.i.buffer(sensnum),
                         t.i.buffer(sensnum));
                  begin private integer pri; global integer head_ready_list,
                        tail_ready_list, priority;
                    pri := priority(h.i.buffer(sensnum));
                    insertp(h.i.buffer(sensnum),head_ready_list(pri),
                          tail_ready_list(pri));
                  end;
                end;
              end-if;
            end;
            begin global integer tct, dlist, dtime;
              if dtime(tct(dlist(1)+1)) > "clock time" then
                quick;
              end-if;
            end;
          end;
        end-if;
      end;
      end-while;
    end;
```

```
emergency_report_generator:
comment Add time dependent information to emergency report and
        put it in the emergency report buffer;
begin private character string;
  while true do
  begin
    begin global structure sosrept of integer(i, h, t);
      i.sosrept := i.sosrept - 1;
      if i.sosrept < 0 then
        begin global integer cmn;
          begin private integer pri; global integer head_ready_list,
                tail_ready_list;
            pri := priority(cmn);
            removep(cmn,head_ready_list(pri),tail_ready_list(pri));
          end;
          insertp(cmn,h.sosrept,t.sosrept);
          processor_allocate;
        end;
      end-if;
    end;
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) > "clock time" then
        quick;
      end-if;
    end;
    string := format("(9Hsos from ,A10)",fetemreport);
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) > "clock time" then
        quick;
      end-if;
    end;
    begin global integer fnt.emrptbuf, s.emrptbuf;
      global integer emrptbuf(s.emrptbuf);
      begin global structure i.emrptbuf of integer(i, h, t);
        i.i.emrptbuf := i.i.emrptbuf - 1;
        if i.i.emrptbuf < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.i.emrptbuf,t.i.emrptbuf);
            processor_allocate;
          end;
        end-if;
      end;
```

```
      begin global structure f.emrptbuf of integer(i, h, t);
        i.f.emrptbuf := i.f.emrptbuf - 1;
        if i.f.emrptbuf < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.f.emrptbuf,t.f.emrptbuf);
            processor_allocate;
          end;
        end-if;
      end;
      emrptbuf(fnt.emrptbuf) := string;
      fnt.emrptbuf := mod(fnt.emrptbuf,s.emrptbuf)+1;
      begin global structure r.emrptbuf of integer(i, h, t);
        i.r.emrptbuf := i.r.emrptbuf + 1;
        if i.r.emrptbuf < 1 then
          begin
            removep(h.r.emrptbuf,h.r.emrptbuf,t.r.emrptbuf);
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list, priority;
              pri := priority(h.r.emrptbuf);
              insertp(h.r.emrptbuf,head_ready_list(pri),tail_ready_list(pri));
            end;
          end;
        end-if;
      end;
      begin global structure i.emrptbuf of integer(i, h, t);
        i.i.emrptbuf := i.i.emrptbuf + 1;
        if i.i.emrptbuf < 1 then
          begin
            removep(h.i.emrptbuf,h.i.emrptbuf,t.i.emrptbuf);
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list, priority;
              pri := priority(h.i.emrptbuf);
              insertp(h.i.emrptbuf,head_ready_list(pri),tail_ready_list(pri));
            end;
          end;
        end-if;
      end;
    end;
  end;
  end-while;
end;
```

```
transmitter:
reentrant program xmit(freq,rptbuf);
comment This program broadcasts a report.  The report
        contents are obtained from the buffer "rptbuf."

        freq: frequency to broadcast report on
        rptbuf: buffer containing the report contents

     Typical parameter values:
        rptbuf      freq
        prptbuf     5000
        arptbuf     161000
        erptbuf     5100
        srptbuf     300
        hrptbuf     5100;

parameter integer freq;
parameter structure rptbuf of integer(fnt,rr,size)
  of structure o of integer(i, h, t)
  of structure r of integer(i, h, t)
  of structure i of integer(i, h, t)
  of structure f of integer(i, h, t)
  of integer b (s.rptbuf);

begin private character char; private integer xmitrnum;
  while true do
  begin
    begin global integer rr.rptbuf, s.rptbuf;
      global integer rptbuf(s.rptbuf);
      begin global structure o.rptbuf of integer(i, h, t);
        i.o.rptbuf := i.o.rptbuf - 1;
        if i.o.rptbuf < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.o.rptbuf,t.o.rptbuf);
            processor_allocate;
          end;
        end-if;
      end;
```

```
begin global structure r.rptbuf of integer(i, h, t);
  i.r.rptbuf := i.r.rptbuf - 1;
  if i.r.rptbuf < 0 then
    begin global integer cmn;
      begin private integer pri; global integer head_ready_list,
            tail_ready_list;
        pri := priority(cmn);
        removep(cmn,head_ready_list(pri),tail_ready_list(pri));
      end;
      insertp(cmn,h.r.rptbuf,t.r.rptbuf);
      processor_allocate;
    end;
  end-if;
end;
rr.rptbuf := mod(rr.rptbuf,s.rptbuf)+1;
char := rptbuf(rr.rptbuf);
begin global structure f.rptbuf of integer(i, h, t);
  i.f.rptbuf := i.f.rptbuf + 1;
  if i.f.rptbuf < 1 then
    begin
      removep(h.f.rptbuf,h.f.rptbuf,t.f.rptbuf);
      begin private integer pri; global integer head_ready_list,
            tail_ready_list, priority;
        pri := priority(h.f.rptbuf);
        insertp(h.f.rptbuf,head_ready_list(pri),tail_ready_list(pri));
      end;
    end;
  end-if;
end;
begin global structure o.rptbuf of integer(i, h, t);
  i.o.rptbuf := i.o.rptbuf + 1;
  if i.o.rptbuf < 1 then
    begin
      removep(h.o.rptbuf,h.o.rptbuf,t.o.rptbuf);
      begin private integer pri; global integer head_ready_list,
            tail_ready_list, priority;
        pri := priority(h.o.rptbuf);
        insertp(h.o.rptbuf,head_ready_list(pri),tail_ready_list(pri));
      end;
    end;
  end-if;
end;
end;
begin global integer tct, dlist, dtime;
  if dtime(tct(dlist(1)+1)) > "clock time" then
    quick;
  end-if;
end;
```

```
begin private boolean not_found;
  not_found := true;
  while not_found do
  begin
    begin global structure ttablchng of integer(i, h, t);
      i.ttablchng := i.ttablchng - 1;
      if i.ttablchng < 0 then
        begin global integer cmn;
          begin private integer pri; global integer head_ready_list,
                tail_ready_list;
            pri := priority(cmn);
            removep(cmn,head_ready_list(pri),tail_ready_list(pri));
          end;
          insertp(cmn,h.ttablchng,t.ttablchng);
          processor_allocate;
        end;
      end-if;
    end;
    begin global structure xmitrtabl of integer(i, h, t);
      i.xmitrtabl := i.xmitrtabl - 1;
      if i.xmitrtabl < 0 then
        begin global integer cmn;
          begin private integer pri; global integer head_ready_list,
                tail_ready_list;
            pri := priority(cmn);
            removep(cmn,head_ready_list(pri),tail_ready_list(pri));
          end;
          insertp(cmn,h.xmitrtabl,t.xmitrtabl);
          processor_allocate;
        end;
      end-if;
    end;
    comment Look in table for available transmitter of proper type and
            set not_found;
    if not_found then
      begin global structure xmitrtabl of integer(i, h, t);
        i.xmitrtabl := i.xmitrtabl + 1;
        if i.xmitrtabl < 1 then
          begin
            removep(h.xmitrtabl,h.xmitrtabl,t.xmitrtabl);
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list, priority;
              pri := priority(h.xmitrtabl);
              insertp(h.xmitrtabl,head_ready_list(pri),
                    tail_ready_list(pri));
            end;
          end;
        end-if;
      end;
    end-if;
  end;
  end-while;
```

```
    comment Mark selected transmitter as in use;
    begin global structure xmitrtabl of integer(i, h, t);
      i.xmitrtabl := i.xmitrtabl + 1;
      if i.xmitrtabl < 1 then
        begin
          removep(h.xmitrtabl,h.xmitrtabl,t.xmitrtabl);
          begin private integer pri; global integer head_ready_list,
                tail_ready_list, priority;
            pri := priority(h.xmitrtabl);
            insertp(h.xmitrtabl,head_ready_list(pri),tail_ready_list(pri));
          end;
        end;
      end-if;
    end;
    xmitrnum := "selected transmitter number";
    xmitr_tune(xmitrnum,freq);
  end;
  begin global integer tct, dlist, dtime;
    if dtime(tct(dlist(1)+1)) > "clock time" then
      quick;
    end-if;
  end;
  send(xmitrnum,char);
  begin global integer tct, dlist, dtime;
    if dtime(tct(dlist(1)+1)) > "clock time" then
      quick;
    end-if;
  end;
  while (char ne "end of report character") do
  begin
    begin global integer rr.rptbuf, s.rptbuf;
      global integer rptbuf(s.rptbuf);
      begin global structure o.rptbuf of integer(i, h, t);
        i.o.rptbuf := i.o.rptbuf - 1;
        if i.o.rptbuf < 0 then
          begin global integer cmn;
            begin private integer pri; global integer head_ready_list,
                  tail_ready_list;
              pri := priority(cmn);
              removep(cmn,head_ready_list(pri),tail_ready_list(pri));
            end;
            insertp(cmn,h.o.rptbuf,t.o.rptbuf);
            processor_allocate;
          end;
        end-if;
      end;
```

```
begin global structure r.rptbuf of integer(i.h.t);
  i.r.rptbuf := i.r.rptbuf - 1;
  if i.r.rptbuf < 0 then
    begin global integer cmn;
      begin private integer pri; global integer head_ready_list,
            tail_ready_list;
        pri := priority(cmn);
        removep(cmn,head_ready_list(pri),tail_ready_list(pri));
      end;
      insertp(cmn,h.r.rptbuf,t.r.rptbuf);
      processor_allocate;
    end;
  end-if;
end;
rr.rptbuf := mod(rr.rptbuf,s.rptbuf)+1;
char := rptbuf(rr.rptbuf);
begin global structure f.rptbuf of integer(i, h, t);
  i.f.rptbuf := i.f.rptbuf + 1;
  if i.f.rptbuf < 1 then
    begin
      removep(h.f.rptbuf,h.f.rptbuf,t.f.rptbuf);
      begin private integer pri; global integer head_ready_list,
            tail_ready_list, priority;
        pri := priority(h.f.rptbuf);
        insertp(h.f.rptbuf,head_ready_list(pri),tail_ready_list(pri));
      end;
    end;
  end-if;
end;
begin global structure o.rptbuf of integer(i, h, t);
  i.o.rptbuf := i.o.rptbuf + 1;
  if i.o.rptbuf < 1 then
    begin
      removep(h.o.rptbuf,h.o.rptbuf,t.o.rptbuf);
      begin private integer pri; global integer head_ready_list,
            tail_ready_list, priority;
        pri := priority(h.o.rptbuf);
        insertp(h.o.rptbuf,head_ready_list(pri),tail_ready_list(pri));
      end;
    end;
  end-if;
end;
end;
begin global integer tct, dlist, dtime;
  if dtime(tct(dlist(1)+1)) > "clock time" then
    quick;
  end-if;
end;
```

```
    send(xmitrnum,char);
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) >"clock time" then
        quick;
      end-if;
    end;
  end;
  end-while;
  begin global structure xmitrtabl of integer(i, h, t);
    i.xmitrtabl := i.xmitrtabl - 1;
    if i.xmitrtabl < 0 then
      begin global integer cmn;
        begin private integer pri; global integer head_ready_list,
              tail_ready_list;
          pri := priority(cmn);
          removep(cmn,head_ready_list(pri),tail_ready_list(pri));
        end;
        insertp(cmn,h.xmitrtabl,t.xmitrtabl);
        processor_allocate;
      end;
    end-if;
  end;
  comment Mark transmitter xmitrnum available in transmitter table;
  begin global structure xmitrtable of integer(i, h, t);
    i.xmitrtabl := i.xmitrtabl + 1;
    if i.xmitrtabl < 1 then
      begin
        removep(h.xmitrtabl,h.xmitrtabl,t.xmitrtabl);
        begin private integer pri; global integer head_ready_list,
              tail_ready_list, priority;
          pri := priority(h.xmitrtabl);
          insertp(h.xmitrtabl,head_ready_list(pri),tail_ready_list(pri));
        end;
      end;
    end-if;
  end;
  begin global structure ttablchng of integer(i, h, t);
    i.ttablchng := i.ttablchng + 1;
    if i.ttablchng < 1 then
      begin
        removep(h.ttablchng,h.ttablchng,t.ttablchng);
        begin private integer pri; global integer head_ready_list,
              tail_ready_list, priority;
          pri := priority(h.ttablchng);
          insertp(h.ttablchng,head_ready_list(pri),tail_ready_list(pri));
        end;
      end;
    end-if;
  end;
```

```
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) > "clock time" then
        quick;
      end-if;
    end;
    begin global structure bcast of integer(i, h, t);
      i.bcast := i.bcast + 1;
      if i.bcast < 1 then
        begin
          removep(h.bcast,h.bcast,t.bcast);
          begin private integer pri; global integer head_ready_list,
                tail_ready_list, priority;
            pri := priority(h.bcast);
            insertp(h.bcast,head_ready_list(pri),tail_ready_list(pri));
          end;
        end;
      end-if;
    end;
    begin global integer tct, dlist, dtime;
      if dtime(tct(dlist(1)+1)) > "clock time" then
        quick;
      end-if;
    end;
  end;
  end-while;
end;
```

HAS.3 HAS Improved Modular Structure

EXAMPLE DESCRIPTION

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Introduction

Last week, the HAS contractor (CSD) sent a memo warning us against making any further changes in the HAS configuration. He complained that the recent decision to use a different kind of transmitter will require such substantial changes to the Computer Program Design Specification (CPDS) that he is not sure he can meet the deadline.

In my opinion, the contractor's reluctance to make any changes is a sign of poorly designed software that will be expensive for the Navy to maintain. It is inevitable that some changes will be needed during the life cycle of the system. The system designer can reduce the cost of future modifications by anticipating areas that are likely to change, and designing the software so that coding changes will be easy to locate and easy to make.

I propose an alternate design for the HAS system, using Information Hiding Modules. I identify design decisions that are likely to change and limit the knowledge of any one decision to a single module. I contend that a system with this structure will be easier to maintain, since the effects of changes will not ripple through the programs causing unexpected errors.

My proposed design has 17 modules, which are described on the following pages.

PRECEDING PAGE BLANK-NOT FILMED

BUF: Buffer Maintenance Module

This module knows all the details about the buffers that are used to communicate information between programs, including the storage representation, how large they are, and what to do when a buffer is full or empty.

The programs that accept data from buffers and that deposit data in buffers are part of this module.

If we have several different types of buffers, there may be a separate submodule for each type, since they may have different sizes and behavior when filled up.

CC: Communications Control Module

The transmission frequencies for the various reports and the frequencies to be monitored for incoming messages are secrets of this module.

The module consists of programs that control the transmission and reception of messages, deciding when to reset frequency or change transmitter power. These programs call the TC and RC programs that actually control the devices.

The CC programs take characters to be transmitted out of buffers where they were put by MF programs.

The CC programs put received characters in a buffer for MF programs that handle incoming messages.

EM: Emergency Equipment Control Module

This module turns the emergency light on or off on demand. Its secret is the computer action that controls the light.

IG: Information Gathering Module

This module contains programs that compute the values to be stored in the Record Storage, using data obtained from the Sensor Control Module.

Each type of value is computed by a submodule, whose secret is the algorithm used in the computation.

MEM: Memory Allocator Module

This module knows and enforces the memory usage policy.

It contains a submodule that knows the actual memory size, and how the memory is allocated. The secret of the submodule consists of tables indicating the memory access rights of programs and the operating status of memory areas. The submodule provides programs to obtain or release portions of memory and to mark portions defective. The MEM module uses these programs to implement the memory usage policy.

MF: Message Format Modules

There is one Message Format module for incoming messages and one for each type of report generated by the buoy. All programs that know the structure, format details and information content of any given message belong to these modules.

The report-generation modules contain programs that build a message and put it in a buffer.

The incoming message module consists of programs that determine the message type and find pertinent information in the message.

MO: Monitor Modules

Each module allocates the use of one type of resource, such as buffers, receivers or transmitters. CPU time is not handled by a monitor module.

Monitor interfaces include programs to grant exclusive or shared use of the resource and to allow programs to relinquish use of the resources.

MI: Message Interpretation Module

This module knows the process that should be started in response to any type of incoming message. It is notified of the message type by the MF module.

PA: Processor Allocator Module

This module puts a process in control of a processor, i.e., registers are loaded and control transferred to the task. The secret of the module is the aspect of the architecture and the data structures relevant to task switching.

RC: Receiver Control Module

The receiver characteristics that are visible to the computer are the secrets of this module. The RC programs are used by CC programs as they monitor frequencies and receive messages.

The module includes programs to tune the device to a new frequency, detect a message coming in on a specified frequency, and receive a character.

RS: Record Storage Module

This module holds the buoy database. Its secret is the representation of the recorded values in storage.

This module includes programs used by other modules to update the values and functions used to retrieve the values.

SC: Sensor Control Module

Hidden in this module are the sensor characteristics that might change if we replaced one sensor with another that delivers the same information. The programs that take readings from sensors are in this module; they know the HAS-BEEN instruction sequences that perform sensor input and the hardware defined memory location corresponding to each device.

This module includes programs to get a new value from a sensor and to run a built-in test if the sensor contains self calibration circuitry. It also includes programs to set or to check the operating status of a particular sensor. Programs outside this module refer to sensors by names (e.g., first air temperature sensor); the correspondence between name and the way the actual device is addressed is known only inside this module.

SCH: Scheduler Module

This module schedules processes as they request processor time. It knows processor capacity and the deadlines and priorities associated with different processes. It uses the Processor Allocator Module to get a particular task running.

SOR: System Organization Module

This module knows all the information needed to generate a working HAS system. The values of various parameters, such as the number of sensors of each type, the intervals at which sensor readings are taken, averages computed, locations determined, reports broadcast, self-tests executed, and other periodic functions performed, are hidden in this module. The module

also contains information such as the number of processes of different kinds in the system, the number of processors, and the number of sensors of each type.

The System Organization Module is used to generate specific HAS systems.

TC: Transmitter Control Module

The transmitter characteristics that are visible to the computer are secrets of this module.

The module includes programs to transmit a character, tune the transmitter to a new frequency, or change the power level.

TIM: Timer Module

This module is responsible for keeping track of events that must occur regularly. It knows the time interval associated with each periodic task and how to tell "real time". It notifies the Scheduler when a particular task should be run.

TST: Performance Testing Module

This module knows the tests that must be performed to determine whether the equipment performance is acceptable.

It has separate submodules for sensor checking, memory checking, and computer function checking. Each submodule knows the range of behavior that is acceptable for the corresponding component.

The sensor testing submodule uses Sensor Control and Record Storage functions to get the sensor readings and averages used in its tests. Some sensors have built in test circuitry that can be activated from the computer and deliver results that can be read by the computer. The control of these devices is a device property, and programs that are dependent on the characteristics of the particular device are part of the sensor module. The test module knows of their availability and uses them, but does so in such a way that, were the device to be replaced by another that could execute similar self tests but had a different computer interface, the test module would be unchanged.

Conclusion

If CSD organizes its documents in accordance with the above structure, both the documents and the software will be less sensitive to change.

HAS.4 A Structured View of HAS

EXAMPLE DESCRIPTION

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INTRODUCTION

Since I reported for duty here at NERL six weeks ago, I have been assigned to review progress on the HAS software procurement. The contractor (CSD) has submitted a Computer Program Design Specification (CPDS), including a set of algorithms in ALGOL-like pseudo code, which is awaiting formal approval. Because of the length of this approval process, and the short timespan of the project, they are now starting the detailed design of data structures and specifications. It seems certain that the design will be approved since they based it on existing functional aircraft software that CSD developed for the MDADC (Melamine Desert Air Development Center).

During the review process, I heard many complaints about the complexity of the documents and the difficulty of keeping track of what is going on as one traces through the program text. CSD personnel constantly assure us that this is necessary in real-time software using HAS-BEEN computers. They point out that all real aircraft software has these characteristics and that no one can suggest a better way.

The purpose of this memo is to suggest a better way. It is based on a course I took at New Haven University from Professor E. Seawaller on process synchronization. It is also based on structuring concepts, such as stepwise refinement and structured programming.

PROCESSES

Professor Seawaller defines a process as a subset of the events in a system. He is interested in sequential processes within which the ordering of the events is obvious and easily determined.

Seawaller is very fond of trains and often uses the following analogy to clarify the concept of sequential processes. Consider a large railway switching yard with several trains entering and leaving at any given time. The events are cars entering the yard. Since the trains are moving at different speeds, slowing down, speeding up and stopping, the order of events in the whole yard cannot be predicted. However, the order of events is easily predicted for a single train: the first car enters the yard before the second, the second before the third, and so on. Therefore, a train entering the yard

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is a sequential process: it is a subset of the events in the system in which the order is easily determined.

Writing programs on a "per-train" basis allows us to take advantage of the ease of predicting the sequence of events. The programs are easy to understand because the order of events makes sense. Programs written on a "process next event" basis are hard to understand because we must deal with an unpredictable sequence of events, where the order is sometimes significant and sometimes not.

The price we pay for the luxury of considering only one process at a time is that each program must include some commands whose only function is to ensure that the processes cooperate harmoniously. We must include commands to make sure that two different processes do not try to update the same variable at the same time because this could result in an erroneous count. These commands may cost us a little execution time, but the benefit of easily understood code is well worth it.

HAS AS A SET OF PROCESSES

The contractor describes HAS as a single process switching its attention from looking at a sensor to preparing part of a report to checking the clock to looking at another sensor to updating an average to .... It struck me that this is much the way a railway yard program would look if we did it on a per-event basis rather than a per-train basis. I think that part of my difficulty understanding the current HAS description is caused by the program being in the middle of so many different things at a time. Also, the order of some of the tests and data modifications is sometimes arbitrary, and sometimes essential for correct functioning. It is hard to tell which is which without very careful analysis, making it even harder to understand the program.

If we are to be able to apply the ideas in Seawaller's course, we must first deal with a problem that he never discussed: we must divide HAS into processes before we can worry about their synchronization. Some of the processes for HAS are described briefly below, and abstract programs for all the processes in the system are included in an appendix.

First we have one process to read each sensor. These sensor reader processes execute the sensing instruction and put the data in core. They repeat that simple sequence forever. The frequency of repetition depends upon the nature of the sensor, but in most cases it will be done at regular intervals and must be executed punctually to achieve accurate time averages.

Instead of raw sensor readings, most of the programs use averages over time to minimize errors caused by noisy readings. I would include another set of processes to read the data stored in core by the sensor readers and compute the tables of average readings used by other programs. I felt rather uncertain about this second set of processes because it seemed as if the single process, "read sensor; compute average" would fit the predictable-sequence criterion for a sequential process: clearly, the sensor had to be read before the average could be calculated. I separated the two because I realized that reading the sensor is time critical, but calculating the average is not. If

HAS gets many requests at once, processor time might get short. It would be important to continue making punctual sensor readings, but it would not be essential to keep up with computing the averages. Putting both actions in a single process forces an all-or-nothing approach to the sensor. In my proposal, the sensor reader processes will place their readings in core buffers; the averagers will empty the buffers. In moments of time pressure, we'll let the averaging processes get behind in their work but keep making the readings on time.

A process can be assigned to calculate each of the required system values. By using a separate process for each value, one can treat some as more urgent than others and avoid making arbitrary sequencing choices when writing the program.

A single process sends the reports that are due every 60 seconds. Since all of the data is prepared by other processes, this process is very simple: it is awakened by the clock, sends its report, and then returns to its resting state.

For each of the requested reports, we will have a report generator process waiting for the request. Since reports are needed quickly, we will have background processes keeping the data up-to-date with whatever computer capacity is available. The actual report process need only work on demand: it is awakened, generates the report, and returns to its resting position.

CONCLUSIONS

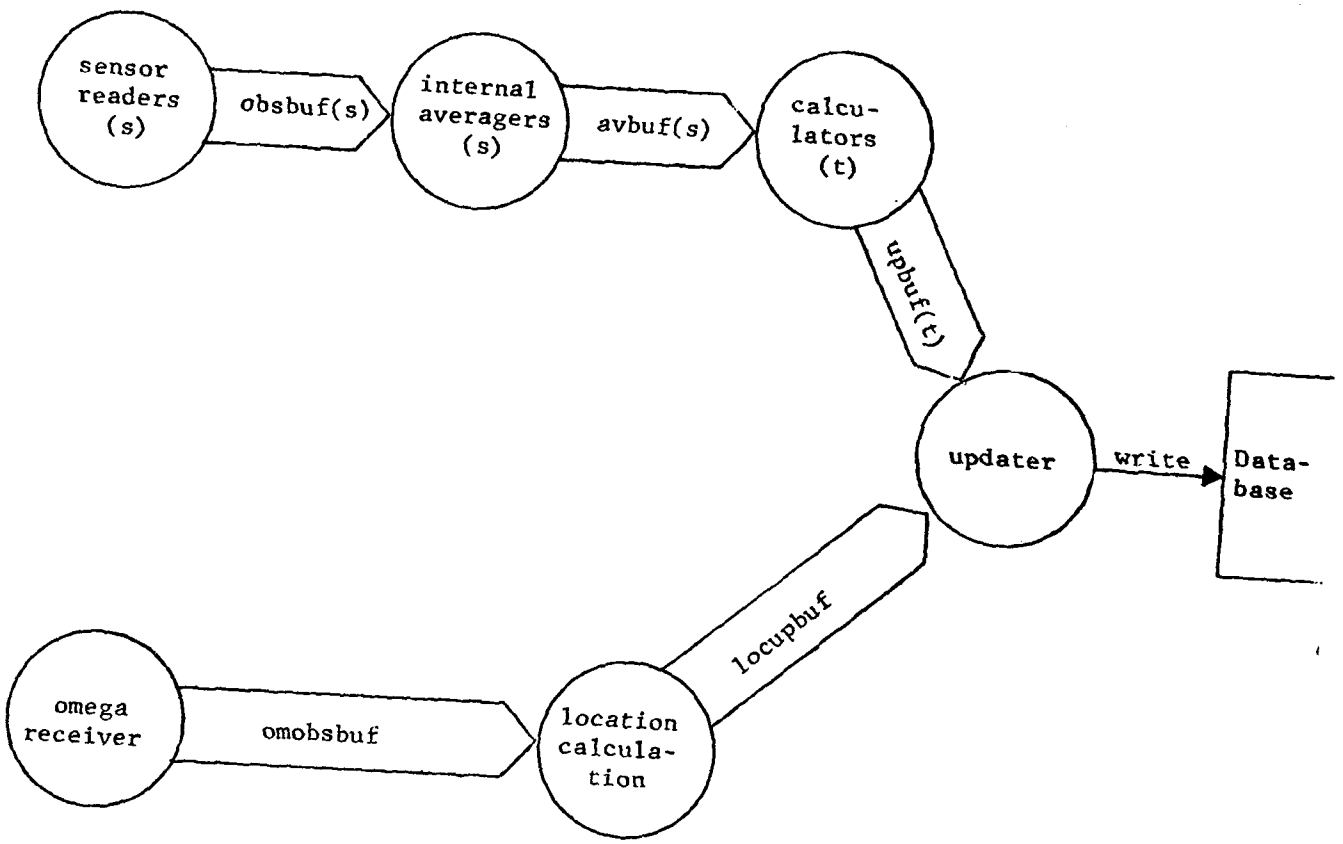
The above discussion is the basis for the enclosed HAS design. The design description includes a diagram of processes and buffers and a set of abstract programs for the individual processes.

As the abstract programs show, the individual processes are controlled by programs that are extremely simple; one might even call them obvious or trivial. Fine: that increases the likelihood that they are correct or at least that we will notice errors. All of the synchronization problems are standard problems dealt with in operating system textbooks (e.g., Shaw 1974). As a result, we can have faith in their correctness.

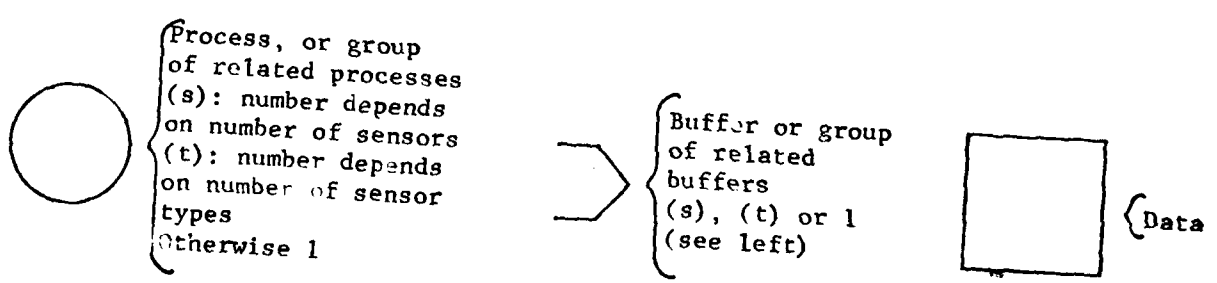
In addition to ease of understanding and verification, there is a side benefit. The design is more easily changed. There are obvious techniques for adding sensors, reports, etc., without changing the existing programs. For example, one can easily add or remove sensor-reader processes if the sensor configuration changes. Seawaller also claims that this type of structure makes it easy to change the number of central processors in a system.

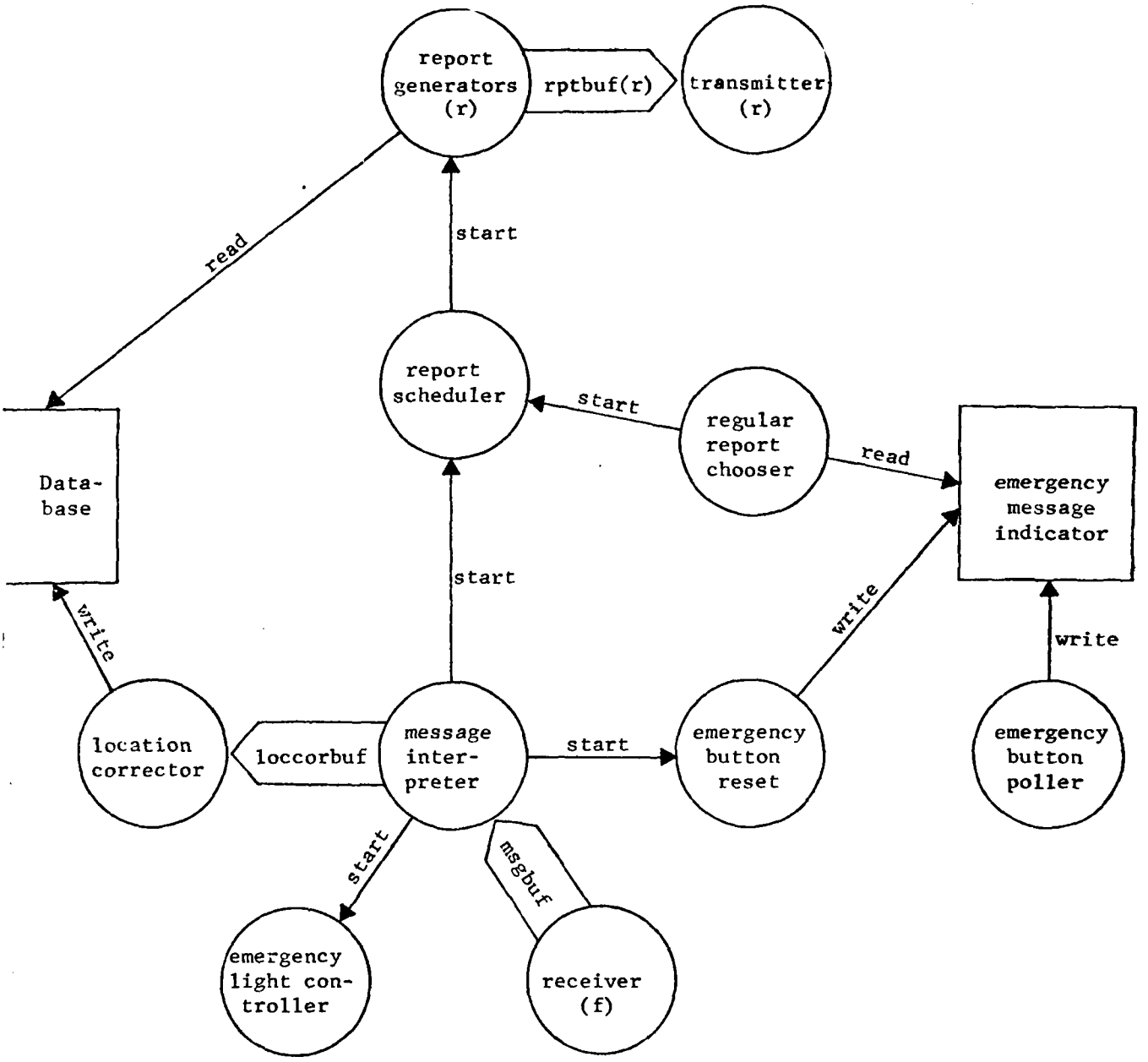
It is my proposal that CSD's CPDS for HAS be rejected, and that they be asked to follow the design in the enclosure.

E. Newhire


sensor readers (s)
obsbuf(s)
internal averagers (s)
avbuf(s)
calcu-lators (t)
upbuf(t)
updater
write
Data-base
omega receiver
omobsbuf
location calcula-tion
locupbuf

Symbol Key:


Process, or group of related processes
(s): number depends on number of sensors
(t): number depends on number of sensor types
Otherwise 1
Buffer or group of related buffers
(s), (t) or 1 (see left)
Data


report generators (r)
rptbuf(r)
transmitter (r)
read
start
report scheduler
start
regular report chooser
read
Data-base
emergency message indicator
start
write
write
write
location corrector
loccorbuf
message inter-preter
start
emergency button reset
emergency button poller
start
msgbuf
emergency light con-troller
receiver (f)

```
sensor_reader:
reentrant program srdr(sensnum,okfcn,fetfcn,buff,sem);
comment  This program reads a sensor and stores the result in an observation
         buffer.

         sensnum: sensor number identifying individual sensor of a particular
                  type
         okfcn:   function to test operation of the sensor
         fetfcn:  function to retrieve a sample from the sensor
         buff:    observation buffer to insert sample into
         sem:     semaphore to wait on for scheduling
```

Typical parameter values:

sensnum	okfcn	fetfcn	buff	sem	sensor type
1 to 3	okat	fetat	atobsbuf	ats	air temperature
1 to 5	okws	fetws	wsobsbuf	wss	wind speed
1 to 5	okwd	fetwd	wdobsbuf	wds	wind direction
1	okom	fetom	omobsbuf	oms	Omega
1	okwt1	fetwt1	wt1obsbuf	wt1s	water temperature, depth 1
1	okwt2	fetwt2	wt2obsbuf	wt2s	water temperature, depth 2
1	okwt3	fetwt3	wt3obsbuf	wt3s	water temperature, depth 3;

```
parameter integer sensnum;
parameter procedure okfcn, fetfcn;
parameter buffer array buff [1:5];
parameter semaphore array sem [1:5];

begin private integer obs;
    while true do
    begin
         P(sem[sensnum]);
         if okfcn (sensnum) then
              begin
                   obs:= fetfcn(sensnum);
                   deposit(obs,buff[sensnum]);
              end;
         end-if;
    end;
    end-while;
end;
```

Note: There is a cross reference table for semaphores and buffers at the end of the document. The semaphore table shows which processes call P or V operations for each semaphore. The buffer table shows which processes call Accept or Deposit for each buffer.

```
intermediate_averager:
reentrant program intavg(sensnum,n,okfcn,obsbuf,avbuf);
comment  This program obtains sensor readings from an observation buffer,
         computes an average, and puts the average into an avbuf.

         sensnum: sensor number
         n: number of readings to average
         okfcn: function to determine the status of a sensor
         obsbuf: buffer containing samples
         avbuf: buffer to insert average into

    Typical parameter values:

    sensnum    n        okfcn          obsbuf       avbuf       sensor type

    1 to 3     4        okat           atobsbuf     atavbuf     air temperature
    1 to 5     4        okws           wsobsbuf     wsavbuf     wind speed
    1 to 5     4        okwd           wdobsbuf     wdavbuf     wind direction;

parameter integer sensnum, n;
parameter procedure okfcn;
parameter buffer array obsbuf [1:5];
parameter buffer array avbuf [1:5];

begin private integer nextobs, temp, sum;
    while true do
    begin
        if okfcn(sensnum) then
            begin
                sum:= 0;
                nextobs:= 0;
                while nextobs lt n do
                    begin
                        nextobs:= nextobs + 1;
                        accept(temp,obsbuf[sensnum]);
                        sum:= sum + temp;
                    end;
                end-while;
                deposit(sum/n,avbuf[sensnum]);
            end;
        end-if;
    end;
    end-while;
end;
```

```
average_calculator:
reentrant program avgcal(numsensors,okfcn,avbuf,upbuf);
comment  This program computes the average reading over all sensors of a given
         type.  The sensor readings are obtained from an avbuf and the
         averages put into an upbuf.
         numsensors: number of sensors
         okfcn: function to determine if sensor is working properly
         avbuf: buffer containing readings
         upbuf: buffer to store averages into

    Parameter values:
         okfcn       avbuf        upbuf     numsensors  sensor type

         okat        atavbuf      atupbuf       3       air temperature
         okws        wsavbuf      wsupbuf       5       wind speed
         okwd        wdavbuf      wdupbuf       5       wind direction
         okwt1       wt1obsbuf    wt1upbuf      1       water temperature, depth 1
         okwt2       wt2obsbuf    wt2upbuf      1       water temperature, depth 2
         okwt3       wt3obsbuf    wt3upbuf      1       water temperature, depth 3

parameter integer numsensors;
parameter procedure okfcn;
parameter buffer array avbuf [1:numsensors];
parameter buffer upbuf;

begin private integer nextobs, sum, average, numobs, temp;
    while true do
    begin
         sum:= 0;
         nextobs:= 0;
         numobs:= 0;
         while nextobs lt numsensors do
         begin
              nextobs:= nextobs + 1;
              if okfcn(nextobs) then
                   begin
                        numobs:= numobs + 1;
                        accept(temp,avbuf[nextobs]);
                        sum:= temp + sum;
                   end;
              end-if;
         end;
         end-while;
         if numobs gt 0 then
              begin
                   average:= sum / numobs;
                   deposit(average,upbuf);
              end;
         end-if;
    end;
    end-while;
end;
```

```
location_calculator:
program loccal;
comment  Calculate location from an Omega reading.  The reading is obtained
         from the Omega observation buffer (omobsbuf) and the calculated
         location is put into the location update buffer (locupbuf);
global buffer omobsbuf,locupbuf;
begin private integer temp, location;
    while true do
    begin
       accept(temp,omobsbuf);
       location:= omega_calculation(temp);
       deposit(location,locupbuf);
    end;
    end-while;
end;



updater:
program updr;
comment  This program updates the database from updated values obtained from
         the update buffers (xxupbuf, where xx is at, ws, wd, loc, wt1, wt2,
         or wt3);
global integer numdepths;
global buffer atupbuf,wsupbuf,wdupbuf,locupbuf,wt1upbuf,wtzupbuf,wt3upbuf;
begin private integer atval, wsval,wdval, locval, wtval[1:numdepths];
    while true do
    begin
       accept(atval,atupbuf);
       accept(wsval,wsupbuf);
       accept(wdval,wdupbuf);
       accept(locval,locupbuf);
       accept(wtval(1),wt1upbuf);
       accept(wtval(2),wt2upbuf);
       accept(wtval(3),wt3upbuf);
       addframe(atval,wsval,wdval,locval,wtval);
    end;
    end-while;
end;
```

```
receiver:
reentrant program rcvr(synch,freq);
comment  This program receives messages and inserts them into the message
         buffer.
         synch: semaphore to signal that it is time to check for a message
         freq : desired monitoring frequency

    Typical parameter values:

         synch        freq

         afrcv        160000
         sfrcv        300
         satfrcv      180000;

comment  Note that obtainrcvr and releasercvr are monitors controlling access
         to the set of receivers.  No other programs even know how many
         receivers there are;

parameter semaphore synch;
parameter integer freq;
global buffer msgbuf;
begin private string msg; private boolean msg_detected,
              end_of_message; private char rchar;
          private integer rcvrnum;
    while true do
    begin
         P(synch);
         rcvrnum:= obtainrcvr(freq);
         msg_detected:= signal_detected(rcvrnum)
         if msg_detected then
           begin
              initmsg(msg);
              end_of_message:= false;
              while not end_of_message do
              begin
                  rchar:= receive(rcvrnum);
                  set_next_char(msg,rchar);
                  if rchar = "eom character" then
                     end_of_message:= true;
                     else end_of_message:= false;
                  end-if;
              end;
              end-while
              deposit(m  ,msgbuf);
           end;
         end-if;
         releasercvr(rcvrn m);
    end;
    end-while;
end;
```

```
message_interpreter:
program msgint;
comment  Examine incoming message to determine desired action.  Messages are
         obtained from the message buffer.  If the message is a report
         request, the appropriate request variable is incremented and the
         report scheduler is signalled.  If the message is a location
         correction, the location is put into the location correction buffer
         (loccorbuf).  If the message is a request to change the emergency
         light or message, the appropriate process is signalled;
global buffer msgbuf, loccorbuf;
global semaphore elon, eloff, emoff, reptsched;
begin private string message; private boolean rept_request;
        global integer ship_rept_req, air_rept_req, hist_rept_req;
    while true do
    begin
      rept_request:= false;
      accept(message,msgbuf);
      case fet_msgtype(message) of
         //shipreq//
            begin
              ship_rept_req:= ship_rept_req + 1;
              rept_request:= true;
            end;
         //airreq//
            begin
              air_rept_req:= air_rept_req + 1;
              rept_request:= true;
            end;
         //histreq//
            begin
              hist_rept_req:= hist_rept_req + 1;
              rept_request:= true;
            end;
         //emlighton//
              V(elon);
         //emlightoff//
              V(eloff);
         //emmsgoff//
              V(emoff);
         //locupdate//
              deposit(findloc(message),loccorbuf);
      end-case;
      if rept_request then
         V(reptsched);
      end-if;
    end;
    end-while;
end;
```

```
regular_report_starter:
program regrepstart;
comment  Decide whether periodic report or emergency report should be
         broadcast based on status of emergency message indicator.  Signal the
         report scheduler;
global semaphore rrs,reptsched;
begin global boolean embc;
    while true do
    begin global integer sos_rept_req, periodic_rept_req;
      P(rrs);
      if embc then
         sos_rept_req:= sos_rept_req + 1;
      else
         periodic_rept_req:= periodic_rept_req + 1;
      end-if;
      V(reptsched);
    end;
    end-while;
end;
```

```
report_scheduler:
program reportsched;
comment  This program ensures that reports are transmitted in the required
         order.  When the report scheduler is signalled, each report request
         variable is checked and its corresponding report generator is
         signalled if a request is outstanding.  The semaphore "bcast" should
         be initialized to the number of simultaneous broadcasts that can be
         made;
begin global boolean sos_rept_req, air_rept_req, ship_rept_req,
       periodic_rept_req, hist_rept_req;
    while true do
    begin
       P(reptsched);
       P(bcast);
       if sos_rept_req gt 0 then
         begin
            sos_rept_req:= sos_rept_req - 1;
            V(sosrept);
         end;
       else if air_rept_req gt 0 then
         begin
            air_rept_req:= air_rept_req - 1;
            V(airrept);
         end;
       else if ship_rept_req gt 0 then
         begin
            ship_rept_req:= ship_rept_req - 1;
            V(shiprept);
         end;
       else if periodic_rept_req gt 0 then
         begin
            periodic_rept_req:= periodic_rept_req - 1;
            V(periodicrept);
         end;
       else if hist_rept_req gt 0 then
         begin
            hist_rept_req:= hist_rept_req - 1;
            V(histrept);
         end;
       end-if;
       end-if;
       end-if;
       end-if;
       end-if;
    end;
    end-while;
end;
```

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SOFTWARE ENGINEERING PRINCIPLES.(U)
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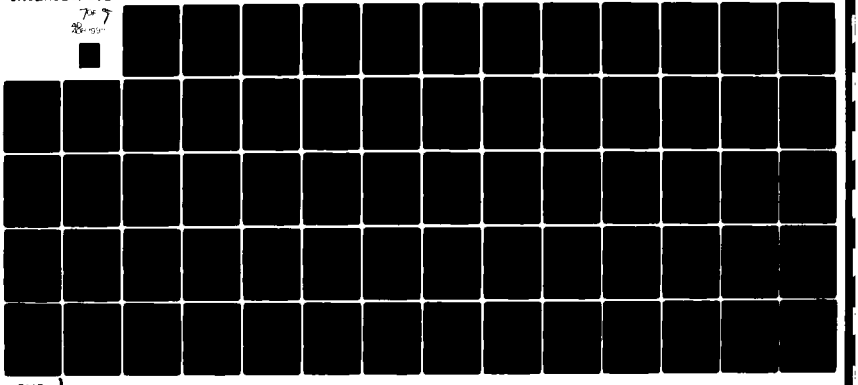

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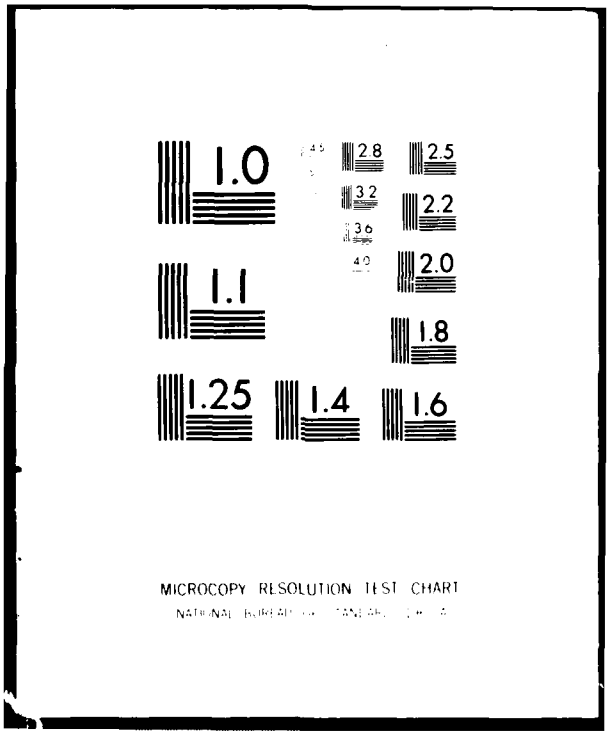
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MICROCOPY RESOLUTION TEST CHART

```
emergency_report_generator:
program emreportgen;
comment  Add time-dependent information to emergency report and put it in the
         emergency report buffer;
global semaphore sosrept;
global buffer erptbuf;
begin private character string;
    while true do
    begin
      P(sosrept);
      string:= format("(9Hsos from ,A10)",fetemreport);
      deposit(string,erptbuf);
    end;
    end-while;
end;



air_report_generator:
program airreportgen;
comment  Generate an air requested report by taking the necessary data from
         the database and enclosing it with any required delimiters.  Store
         strings in arptbuf for the transmitter;
global semaphore airrept;
global buffer arptbuf;
begin private string string;
    while true do
    begin
       P(airrept);
       string:= initmsg("a");
       deposit(string,arptbuf);
       string:= format("(9Hair temp=,I4)",fetatemp);
       deposit(string,arptbuf);
       string:= format("9Hwind dir=,A30",fetwdir);
       deposit(string,arptbuf);
       string:= format("(11Hwind speed=,I4)",fetwspeed);
       deposit(string,arptbuf);
       string:= end_of_message;
       deposit(string,arptbuf);
    end;
    end-while;
end;
```

```
history_report_generator:
program histreportgen;
comment  Generate a history report by taking the necessary data from the
         database and enclosing it with any required delimiters.  Store
         strings in hrptbuf for the transmitter;
global semaphore histrept;
global buffer hrptbuf;
begin private string string;
    while true do
    begin
       P(histrept);
       string:= initmsg("h");
       deposit(string,hrptbuf);
       while not histcomplete do
       begin
         string:= format("(9Hair temp=,I4)",histatemp);
         deposit(string,hrptbuf);
         string:= format("(9Hwind dir=,A3)",histwdir);
         deposit(string,hrptbuf);
         string:= format("(11Hwind speed=,I4)",histwspeed);
         deposit(string,hrptbuf);
         string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                  histdepth1,histwtemp1);
         deposit(string,hrptbuf);
         string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                  histdepth2,histwtemp2);
         deposit(string,hrptbuf);
         string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                  histdepth3,histwtemp3);
         deposit(string,hrptbuf);
       end;
       end-while;
       string:= end_of_message;
       deposit(string,hrptbuf);
    end;
    end-while;
end;
```

```
periodic_report_generator:
program perreportgen;
comment  Generate a periodic report by taking the necessary data from the
         database and enclosing it with any required delimiters.  Store
         strings in prptbuf for the transmitter;
global semaphore periodicrept;
global buffer prptbuf;
begin private integer nexttime; private string string;
    while true do
    begin
       P(periodicrept);
       string:= initmsg("p");
       deposit(string,prptbuf);
       string:= format("(9Hair temp=,I4)",fetatemp);
       deposit(string,prptbuf);
       string:= format("(9Hwind dir=,A3)",fetwdir);
       deposit(string,prptbuf);
       string:= format("(11Hwind speed=,I4)",fetwspeed);
       deposit(string,prptbuf);
       string:= format("(20Hwater temp at depth ,I4,1H= I3)",
                fetdepth1,fetwtemp1);
       deposit(string,prptbuf);
       string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                fetdepth2,fetwtemp2);
       deposit(string,prptbuf);
       string:= format("20Hwater temp at depth ,I4,1H=,I3)",
                fetdepth3,fetwtemp3);
       deposit(string,prptbuf);
       string:= end_of_message;
       deposit(string,prptbuf);
    end;
    end-while;
end;
```

```
ship_report_generator:
program shipreportgen;
comment  Generate a ship requested report by taking the necessary data from
         the database and enclosing it with any required delimiters.  Store
         strings in srptubf for the transmitter;
global semaphore shiprept;
global buffer srptbuf;
begin private string string;
    while true do
    begin
       P(shiprept);
       string:= initmsg("s");
       deposit(string,srptbuf);
       string:= format("(9Hair temp=,I4)",fetatemp);
       deposit(string,srptbuf);
       string:= format("(9Hwind dir=,A3)",fetwdir);
       deposit(string,srptbuf);
       string:= format("(11Hwind speed=,I4)",fetwspeed);
       deposit(string,srptbuf);
       string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                fetdepth1,fetwtemp1);
       deposit(string,srptbuf);
       string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                fetdepth2,fetwtemp2);
       deposit(string,srptbuf);
       string:= format("(20Hwater temp at depth ,I4,1H=,I3)",
                fetdepth3,fetwtemp3);
       deposit(string,srptbuf);
       string:= format("(6Hdrift=,I3)",fetdrift);
       deposit(string,srptbuf);
       string:= end_of_message;
       deposit(string,srptbuf);
    end;
    end-while;
end;
```

```
transmitter:
reentrant program xmit(freq,rptbuf);
comment  This program broadcasts a report.  The report contents are obtained
         from the buffer rptbuf.
         freq  : frequency to broadcast report on
         rptbuf: buffer containing the report contents

    Typical parameter values:

         rptbuf       freq        report type

         prptbuf      5000      periodic report
         arptbuf      161000    aircraft report
         erptbuf      5100      emergency report
         srptbuf      300       ship report
         hrptbuf      5100;     history report;

parameter integer freq;
parameter buffer rptbuf;
global semaphore bcast;

begin private char char; private integer xmitrnum;
    while true do
    begin
       accept(char,rptbuf);
       xmitrnum:= obtainxmitr(freq);
       send(xmitrnum,char);
       while (char ne "end of report character") do
       begin
         accept(char,rptbuf);
         send(xmitrnum,char);
       end;
       end-while;
       releasxmitr(xmitrnum);
       V(bcast);
    end;
    end-while;
end;
```

```
location_corrector:
program loccor;
comment  Obtain locations from the locorbuf buffer and the history database.
         Check to see if the difference is greater than tolerance.  If so,
         start the diagnostics.  Update the location in the history file;
global buffer locorbuf;
begin private integer location, dblocation, tol;
   tol:= "maximum acceptable error in location";
   while true do
   begin
       accept(location,locorbuf);
       dblocation:= fetloc;
       if compare(location,dblocation) lt tol
         then locrec(location);          comment  diagnostics program
       end-if;
       setloc(location);
   end;
   end-while;
end;



emergency_button_poller:
program embuttonpol;
comment  Check to see if the emergency button has been pushed; if so, set
         emergency message indicator so future periodic reports are replaced
         by emergency broadcasts and signal the regular report starter;
global semaphore ebp,rrs;
begin global boolean embc;
   while true do
   begin
       P(ebp);
       if fet_embutton then
         begin
            embc:= true;
            V(rrs);
         end;
       end-if;
   end;
   end-while;
end;
```

```
emergency_message_reset:
program emmsgreset;
comment  Turn off emergency message indicator;
global semaphore emoff;
begin global boolean embc;
    while true do
    begin
       P(emoff);
       embc:= false;
    end;
    end-while;
end;
```

```
emergency_light_on:
program emlighton;
comment  Turn emergency light on;
begin global semaphore elon;
    while true do
    begin
       P(elon);
       set_emlight(on);
    end;
    end-while;
end;
```

```
emergency_light_off:
program emlightoff;
comment  Turn emergency light off;
begin global semaphore eloff;
    while true do
    begin
       P(eloff);
       set_emlight(off);
    end;
    end-while;
end;
```

Semaphore	P Called by	V Called by
airrept	air_report_generator	report scheduler
ats(i)	sensor_reader	periodic scheduler*
bcast	report_scheduler	transmitter
eloff	emergency_light_off	message_interpreter
elon	emergency_light_on	message_interpreter
emoff	emergency_message_reset	message_interpreter
epb	emergency_button_poller	periodic scheduler
histrept	history_report_generator	report scheduler
oms	sensor_reader	periodic scheduler
periodicrept	periodic_report_generator	regular_report_starter
reptsched	report_scheduler	message_interpreter OR regular_report_starter
rrs	regular_report_starter	periodic scheduler OR emergency_button_poller
shiprept	ship_report_generator	report_scheduler
sosrept	emergency_report_generator	report_scheduler
synch	receiver	periodic scheduler
wds(i)	sensor_reader	periodic scheduler
wss(i)	sensor_reader	periodic scheduler
wt1s(i)	sensor_reader	periodic scheduler
wt2s(i)	sensor_reader	periodic scheduler
wt3s(i)	sensor_reader	periodic scheduler

Buffer	Accept called by	Deposit called by
**&_obsbuf(i)	intermediate_averager	sensor_reader
omobsbuf	location_calculator	sensor_reader
&_avbuf(i)	average_calculator	intermediate_averager
locupbuf	updater	location_calculator
&_upbuf	updater	average_calculator
msgbuf	message_interpreter	receiver
loccorbuff	location_corrector	message_interpreter
emrptbuf	transmitter	emergency_report_generator
arptbuf	transmitter	air_report_generator
hrptbuf	transmitter	history_report_generator
prptbuf	transmitter	periodic_report_generator
srptbuf	transmitter	ship_report_generator

* periodic scheduler not described in this document

** &_ represents at
ws
wd
wt1
wt2
wt3

HAS.5 Academic Poppycock

EXAMPLE DESCRIPTION

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Computer System Distributors, INC.
Melamine Desert, California

0. Introduction

Every few years those of us who have been toiling at the production of real-time software for relatively small and slow computers are attacked by newly hired youngsters. Still wet behind the ears and fresh from their "alma mater," they accuse us of producing old-fashioned (now its called unstructured) software. Annoyed by their inability to comprehend instantly programs that have taken years to develop, they attack rather than waiting to learn. They interpret the confusion caused by their own lack of experience with real-world software as a confusion caused by muddy thinking on the part of the people who made the software work.

Einar Newhire's memorandum, "A Structured View of HAS" is a perfect example of the phenomenon. Normally, we just ignore such memos and get on with our work. This one, however, is being taken more seriously than most (perhaps because the name Seawaller has become a household word). For that reason, and because it does happen every year, I have decided that it is worthwhile recording the errors in the Newhire paper. This document can be reissued each time that a new youngster arrives from some ivory tower.

There are three basic faults with the "structured view" which I will discuss in depth:

1. It is an oversimplification -- important problems are simply omitted,
2. There are technical problems in implementing the concepts -- run-time and memory usage become excessive,
3. It restricts the designer too much -- making his work harder when it is hard enough already. Development costs will increase if we go that route.

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1. Oversimplifications

1.1. Omissions

One of the easiest ways of making a computer system or language appear simple and obviously correct is to leave out the hard parts. I do not mean eliminating the hard parts by replacing them with a powerful mechanism; I mean ignoring them in the description. This is a ploy commonly used by professors who write textbooks or tutorial papers on complex systems. They are often complimented on their ability to find a simple description of a system previously thought to be too complex for students to understand. It is only when one attempts to apply the knowledge that one gets from such papers that one discovers that essential information has been omitted and that essential problems have been ignored.

In the case of the Newhire paper, the omission technique has been applied in spades. The paper is written as if all that HAS software has to do is read sensors and write reports. The real HAS software is going to be much more complex because it does more. Among other things, the real software must:

a. allocate memory,
b. allocate registers,
c. keep track of the real-time clock,
d. estimate processor time for completion of incomplete tasks,
e. calculate deadlines,
f. make priority decisions for processors and data areas.

None of these problems is even mentioned in the "structured view" document. It is no wonder that the document has an appealing simplicity.

1.2 Unrealistic distribution of emphasis

Another ploy used by academics in the "structured view" game is to emphasize the simple things. The newer operating systems textbooks devote 70% or 80% of their space to discussing perhaps 20% of the actual code in an operating system. These books spend most of their time discussing the easier things in depth (mutual exclusion, producer/consumer) but the actual implementors spend their time on device handlers, device error analysis, data organization, directories, file systems, etc. The academic may say fervently, "We have to stop thinking in terms of unpredictable interrupts and start thinking in terms of cyclic processes," but the programmer spends a lot of his time writing the interrupt-handling routines anyway.

The same phenomenon occurred in the HAS-structured view paper. The HAS-BEEN computer does not have interrupts; if it had, I would have had one more item for my list of omissions. Because of that, a great deal of code is going to be devoted to scanning input registers checking for conditions that would cause interrupts on more modern computers. I am sure that both Seawaller and Newhire would dismiss this with a "We'll do that in our lowest level," and then go on to talk about a new problem in asynchronous programming. Meantime,

we have to write our polling code and make sure that it gets done in all sections of the programs.

1.3 Implementation of processes ignored

Another illustration of the fact that "A Structured View" is an oversimplification is the issue of the processes. The paper is written as though processes existed already. It ignores the fact that by introducing the concept of processes one has added an implementation problem to the set of things to do. Processes have to be represented by data structures; they have to be synchronized; they have to be scheduled. That doesn't happen by magic; it happens by code. Some of that code might not even be needed if we did not think in terms of processes.

1.4 Interprocess interference

Another example of this oversimplification is the way Newhire handwaves about interference between processes. He blithely has some processes writing in a data structure while others read from it. He acts as if the problem with that is easily solved. Here, he is ignoring even those problems that academics know about. Before I got disgusted with the whole thing, I remembered that a heated debate appeared in the literature about various ways of solving just that one problem. If the Government forces us to go the "structured route" on HAS, they'll discover the reader-writer problem later. Newhire didn't think it important enough to bring it up now, before the decision.

2. Technical problems

2.1 Space requirements for many processes

Newhire's approach is based on having many little processes. He overlooks the fact that, in implementing these processes, he is going to have to reserve a large block of space for each of them. Each process is represented by a data structure that describes both the code that controls the process and the data that the process uses, to say nothing of the data needed to schedule it. Lots of processes -- lots of space. Lots of similar processes -- lots of duplicate data. On a HAS-BEEN computer we can't afford it.

2.2 Unpredictable delays produced by process synchronization

The process synchronization models that Newhire cites were developed for multiprogramming, not real time. Dijkstra clearly considers the speed of a program to be unimportant. Brinch Hansen has dismissed arguments against his conditional critical sections because they relate to "extreme real-time" situations. Well, in our situation, we are in a real-time situation, possibly even an extreme one, given the incredibly slow speed of HAS BEEN. The process synchronization concepts deal with all processes as if they were the same. They are simple because they do not distinguish between processes. An urgent process and a normal process might be on the same queue and the urgent one might then be delayed. If all that you care about is the state at the end of the computation, that's fine. But that's <u>not</u> all that we care about.

2.3 Process switching time overhead

Every time a process has to be scheduled or rescheduled, time must be spent in the process scheduler. Because of the slowness of the HAS BEEN, we can ill afford such switching overhead.

2.4 Size of the minimal system

Seawaller may be the name most commonly associated with the process concept, but Brinch Hansen has actually gone much further. He has written a how-to-do-it book that everyone can follow; he has built systems. By looking at those systems, one can see yet another aspect of the problem. At a recent meeting in San Francisco, Brinch Hansen admitted that the most trivial system required 6000-7000 words. To that amount we must add all of the real code and the data structures described above. Perhaps with a large machine like a PDP-11 that is acceptable, but with the HAS-BEEN computer it is not.

2.5 Procedure call overhead

A general problem with structured approaches to software is their reliance on procedure calls to keep things simple. Procedure calls require a great deal of environment changing (register saving and restoring). In real-time systems with outdated computers we cannot afford that.

2.6 Inability of the program to take actions conditional on real-time

Key to the process concept is that each process continues in its sequence of actions irrespective of the exact rate of progress. One of the "other processes" in our situation is the advance of real time. There are numerous cases in systems like HAS where an action will be taken only if time permits and will be curtailed when time is scarce. The simplest example is the self-test code, which Newhire doesn't even bother to describe. We do it whenever we have spare time. All of the self-test routines check the real-time clock and relinquish control when time does not permit the test to go on. Programs written using Newhire's approach could not do that.

3. Increased development costs

Most of the structured programming missionaries imply or claim that development costs may be reduced by such methods. Strangely enough, there is no solid experimental evidence in that direction. People have published data, but it's like comparing lightbulbs and pears. In some cases productivity increases but the quality of code goes down. In other cases, the cost of the language development is written off in a research budget. Even in cases where the same job has been done twice, we are left without hard evidence because doing a job the second time is not doing the same job. In the sequel, I wish to argue that a structured approach can actually increase development costs.

3.1 Structuring restricts the programmer thereby making his job harder.

Working on real-time software is, in some ways, very much like surgery. One has to work very, very carefully and use one's complete knowledge of the system's anatomy. Just as a surgeon cannot perform an appendectomy without some knowledge of the circulatory system, the real-time programmer cannot work on a program to record sensor data without knowledge of the memory allocation policy. If we asked the surgeon to perform his operations in such a way that it would work even if the patient's circulatory system were changed, we would be making his job much harder -- perhaps impossible. The real-time programmer's job is hard enough -- why make it harder?

3.2 Reversing early design decisions

Parnas has pointed out that the most critical design decisions are those made early in the project because later decisions are based on the earlier ones. Reversal of the earlier decisions is costly because it implies reconsideration and possible reversal of all later decisions. The Newhire approach represents a design decision that he wants us to make early in the project. Subsequent reversal of that decision will be very costly. The reversal is inevitable because we need the control that he wants to deny us.

Throughout structured programming one makes decisions on the assumption that future decisions can be ignored. Correcting errors will be very expensive.

3.3 There will be extra documentation costs

If we take the Newhire approach, we will start out documenting a fictitious "virtual" system. We will then start to refine that design (following the precept of stepwise refinement). Each refinement will have to be completely documented. If we were to bypass this documentation, no one would understand what was going on in the abstract programs. At each new stage the old information must be included again. If we just write our program, we only have to document the decision once. Moreover, SECNAV INST 3560.1 will cause us to write yet another set of documents because it does not allow "abstraction".

3.4 Repeated testing

Testing is a necessary process in software development. No one in his right mind believes a program if it has not been run. Newhire's memo already contains some programs. They have to be tested. Testing such programs is not easy because we'll have to simulate the missing operations. Worse, this testing process should be repeated with each refinement. With conventional programming, you only have to test when you finish the subprogram and once more at integration.

3.5 More source code will be produced

Even academic papers have shown that structured programming tends to lead to bigger programs. More code, more cost.

Conclusions

When university computer science departments were first proposed, many opposed them on the grounds that the graduates would have no basic training in either fundamental mathematics or engineering techniques. They would have learned theoretical approaches that had not been proven. Nothing personal, mind you, but Einar Newhire is just such a graduate. He would be more useful to us if he had never heard of a computer. Then he would come here without ridiculous ideas, and we could have taught him what he needs to know. He's a bright guy who has been brainwashed. Maybe this paper will cause him, and his ilk, to see the light and to recognize the "structured view" for the academic poppycock that it is.

The CPDS that we submitted for HAS is an unusually complete piece of documentation. It is unfair but typical for Newhire to complain that it is too complex: thorough documentation of real-life programs contains many details that academics tend to "abstract away" in their programs.

In the meantime, the government must look at the track record. Our approach, whatever its faults, has produced programs that fly. The structured approach has not. Until a real project has been successfully completed using the structured approach, no project manager in his right mind will bet on it.

HAS.6 Separation of Concerns

EXAMPLE DESCRIPTION

Eric W. Seawaller
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(submitted to SIGOPS)

Introduction

Professor E. W. Dijkstra has introduced two distinct topics into the computer literature:

(1) process synchronization: how to write programs that control several computations proceeding "in parallel" at unknown relative speeds, given that these computations share variables and other resources (1968a; 1968b).

(2) separation of concerns: how to organize a program so that programmers need not think about too many things at one time (1968b; 1972; 1976).

The purpose of this note is to relate these two fields of study, showing how "separation of concerns" can help us evaluate synchronization and resource allocation control structures.

This thesis is not new. Dijkstra's original T.H.E. operating system papers (1968b) clearly indicate that he introduced process synchronization to confine the processor allocation policy to one portion of his system. He stated that a change in the number of processors would impact only one level of his hierarchical structure. In this paper, I want to take real-time constraints into account and discuss some limitations they impose on our ability to separate concerns.

Concerns in real-time programs

By examining existing real-time programs one can distinguish seven classes of concerns:

(1) Sensing, i.e., reading input lines and recording the observed values in internal storage.

(2) Initiating sensing.

(3) Decoding, i.e., recognition of an event defined by a predicate on internal variables.

(4) Calculating system values from the input values.

(5) Responding to events that have been decoded and recorded.

(6) Scheduling, i.e., allocating the processor among the processes that are eligible to run.

(7) Coordinating access to shared resources.

Although conventional real-time programs deal with many of these concerns in the same program text, the concerns are independent in the sense that they can change independently. Observe that:

(a) The algorithm involved in sensor reading is largely independent of the period of observation.

(b) Initiating sensing is critical because information may be lost if sensor reading is delayed. The initiating policy depends more on processor speed than on the interface to the input sensors.

(c) If the sensor values have been recorded in internal variables, decoding them to recognize significant events may usually be delayed without deleterious effect. Similarly using them to calculate system values may also be delayed.

(d) Response to an external event is often complex and may extend over a time period that is much longer than the sensor observation period. Sensor observations often must continue throughout the period of response.

(e) Processor scheduling can be performed knowing only the processor demands of the various tasks and their deadlines. It is not influenced by other properties of the tasks.

(f) Coordinating the usage of shared resources is primarily constrained by the number and nature of the resources. For the most part, it can be arranged without keeping track of momentary processor allocation.

However, the average allocation to each process cannot be ignored if real-time deadlines are to be met.[1,2]

The process model

We assume that we have available a number of parallel processes that communicate by means of

(a) shared variables, and

(b) special synchronization variables that are accessed only by special synchronization operations.

We also assume that synchronization operations can block and release processes. A blocked process may not be scheduled to run; when it is released it becomes eligible to run again.

The duration of a process may be long either because it is complex or because it is not allocated the processor by the scheduler. Delays caused by scheduling are hidden from the process, so it cannot affect them. Synchronization operators explicitly block and release processes, constraining the actions that the scheduler may take. Thus, processes are subject to scheduling, while synchronization operations restrict scheduling by defining which processes are eligible to run.

Proposed real-time software organization

I propose that the software be organized into three kinds of units: processes, schedulers, and monitors.

(A) Processes are sequential subsets of the activities of the system. We use the term "sequential" to indicate that the sequence of events within a process can be determined by an examination of the task to be performed and is not influenced by the number or speed of the available processors and devices. The relative order of events within a single process is determined by a conventional program that controls that process, but the relative order of events in different processes is affected by processor speed and resource speed as well as scheduling policies. In order to be able to ignore processor

---

1 There are two concerns of processor allocation: 1) momentary allocation: which process has the processor at any given instant, and 2) average allocation: how much of the processor time is allocated to each process on the average over a period of time.

2 Whether one can ignore momentary allocation is a more complex point than it may appear; we will return to it in the section titled "A fundamental limitation of separation of concerns."

speed and scheduling policies while designing the other algorithms, processes are regarded as proceeding in parallel at unknown relative speeds, but at real speeds sufficient to satisfy the real-time constraints.

There would be four classes of processes:

(1) Cyclic processes that observe external inputs and record their values in internal variables (Sensing [3]).

(2) Processes that examine recorded data to recognize events of significance to the system (Decoding).

(3) Processes that process the recorded data to compute the information required (Calculating).

(4) Processes that are awakened whenever an event is noted and carry out the system's response to the event (Responding).

(B) Schedulers allocate the processor to processes, using scheduling policies to decide which process should run next. There would be two schedulers.

(1) A simple scheduler that deals only with the periodic waking of sensing processes (Initiating). It is assumed that the sensing processes use small, fixed amounts of processor time in each observation cycle. That time is effectively reserved for them and is not available for other processes.

(2) A deadline scheduler that allocates the remaining processor time, giving priority to processes with the most imminent deadlines (Scheduling).

(C) A monitor is simply a module, or a collection of routines called by other programs in order to obtain access to a shared resource (Coordinating). There would be one for each type of resource. Each monitor hides both the synchronization method used internally and the changeable aspects of the allocation policy. The monitors will use synchronization primitives (Parnas 1978).

Separation of concerns achieved by proposed organization

The following examples illustrate the separation of concerns achieved by the proposed organization:

(a) If a sensor is replaced by one with a different interface to the computer, the program controlling the process that reads and interprets that sensor is the only program that needs to be changed.

---

[3] Names in parentheses key objects in the proposed organization to the seven concerns in real-time programming.

(b) If accuracy requirements or other factors dictate a change in the frequency of reading a sensor, the periodic awakener is changed. This may make a change in the amount of time available for demand scheduling, but in most cases there will be no ripple effect.

(c) Replacing a single processor with a faster or slower model (or with a multiprocessor system) will affect the schedulers, but in fairly straightforward ways. If the code was properly parameterized when written, reprogramming will be minimal.

(d) Changes in the way of detecting or responding to a significant event can usually be confined to the program controlling a single process.

(e) Changes in the availability or allocation policy for resources other than the processor result in changes to individual monitors. The process synchronization routines that are used by these monitors are distinct and should not be affected. Unless required processor time is changed drastically, scheduling is not affected. Processes using the resources need not be affected by the changes.

A fundamental limitation of separation of concerns

Unfortunately, separation of concerns in the area of resource allocation is not always possible. The resource allocation strategies may interact strongly through their effects *on processes* that are using two or more distinct resources. If a process that has been allocated some of resource B is slowed by the monitor that allocates resource A, then the policy used in allocating A may have noticeable effects on the allocation of B.

P. J. Courtois (1975; 1977) has carefully investigated this problem and developed statistical criteria to help recognize situations where there would be too much error caused by ignoring the allocation policy for one resource when designing an allocator for another. Very roughly, if we wish to neglect the dynamics of resource A when concerned with resource B, the actions that change the state of resource A must be of short duration and occur relatively frequently when compared to actions that change the state of resource B. When this is valid, one is justified in considering A to be almost continually available but somewhat slower than the actual A when allocating resource B. For a particular process, we will consider A to perform at a rate equal to its actual rate multiplied by the fraction of the time that it is available for that process.

In designing systems of cooperating processes, we want to be able to neglect the momentary processor allocation, including the time used to accomplish process switching, when allocating other resources. We will only succeed if operations requesting or releasing the processor can be of significantly shorter duration than operations requesting and releasing other resources. If this is so, then we can view the processor as almost continually available for each process, but considerably slower then the actual processor.

Process synchronization primitives

The fundamental limitation suggests that successful application of the process concept will require that the software include several levels of process synchronization primitives (Parnas 1978).

1. The lowest level must include only operations with extremely short execution time. They serve primarily to inform the schedulers of changes in the state of readiness of processes.

2. Using the lower level operations, one can implement monitors or other operations that are convenient for resource allocation. The implementation must keep processes that are waiting for a chance to execute the lower level operations distinct from processes that are waiting for entrance to the monitors and processes waiting for resources.

3. Decoding problems such as those discussed by Patil (1971) and Parnas (1975b) are implemented using the lowest level primitives. The real-time constraints on the duration of the lowest level primitives do not necessarily apply to decoding operators such as those proposed by Patil.

Conclusions

The structure described above seems a plausible way to improve the organization of real-time software. It should be further evaluated by means of prototype software.

HAS.7 Implementing Processes in HAS

EXAMPLE DESCRIPTION

S S S S

SEAWALLER SOFTWARE SYSTEMS SERVICE

our motto

STRUCTURED SOFTWARE SAVES

Introduction

Software Technologist Einar Newhire of the Naval Electronics Research Lab (NERL) has proposed that the Host at Sea (HAS) software be implemented using processes as a structuring concept. O. U. De Zeeman of Computer System Distributors (CSD) has written a rather sharply worded pape indicating that practical limitations prevent the implementation of processes for HAS. Under terms of NERL contract NERL-CSS 42089a-216, this paper has been written to resolve the conflict.

SSSS's position on the controversy is clear. The arguments on both sides have definite merit. Newhire's approach leads to a better structured system, but she failed to describe the system completely. The failure to deal with certain issues creates the impression that they have been overlooked. In fact, Newhire simply abstracted. Those issues can be dealt with separately from the ones discussed.

This report is divided into two sections. Section I, a modification of a SIGOPS paper (HAS.6), discusses the motivation for the process concept in HAS. Addressed specifically to HAS, it indicates what can be gained by using processes as a structuring concept. Section II addresses the question of how to implement processes. It includes a set of macros that can be used to translate the processes described in Einar Newhire's proposal into code for the HAS-BEEN computer. Because this contract did not call for study of HAS-BEEN assembly language, we have used a simple, machine-independent notation to describe our code. To avoid confusion, we have used the same notation that CSD used to describe its proposed implementation of HAS.

SECTION I

Professor E. W. Dijkstra has introduced two distinct topics into the computer literature:

(1) Process synchronization: how to write programs that control several computations proceeding in parallel at unknown relative speeds, given that these computations share variables and other resources.

(2) Separation of concerns: how to organize a program so that programmers need not think about too many things at one time.

The purpose of this section is to relate these two fields of study to HAS.

Concerns in HAS

By examining the CSD design for HAS, one can distinguish seven classes of functions to be performed.

(1) Sensing, i.e., reading input lines and recording the observed values in internal variables.

(2) Initiating sensing.

(3) Decoding, i.e., recognition of an event defined by a predicate on several internal variables.

(4) Calculating system values from input values.

(5) Responding to events that have been decoded.

(6) Scheduling i.e., allocating the processor among the processes that are eligible to run.

(7) Coordinating access to shared resources.

Although the CSD design for HAS deals with many of these concerns in the same program text, the concerns are independent because they could change independently. Observe that:

(a) The algorithm involved in sensor reading is largely independent of the period of observation.

(b) Initiating observations is critical because information may be lost if sensor readings are delayed. The initiating policy depends more on processor speed than on the interface to the input sensors.

(c) If the sensor values have been recorded in internal variables, decoding them to recognize significant events may usually be delayed somewhat without deleterious effect. Similarly, using input values to calculate system values may usually be delayed.

(d) Response to an external event is often complex and may extend over a time period that is much longer than the sensor observation period. Sensor observations often must continue throughout the period of response.

(e) Processor scheduling can be performed knowing only the processor demands of the various tasks and their deadlines. It is not influenced by other properties of these tasks.

(f) Coordinating the usage of shared resources is primarily constrained by the number and nature of those resources and may often be arranged without taking the momentary processor allocation into consideration. The average processor allocation cannot be ignored because HAS has real-time constraints.[1], [2]

The process model

Einar Newhire's design assumes that we have available a number of processes that communicate by means of:

(a) shared variables, and

(b) special synchronization variables that are accessed only by special synchronization operations.

We also assume that synchronization operations can block and release processes. A blocked process is not eligible to run until it is released.

The duration of a process may be long either because it is complex or because it is not allocated the processor by the scheduler. Delays caused by scheduling are hidden from it, so that it cannot affect them. Synchronization operators explicitly block and release processes, restricting scheduling by defining which processes are eligible to run.

---

1 There are two separate concerns of processor allocation that are being distinguished here: 1) momentary allocation: which process has the processor at any given instant, and 2) average allocation: how much of the processor time is allocated to each process on the average over a period of time.

2 Whether one can ignore momentary allocation is a more complex point than it may appear and we will return to it in the section called "A fundamental limitation of separation of concerns."

Proposed real-time software organization

The HAS software should be organized into two kinds of units to be known as processes and modules. The modules include monitors and schedulers, as described in Newhire's module design (HAS.3).

Processes are sequential subsets of the activities of the system. We use the term "sequential" to indicate that the sequence of events within a process can be determined by an examination of the task to be performed and is not influenced by either the number or the speed of the processors and devices. The relative order of events within a single process is determined by a conventional program that controls that process, but the relative order of events in different processes is affected by processor speed and scheduling policies. To achieve separation of concerns, processes are regarded as proceeding in parallel at unknown relative speeds, but at real speeds sufficient to satisfy the HAS timing constraints.

There are four classes of processes:

(1) Cyclic process, run periodically, that observe external inputs and record their values in internal variables (Sensing)[3].

(2) Processes that examine recorded data to recognize events of significance to the system (Decoding).

(3) Processes that process recorded data to compute the information desired (Calculating).

(4) Processes that are awakened whenever a significant event is noted and carry out the system's response to the event (Responding).

There are two schedulers:

(1) A simple scheduler that deals only with the periodic starting of sensing processes (Initiating). It is assumed that the sensing processes use small, fixed amounts of processor time in each observation cycle. That time is reserved for them and unavailable to other processes.

(2) A deadline scheduler that allocates the remaining processor time among the other processes (Scheduling).

A monitor module is a collection of routines that are called by the other programs when they need to obtain access to a shared resource (Coordinating). There would be one monitor for each type of resource. Each monitor hides both the synchronization method that is used internally and the changeable aspects of the allocation policy. The monitors use synchronization primitives (Dijkstra 1968; Parnas 1976) to implement coordination.

---

[3] Names in parentheses key these objects to the seven HAS concerns mentioned earlier.

The following examples illustrate the separation of concerns achieved by the proposed organization:

(1) If a sensor is replaced by one with a different interface to the computer, the program controlling the sensing process for that sensor is the only program that needs to be changed.

(2) If accuracy requirements or other factors dictate a change in the frequency of reading a sensor, the simple scheduler that initiates periodic processes is changed. This may make a change in the amount of time available for demand scheduling, but in HAS there will be no ripple effect because the HAS BEEN has plenty of extra CPU cycles according to our analysis.

(3) Replacing a single processor with a faster or slower model or with a multiprocessor system will affect the schedulers in fairly straightforward ways. Reprogramming will be minimal. The code describing the processes themselves need not change at all.

(4) A change in the algorithm used to detect or to respond to a significant event can be confined to the program controlling a single process.

(5) Changes in the availability or allocation policy for non-processor resources result in changes to individual monitors. The process synchronization routines that are used by these monitors will not be affected. Unless processor time required is changed drastically, scheduling is not affected. Processes need not be affected by such changes.

A fundamental limitation on separation of concerns

Unfortunately, separation of concerns in the area of resource allocation is not always possible. The resource allocation strategies may interact strongly through their effects on processes that are using two or more distinct resources. If a process that has been allocated some of resource B is slowed by the monitor that allocates resource A, then the policy used in allocating A may have noticeable effects on the allocation of B.

P. J. Courtois (1975; 1977) has carefully investigated this problem and developed statistical criteria to help recognize situations where there would be excessive error caused by ignoring the allocation policy for one resource when designing an allocator for another. Very roughly, if we wish to neglect the dynamics of resource A when concerned with resource B, the actions that change the state of resource A must be of short duration and occur relatively frequently when compared to actions that change the state of resource B. When this is valid, one is justified in considering A to be almost continually available but somewhat slower than the actual A when allocating B. For a particular process, we will consider A to be performing at a rate equal to its actual rate multiplied by the fraction of the time that it is available for that process.

In HAS, we want to be able to neglect the momentary processor allocation when allocating other resources. We will only succeed if operations requesting or releasing the processor (synchronization operations) can be of significantly shorter duration than operations requesting and releasing other resources.

These conditions can be satisfied by the HAS design proposed by Einar Newhire.

SECTION II

In Section I of this paper, we showed that the motivation for using Newhire's approach is to achieve separation of the seven types of concerns encountered in HAS. The processes given in Newhire's proposal take care of four of them: sensing, decoding, calculating, and responding. To make a complete system, it is necessary to write the code for periodic scheduling, processor allocation, and resource coordination. We propose to do this in four stages. In the first stage we will take care of resource coordination by introducing monitors for the shared resources. In the second stage we will take care of the periodic scheduling or "initiating" by introducing a special process analogous to a hotel desk clerk to function as an alarm clock. It waits until a certain time is reached, and then awakens another process. In the third stage, we will implement the synchronization routines that change the set of processes eligible to run. In the final stage, we will implement the scheduler that allocates the real processor(s) among the processes eligible to run, so that all make smooth progress.

We ask Mr. De Zeeman and other readers to be patient with this slow, multistage approach. Our purpose, like Newhire's, is to deal with one problem at a time so that the human brain can handle the degree of complexity required at any given time.

Stage 1: Coordination of Shared Resources.

In HAS resources are shared in two ways: explicitly and implicitly. The explicitly shared resources are primarily data structures, tables, and I/O devices. The implicitly shared resources are the "private" memory areas of the processes. Although we chose to ignore this problem while writing the basic process controller programs, there comes a time when we must recognize that the memory areas of all processes are shared with the memory check process(es), so that no area is really private to a process.

When do we need a monitor?

We need a monitor for any resource such that (a) it is used by more than one process and (b) simultaneous or overlapping attempts to use the resource would result in errors. We need a monitor for any such resource whether it be a single boolean variable, an I/O device, or a mass storage device. For each type of resource there is a usage discipline or protocol that will guarantee that the user processes do not interfere with each other. The monitor is a set of supervisory routines guaranteeing that the discipline is followed.

An example of a shared resource is a buffer that is used to communicate between two processes. Another example is a shared variable, such as embc in HAS.4, that is set by one process and checked by another. All of the data structures used to store the temperatures, wind speeds, and other data are also considered to be shared variables in this context.

It is essential to observe that we are talking about variables that are shared among processes, not about variables that are shared among modules. The recorded data are stored in variables that are private to a record storage module, but the module is used by several processes. Those processes may all call the module's access functions, and we must guard against the danger of simultaneous or overlapping access by two or more processes.

What is a monitor?

Some authors (e.g., Brinch Hansen, Hoare) give the term monitor a very narrow meaning as a specific construct in a programming language. At Seawaller Software Systems Service, we use "monitor" in its original and more general sense. Monitor refers simply to the collection of procedures that access the resource directly and hence are able to monitor the accesses. We are not going to propose a specific language construct for monitors for two reasons:

(1) HAS will be implemented using an existing language.

(2) Different types of resources require different types of monitors.

SSSS considers designing the monitors to be a system design problem, not a language design problem. For example, for a data structure that consists of a single word in core, the hardware provides the necessary "monitor" by prohibiting simultaneous reads and writes.

The monitor procedures will use the access procedures of the modules that hide the implementation details of the resource. These access procedures, such as GET and SET functions, hide the data structures and access algorithms. They would suffice if simultaneous calls were not a danger. For more general situations, these procedures will be used by additional programs that synchronize use of the resource by multiple processes. The external interface to the monitor may look like the basic access functions, but it need not. The design criteria and the monitors needed in HAS are discussed below.

Monitors for HAS

The HAS structure proposed by Newhire contains four types of computer resources that are shared among processes: single variables, buffers, the data structures hidden by the record storage module, and the "private" variables of each process. In addition, there are system resources, such as transmitters and receivers.

Buffer Monitors

For buffers, Habermann's ACCEPT and DEPOSIT procedures (1972) can be used as monitors. They use Dijkstra's P and V operators to guard against incorrect simultaneous access by multiple processes. Note that, unlike the monitors built into CONCURRENT PASCAL (Brinch Hansen, 1975), they do not always exclude each other's executions. Mutual exclusion is not necessary for this type of buffer; unless the routines try to operate on the same frame in the buffer, an ACCEPT and a DEPOSIT may occur simultaneously without ill effect.

In the algorithms below, the semaphores "out.xbuf" and "in.xbuf" prevent more than one process from simultaneously accepting from or depositing into a buffer, respectively. The semaphore "space.xbuf" synchronizes the processes, preventing buffer overflow and "data.xbuf" prevents buffer underflow; these two semaphores prevent a simultaneous ACCEPT and DEPOSIT on the same frame. "space.xbuf" must be initialized to the number of initially available frames in the buffer, "data.xbuf" is initialized to zero, and the other semaphores are initialized to 1.

"front.xbuf" is an index to a buffer location; it always points to the first empty buffer slot if no DEPOSIT is in execution. Similarly, "rear.xbuf" points to the frame preceding the first full frame unless an ACCEPT is in progress. "successor" returns a pointer to the next buffer frame succeeding the one pointed to by the parameter.

```
procedure deposit(x, xbuf);
begin global pointer front.xbuf; parameter x;  comment  x is the data to be
                                                        stored
    global buffer xbuf;
    semaphore in.xbuf, space.xbuf, data.xbuf;
    P(in.xbuf);           comment  only one process can deposit at a time;
    P(space.xbuf);        comment  wait if the buffer is full;
    xbuf(front.xbuf):= x;
    front.xbuf:= successor(front.xbuf);
    V(data.xbuf);         comment  signal that the buffer is not empty;
    V(in.xbuf);
end;

procedure accept(x, xbuf);
begin global pointer rear.xbuf; parameter x;  comment x is the data to be
                                                       retrieved
      global buffer xbuf;
      semaphore out.xbuf, space.xbuf, data.xbuf;
    P(out.xbuf);          comment  only one process can accept at a time;
    P(data.xbuf);         comment  wait if the buffer is empty;
    rear.xbuf:= successor(rear.xbuf);
    x:= xbuf(rear.xbuf);
    V(space.xbuf);        comment  signal that the buffer is not full;
    V(out.xbuf);
end;
```

Data Structure Monitors

The record storage functions represent a shared data structure that is a classic instance of the "reader-writer" problem (Courtois, 1971). For each such "holder" there is a process that periodically updates the information, and there are several other processes (the report generator processes) that use the information to prepare messages. The latter are "reader" processes and do not interfere[4] with each other. Since the updating processes write

[4] They may slow each other down but they cannot affect the results.

in the data structures, the information in the holder will be inconsistent while one of these processes is in the middle of an update. To design the monitor for each type of record, it is first necessary to decide exactly what is meant by consistent data. If the data items being stored are not to be compared to each other, then the data may be considered consistent after each individual item has been completely updated. On the other hand, if the data are to be compared (e.g., to compute temperature gradients), then it is important that all items taken from the storage represent the same point in time. In that case the data will not be considered consistent between the time that the updating process starts to insert new values and the time that it finishes.

In the first case, where individual data items may be updated and the report is considered consistent, the update access functions provided by the monitor will look like the individual SET functions provided by the basic module. In the second case, since a number of items must be considered consistent, the monitor must provide a single access function for updating all of them.

Example of the Second Case:

If the record storage module provides functions SETTEM1, SETTEM2, and SETTEM3 to store temperature values, and all three temperatures should represent the same moment because differences will be computed, the access monitor will use the three SETTEM functions to implement SETTEM(P1,P2,P3).

SETTEM and the other monitor access functions will contain the necessary synchronization operators to guarantee that after one of the TEMP items has been updated, no data will be used until all three have been updated. At all other times, access to TEMP1, TEMP2, TEMP3 need not be restricted.

Assuming the availability of the three functions above and FETTEM1, FETTEM2, and FETTEM3 to fetch values in a similar way, the monitor procedures would look as follows:

```
INITIALIZATION
begin global integer readcount:=0;
    global semaphore temcs, temw;
    temcs:=1; temw:=1;
end;
```

```
procedure SETTEM(p1, p2, p3);
begin semaphore temw; parameter p1, p2, p3;
    P(temw);                                  comment  wait if any other process
                                                       operating on data, else
                                                       lock out other processes;
    settem1(p1);
    settem2(p2);
    settem3(p3);
    V(temw);
end;

procedure FETTEM(p1, p2, p3);
begin integer readcount; parameter p1,p2, p3;
      semaphore temw, temcs;
    P(temcs);                                 comment  mutually exclusive access
                                                       to readcount;
    readcount:=readcount+1;
    if readcount = 1 then P(temw); end-if;    comment  if first reader, lock out
                                                       writers, wait if writer
                                                       already in progress;
    V(temcs);
    p1:=fetteml;
    p2:=fettem2;
    p3:=fettem3;
    P(temcs);
    readcount:=readcount-1;
    if readcount=0 then V(temw); end-if;      comment  allow waiting writer to
                                                       proceed if no other
                                                       reader;
    V(temcs);
end;
```

Monitor for private memory areas

One of the requirements for the HAS program is that all areas of memory are periodically tested by a memory check process. This includes the areas storing code and data that are private to the other processes. Since memory checking destroys the contents of the memory, the contents must be copied to an area that is private to the memory check process before the test begins. They will be returned after the check is complete. During the test it is not possible to execute the relocated code or access the relocated data.[5] Thus, a process may not run while its memory is being checked.

Each of the processes in Newhire's proposal has a clearly defined homing state, that is, a state in which it remains most of the time and in which it may be safely suspended. To build the monitors for the private code and data of each process, we will introduce one additional semaphore per process. The process does a V on this semaphore before entering the homing state and a P upon starting up again. The memory check process does the P before beginning to relocate the data and a V when the data is returned. Thus, execution of the process and its memory check cannot occur at the same time.

Because shared data areas are already protected by semaphores, the memory check process can use them like any other user.

Shared code areas used by reentrant processes are not already protected because the processes that execute them are "readers": they do not alter the code. In such cases, the shared code must be equipped with reader-writer entry points. The memory check process is the writer.

---

5 This design for memory checking is based upon the following two assumptions that hold for HAS at present. The assumptions must be noted because the design must be changed if the assumptions no longer hold.

(1) The HAS BEEN computer is not equipped with hardware that supports run-time relocatable code or data (such as the PDP-11/40 segmentation hardware). If we had such hardware it would be a simple matter to relocate the data and code and perform the memory check without concern for the progress of the process.

(2) The time frame in which sensor readings must be made is relatively long compared to the time required to check the memory belonging to a process. Therefore, not scheduling the process during that time is an acceptable solution. If the time frames involved were shorter, it would be necessary to segment the code and data, thereby reducing the time for any one memory check, or to duplicate the code and data so that progress could be made during the memory check.

There are two areas of memory that are not covered by the above discussions. These are the areas of memory in which the memory-check process resides and the areas of memory devoted to the semaphores. If the memory-check process is to check its own memory, it must have a copy of itself (or a subset) elsewhere. This copy checks the memory-check process as if it were any other process.

The semaphores are a problem because they are not private to any other process and can not be protected by semaphores. Luckily, they represent a very small part of memory, so that all other processes can be suspended while they are being checked.

Stage 2: The "desk clerk" procedure

Even after all of the processes in Newhire's proposal have been refined to include the synchronization implicit in the resource monitors, there is nothing in the code that refers to real time. All of the processes are now synchronized; they will not interfere with each other. This can be proved without making any assumptions about their real speeds or relative speeds. This is a very important property. Designing a system of processes so that their correct cooperation depended on each process proceeding strictly according to a rigid schedule would be like planning a subway system without safety interlocks, on the assumption that the trains would always be on time.

Unlike some multiprogramming systems, the HAS system has real-time deadlines for some of its work that are really "hard" deadlines. By hard deadlines, we mean that the old adage, "better late than never", does not hold. Data that is not read in time is lost forever. Out-of-date data may lead to drastic errors. We must take real time into account somewhere.

Even though many processes may wait for particular points in time, we propose that all observation of the actual time be confined to a single procedure. Each process that needs to wait executes a P operation on a semaphore. The single procedure that observes real time will do the necessary V operation at the proper time. When that happens, the waiting process is marked ready and begins to compete for the processors, making progress in accordance with the scheduling policies. We stated earlier that blocks of time are reserved for these periodic, time-driven processes. This is implemented by assigning them higher priorities than the demand processes.

This approach has certain advantages:

(1) The concern, "What do I do when my time comes?" is separated from "Is it my time to run yet?"

(2) The concern "Which of the ready processes should be run now?" is separated from "Which processes should be ready at this point in time?" (Both of these have been called scheduling and considered one problem in the past.)

(3) Waiting for a given amount of time to pass is only done by one procedure. Certain inaccuracies that can occur because two processes are waiting until the same point in time are more easily avoided.

(4) Changes in the real-time schedule are confined to the desk-clerk program sketched below. When this program runs is discussed later.

```
if time interval elapsed then
  begin
     V(semaphores on list for this interval);
     determine next interval;
  end;
end-if;
```

Stage 3: Implementing the P and V routines

Our code now contains many calls of the synchronization routines invented by E. W. Dijkstra (1968a, 1968b). P is used by a process to try to pass a semaphore and to mark its passage. V is used to allow a semaphore to be passed. The specifications for P and V could be written as shown below:

P AND V WITH TRACES

The specification for P and V recognizes the fact that, when dealing with parallel processes, the events that are described by a trace are not simply calls of routines. We must introduce P_b, which is the event of the start of a P, and P_e, the end of a P. Only by treating these as distinct events can we describe the waiting that occurs during a P. In this specification, illegal traces never occur. A call on P (the event P_b) is always allowed. The P-V module delays the P_e until it is legal. Thus, for this specification, the legal traces might be more accurately called possible traces. These assertions refer only to traces on the events for one semaphore.

SYNTAX:

(1) P: semaphore --) semaphore
(2) V: semaphore --) semaphore

gt: greater than
le: less than or equal to
L: Legal
=: equivalence

SEMANTICS:

Legality:

i = number of P operations that can be completed before any V operation is done (usually one)

(1) (n gt 0) =) $L(V^n.P_b.P_e)$
(2) (n gt 0) =) $L((P_b.P_e)^i.P_b^n.V.P_e)$
(3) (n le i) =) $L((P_b.P_e)n.V)$

Equivalences:

(1) $L(T.P_b.P_e.V)$ =) $T = T.P_b.P_e.V$
(2) $L(T.P_b.V.P_e)$ =) $T = T.P_b.V.P_e$
(3) $L(T.V.P_b.P_e)$ =) $T = T.V.P_b.P_e$

This does not bind us to any particular implementation.

Dijkstra has published two slightly different implementations of the P and V operations (1968a, 1968b). Both satisfy the above requirements, but we believe that the implementation proposed in this section is appropriate for HAS.

We implement each semaphore using an integer variable and a set variable. The set variable can contain zero, one, or more processes. There are operators to insert a process in the set, to remove a process from the set, and to ask if a specific process is in the set. The integer variable is usually initialized to 1 and the set variable to empty. However, it would be permissible to initialize the integer variable to any non-negative value if the set variable is empty, and to negative values if the number of processes in the set variable is equal to the magnitude of the integer variable.

A P-operation is then implemented by decrementing the integer variable and testing it. If the integer variable is negative when tested, the process enters itself in the semaphore's set variable and releases the processor to ready processes. The process is now blocked. This action corresponds to P_b. If the integer variable is non-negative, the process may continue. This action corresponds to P_e.

The V-operation increments the integer variable. If the result is negative or zero, one of the processes is removed from the semaphore's set variable, and entered in one of the sets of ready processes. This process is now "ready" to run. Removing a process from the semaphore set corresponds to P_e.

In this implementation, if the integer variable is negative, its magnitude always represents the number of processes in the set variable. In this case, the integer value is redundant since we could get the same information by counting the entries in the set variable. When the integer value is positive, it is not redundant.

The operation P followed by a V or the operation V followed by a P will leave the number of the processes in the set unchanged. The fact that the order of these events does not matter, except with regard to the identity of the processes in the set, makes it easier to prove that certain properties of the system will hold even if the speeds of processes change.

There are still two portions of the P and V operation to be refined. If the processor is released in the P operation, a "ready" process must be selected to run. If a process is removed from the semaphore's set in the V operation, one of the members of the set must be selected to be made ready. In neither case have we yet specified which one. If you look back at the specifications for P and V, you will find no help on this question. The choice of a process from the set members is not constrained by the requirements. This has the advantage that any program proven correct using only the specifications of P and V, will work correctly with any policy for selecting set members. For HAS, we suggest two simple policies. We will always remove the longest waiting process from a semaphore set variable. When a process is marked ready, we assign it a priority. We will always select the highest priority process when allocating the processor.

The sets may be represented as First-in-First-out (FIFO) queues of process descriptors. Each process descriptor will contain the process number, priority, and state information such as register contents and program counter.

Implementations for standard queue manipulation procedures are found in most programming texts; we will not include them here. We will assume we have two procedures, INSERTP (process, queue) to insert a process in the queue, and REMOVEP (process, queue) to remove the longest waiting process from the queue, placing its descriptor in the parameter "process."

The final code for P and V now looks like:

```
procedure P(s);
begin global integer int.s;  global process-descriptor queue set.s;
    int.s:=int.s-1;
    if int.s lt 0 then
       begin
       comment  current_process is a function returning the process descriptor
                of the process running on this processor;
       insertp(current_process, set.s);
       processor_allocate;
       end;
    end-if;
end;

procedure V(s);
begin global integer int.s; global process-descriptor queue set.s;
private process descriptor process;
    int.s:=int.s+1;
    if int.s le 0 then
       begin
       removep(process, set.s);
       make_ready(process);
       end;
    end-if;
end;
```

The "processor_allocate" and "make_ready" routines are described later.

Stage 4: Completing Process Implementation

Adding Preemptive Scheduling

The code that we have now is complete and could be directly translated into running code if we could live with non-preemptive processor scheduling. It has a lot of processes that voluntarily release the processor when they try to execute a P operation and cannot finish it. Because of the mutually cooperative nature of the process structure and the fair scheduling strategy that we have taken, things would go well if we had no real-time deadlines and we really did not care about the relative speeds of the processes. The behavior of the system would be a bit "jerky". One process would run until its input or output buffer emptied or filled, another would then run until a similar event occurred to it, etc.

For HAS, this behavior is not acceptable. We must now add provisions to have the processor preempted between synchronization events. Unfortunately, one of the properties of the HAS-BEEN computer is that it has no interrupt system. Although we may wish to preempt processors, we must really implement things so that the processes release them voluntarily. To ensure smoothness, we will insert instructions every so often to check the priorities of waiting processes and release the processor whenever a waiting process has higher priority than the one currently running. This will be done automatically by postprocessing the code generated by the above expansion and inserting a macro call to the scheduler after every few statements. We are fortunate that the HAS-BEEN computer does have adequate speed for our application even if we insert many instructions in this way.

It is interesting to note that the T.H.E. system (Dijkstra 1968) at one time had a preemptive clock implemented in a similar manner. However, this code was removed permanently after an experiment revealed that the behavior was satisfactory without it. T.H.E. had no real-time demands, but we have the option of trying the same experiment.

The "desk clerk" is given control whenever the processor is reallocated, since checking the real-time clock is the top priority activity.

We will adopt a round-robin policy for processes of equal priority. This strategy is implemented using one queue of ready processes for each priority. When a process gives up running, it inserts itself at the back of the queue with its priority. Then it calls the processor_allocate routine to select and start the next process. The next process is removed from its ready queue before it is run. Code for this routine is shown below:

```
procedure round_robin;
begin
   make_ready(current_process);
   desk_clerk;
   processor_allocate;
end;
```

Process switching routines

The procedure "make_ready" inserts a process into a FIFO queue of ready processes. Code is shown below:

```
procedure make_ready (p);
    begin process-descriptor parameter p; private integer pri;
    global process-descriptor queue array ready_list;
    comment p = process number to insert in ready queue, ready_list
              is an array of queues, one for each process priority level;
    pri:= priority(p);
    insertp (p, ready_list(pri));
    end;
```

The operation of releasing a processor and reassigning it is machine dependent and so will only be sketched here. It involves storing copies of the processor registers in the old process's data area and loading new values into the registers from the new process's data area. The abstract program is shown below:

```
procedure processor_allocate;
begin global process-descriptor queue array ready_list;
    private process-descriptor proc;
    private integer i;
    private constant integer maximum_priority;
    "save registers and PC;"
    comment  find highest-priority, non-empty ready set. If all the
             other ready sets are empty, there is always a process in the
             0 priority set that consumes time and calls
             processor_allocate again;
    i:= maximum_priority;
    while  ready-list(i) is empty do
        begin i:= i-1; end;
    end-while;
    removep(proc, ready_list(i)); comment  places process descriptor in
                                           proc#;
    load registers and PC from descriptor for process proc;
end;
```

Conclusions

O. U. De Zeeman called Einar Newhire's design unrealistic academic poppycock. He would have been more accurate if he had simply called it incomplete. In this report we have shown how Newhire's design can be refined in a step-by-step way, adding code to implement the missing portions. This code could be added in the form of subroutine calls but we do not recommend that. We propose that the code given here be implemented as macros and inserted in-line so that the many calls will not incur excessive overhead. The resulting code will be a bit hard to read, but no one need read it. The macro expansion process should be automated so that changes can be made to the separate sections rather than to the expanded code. This will save immense labor during the program maintenance part of the HAS system's life cycle.

EVAL.1 Comment Sheets

Name (optional):_____

Instructions

Please use the following sheets to record your observations as we progress through the course. Identify lecture, example, or exercise material under discussion by using the relevant document identifier. Highlight what you liked as well as the problems you found. Lengthy comments may be extended into the following entry and should be so indicated by crossing out the intervening typing. Examine the example below.

Turn in all comments at the end of the course.

Example

Relevant document: PF.2

Not enough time allocated, but good exercise.

Typo: "propreties" on next to last line of first page.

Relevant document:_____

Relevant document:_____

Relevant document:_____

Relevant document:_____

Relevant document:_____

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EVAL.2 Course Evaluation

Name (optional)_____

Instructions

1. There are eight questions or requests for information. Please respond to all eight.

2. For questions followed by a rating scale, mark the scale with a bar, | , to indicate your answer to the question. Scale calibrations appear below the rating bars. You may rewrite scale calibrations you dislike or do not understand.

   If you are a bit uncertain about your rating, mark a lower bound with a left parenthesis, (, and an upper bound with a right parenthesis,) .

   We encourage you to elaborate on your rating in the space provided below the scale.

   Your rating might look something like .....(..:.....|....:...).....
   XXX XXXX

   I think that this material should ...

3. Please attach any comment sheets (EVAL.1) you completed during the course.

Questions

1. What percentage of the time that you devote to software do you spend on the following software activities? Try to have the sum approximate 100%.

	0%	25%	50%	75%	100%
Project or Acquisition Management (including contracting, financial management, data item management)					
Software Construction (including analysis, design, code, debug, maintenance, and documentation)					
Software Testing or System Evaluation					
Configuration Management or Quality Assurance					
Software Engineering Research or its Funding					
Teaching					
Other (_____)					

2. How well were the course goals met? (See section VIII of GEN.1.)

not at all	one-fourth	halfway	three-fourths	totally

3. What is your overall understanding of the course material?

lost	vague	basics	good	total

4.a. How useful will the course be to your work?

fatal	harmful	neutral	helpful	vital

b. If you feel it will be useful, how often will it be so?

once	yearly	monthly	weekly	daily

5. How was the overall performance of the instructors?

terrible	poor	fair	good	excellent

6. How do you rate the course overall?

terrible	poor	fair	good	excellent

7. For each course topic, rate how useful the material will be to your work and rate the quality of presentation. If a bad presentation ruined otherwise useful material, please note this.

	Utility					Presentation				
PROGRAM FAMILIES	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
UNDESIRED EVENTS	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
INFORMATION-HIDING MODULES	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
SPECIFICATIONS	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
ABSTRACT INTERFACE MODULES	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
HIERARCHICAL STRUCTURES	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
LANGUAGE CONSIDERATIONS	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent

(Question 7 continued)

	Utility					Presentation				
PROCESS STRUCTURE										
	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
PROOFS OF CORRECTNESS										
	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent
DOCUMENTATION										
	fatal	harmful	none	helpful	vital	terrible	poor	fair	good	excellent

8. A list of questions on miscellaneous topics follows. Please add topics of your own.

   a. What were the good and bad aspects of the programming assignment (MADDS)?

   b. What were the good and bad aspects of the MP and HAS examples?

c. What problems, if any, are there with the pseudo code (GEN.5)?

d. What definitions should be improved or should be added to the glossary (GEN.6)?

e. What new topics should be added to the course; which current topics should be dropped?

f. How will you use some of the course ideas in your future work?

g.

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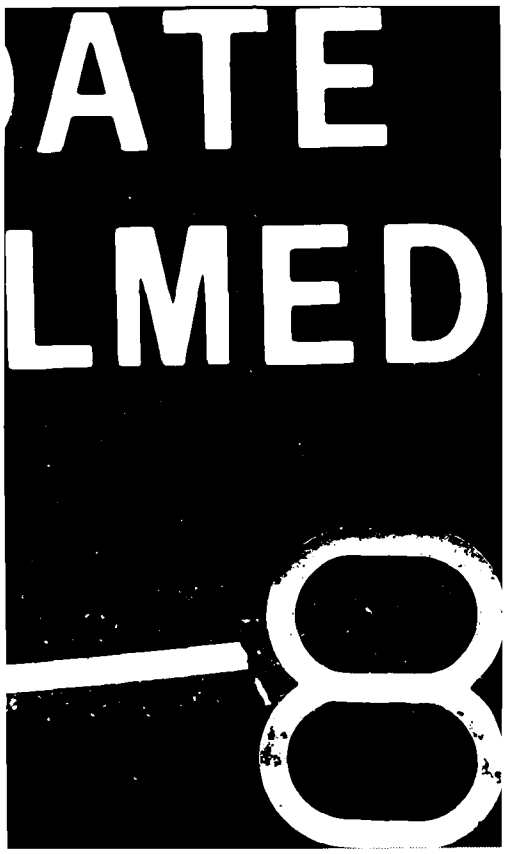
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