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SOFTWARE ACQUISITION MANAGEMENT GUIDEBOOK: SOFTWARE DEVELOPMENT AND MAINTENANCE FACILITIES

APRIL 1977

Prepared for

DEPUTY FOR COMMAND AND MANAGEMENT SYSTEMS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Hanscom Air Force Base, Bedford, Massachusetts

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Bedford, Massachusetts
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This document is one of a series of guidebooks covering important aspects of software acquisition. The guidebooks are prepared for use by Air Force program office personnel responsible for the management and planning of software development. This guidebook focuses on the management decisions and technical issues related to planning and acquisition of software development and maintenance facilities.

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ABSTRACT

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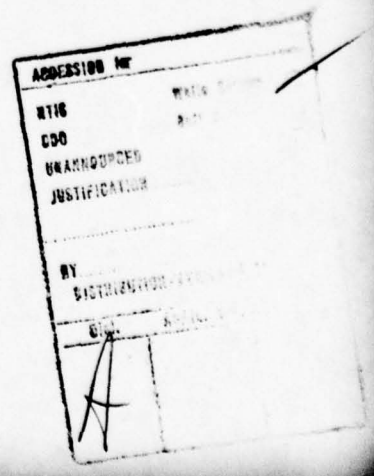

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PREFACE

This report is one in a series of guidebooks intended to assist system program office personnel in software acquisition management. The contents of the guidebooks will be revised periodically to reflect changes in software acquisition policies and practices and as the result of feedback from users.

This guidebook has been prepared under the direction of the Computer Systems Engineering Directorate (MCI), Electronics Systems Division (ESD), Air Force Systems Command. The Software Acquisition Management Guidebook series is currently planned to cover the following topics. (National Technical Information Service accession numbers for those published to date are in parentheses where available.)

1. Project Guide to Content Requirement and Audience Needs (AD-A019124)
2. Regulations, Specification & Standards (AD-A016401)
3. Contracting for Software Acquisition (AD-A020444)
4. Monitoring and Reporting Software Development Status (AD-A016488)
5. Statement of Work Preparation
6. Reviews and Audits
7. Configuration Management
8. Requirements Specification
9. Software Documentation Requirements (AD-A027051)
10. Verification
11. Validation and Certification
12. Overview of the Series
13. Software Maintenance
14. Software Quality Assurance
15. Software Cost Estimating and Measuring
16. Software Development and Maintenance Facilities
17. Life Cycle Events

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1. INTRODUCTION

The primary purpose of the guidebook series is to assist Air Force program office personnel in planning and managing the software aspects of system acquisition. Among the critical resources that require careful planning in system acquisition are facilities necessary for development and maintenance of computer programs. For contracting purposes, a Software Development Facility (SDF) or Software Maintenance Facility (SMF) can be viewed as a number of resources, i.e., buildings, computers, programs, personnel, etc.

This guidebook:

- Examines the need for such SDF's and SMF's and their roles.
- Indicates policy affecting their acquisition.
- Identifies key management decisions and technical issues involved in their planning.
- Surveys existing SDF's and SMF's.
- Identifies potential problems and provides recommendations.

This information should be useful to program office personnel who must plan and acquire such facilities for Air Force use or specify requirements for contractor software development or maintenance.

A secondary purpose of this guidebook is to inform using, supporting, and higher level headquarters of the need for facilities throughout the system life cycle, from early development through operations. SDF requirements are not normally recognized early enough, and maintenance support following system development is sometimes ill-planned.

SDF's or SMF's may be acquired, operated or managed by the Government, contractor(s) or some combination of the two. Generally, they are acquired incidentally as a means to develop operational software. This guidebook focuses on SDF's and SMF's acquired within the framework of the 800 series of Air Force regulations (AFR 800 series).

Only SDF and SMF requirements for command, control and communications systems are discussed, although these requirements often overlap other applications. This guidebook focuses on the hardware and software issues. Other aspects of facilities such as building construction or plant engineering are not discussed.

The reader is advised to examine the various policies and regulations referenced throughout the guidebook for further details. The remainder of this section describes the guidebook's organization.

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Section 2 discusses the need for SDF's and SMF's within the context of the life cycle phases defined in AFR 800-14, Volume II, Acquisition and Support Procedures for Computer Resources in Systems [1].

Section 3 examines SDF and SMF characteristics of several existing or planned command, control, and communications systems. There were important reasons for doing such a survey:

- To examine the key management decisions involved in planning, contracting, and operating SDF's and SMF's.
- To examine the roles and types of support hardware and support software used in existing SDF's and SMF's.
- To find out how SDF and SMF requirements for planned, but as yet unacquired, systems have been specified.
- To uncover common problems encountered in planning and using a SDF or SMF.

Significant SDF and SMF characteristics for all surveyed systems are summarized at the beginning of Section 3. The systems are then briefly discussed in Sections 3.2 through 3.5 and Appendices A and B for the benefit of those who want more detail.

Section 4 summarizes the key management decisions and technical issues to resolve in planning, contracting for, and operating any SDF or SMF. The types of support hardware and software that should be considered are identified and various trade-offs are examined. Appendix C discusses the most important types of support software used in the systems surveyed.

DoD and Air Force policies that impact SDF and SMF planning are also discussed. The documents in which their requirements are specified are identified, and the steps in contracting are discussed. Factors to be considered at Preliminary Design Reviews (PDR's) and Critical Design Reviews (CDR's) are also identified.

The survey uncovered several common problems in planning and contracting for SDF and SMF resources. These problems are identified, and recommendations for avoiding them are provided in Section 5.

2. SOFTWARE DEVELOPMENT AND MAINTENANCE FACILITY ROLES IN SYSTEM ACQUISITION

SDF's and SMF's can take many forms, depending on the management constraints and system support requirements. This section discusses their roles within the context of acquisition life cycle and computer program life cycle phases.

2.1 Acquisition Life Cycle Phases

Air Force direction pertaining to defense weapon system acquisition is included in the AFR 800 series of regulations. Acquisition life cycle phases are defined in AFR 800-14, Volume II [1] as follows:

Conceptual Phase. "This is the initial planning period when the technical, military and economic bases are established through comprehensive studies, experimental development and concept evaluation. The objective of this initial planning may be directed toward refining proposed solutions or developing alternative concepts to satisfy a required operational capability."

Validation Phase. "This is the period when major system characteristics are refined through studies, system engineering, and preliminary equipment and computer program development, test and evaluation. The objective is to validate the choice of alternatives and to provide the basis for determining whether or not to proceed into the next phase."

Full-Scale Development Phase. "This is the period when the system, equipment, computer programs, facilities, personnel subsystems, training, and the principal items necessary for support are designed, fabricated, tested, and evaluated. The intended outputs are a system which closely approximates the production item, the documentation necessary to enter the production phase, and the test results which demonstrate that the system to be produced will meet the stated performance requirements."

Production Phase. "This is the period from production approval until the last system item is delivered and accepted. The objective is to efficiently produce and deliver effective and supportable systems to the using command(s)."

Deployment Phase. "This period commences with delivery of the first operational unit and terminates when the system is removed from the operational inventory."

The acquisition life cycle phases of a command, control, and communications system are depicted in the upper portion of Figure 1.

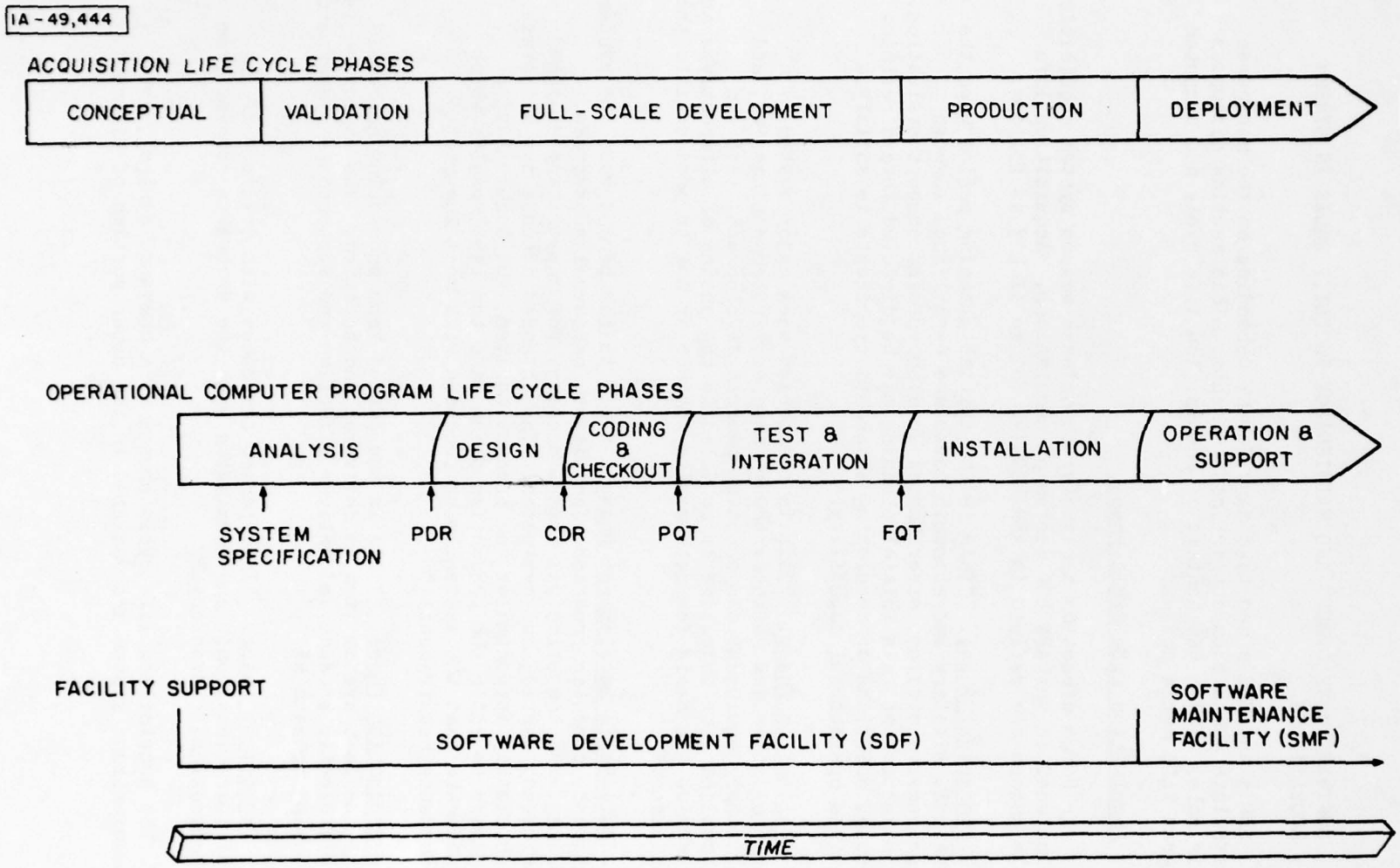

Figure 1. Life Cycle Phases

2.2 Computer Program Life Cycle Phases

According to AFR 800-14, Volume II, the computer program life cycle consists of the following six phases: analysis, design, coding and checkout, test and integration, installation, and operation and support. Although the AFR 800-14 allocation of tasks to phases is somewhat arbitrary, it closely approximates what actually occurs in software production and use of command, control, and communications systems.

The middle portion of Figure 1 identifies the computer program life cycle phases involved in production of such a system's operational software. These phases could occur earlier or later for development of support software (e.g., a compiler). It should also be noted that there may be more than one operational software Configuration Item (CI), that there is a separate computer program life cycle for each CI, and that these life cycles may be independent.

The Software Acquisition Management Guidebook: Life Cycle Events [2] describes the activities and products within each phase. The following paragraphs discuss those activities associated with development of the operational software that require or may require SDF or SMF support.

Analysis. The purpose of this phase is to define the functional and performance requirements for a computer program (i.e., Computer Program Configuration Item (CPCI)). For operational software, the analysis is based mainly on the initial version of the system specification which is a product of the conceptual phase of the acquisition life cycle.

The computer program life cycle analysis phase basically falls within the time frame of the acquisition life cycle validation phase. Computer program development specifications are produced during this phase. It should be noted that system level analysis (e.g., requirements analysis, preliminary system design, prototyping, modelling) which involves some software analysis may occur during the conceptual phase to analyze various tradeoffs and provide a basis for development of the initial system specification.

During the computer program life cycle analysis phase, various software design approaches are considered and trade-offs performed. The selected design approach must satisfy the requirements as defined in the system specification and computer program development specification (see Appendix A of the Life Cycle Events Guidebook [2]). The design approach for each CPCI should be reviewed at a PDR.

Design. Design includes the selection of algorithms, data structures and computer program logic necessary to implement the CPCI requirements. The result is a detailed definition of the computer programs, their interfaces, overall program flow, division of programs into units, and incorporation of features to facilitate testing. The design approach is documented in the preliminary computer program

product specification. This specification is reviewed against the system specification and computer program development specification during CDR.

Coding and Checkout. Coding involves the translation of the design into programming language statements. These statements are then compiled or assembled into instructions executable by the operational computer. Each computer program undergoes preliminary checking and debugging to verify that it functions satisfactorily (e.g., generates the appropriate output). The Preliminary Qualification Test (PQT) for each CPCI may begin in the late stages of coding but generally occurs at the end of the coding and checkout phase.

Test and Integration. During test and integration, the operation of the individual computer program modules is verified against the requirements specified in the computer program development specification and ultimately the system specification. The modules are integrated stepwise until the total system is built and tested. The use of top-down structured design and programming techniques could alter the sequence of events. In particular, not all design would need to be completed before coding began and there might not be a separate series of module integration tests for each module.

There are two types of formal testing of CPCI's: PQT (previously mentioned) and Formal Qualification Test (FQT). PQT is performed for critical functions and occurs in the time period between CDR and FQT. FQT is a complete and comprehensive test of each CPCI.

Installation. Installation includes the loading, operation, and testing of computer programs within the operational environment. Following the completion of FQT's for all CPCI's, the system is released for system level Development, Test and Evaluation (DT&E). System level DT&E is a formal qualification of the total system against the requirements of the system specification. Such system testing is performed in an environment as near as possible to the operational environment. Initial Operational Test & Evaluation (OT&E) is performed prior to the production decision which terminates the full-scale development phase of the acquisition life cycle. Initial OT&E may overlap system level DT&E. Follow-on OT&E is conducted after the production decision. OT&E measures the system's military utility and operational effectiveness.

Operation and Support. Follow-on OT&E is continued, as necessary, during and after the production decision to ensure that the system continues to meet operational needs. SMF's must be provided to support maintenance of operational software beginning with the system's deployment.

It is necessary to distinguish between software maintenance and development. Maintenance generally involves minor modifications of the operational or support software in order to correct software errors (e.g., latent defects discovered after qualification testing) or adjust

system parameters for a changing operational environment. For purposes of this guidebook, maintenance also includes minor changes to system requirements (e.g., low-level type Engineering Change Proposals) that do not involve major development of software. It is unrealistic to assume that such changes will not occur, and a SMF should accommodate these changes. A new SDF may need to be established or an existing SMF upgraded in order to perform major system alterations or upgrades. The Software Acquisition Management Guidebook: Software Maintenance [3] discusses in more detail computer program maintenance activities.

2.3 Software Development and Maintenance Facility Roles

The factor that distinguishes a development facility from a maintenance facility for a specific system is the phase of the acquisition being supported. A SDF may be used during the conceptual and validation phases of the acquisition life cycle to support system modelling and prototyping; however, a SDF is required from full-scale development through production (see Figure 1). When the system is deployed a SMF is required. It should be noted that a SDF and SMF:

- Are not necessarily the same physical facility.
- May have different users and operators.
- Normally have different approaches to facility operations and management.
- May overlap in time.

There may be more than one SDF or SMF for a given system. In some cases, maintenance is performed at the operational site. In other cases, maintenance is performed at a facility which supports maintenance and development of other systems. A SDF or SMF may also support user training and system exercises; however, it is beyond the scope of this guidebook to discuss these latter two roles. The survey of typical SDF's and SMF's reported in Section 3 illustrates all combinations of facility roles.

A SDF or SMF may include more than one support computer. Each computer may support a separate set of activities (e.g., compilations, module tests, CPCI FQT's). The set of hardware and software that one should consider in supporting each of the computer program life cycle phases is discussed in Section 4.

3. EXISTING SOFTWARE DEVELOPMENT AND MAINTENANCE FACILITIES

SDF's and SMF's for 14 systems were surveyed to determine what types of such facilities currently exist or are planned for command, control, and communications systems within the Air Force. Significant features of these facilities are summarized in Section 3.1. Appendix A briefly describes each system's operational role. Four of the 14 systems have been selected for further analysis and are described in Sections 3.2 through 3.5. The SDF's and SMF's of the remaining ten are described in Appendix B. These 14 systems provide good examples of the:

- Major decisions involved in planning a facility.
- Different roles of a facility.
- Typical support hardware and software.
- Transition from development to maintenance.

In order to gather the survey data, personnel at ESD or MITRE involved in each program were interviewed. Selected sites were visited by the author in order to tour specific SDF's and SMF's and interview personnel involved in their planning, management, and operation. Many of the recommendations listed in Section 5 are based on these interviews. The survey data presented in this guidebook reflect the status of the systems as of August 1976, and have been reviewed for accuracy by the ESD organizations responsible for each system's acquisition.

3.1 Significant Characteristics and Trends

Table 1 summarizes the significant characteristics of the SDF's and SMF's in each of the surveyed systems. The solid lines in Table 1 separate the various systems (e.g., E-4 and AFSATCOM I). Facilities within each system are delineated with a dashed line. As an example, there were two SDF's for E-4: one at the contractor's plant and the other at a subcontractor's plant. Most of the terms in the table are self-explanatory (e.g., System, Location). The other terms are defined as follows:

- Facility (Role): A facility can support the development or maintenance of the operational system. In some cases, a facility may be used for training the user or for mission exercises. The primary roles of each facility in the system are listed. The type of facility (SDF, SMF, or both) can be equated to the roles listed (development or maintenance).
- Facility (Type): Two descriptors are used to typify how a facility is used. A shared facility is a facility that supports the development or maintenance of more than one system. A dedicated facility is a facility that supports only one system.

- Support Hardware (Type): The primary types of processors used to develop the operational software are listed.

- Support Hardware (Same Type Proc. As Op. Sys.): This heading is an abbreviation for "same type processor as operational system", and each entry indicates whether the processor used to develop the software is the same as that used to run the software.

- Support Hardware (Source): The source of the support hardware is listed.

- Support Software (Type): The primary support software used to develop the operational software or new support software is listed. Section 4.3.1 describes the differences between support software and operational software.

- Support Software (Off-the-Shelf): This entry indicates whether the support software is off-the-shelf.

The use of the term "undetermined" (abbreviated as "undet.") refers to whether a particular location, computer, etc. has been selected. Where detailed requirements have been established in a Statement of Work (SOW) or specification, the requirements are summarized. The remaining abbreviations are defined as follows: Contr. (Contractor), Subcontr. (Subcontractor), Develop. (Development), Maint. (Maintenance), Ded. (Dedicated), Op. (Operational), Appl. (Application), Exec. (Executive), Modif. (Modification), Config. (Configuration), Spec. (Specification), and Microprog. (Microprogramming).

Based on Table 1 and the supporting data in Appendix B, the following general characteristics and trends can be observed:

- Each system requires or has required a development facility.

- Most of the development facilities have been established at a contractor or subcontractor plant.

- Most of the maintenance facilities have been established at Government owned and operated locations.

- Maintenance of the software is not usually performed at the original development facility.

- Development facilities are generally dedicated.

- Contrary to what one might expect, most maintenance facilities are dedicated.

- A number of systems performs maintenance at the operational site.

Table 1

Software Development and Maintenance Facility Characteristics
(As of August 1976)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
E-4 (AABNCP)	Contr.	Develop. of Appl.	Ded.	Customized Burroughs D Machine	No, but can Emulate Op. Machine	Subcontr.	Standard Burroughs Series 700 Support	Yes
							Test Support	No
	Subcontr.	Develop. of Firm-ware and Diagnostics	Ded.	Same as Above		Subcontr.	Same as Above Except without Test Support	
	Undet.	Maint.	Undet.	Undet.			Undet.	
AFSATCOM I	Contr.	Develop.	Shared	UNIVAC 1108	No	Contr.	Standard UNIVAC Support	Yes
				ROLM 1601			1108 Host-Resident Cross Assembler for ROLM 1601	Yes
	AFCS/CCPC Tinker AFB	Maint.	Shared	Undet. Spec. calls for Message Processor, Interface Simulator, & Maint. Peripherals	Undet.	Contr.	Undet. Spec. calls for DOS, Assembly, Load, Edit, Debug, IPL, & Diagnostic Capabilities	Undet.

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
E-3A (AWACS)	Contr.	Develop.	Ded.	Two IBM S/370-155's	No	One Contr. & One GFE	Standard IBM Support	Yes
							Special Utility Programs	No
							JOVIAL Compiler	No
							4 PI Cross Assembler & Simulator	No
				IBM 4 PI CC-1 CPU's Used in Labs & Mission Simulator	Yes	Contr.	Diagnostics	No
	Tinker AFB	Maint. Exercise Training	Ded.	IBM S/370-155	No	GFE Moved from Contr. Plant	Basically Same as Contr.	Yes
COBRA DANE	Contr.	Develop.	Ded.	CDC CYBER 74-18	Yes	Contr.	Modified CDC Support	Partial Modif. of CDC Scope 3.4 OS

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
	Sheyma AFB Alaska	Maint.		CDC CYBER 74-18 & 74-14	Yes	Moved from Contr. Plant	See Above	See Above
	AFGL Hanscom AFB	Some Maint.	Shared	CDC 6600	No	AF Facility	Standard CDC Support	Yes
COMBAT GRANDE	Initially at Subcontr.	Develop.	Shared	IBM S/370 with Remote Terminals	No	Existing Facility	Standard S/370 Support	Yes
				Hughes H4118 CPU Used in Place of H5118M	No	Subcontr.	S/370 Host-Resident Interactive Simulator for H5118M	Yes
	Later at Contr.	Develop.	Ded.	Hughes H5118M	Yes	Subcontr.	JOVIAL Compiler, Assembler, Tape Generator, Maint. Tools	Mix of Newly Develop. & Off-The-Shelf
				Controller	Yes	Subcontr.	Assemblers, Tape Generator Program Checkout	Yes
	Operational Site	Maint. Operations	Ded.	Hughes H5118M	Yes	Delivered by Contr.	Same as Contr. Facility	
CONUS OTH-B PRS	Subcontr.	Develop.	Ded.	UNIVAC 1110	Yes	Contr.	Standard UNIVAC Support	Yes

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
	Contr.	Develop.	Ded.	UNIVAC 1616	Yes	Contr.	Standard UNIVAC Support	Yes
				GE MPS	Yes	Contr.	Assemblers, Simulators, Debug Utilities	No
	Receive Site	Maint. Operations	Ded.	UNIVAC 1110 UNIVAC 1616 GE MPS	Yes	Subcontr. SDF Contr. SDF Contr. SDF		
JSS	Probably Contr.	Develop.	Undet.	Undet.	Undet.	Contr.	Undet.	Preferred, but Undet.
	Collocated with SE ROCC	Maint. Develop. Operations Training	Ded.	Undet.	Will Closely Approximate ROCC	Contr.	Undet.	Preferred, but Undet.
JTIDS/ ASIT	Undet., but Probably Contr.	Develop.	Undet.	Undet.	Undet.	Contr.	Undet. Spec. Calls for Assembler, Compiler, Binder, Loader	Yes, According to Spec.
	Undet.	Maint.	Undet.	Probably Same as Develop.		Undet.	Probably Same as Develop.	

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
MACIMS	User Command Hq.	Develop. Maint. Operations	Basically Ded.	WWMCCS Force Control System, WWMCCS General Staff Support System.	Same	WWMCCS Contract	Standard WWMCCS Support	Yes
NORAD (427M)	Contr.	Develop. of CSS & MDS Segments	Ded.	Honeywell H6050's, Data General NOVA 840's	Yes	Contr.	Commercial Honeywell H6050 & Data General Support	Yes
	ENT AFB	Develop. of SCC Segment	Ded.	WWMCCS Force Control System (Similar to Honeywell H6080)	Yes	WWMCCS Contract	Standard WWMCCS Support	Yes
	NORAD Mountain Complex	Develop. of NCS	Ded.	WWMCCS Force Control System (Similar to Honeywell H6080)	Yes	WWMCCS Contract	Standard WWMCCS Support	Yes
		Maint. Operations		See Above		Contr. & ENT AFB Computers Moved into Mountain	See Above	

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
PAVE PAWS	Contr.	Develop.	Ded.	CYBER 174-12	Same	Contr.	Standard CDC Operating System Being Modif.	No, Modif.
							Structured Programming Tools (e.g., JOVIAL Preprocessor)	No
				MODCOMP IV/25	Same		Standard MODCOMP IV/25 Support	Yes
	Two Sites (Otis AFB & Beale AFB)	Maint. Operations	Site	Same as Above	Same	Delivered from Contr. Facility	Same as Above	Same as Above
SATIN IV	Contr.	Develop. of Exec.	Ded.	Undet., but Spec. Indicates Config. Should be Same as that Delivered to CCPC	Undet.	Contr.	Undet., but same as that at CCPC	Yes, According to Spec.
		Integration of Exec. & Appl.						

Table 1 (Continued)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
	AFCS/CCPC Tinker AFB	Develop. of Appl.	Shared	Undet., but Same as Contr. Facility	Undet.	Contr.	Undet., but Same as Contr.	Yes, According to Spec.
	Offutt AFB	Maint.	Ded.	Undet.	Undet.	Contr.	Undet., but Spec. Calls for Assembly, Compile, Debug, Test, & Load Capabilities	Yes, According to Spec.
TACC AUTO	Subcontr.	Initially Develop. of AN/UYK-7 Support & Exec. Software	Shared	UNIVAC 1108	No	Existing Facility	Standard UNIVAC Suport, AN/UYK-7 Cross Assembler & Compiler	Yes
				UNIVAC AN/UYK-7	Yes	Subcontr.		
	Subcontr.	Initially Develop. & Modif. of AN/ UYK-25 Software	Shared	Microprog. Lab	No	Existing Facility	Microprog. Support	Yes

Table 1 (Concluded)

SYSTEM	FACILITY			SUPPORT HARDWARE			SUPPORT SOFTWARE	
	LOCATION	ROLE	TYPE	TYPE	SAME TYPE PROC. AS OP. SYS.	SOURCE	TYPE	OFF-THE-SHELF
	Contr.	Initially Continued Develop. & Modif. of AN/UYK-7 OS & Diagnostics	Ded.	UNIVAC AN/UYK-7	Yes	Contr.	AN/UYK-7 Support	Mix
	Langley AFB	Develop. Maint.	Ded.	UNIVAC AN/UYK-7	Yes, but Initially Some Proto-type Equipment	Delivered from Contr. Facility	Same as Contr.	See Above
TRI-TAC	Subcontr.	Develop. & Modif. of UNIVAC U1600 Hardware & Support Software	Existing Facility	UNIVAC U1600	Yes	Subcontr.	Standard AN/UYK-20 Support Software Modified	Yes, but Some Modif.
	Subcontr.	Develop.	Ded.	UNIVAC U1600	Yes	Subcontr.	See Above	See Above
	Contr.	Develop.	Ded.	UNIVAC U1600	Yes	Moved from Subcontr. Facility	See Above	See Above
	Undet.	Maint.	Ded.	UNIVAC U1600	Yes	Moved from Contr. Facility	See Above	See Above

- The support software is generally off-the-shelf; however, some portions of the support software for certain systems (e.g., E-3A) were newly developed.

- Some systems have not established any definite plans for maintenance, despite a need.

- Facilities for development or maintenance are generally expansions of the operational system with peripherals necessary to support software development or modifications.

- Maintenance support is generally a subset of the development support.

- The types of maintenance performed vary greatly from simple release of the operational software at new sites to major system modifications.

- In some cases, the hardware at the contractor's facility is moved to a Government maintenance location.

- In most cases, the operational software is developed by more than one contractor or Government agency.

3.2 E-3A (AWACS)

The E-3A system was selected for further analysis since it included several development laboratories (i.e., sets of computer equipment and other hardware within a facility), has a long history of development, and illustrates the transition from development to maintenance. The Model I phase of E-3A was contracted in July 1970 to Boeing on a cost plus incentive fee contract. As of August 1976, Model I software was undergoing system test at the Boeing plant and E-3A test flights were being flown. The operational Model I software will be delivered to Tinker AFB in conjunction with the first production delivery of the E-3A in March 1977.

The Tactical Air Command (TAC) and the Air Force Logistics Command (AFLC) will maintain the Model I software at Tinker AFB. Concurrently with Model I software maintenance, the E-3A program office will be developing follow-on software models in conjunction with E-3A enhancement activities.

An AWACS Life Cycle Computer Program Management Plan delineates a concept for development, transition, and operation of AWACS software and discusses the E-3A facilities, hardware, software, configuration management, testing, organization, manning, and training. An E-3A Software Support Phase-in Plan outlines the tasks to be performed during early operation of the Tinker AFB maintenance facility.

An E-3A Transitional Phase Operational/Support Configuration Management Procedures (O/S CMP) provides more detailed plans and

procedures to be used for software maintenance during the transitional phase of the program. This document provides an in depth treatment of such subjects as configuration management, problem reporting, testing, documentation, organizational interfaces, and the concurrent maintenance of Model I with the ongoing development of Model II software.

3.2.1 Acquisition Approach

Boeing is the prime development contractor for the E-3A system and has developed the airborne operational program which operates on the IBM 4 PI CC-1 (4PI) computers. The airborne surveillance radar programs and the navigation programs have been subcontracted to Westinghouse and Delco/Northrup, respectively. Some of the support software (see Section 4.3.1 for the distinction between support and operational software) development was subcontracted to IBM (e.g., the 4PI cross-assembler, simulator, diagnostics, and master tape generator) and System Development Corporation (SDC) (i.e., the JOVIAL compiler). Boeing has developed most of the ground-based computer programs which include the:

- System Exercise & Analysis Computer Program, which operates on an IBM System 370-155 computer and generates exercise tapes and materials for testing the operational program and for training personnel. It also reduces data recorded during a live mission or test.
- Mission Simulator Program, which operates on a 4PI computer configuration similar to the airborne configuration.
- Ground Support Computer Program, which operates on a 4PI and supports the preparation, maintenance, and testing of the E-3A data base.
- Individual Positional Trainer Program, which operates on a 4PI configuration and provides the capability of qualifying E-3A crew personnel.
- Utility Computer Programs, which support the production and maintenance of E-3A programs that execute on an IBM 4PI and System 370-155.
- Surveillance Radar Ground Support Computer Programs, which operate on an IBM System 370-155 and a radar computer.

3.2.2 Software Development and Maintenance Facilities

Boeing established an E-3A software development facility at a plant in Seattle, Washington. As of August 1976, an E-3A Computer Program Ground Support Facility was being installed at Tinker AFB, which is the E-3A main operating base.

The Boeing facility consisted of several development laboratories and training centers. An Avionics Integration Laboratory, the ground test bed for the E-3A, was used to conduct integration tests. It basically was a mock-up of an E-3A aircraft configuration. A Software Development Laboratory was established to develop and test the Airborne Operational Computer Programs and other software that run on the 4PI computers.

An Engineering Development Laboratory was used to test selected vendor equipment prior to installation in the Avionics Integration Laboratory. Another laboratory was established to support the Time Division Multiple Access (TDMA) development and provide additional processing support for E-3A software development. The Mission Simulator was used to train mission crews and also provided a means to check out the Airborne Operational Computer Program. An Individual Positional Trainer was set up to train individual crew members. One IBM System 370-155 and the Mission Simulator were moved from Boeing to Tinker AFB for use by TAC and AFLC in maintaining E-3A software.

3.2.3 Support Hardware and Software

Two IBM System 370-155 computer systems were used at Boeing for the development of the airborne and ground support programs. One of the IBM System 370-155's was provided as Government Furnished Equipment (GFE). The other was supplied by the contractor.

The two IBM System 370-155 computers operated under a slightly modified version of the IBM operating system release 21.7. Each system was functionally equivalent and consisted of main memory, tape, disk, line printers, card reader/punch, system console, paper tape punch, and paper tape reader. Boeing developed a number of tools in addition to the standard IBM utilities to support development of the operational software.

Boeing's philosophy in setting up the development laboratories has been to extend the operational hardware to accommodate software development. In some cases, additional core was added to run on-line debugging utilities. In other cases, special adapters were designed to interface standard commercial peripherals to the 4PI processor systems.

3.2.4 Key Decisions

Since the system development was contracted to a single contractor, only one development facility needed to be established. The contractor defined and installed the required facility at his plant.

The original contract called for delivery of support software necessary for maintenance of E-3A software. This decision should help ensure that the Air Force can organically maintain the system. It should be noted that some of the support tools developed by

the contractor were not listed on the original Contract Data Requirements List (CDRL); however, since these tools were developed with Air Force money, they will be delivered to the Air Force along with available commercial documentation for use at Tinker AFB.

One major decision was to change the development support computers from 4PI's to IBM System 370's. Engineering Change Proposal 165 recommended that IBM System 370's would be more cost effective than the 4PI computer systems and would better support some of the large data reduction processing. The change in midstream from one support system (4PI) to another (IBM System 370) resulted in changing many of the original support software requirements, including the JOVIAL compiler. The contractor thus developed some of the IBM System 370 support software concurrently with the operational software.

Responsibility for the development, maintenance, and modification of the specific E-3A computer programs was assigned to TAC and AFLC according to their respective operational and support functions. By collocating the 552 AWAC Wing with the Oklahoma City Air Logistics Center (ALC) at Tinker AFB, TAC and AFLC will be able to jointly use the Computer Program Ground Support Facility for software maintenance, thus eliminating the need for separate TAC and AFLC support facilities. In order to further enhance TAC's organic software maintenance capability, nine TAC personnel were assigned to work as programmers at Boeing during the software development phase. As the development phase neared completion, these personnel were reassigned to Tinker AFB to form the cadre of the TAC organic maintenance team.

3.3 NORAD Cheyenne Mountain Complex Improvement Program

The North American Air Defense Command (NORAD) 427M program was selected for study since it includes a number of contractor and Government development facilities and illustrates the use of a variety of World Wide Military Command and Control System (WWMCCS) and commercial hardware and software. The 427M system is a joint development effort by Government and contractor agencies. The system has been in development approximately seven years. It will replace the 425L (NORAD Combat Operation Center) and the 496L (Space Defense Center) systems presently installed in the NORAD Cheyenne Mountain Complex (NCMC). Portions of the 427M system were ready for "informal" testing as of August 1976.

The 427M operational system (see Figure 2) will consist of three segments: Communications System Segment (CSS), Core Processing System (CPS) segment, and Modular Display System (MDS) segment. The CPS segment consists of the Space Computational Center (SCC) subsystem and the NORAD Computer subsystem (NCS). Each of the CPS subsystems will operate on a separate WWMCCS H6080 processor. There is also a backup H6080 processor that can be used for testing, exercising, NCS and SCC backup, and maintenance.

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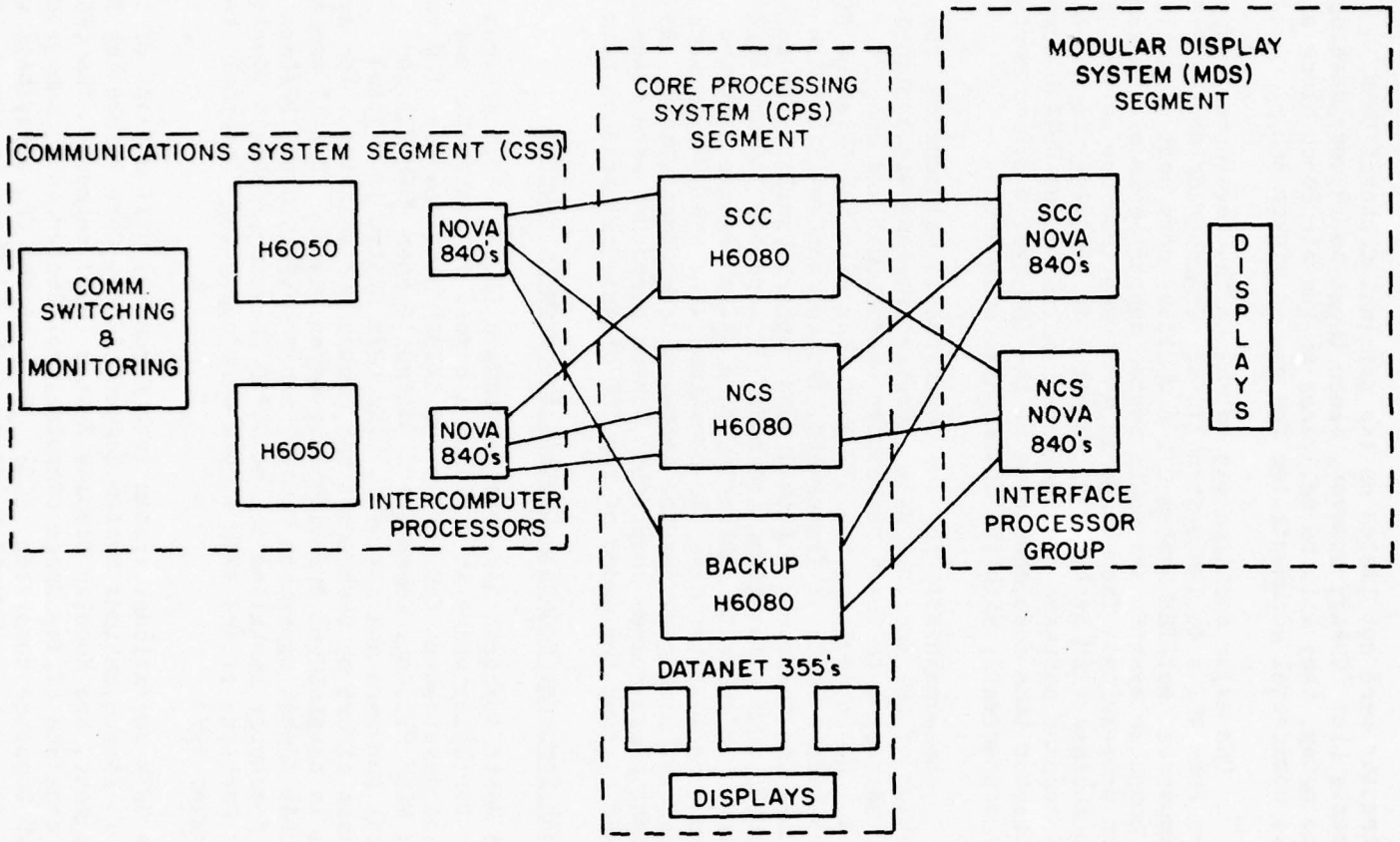

Figure 2. Simplified Diagram of Major 427M Operational Segments

3.3.1 Acquisition Approach

Aerospace Defense Command (ADCOM) developed the NCS software. The SCC development was contracted to SDC. Aeronutronic Ford Corporation was selected as the prime contractor for the CSS development; however, SDC was subcontracted to develop four CPCI's of the CSS. The display subsystem development for the CPS was also contracted to SDC; however, when another processor was added to the CPS, it was necessary to redesign the display subsystem (now designated as the MDS segment) for a three-processor system. This display subsystem upgrade was contracted to Aeronutronic Ford Corporation with the SDC display software provided as Government Furnished Property (GFP). The MDS is a slight modification of the equipment and software developed by SDC.

3.3.2 Software Development and Maintenance Facilities

Three facilities were used for development of 427M software:

- The Staging and Test Facility (STATF) at Aeronutronic Ford Corporation was used primarily for development of the CSS. Some minor development was performed on the STATF for the MDS upgrade.

- Computers at the NCMC were used for development of the NCS portion of the CPS.

- The Computer Programming Production Facility (CPPF) at Ent AFB was used for the development of the SCC portion of the CPS. The CPPF was also initially used for development of portions of the NCS software before this development was moved into the NCMC. Some of the original display subsystem software was also developed at the CPPF.

A Display and Programming Terminal subsystem is being developed and may be used as a maintenance terminal from a remote location (possibly Peterson AFB) after the CPPF hardware is moved within the NCMC. At the time of the NORAD visit in August 1976, the CPPF and STATF hardware had not been moved into the NCMC, but the NCMC area (e.g., space, cabling) was being prepared. The final stages of integration and system test will be performed in the NCMC.

Aeronutronic Ford Corporation installed the STATF and was responsible for running it. After the STATF equipment is relocated to the NCMC, Aeronutronic Ford Corporation will be allowed computer time at the NCMC. ADCOM will contract for maintenance of all hardware and software within the NCMC.

3.3.3 Support Hardware and Software

Figure 2 depicts the major hardware components of the 427M operational system. The STATF and CPPF facilities included basically the same processor and peripheral hardware for development as that to be used in the operational segment configurations. Figure 3 illustrates the CPPF facility configuration as of April 1976. Standard WWMCCS support software was used at the CPPF for development of the SCC including the General Comprehensive Operating System (GCOS). The SCC is coded in FORTRAN, COBOL, JOVIAL, and Honeywell's General Macro Assembly Program (GMAP).

The CSS was developed at the STATF on two commercial Honeywell H6050 processors using JOVIAL (Honeywell commercial version) and GMAP. A special real-time executive was developed for the CSS operational software since the standard GCOS does not provide the required throughput capabilities. The special executive is called the Real-Time Controller and is loaded along with the operational software as a master job under GCOS control. The CSS was developed using the standard commercial utilities provided by Honeywell. Some special support software was developed to aid in debugging and testing. These tools include memory display/change/insert, buffer utilization, tracking, snapshot dump, and message capture capabilities.

The MDS segment was developed on Data General NOVAs using assembly language. Data General's Real Time Operating System Version 2 has been slightly modified for use as the MDS NOVA operational executive; however, the standard Data General Real Time Disk Operating System and its associated support were used for development of the MDS.

The NCS is coded in JOVIAL (WWMCCS version) and GMAP. Standard WWMCCS support software was used in the development using a WWMCCS H6080 processor within the NCMC.

3.3.4 Key Decisions

The division of the development effort between Government agencies and contractors resulted in the establishment of three large-scale development facilities. The decision to use the same hardware for development as for operation will reduce costs and will ease the transition to maintenance; however, use of both WWMCCS and non-WWMCCS support software and many different types of hardware and languages (JOVIAL, COBOL, FORTRAN, Assembly) will complicate the maintenance effort. The ability to perform software maintenance using the backup H6080 processor is largely untested. The main questions are how much maintenance will be performed and will enough time be available.

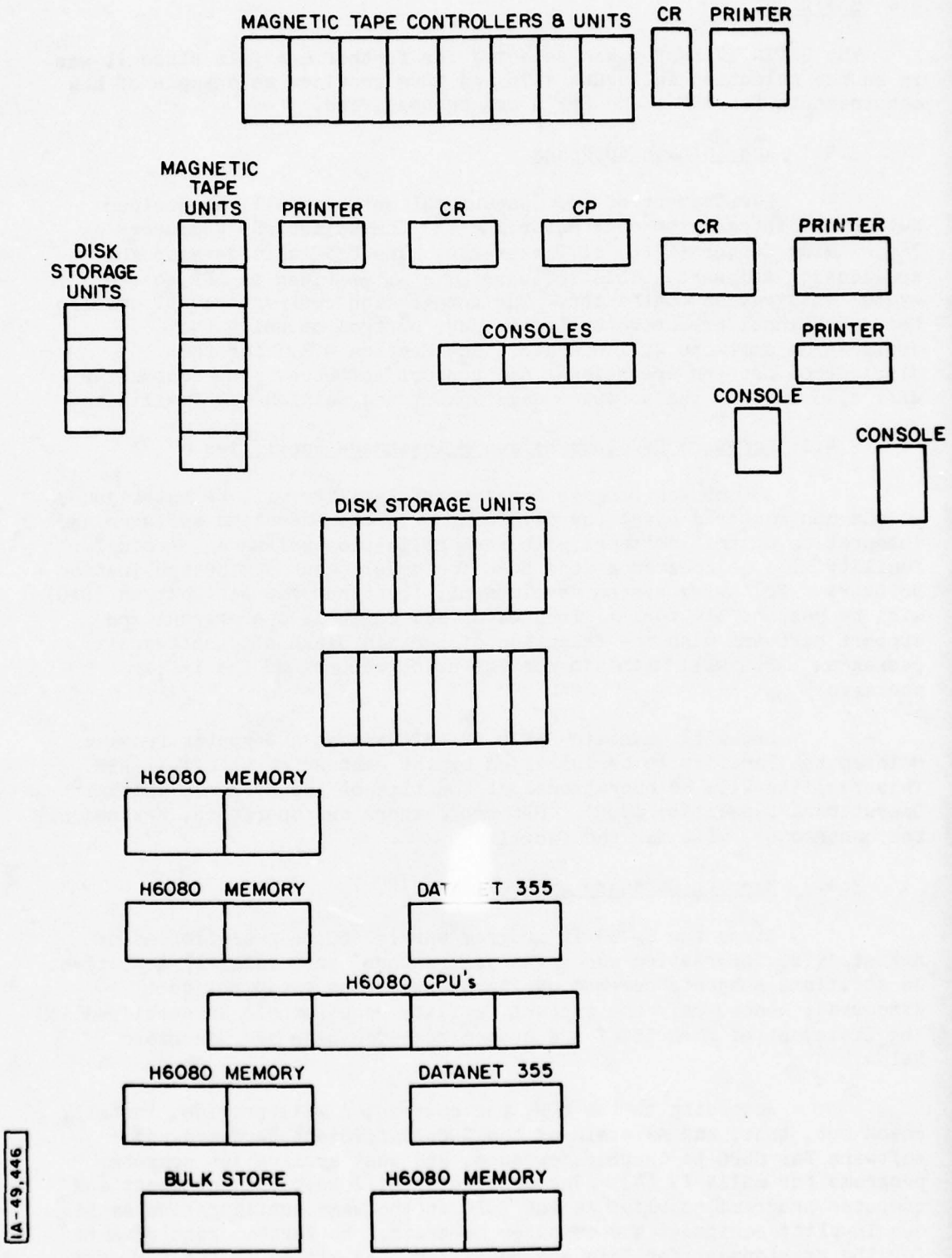

Figure 3. NORAD (427M) Computer Program Production Facility

3.4 SATIN IV

The SATIN IV system was selected for further analysis since it was in source selection in August 1976 and thus provides an example of how requirements for SDF's and SMF's can be specified.

3.4.1 Acquisition Approach

Development of the operational software will be divided between an integration contractor and the Communications Computer Programming Center (CCPC) at Tinker AFB. The CCPC will develop the application software. This software will be provided as GFP to the system integration contractor. The integration contractor will develop the operational executive software under control of which the application software will operate. See Section 4.3.1 for the distinction between operational and support software. The contractor will also install the software development and maintenance facilities.

3.4.2 Software Development and Maintenance Facilities

A Computer Program Development Facility will be established at the contractor's plant for development of the executive software and integration of this software with the application software. A similar facility will be located at the CCPC for development of the application software. Following system development, the Strategic Air Command (SAC) will be responsible for maintenance of all SATIN IV operational and support software with the exception of certain diagnostic software packages. AFLC will maintain configuration control of the latter packages.

SAC will maintain SATIN IV software at a Computer Program Maintenance Facility to be installed by the contractor at Offutt AFB. This facility will be operational at the time of the system's Initial Operational Capability (IOC). SAC programmers and operators, trained by the contractor, will man the facility.

3.4.3 Support Hardware and Software

Since the SATIN IV program was in source selection as of August 1976, information about the contractors' proposals was sensitive. In addition, subjects covered during negotiations could not be discussed; hence, only the support facility requirements as specified in the Statement of Work (SOW) and system specification are described below.

According to the SOW, the contractor will provide, install, check out, test, and maintain at the CCPC sufficient hardware and software for CCPC to develop, produce, and test application computer programs for SATIN IV [4]. The contractor will keep the equipment and computer programs supplied to the CCPC in the same configuration as his own in-plant equipment and computer programs. No further requirements for the development facility are specified. As stated in the SOW, the

CCPC development facility equipment could be transferred to the maintenance facility at Offutt AFB following system turnover of program management responsibility.

A Computer Program Maintenance Facility will be installed at Offutt AFB and will provide SAC the capability to maintain the operational computer programs. Operational computer equipment will be installed and checked out by the contractor. According to the system specification, the Computer Program Maintenance Facility system segment shall have sufficient processors, peripherals, and software to accomplish the following program maintenance, development, and test functions:

- Assemble, compile, debug, and test new or modified software modules.
- Generate new or modified software modules or systems.
- Perform static and dynamic tests on new or modified software modules.
- Format new software modules for transmission across the network.
- Generate machine-loadable programs to be delivered to other processors.
- Generate tapes containing pre-formatted messages.

A standby processor associated with the operational processor is acceptable for maintenance. The requirements also specify that the system should include a special line printer and a capability to enter data from a console.

The system specification further requires that the system and utility software for the Computer Program Maintenance Facility must include at a minimum:

- Assembler (macro)
- Compilers
- Loaders (bootstrap and relocatable)
- Linkage editor
- Cross-assembler and compiler (if support hardware is different from operational hardware)
- Program dump capabilities (snapshot, program, system)

- Software monitor (minimum statistical data requirements are specified)
- Program trace
- Off-line utility programs (e.g., tape copy, merge, and compare)
- Software support library
- Other support programs (e.g., debugging aids and diagnostics)

According to the requirements, the maintenance facility to be installed at Offutt AFB need not have the same hardware and software configuration as the CCPC. Also, the hardware and software requirements listed above apply to the maintenance facility - not to the development facility.

The source selection evaluation board, source selection advisory council, and source selection authority are responsible for determining whether the support hardware and software proposed for the Computer Program Development Facility and Computer Program Maintenance Facility are adequate. During source selection, the Government will negotiate with the contractor for delivery of the necessary support tools and ensure that the support hardware and software are delivered on a schedule that enables the CCPC to develop and SAC to maintain the system.

3.4.4 Key Decisions

The decision to divide the development effort between the Air Force and a contractor resulted in the specification of two development facilities. Since SAC rather than the CCPC will maintain the software, a separate maintenance facility was required. Each facility will be managed, staffed, and operated by a separate agency. As a result, adequate planning and appropriate phasing of the transition from development through maintenance is more critical for these facilities than for a facility that supports a system for the total life cycle. The SATIN IV Computer Resources Integrated Support Plan (CRISP) identifies the organizations and their responsibilities for this transition. Configuration control of both hardware and software among the facilities is also a primary issue. The possibility of differing maintenance and development support necessitates a careful review and evaluation of tools to be delivered to SAC for maintenance.

The decision to assign the application software development to the CCPC impacts how the Computer Program Development Facility there will be used. The SATIN IV support hardware will be housed in the same building as other support hardware. Space may be critical and use of the equipment may be shared among more than one system development effort. Some space has already been allocated for SATIN IV development.

Off-the-shelf support software is specified as a requirement. This decision should reduce the risk in software development since the support software should not be developed concurrently with the operational software. Higher support software reliability should also be expected. The identification in the system specification of specific types of software support to be delivered to the Computer Program Maintenance Facility should ensure that, at a minimum, certain tools will be proposed. The details will be negotiated during source selection.

Many of the SDF and SMF management issues have been addressed in the CRISP. Two separate Computer Program Development Plans (CPDP's) will be written: one by the Air Force for application software development and the other by the contractor. Each CPDP will describe the management of the software development effort. The Computer Resources Working Group (CRWG) may coordinate the two plans. Many of the key decisions affecting the SDF's and the SMF, of course, will be made during source selection and negotiation.

3.5 TACC AUTOMATION

The first phase of TACC Automation (485L), called Package I, will support TACC planning, monitoring, and reporting operations, primarily those concerned with fighter reconnaissance and airlift missions. The 485L operational hardware has passed first article acceptance test. System test is scheduled for 1977, with an estimated operational date for the production systems in 1982.

As of December 1976, the plan was to move the first article operational hardware to Bergstrom AFB for system tests. TAC will eventually maintain TACC Automation software at Langley AFB. There will presumably be a transistion period after the TACC software is delivered during which the contractor programmers will assist TAC programmers in software maintenance.

3.5.1 Acquisition Approach

In 1972, TACC Automation hardware and support software was contracted to the Convair Division of the General Dynamics Corporation. The original contract requested the delivery of the computers (UNIVAC AN/UYK-7's and CDC AN/UYK-25), display and peripheral equipment, and support software. The First Article Hardware was to be delivered within eighteen months to the first article acceptance test. In addition, the development facility hardware was to be delivered within six months of contract award to Langley AFB, Virginia.

UNIVAC developed the AN/UYK-7 operating system and JOVIAL compiler at their plant in St. Paul, Minnesota. Initially, General Dynamics planned to use UNIVAC as a subcontractor to modify and extend the AN/UYK-7 operating system software to meet TACC Automation software requirements. However after prime contract award, General Dynamics encountered difficulty in negotiating a contract with UNIVAC and elected

to do some of the critical parts of the operating system modifications and extensions themselves at their Ft. Worth plant.

In 1973, Computer Sciences Corporation (CSC) received a contract to develop the Package I application software, with TAC personnel providing direct program development support. By late 1974, CSC assumed greater responsibility by also taking over the support software development from General Dynamics.

3.5.2 Software Development and Maintenance Facilities

The primary TACC Software Support Facility (SSF) was established at Langley AFB in the fall of 1973, slightly behind the six-month target. The Langley AFB SSF roles are to include system test, training, and software development.

Besides the facility at Langley AFB, three other facilities were used for developing software during the course of the program. These additional facilities included an installation at UNIVAC, St. Paul, Minnesota which UNIVAC used to develop part of the support software, particularly the JOVIAL compiler and operating system for the AN/UYK-7. Control Data Corporation developed and modified some of the support software for the AN/UYK-25 at their plant.

General Dynamics in Ft. Worth, Texas, established a facility which was used for the further development and modification of the UNIVAC operating system as well as for the development of diagnostic programs. These additional facilities were not explicitly required by the contracts and were not deliverable to the Air Force; however, some problems associated with them did affect the progress of the program.

3.5.3 Support Hardware and Software

The requirement in the original Request for Proposal (RFP) was that the hardware be off-the-shelf, since the SSF hardware had to be available for program development very soon (6-9 months) after contract award. The original RFP for the hardware contract also allowed the hardware bidders to define the configuration of hardware to be provided for the Langley AFB SSF. The requirement was that the SSF equipment be "functionally equivalent" to the first article operational hardware. This requirement was established to allow the contractor to propose delivery of a set of compatible commercial hardware for the SSF if militarized hardware was proposed for the First Article Hardware.

Some of the hardware delivered to the Langley AFB SSF was prototype operational hardware. Since the prototype hardware caused some problems, the first article operational hardware was used in place of prototypes for software development when it became available.

The Langley AFB SSF consisted of the following hardware:

- Data Processing and Display
  UNIVAC AN/UYK-7 computer
  Display consoles and group display
  Primary mass storage (discs)
  Secondary mass storage (tapes)

- Communications Processor
  Control Data Corporation (CDC) AN/UYK-25 computers
  Primary mass storage (discs)
  Secondary mass storage (tapes)

- Data Source Terminal
  CDC AN/UYK-25 computer
  Display consoles
  Primary mass storage (discs)
  Secondary mass storage (tape)

Since the SSF was originally installed, various additions have been made. As an example, the UNIVAC 9200 support system for the AN/UYK-7 was upgraded to a UNIVAC 9300.

The TACC Automation support software was to include operating systems for all computers, JOVIAL compilers, assemblers, and a minimal set of off-the-shelf support tools. The operating systems and compilers transferred to CSC still required further work.

The remainder of the support tools, the available assemblers for AN/UYK-7 and AN/UYK-25, utility tools (debugging aids, etc.), and data reduction and analysis programs were operable when delivered. Some additional support programs have been developed by CSC. Software monitors and hardware diagnostics are available for all subsystems.

3.5.4 Key Decisions

The acquisition decision to split the software development responsibilities did not work well. Problems were encountered by General Dynamics in providing the support software. Without a working operating system and compiler early in the development, application program development was seriously impeded. The split responsibilities did cause some technical problems. Coordination and communication during development were much harder than if a single contractor had developed all the software. The split development also resulted in the facility becoming a "shared" responsibility, i.e., one contractor providing hardware and support software and another doing application software. This situation has since changed.

Selecting a SSF location removed from the contractor, especially the hardware contractor, created an extra risk. A facility remote from both the hardware and software contractors' bases created even more difficulties. The original version of the RFP had assumed that the SSF would be established at the application software contractor's plant. The decision to locate the SSF at Langley AFB was

made by the Office of the Assistant Secretary of the Air Force. The reason given for this change was to provide a closer coupling between the application software developers and the user community at TAC. It was recognized at that time that TAC would eventually take over responsiblity for the maintenance of the software, and therefore locating the SSF at Langley AFB at the outset would save the cost of relocating the facility at a later date.

In 1975, CSC claimed that the original SSF which had been installed at Langley AFB was, or would be, oversubscribed, and thus could not support the software development load which was anticipated; hence CSC and other agencies proposed that the First Article Hardware be used to augment the original SSF hardware. This use was possible because the First Article Hardware had completed its qualification test program. The TACC Automation program has initiated development of a CRISP.

4. SOFTWARE DEVELOPMENT AND MAINTENANCE FACILITY PLANNING AND ACQUISITION

Guidelines for computer resource planning and acquisition are generally outlined in AFR 800-14 [1]. The primary purpose of this section is to identify the key management decisions and technical issues that should be considered in planning SDF's and SMF's. Section 4.1 identifies the various Department of Defense (DoD) and Air Force policies and regulations that affect SDF and SMF planning and acquisition. The management decisions and technical issues are discussed in Sections 4.2 and 4.3, respectively. Section 4.4 describes those planning documents in which SDF and SMF requirements should be specified. Considerations in contracting for these facility resources are provided in Section 4.5. Finally, support hardware and support software items which should be reviewed at PDR and CDR are summarized in Section 4.6.

4.1 Applicable Policies and Regulations

This section discusses those DoD Directives (DODD), DoD Instructions (DODI) and military regulations that impact SDF and SMF planning and acquisition. On the whole there is little guidance on how to plan and contract for facility support.

4.1.1 Department of Defense

The most recent DoD guidance impacting the management of computer resources is contained in DODD 5000.29, Management of Computer Resources in Major Defense Systems [5]. It covers such areas as configuration management, life cycle planning, support software deliverables, and government rights. Several other directives include clauses that apply to the planning and management of SDF's and SMF's. In particular, DODI 4105.65, Acquisition of Automatic Data Processing Computer Programs and Related Services [6], directs that there be an explicit statement in the purchase request of expected Government rights in technical data, and rights and responsibilities regarding the use, alteration, maintenance, and documentation of all deliverables including computer programs, program test output, and all data - during and after the period of the contract. Rights in data are also specified in Sections J and L of the model contract.

Consideration must also be given to possible participation in the Government-wide Automatic Data Processing (ADP) software sharing program of Government-owned or leased resources according to DODI 5030.40, Government-wide ADP Sharing Program [7]. DODD 4160.19, DoD Automatic Data Processing Equipment Reutilization Program [8], directs that ADP equipment be reused to the maximum extent practicable prior to procurement of new equipment and facilities. DODI 5010.21, Configuration Management Implementation Guidance [9], provides guidance on the implementation of DoD policies on configuration management.

DODI 5000.31, Interim List of DoD Approved High Order Programming Languages (HOL) [10], specifies high order programming languages that are approved by the DoD for development of software in major defense acquisition programs. These language restrictions have significant impact on the types of computer systems and associated support software that can be selected for software development.

Procurement of facilities and related services follows conventional practice. The Armed Services Procurement Regulations (ASPR) are the foundation for the contracting policies and practices of all the military services. Major software procurement guidance clauses for software are contained in ASPR Section IX, Part 5, "Acquisition of Technical Data" [11]. This part covers "rights" in data and the form of deliverables. Since support software is one major resource of SDF's or SMF's, many of the clauses apply. Another guidebook, An Air Force Guide to Contracting for Software Acquisition [12], provides more detail on software clauses within the ASPR.

4.1.2 Air Force

The AFR 800 series addresses computers and software acquired as part of a weapons or command and control system. AFR 800-2, Program Management [13], states policy for the management of all Air Force acquisition programs which are funded under research, development, test, and engineering or procurement appropriations. It implements DODD 5000.1, Acquisition of Major Defense Systems [14].

AFR 800-14, Volume II [1] consolidates and amplifies Air Force policy in other regulations that apply to the acquisition and support of computer resources. Those regulations which impact SDF and SMF planning cover such areas as configuration management, equipment maintenance policy, test and evaluation, logistics support, and system equipment turnover. AFR 800-14 amplifies policies in these regulations to ensure that specific attention is focused on the computer resource aspects of system acquisition. These regulations are listed in AFR 800-14 and should be used in conjunction with AFR 800-14 where they apply.

Chapter 3 of AFR 800-14, Volume II [1] provides guidance for the planning of computer resources, including support software and hardware. It covers areas which impact SDF and SMF planning and identifies the major planning documents as the:

- Program Management Directive (PMD)
- Program Management Plan (PMP)
- Computer Resources Integrated Support Plan (CRISP)
- Computer Program Development Plan (CPDP)
- Operational/Support Configuration Management Procedures (O/S CMP)

The uses of these documents for facility planning are discussed in Section 4.4.

4.2 Management Decisions

Section 3 identifies the key decisions involved in planning SDF's and SMF's for four systems (E-3A, NORAD's, SATIN IV, and TACC Automation). Several such decisions apply to any system acquisition. The major questions relate to defining facility requirements. Figure 4 depicts a sequence of decisions and actions that can be used to define these requirements. The letters at the end of the statements below correspond to decision points or actions on the flowchart.

The first steps are to define what is to be developed (A) and who will develop it (B). There are three choices for development: Government agencies, contractors or some combination of the two (see Table 1 in Section 3.1). This decision has major impact on the numbers and locations of the facilities.

For either Government or contractor development, the next question is whether a SDF is required. If the system is new, a SDF should be planned (C). If modifications are to be made to an existing system that has an SMF, its SMF may suffice for software development purposes, depending on the extent of the modifications (D&E).

Once the software development tasks have been allocated between the Government and contractor(s) and the need for a SDF established, each agency should examine existing facilities to see if they can be utilized (F). AFR 800-14, Volume II [1], states that

> "common and existing facilities will be used whenever practicable. The size and scope of the support facility will be based on workload predictions."

If the upgrade of an existing facility is possible (physically and technically) and cost-effective (G), the necessary hardware and software improvements, and operational and management support, should be planned (H). Otherwise, the locations, tasks, hardware, software, management and operational support for these SDF(s) must be planned (I).

The maintenance tasks for the system should then be defined (J). A maintenance facility is always required if the system is to become operational. Who will perform the maintenance should also be determined (K). SDF's are obvious candidates for SMF's (L). According to AFR 800-14, a decision to provide organic, contractor, or some combination of the two types of support must be based upon the policies of AFR 26-2, Use of Contract Services and Operation of Commercial or Industrial Activities [15]. This decision should include consideration of such factors as cost, system stability, interface, and test requirements. If a SDF is to be utilized for maintenance (P), its hardware, software, personnel, etc., must be examined to determine whether it can support

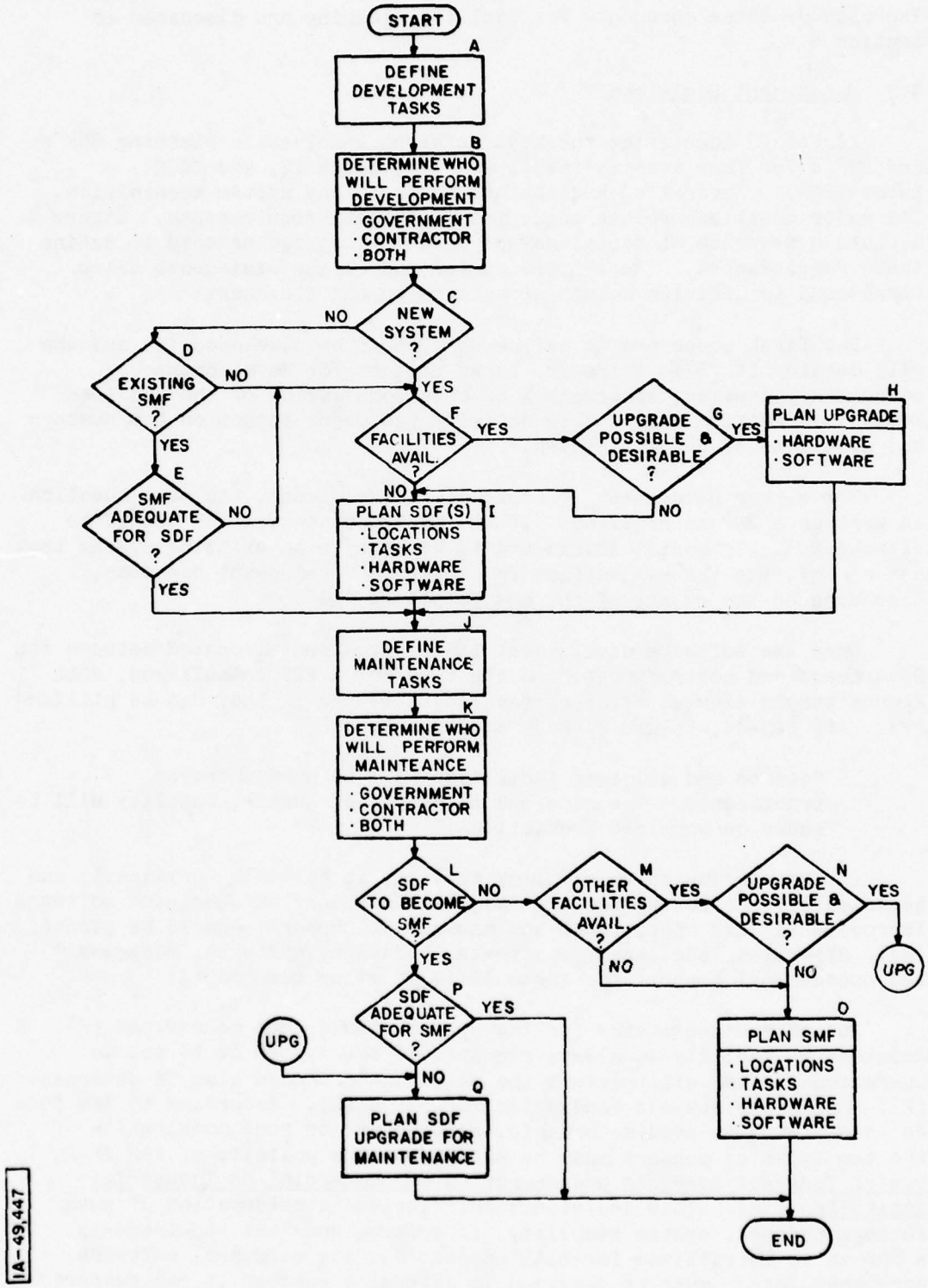

Figure 4. Management Decisions in Planning SDF's and SMF's

the maintenance tasks. If the SDF is not adequate, upgrading should be planned (Q).

If the SDF is not to become the SMF, other SDF's and SMF's should be examined for possible use (M). The system may be maintained at an operational site. If no SMF presently exists or is suitable, then the locations and tasks of the SMF(s) should be defined (O). If the locations of the system operation change, SMF requirements may need to be reexamined.

If the contractor is to provide either software development or maintenance facilities, the Air Force must define their requirements in such a manner that they can be incorporated into the RFP (see Section 4.5). If the Government is to provide the SDF or SMF support to the contractor, the Air Force must ensure that the support is adequate; otherwise, the contractor may be forced to develop additional support software, procure other equipment or slip the schedule.

Planning for SDF's and SMF's should occur throughout the conceptual and validation phases. An Air Force program office has a supporting role in determining both the software development and maintenance requirements during these phases. The program office's primary goal, in this regard, is to obtain the support equipment and software necessary to meet the needs of the development and maintenance agencies as part of the system procurement.

The CRWG is responsible for making many of the major decisions regarding software maintenance and operational support. The CRWG is initially chaired by the program office and consists of representatives from implementing, supporting, and using commands. There is a need for well defined SMF requirements in the system specification and SOW. Trade-off studies should be performed by the supporting and using commands with assistance of the CRWG during development of the system specification. Estimated costs should be included in a life cycle cost model for the system.

The software development management concepts and support resources are generally documented in the CPDP, and the maintenance and support concepts are documented in the CRISP. Section 4.4 further discusses these planning documents.

As depicted in Figure 4, many decisions relate to how support will be transitioned from development to maintenance. This transition requires careful planning. If maintenance support is not planned for early in acquisition, critical support requirements may not be included within the RFP. If the support hardware is not deliverable, it may be unavailable when the Government takes over the maintenance responsibility. Changing Government SDF configurations to suit maintenance needs in such a situation may be impossible or prohibitively costly.

The determination as to whether or not the SDF resources can be used for the SMF may be dependent on the contractor's developmental approach. An analysis of the best maintenance approach following development could be performed by a contractor and included in his technical proposal (e.g., CPDP) if the Government requests such an analysis in the RFP.

Hardware and software delivered to the SMF must be adequate to support the system. If program funding levels must be cut, the SMF is not the place to do so. Obtaining more equipment and software to support an SMF after it is transitioned to the using or supporting commands is a difficult and time consuming task that may have a direct impact on the operational mission; therefore, a SMF should be as complete as possible when delivered as part of the total system.

Transition from development to maintenance is simplified if:

- Only one group (a specific contractor or the Government) is responsible for both development and maintenance.
- The development facility becomes the maintenance facility.

Special problems can be anticipated for maintenance at each of several operational sites versus centralized maintenance, especially if a number of the sites are remotely located from one another. Under these circumstances:

- More support personnel are required.
- Configuration control problems will increase when program changes are made at each site.
- Additional hardware will be required at each site to support software maintenance.
- More standardization, documentation, and formal maintenance procedures may be necessary.

Some of the development support software may <u>not</u> be useable for maintenance if different support hardware is used for development and maintenance, and the development software is not transferable to the maintenance computer systems.

Prior to the operation of either type of facility, other important questions must be addressed, including:

- Who may use the SDF or SMF and who decides?
- Who establishes shared (central) SDF or SMF operating schedules and priorities among the various software development, maintenance, and operations organizations?

- Who controls access to proprietary support software?
- Who is responsible for support software fault isolation?
- Who is responsible for ordering and controlling new computer equipment? To whom does this new equipment belong?

4.3 Technical Issues

SDF and SMF software and hardware requirements cannot be separated. In many cases, available hardware dictates the types of support software that is available or can be developed. The remainder of this section identifies the types of support software and support hardware that are essential or very useful and discusses special issues that impact how one should contract for this support.

4.3.1 Software

It is necessary at this point to distinguish operational software from support software. Operational software is that set of programs which accomplishes the system functional processing. Operational software usually includes an executive and application programs. Application programs directly perform the system-unique functional tasks in support of operational requirements such as tracking in a control system like E-3A, tabular or graphic display output, or data entry. The application programs generally run under control of an executive or in some cases a general purpose operating system. An example of a general purpose operating system used for controlling application programs is GCOS in the Military Airlift Command Integrated Management System (MACIMS) (see Appendix B). SATIN IV is contracting for development of a special purpose executive under which its application programs will operate (see Section 3.4.1). There may be more than one operational program. For example, in the case of E-3A, some of the operational programs operate aboard the aircraft and others operate on the ground-based computers.

Support software includes all other programs used to develop and maintain the operational programs. Examples of support software are compilers, assemblers, and utilities. A general purpose operating system can be used to control (that is to load and operate) both operational and support software; therefore, an operating system can fall into both classes, depending on how it is used within a given system. Appendix C discusses the most important types of support software used in the systems surveyed. Support software can be described in terms of the development activities it supports as follows:

- Analysis & Design: tools that facilitate the development of system requirements specifications or design specifications, and that aid validation of program logic.

- Software Production: tools which actually process, compile, and assemble the program code, and bind the results into executable modules.

- Configuration Control: tools that aid configuration control and library maintenance. Configuration control involves those steps (manual or automated) necessary to identify and document the system elements (e.g., functional, physical), control changes, and record changes.

- Test: tools that aid program and system testing.

- Hardware Diagnostics: tools used to isolate and diagnose hardware failures.

- Performance Measurement: tools that provide data on the system performance. These data may be used to locate inefficiencies in the system.

- Documentation: tools which help generate management reports and documentation on the system and its parts.

Verification and validation tools are included in the above list. These tools will be further discussed in the verification guidebook [16].

Figure 5 depicts the types of support software required at each phase of the computer program life cycle. Examples of specific software tools are listed within each type.

4.3.1.1 Host-Resident vs. Self-Resident Support Software. One major software development question is whether the operational software is to be developed on the same hardware configuration as that on which it will operate. Support software that runs on one system, such as an IBM System 370, to produce code that operates on another (e.g., a Data General NOVA) is called "host-resident". In contrast, "self-resident" support software runs on the operational computer system. A SDF or SMF can include a combination of both host-resident and self-resident support software. There are several considerations in selecting one or the other:

- Many processors used in command, control, and communication systems have too little core or peripheral capacity to adequately support software development.

- Many minicomputers (especially militarized ones) have a very limited selection of off-the-shelf support software; whereas large scale systems, such as the IBM System 370 have a large inventory of support software.

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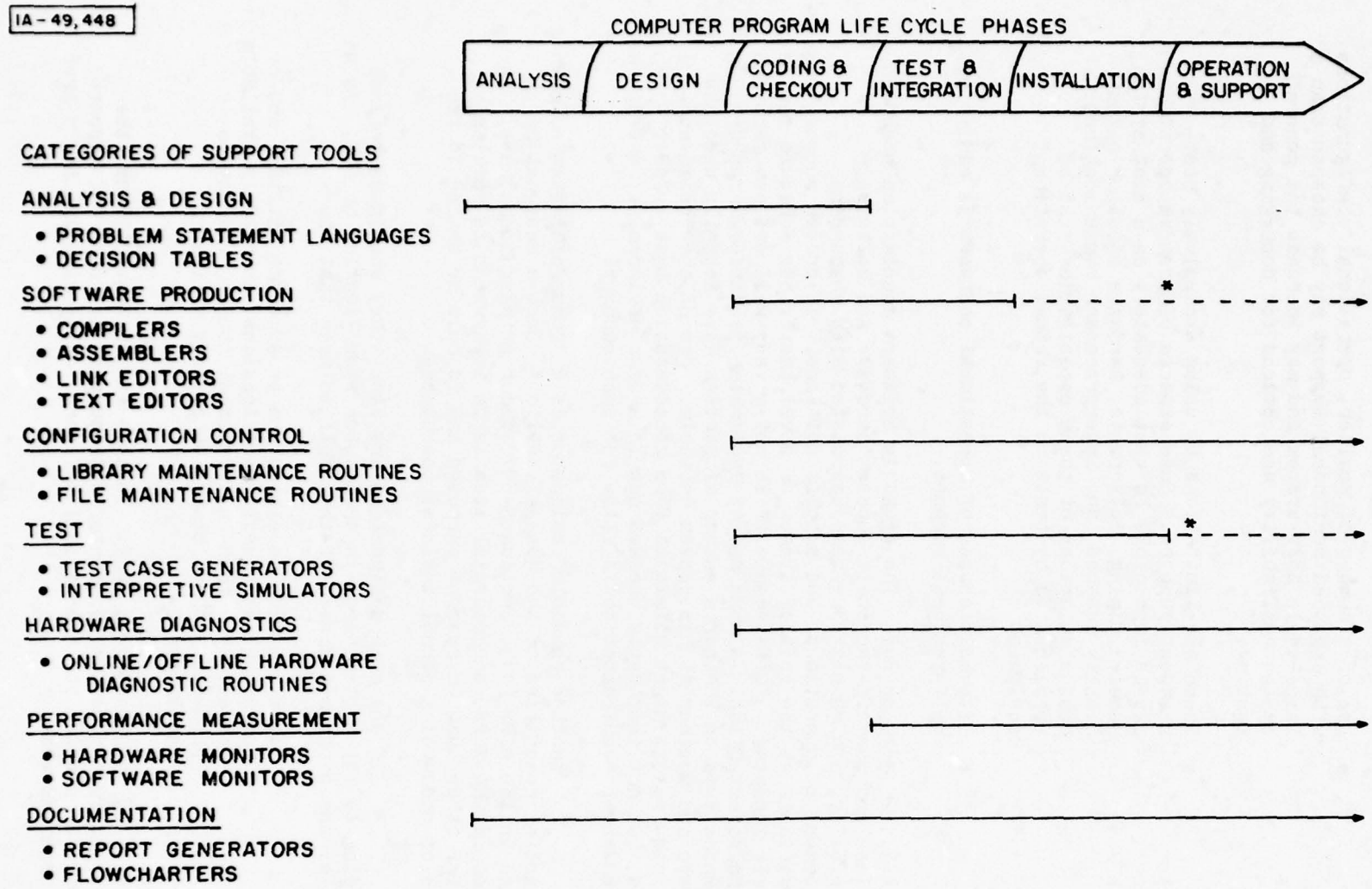

Figure 5. Categories of Support Tools

- Use of a number of smaller, operational configurations with expanded peripheral support may be cheaper than a large-scale host system and may increase the general system availability and options for debugging and testing.

- There are limitations to using exclusively host-resident support. Some aspects of program operation may be impossible to test adequately on a host system, namely: timing, interrupts, hardware input or output, overlay schemes, and interprocessor communications. Host simulations of these capabilities must be supplemented by tests on the actual operational equipment.

- Site maintenance of operational software is easier with self-resident support.

4.3.1.2 Make or Buy. The trend in software acquisition has been to select and use off-the-shelf support hardware and software. Historically, a high risk has been associated with concurrent development of operational and support software. If proven support is not available at the initial stages of development, the schedule can be severely impacted. "Off-the-shelf" is not a very well defined term and is hard to establish. A more recent designator is "tried-and-true". The emphasis is on whether a number of parties have actually used the software and whether it has proven reliable. Use of the "tried-and-true" requirement might eliminate from consideration that support which is new, but not thoroughly checked out in a user environment; whereas an off-the-shelf requirement could allow for such support.

Another possible designator is a "commercial item sold in substantial quantities to the general public." Such a designation is defined in the ASPR [11], Section 3-807, under pricing techniques. As defined in the ASPR, a commercial item is an item which is regularly used for other than Government purposes and is sold or traded in the course of conducting normal business operations.

If any such designators are used, they should be defined according to the system needs in the system specification or SOW. As an example, one program defined off-the-shelf to mean that the

> "item has been developed and produced to military and/or commercial standards/specifications, is readily available for delivery from an industrial source, and may be procured without change to satisfy military requirements."

4.3.1.3 Contractor vs. GFP. In some system acquisitions, the Government furnishes the contractor with support hardware and support software to develop the operational software. Historically, there have been problems when:

- The GFP software developed by one contractor was not delivered to the Government in time for use by the development contractor.

- The GFP software did not have adequate capabilities and the contractor had to develop other support software.

When a contractor returns GFP hardware and software for use by the Government or another contractor in maintaining the operational system, the following questions arise:

- Does the Government rebenchmark the hardware and software?

- Has the contractor modified (on purpose or inadvertently) any of the support hardware or software?

4.3.1.4 Data Rights. Air Force rights to support software and related data must be positively identified and understood by all parties to the contract. To avoid potentially serious problems, the Air Force should contract for unlimited rights to obtain, reproduce and use in any fashion computer programs (including support software and its documentation) developed under the contract.

Proprietary support software, firmware, and related data can cause special problems. Firmware may be included in off-the-shelf support computer equipment or in support equipment developed under the contract. Such firmware traditionally has proprietary data associated with it. Unless special agreements to use such proprietary data are negotiated, the Government may have absolutely no documentation on key components of their computer systems.

It is appropriate at this point to define what is meant by firmware since it is a term that is often misunderstood. According to DODI 5000.29 [5], computer firmware is the logical code of computer equipment which interprets the control functions of that equipment. In this context, firmware is a form of software, namely microcode (i.e., low-level code) which controls the sequence of events that affect execution of the native machine instructions. Firmware always resides in a control store (e.g., read-only memory or Programmable Read-Only Memory (PROM)). This definition is in conflict with that specified in MIL-STD-1521A, Technical Reviews and Audits for Systems, Equipments, and Computer Programs [17]; however, the DODI definition is more accurate and will be used for the purposes of this guidebook.

Proprietary support software used for computer program development may be unavailable for maintenance. In this case, the Government cannot maintain the system organically. Even if this support is made available for Government use, proprietary data requires special handling and storage within the facility to restrict its access. Section IX of the ASPR [11] provides some guidance on data rights.

4.3.1.5 Deliverables & Schedule for Delivery. The contract's delivery schedule and the CDRL should identify all deliverable support equipment, support software, and documentation under the contract. If any items are not specified, the contractor is not obligated to deliver them. Support software and support hardware may be identified as configuration items and specified accordingly in the delivery schedule. See Software Acquisition Management Guidebook: Statement of Work Preparation, Appendix C [18] for special requirements affecting delivery of software. The form in which support computer programs are to be provided (i.e., as source or object code, as card decks or magnetic tapes) should also be identified. If only the object or load module is provided, maintenance or modification of the programs may be impossible.

A sometimes unforeseen problem occurs when a contractor develops originally unplanned, special support programs to aid in the development of operational software. In many cases, the programs are not documented and cannot be used or altered by Air Force personnel. To avoid this problem the contract should provide for delivery of all support software developed under the contract with full documentation and unlimited rights.

If the contractor develops the system with tools other than those delivered, the deliverable tools:

- May not be adequately tested.
- May not be useable, since the contractor avoided using them.

Obviously, this situation should be avoided.

The schedule for delivery is another area for concern. If the support is not available when needed, the development schedule will be impacted. The Air Force should be cautious about deferring delivery of support software in contracts. It is advisable to get and use the support software early enough to shake out any potential problems.

4.3.1.6 Documentation. An Air Force Guide to Software Documentation Requirements [19] addresses the requirements for software documentation. One common complaint expressed during the survey was that support software was not documented well enough. Consequently, in some cases the software could not be adequately maintained; in others, there was not enough information for its operation. With the rather large turnover of personnel in Air Force development facilities, good documentation is essential. One area that is sometimes overlooked is documentation on microprogramming support software.

4.3.1.7 Functional Demonstrations or Benchmarks. One RFP option is to require demonstration of the proposed support software. These demonstrations can provide invaluable data as to the actual capabilities of the proposed systems. Demonstrations can also be used to establish that support software actually exists and that a particular support

function operates as claimed (e.g., compilation of a program or creation of a program library). Other tests can be more standardized such as the compiler validation test cases established by the National Bureau of Standards. Compiler expansion ratios or compilation times can be measured or compared through benchmark tests.

4.3.1.8 Installation, Checkout, and Acceptance. The major questions regarding installation and acceptance of support software are:

- Who will develop the test plans and perform the tests?
- Has adequate testing of the software been performed prior to its installation?
- Do the acceptance tests adequately test the support software and exercise those conditions that will be experienced in the facility?

Support software can be designated as one or more CPCI's and formally qualified. This alternative is highly recommended in those cases where the software is newly developed or largely untested within industry and the Government.

There are problems with acceptance testing of contractor provided free-but-unsupported software packages. Generally a high risk is associated with their use. The problem is sometimes compounded when a package does not quite meet the user requirements and therefore must be modified. Although acceptance testing is a major issue according to the survey, it is beyond the scope of this guidebook to fully discuss this issue.

4.3.1.9 Maintenance. The main questions regarding support software maintenance are:

- Will the Air Force or a contractor be responsible for maintenance?
- Which Air Force agency or agencies will maintain the software?
- What types of support software will be maintained by each agency?
- Does the Air Force agency have the resources necessary to maintain certain types of support software such as compilers and operating systems?
- Is the documentation good enough to support organic (Air Force) maintenance?
- What are the projected costs of organic maintenance?

Historically, there have been problems in acquiring and keeping Air Force personnel with the training needed to maintain support software.

4.3.2 Hardware

The basic hardware questions related to SDF's and SMF's are:

- How many development laboratories (e.g., systems of computer hardware and other test equipment) should be established within a SDF or SMF?
- What tasks and workloads should each laboratory support?
- What equipment configurations are necessary to support the assigned tasks?
- Can the support software operate satisfactorily within the computer hardware constraints?
- Is the hardware reliable enough to adequately support all of its planned uses?
- Can the hardware be expanded (e.g., by adding memory modules) to support increased processing loads if these occur at some future point?

Subject to Government approval, a contractor should have the option of ordering more hardware or sharing hardware among more than one project if hardware availability is a problem. An Air Force development organization often has major difficulty in ordering more memory, additional processors, or more peripherals. Extensive justification and time are involved in ordering such additional support; it is essential, therefore, that hardware needs be anticipated early and accurately.

A common complaint by both Air Force and contractor development groups is that more hardware should have been ordered for the initial stages of development. The adequacy of the hardware for operation of support software is another issue. The host-resident vs. self-resident support issues were previously discussed.

The following should be considered when selecting (or evaluating) hardware configurations for software development:

- Is the primary storage sufficient for operation of the compilers, debug aids, operating systems, and modelling tools, in all combinations planned? Is this storage sufficient for concurrent operation and development if this mode is planned?
- Is the secondary storage (disk, drum, tape, etc.) adequate for operating system use, program libraries, historical data, backup and restart, logging of messages,

utilities, and transfer of the software to the operational system?

- Are there sufficient peripheral devices, (e.g., printers, card readers, punches, and tape readers) for development?
- If remote terminals (e.g., CRT, batch, graphic) are required, is there adequate communications equipment (front-end processors, communication lines, crypto equipment)?
- Is an operational system mockup (e.g., E-3A Avionics Integration Laboratory) necessary for system testing?
- Are the number and types of terminals sufficient for software development including:
  - Alphanumeric CRT terminals (with or without printers) for program entry, editing, and interactive debugging?
  - Graphic CRT's and associated hardcopy output devices for testing the graphics capabilities of the operational system?
  - Remote batch terminals to enter program data and receive output?
  - Operational system consoles to support testing and training?
- Is special test equipment needed to check out hardware prior to its installation?
- Has consideration been given to PROM burners and associated microprogramming support hardware if these are proposed?

The software development and maintenance trade-offs (e.g., contractor vs. GFP) discussed in the previous section also apply to hardware. Section 3 and Appendix B provide examples of how various systems have configured their SDF's and SMF's. The next section describes the planning documents in which support hardware and software requirements are specified.

4.4 Planning Documents

There are four major planning documents in which computer resource requirements, including SDF and SMF hardware and software resource requirements, are specified. These are the:

- PMD
- PMP

- CRISP
- CPDP

Preliminary SDF and SMF management decisions discussed in Section 4.2 should be reflected as direction in the PMD and PMP. The more detailed requirements and plans for management and operation of the facilities are detailed in the CRISP and CPDP.

The PMD authorizes development of the system. The following directives that especially relate to SDF's and SMF's may be included in the PMD, according to AFR 800-14, Volume II, Section 3-6 [1]:

- "Solicitation Documents will include explicit statements defining Air Force rights to computer equipment and computer programs required to operate, simulate, and support the system. This includes computer program and associated documentation (content and media) required for maintenance and modification."

- "Supporting and using commands will participate in the requirements definition, development, audits, test, and maintenance, and major modification of computer programs and equipment."

- "Acquisition of support equipment (such as a dynamic avionics integration laboratory) and documentation will be identified when determined necessary to establish organic or competitive contractor support facilities."

- "Computer equipment reliability, maintainability and availability will be prime development objectives."

- "Functional analyses, trade-off studies and cost effective optimizations will be performed to determine and define a low risk development approach to computer equipment and computer programs."

- "Computer equipment and computer programs will be identified as configuration items."

- "Computer program development and support requirements will be defined including the use of Government-funded equipment and facilities."

The PMP includes a plan for the acquisition management of the computer resources and identifies the support concepts based upon studies, economic analyses, and using and supporting command inputs. Among the SDF and SMF requirements that can be specified in the PMP are:

- Computer program data rights.

- Simulation, integration and other special support.

- Configuration management concepts.

According to AFR 800-14, Volume II, Section 3-8 [1], the CRISP identifies computer resources necessary to support computer programs after transfer of program management responsibility and system turnover. It identifies the organizations, their relationships and their responsibilities, and serves as the basic agreement between supporting and using commands following system turnover. Qualified support personnel and their training requirements are also identified in the CRISP.

The CRISP also includes plans for configuration management of computer programs including configuration control responsibilities during the deployment phase. An O/S CMP can be used to further detail configuration management procedures outlined in the CRISP.

The SATIN IV CRISP provides an example of how these requirements can be specified. It covers such areas as:

- Organizations responsible for management and operation of the Government facilities and their relationships.
- Security controls.
- Personnel and training requirements.
- Software support organization structure.

The AWACS Life Cycle Computer Program Management Plan basically serves as the CRISP for E-3A. It:

- Describes the operational facilities.
- Discusses the joint utilization concept (TAC, AFLC, Air Training Command (ATC)).
- Identifies the support and maintenance responsibilities for each computer program (support or operational).
- Describes the TAC support organizational structure responsibilities.
- Addresses personnel training.
- Lists manpower requirements and schedules.

The CPDP is the major plan that addresses SDF requirements. A CPDP may be prepared by each prime or associate contractor and approved by the implementing command if the development is contracted; otherwise the program office must prepare the CPDP. Among the CPDP items listed in AFR 800-14, Volume II [1] which impact SDF requirements are:

- "The organization, responsibilities and structure of the group(s) that will be designing, producing, and testing all computer programs."

- "The methodology for insuring satisfactory design and testing, including quality assurance."

- "The resources required to support the development and test of computer programs. Special simulation, data reduction or utility tools that are planned for use in development of computer programs should be identified."

- "The methods and procedures for collecting, analyzing, monitoring, and reporting on the timing of time critical computer programs."

- "The management of computer program development masters, data base, and associated documentation including its relationship to the configuration management plan."

- "The approach for developing computer program documentation."

- "Training requirements and associated equipment for the deployment phase."

- "Security controls and requirements."

- "Simulation techniques and tasks."

4.5 Contracting

Another guidebook [12], covers contracting from early procurement planning through the source selection process to the management of the contractor's work. This section highlights the contractual aspects of SDF's and SMF's to consider in these phases.

The procurement plan describes and justifies the procurement approach. It is based on technical assessment of the operational and support requirements, the management decisions of the Air Force program office director, and inputs from the contracting office. The SDF or SMF management decisions discussed in Section 4.2 should, therefore, be reflected in the procurement plan.

The RFP invites contractors to submit proposals and includes the following:

- Model contract including a schedule
- SOW
- CDRL
- Specifications
- Instructions to offerers

The RFP is discussed in greater detail in the SOW guidebook [18].

The SOW is that part of an RFP that describes the scope of work the Government wants done by the selected contractor. SDF and SMF requirements including support programs, equipment and documentation should be specified in the SOW and system specification, and itemized as deliverables in the CDRL and delivery schedule. The SOW should be cross-checked against the CRISP for consistency or vice versa if the SOW is prepared first. Support software deliverables may be identified as CPCI's.

If a facility is to be constructed, a facility development specification (referred to as a type B4 specification) may need to be developed (see MIL-STD-490, Specification Practices [20], Appendix V). This specification covers such facility requirements as civil, architectural, structural, mechanical, and electrical.

The JTIDS/ASIT (see Appendix B) and SATIN IV system acquisitions illustrate how support requirements can be incorporated into the RFP. The RFP may request the contractor, where appropriate, to submit a CPDP with his proposal (e.g., ASIT procurement). This procedure allows the Air Force to better evaluate the contractor's capability to perform and manage software development within the specified support resources.

Following receipt of the proposals, the actual evaluation of the proposal and selection of the contractor is performed by a source selection organization. Evaluation criteria are established prior to receipt of the proposals. The RFP indicates the major criteria and their order of priority. Common areas of evaluation are technical, cost, and management. Each area is further broken down into items and items into factors. Standards (i.e., specific evaluation criteria) are developed for factors.

It is important that criteria be established to evaluate the support software and hardware proposed if requirements for these exist. Whether the support requirements are reflected as separate items or factors depends on their relative importance in the software acquisition. In either case, the criteria are derived from RFP requirement statements (i.e., they must be traceable). The proper preparation of these standards has major impact as to:

- Whether significant parts of the support requirements are evaluated.

- How much impact the support requirements have on the total system evaluation.

The JTIDS/ASIT source selection also included a benchmark (i.e., a functional demonstration) of the operational hardware and support software proposed by each contractor.

In the next phase of source selection, contractors are asked to clarify the ambiguous aspects of their proposal. It is important in the area of SDF's and SMF's to clearly understand such items as:

- Number of facilities
- Their locations
- Hardware configurations
- Specific versions or releases of the support software
- Government rights
- Deliverables and non-deliverables
- Newly developed vs. off-the-shelf items

The Government then enters into negotiations. Negotiations are a crucial step in the acquisition process. If the Government does not negotiate the essential SDF and SMF support items, the whole program may be in jeopardy. However, support that is unnecessary should be avoided. Again, the deliverables, schedules and data rights should be clearly understood between both parties.

Management of the contract begins after the contract is negotiated and signed. Contract changes can be instituted either by a supplemental agreement (mutual agreement between the Air Force and contractor) or by a change order (unilateral action by Air Force). Engineering change proposals can be used to change support hardware and software specifications in a contract.

4.6 Technical Reviews

During PDR's and CDR's, computer program development facility (i.e., referred to as an SDF in this guidebook) support software and support equipment must be reviewed. MIL-STD-1521A [17] lists several items that should be checked. In particular, Sections 30.22 and 30.23 indicate that the availability and planned utilization of any computer program development facility should be addressed at PDR. The contractor should provide information on the design of support programs that are produced to aid the development of the CPCI(s). In addition, he should identify any special simulation, data reduction or other software tools that are not deliverable under terms of the contract, but which are planned for use during program development. MIL-STD-1521A recommends that the following steps be performed when reviewing any support equipment.

- Review considerations that are applicable to support hardware and support computer program CI's (i.e., the same reviews should be performed for support hardware and computer program CI's as are performed for other CI's).

- Verify that adequate trade-offs have been performed for built-in test equipment vs. separate test equipment.
- Verify that designated GFE is planned to be used to the maximum extent possible.
- Review progress of long-lead time support equipment items.
- Review progress toward determining requirements for installation, checkout, and test support.
- Review reliability and maintainability requirements.
- Identify logistic support requirements.
- Review calibration requirements.
- Identify technical manuals and data availability for support equipment.
- Verify compatibility of proposed equipment with the system maintenance concept.

At CDR, the reviews listed in MIL-STD-1521A [17], Sections 40.1.3.1 through 40.1.3.3, that are applicable to support hardware and support software should be performed. MIL-STD-1521A also lists special checks that are to be made on firmware and microprogramming support tools. In particular, the contractor should provide descriptions and status for any microprogramming development tools such as self-resident assemblers, loaders, debugging routines, and executives; and host-resident assemblers, compilers, and instruction simulators.

At either PDR or CDR, the technical issues raised in Section 4.3 and potential problems listed in Section 5 of this guidebook should be addressed in order to determine the adequacy of any support equipment or support software planned by the contractor.

5. POTENTIAL PROBLEMS AND RECOMMENDATIONS

Certain problems in the planning, acquisition, and operation of SDF's and SMF's were discussed in Section 3. Various people interviewed during the facility survey also related "lessons learned" from their past facility experiences. The following list summarizes some of the common problems and includes recommendations for their solutions.

- System development and maintenance responsibilities were too fragmented.

  Recommendations: Avoid separation of the software development effort among the Government and contractors. Different portions of the operational software are sometimes developed or maintained by various contractor and Government agencies. For example, executive software could be developed and supported separately from the application software. This division significantly complicates the management process, increases the SDF resource requirements, and aggravates configuration control problems.

- The SDF's did not provide the required capabilities for software development.

  Recommendations: Establish SDF requirements early after careful analysis of the proposed tasks and uses. Make sure these requirements are incorporated into the PMD, PMP, CRISP, CPDP, and RFP. Carefully develop source selection evaluation criteria to ensure that critical support areas are evaluated. Negotiate for that support that is essential.

- The support hardware or software was not reliable because it was newly developed.

  Recommendations: Use well tested, off-the-shelf hardware and software for development wherever possible. If new or modified support software or equipment is required, allow enough time for its development, testing, and documentation before its use. If the contractor has developed a support tool for subsequent delivery to the Air Force, ensure that he has actually used the support tool in the development of the operational software and has adequately tested it before such usage.

- The support tools were not available when they were needed in the early stages of development.

  Recommendations: Schedule delivery of the support software and hardware so that they are available early in the development. Allow enough time for check out and shake down of this support. Do not develop support tools concurrent with operational software whose development they will support.

- The support computer hardware was not available early enough to adequately check out the support software.

  Recommendations: Ensure that support computer hardware is delivered on a schedule that allows it to be used to test the support software. Use previously well tested support software where feasible to minimize the need for such testing.

- The SMF did not have adequate support hardware and software.

  Recommendations: Carefully examine the types of maintenance support required (e.g., simple program version releases or major modifications) and the anticipated workloads. Ensure that this support is delivered. Consider the use of an integrated support facility to maintain both the operational and support hardware and software if total system maintenance is the responsibility of an Air Force agency (e.g., AFLC).

- The support software could not be maintained organically (in-house).

  Recommendations: Ensure that the form of the delivered software includes source code. Require adequate documentation, including source code listings. Plan for assignment and training of the proper numbers of maintenance personnel with appropriate backgrounds before they will be needed. Use standard maintenance support by vendors wherever possible.

- There was poor documentation on the support software.

  Recommendations: Ensure that well commented source listings, flowcharts, and narratives are delivered with support tools. Make sure there is adequate information (e.g., user's manual) for use of any support tool. In general, standard vendor manuals should be available for any off-the-shelf support. Review these to assure their adequacy. Ensure that there is adequate documentation on all support hardware. Also see the guidebook on software documentation [19].

- There was not enough hardware for development.

  Recommendations: Plan enough hardware (e.g., memory, secondary storage) to support development based on a thorough analysis of all anticipated uses of the hardware and support software requirements. This analysis is particularly important where an operational minicomputer configuration is expanded to support software development.

- The hardware did not come bundled with adequate support software.

Recommendations: If a minicomputer is selected as the development system, carefully examine the available support software for adequacy. The operating system and other support software advertized for a particular vendor's minicomputer system should be examined to see if it really exists, is reliable, and provides the necessary capabilities. Some militarized minicomputers have a commercial counterpart (often less expensive) that comes bundled with a large complement of support software. This software can also operate on the militarized version. Consider the use of host-resident support where the capabilities of the minicomputer (e.g., peripherals) are limited. Also consider the use of hardware adapters that interface commercially available peripherals to militarized processors. If these measures do not suffice, plan development and early delivery of supplementary support software.

- Hardware diagnostics were lacking.

  Recommendations: This requirement is often overlooked. Development of software is a difficult enough task without trying to resolve whether the errors are hardware or software related. Make sure these tools are available and deliverable.

- Standard procedures and programs for acceptance testing of the support system were not adequate.

  Recommendations: Ensure that acceptance test procedures and plans are available and that the acceptance test tools are adequate.

- Test tools were inadequate.

  Recommendations: PQT, FQT, System DT&E, and OT&E are crucial steps in software development. Carefully examine the test requirements and ensure that the right tools are contracted for.

- There was not enough physical space in the facility. (This problem was very common.)

  Recommendations: Plan enough space in the SDF or SMF for the hardware. libraries, programmer work areas, and maintenance spares, considering all concurrent uses.

- The operating system had to be modified in order to meet the user requirements.

  Recommendations: Carefully examine operating system requirements for the support system. Avoid modification of any operating system wherever possible. The decision to modify an executive or operating system must be heavily weighed against all potential consequences. In particular, maintenance of a modified operating system can be extremely costly over the total

system life cycle. A survey of off-the-shelf operating systems should be made to determine if any existing systems are adequate. If an operating system is to be modified, allow enough time and effort for the changes to be made and tested before its use. The design, documentation, and integration of such changes must be carefully controlled.

- The compiler was not adequate.

  Recommendations: Carefully examine compiler requirements. Compiler limitations can severely impact the development effort. Avoid development of a new compiler concurrent with development of the operational software.

APPENDIX A

BRIEF DESCRIPTION OF AIR FORCE SYSTEMS INCLUDED IN SURVEY

E-4 (AABNCP) - Advanced Airborne Command Post

AABNCP will provide a survivable command post capability for SAC and the Joint Chiefs of Staff. The Block I system will basically include an AUTODIN terminal capability aboard the airplane.

The AABNCP functions include:

- Situation monitoring
- Tactical warning and attack assessment
- Force status monitoring
- Force and planning execution monitoring
- Civilian responsibility support
- Negotiation and termination

There are plans for six E-4 airplanes and one ground facility at Offutt AFB.

AFSATCOM I - Air Force Satellite Communications System

The AFSATCOM system will provide satellite communications to satisfy high priority Air Force requirements for operational command and control of forces on a worldwide basis. Some of the communications functions satisfied by AFSATCOM include presidential communications, message transmission to Single Integrated Operational Plan forces, force control, and airborne command post intercommunications.

E-3A (AWACS) - Airborne Warning and Control System

E-3A will provide airborne surveillance, command and control, and communication capabilities with a complex and closely integrated hardware and software system. It presently includes three E-3A test aircraft. Eventually up to 34 aircraft may be produced.

COBRA DANE

COBRA DANE is a large L-band phased array radar system located at Shemya AFB, Alaska. It is being procured by ESD for use by the Foreign Technology Division and ADCOM. Its missions are collection and dissemination of intelligence data on Soviet ballistic missile test firings, detection and warning of missile firings impacting in the continental United States, and collection and dissemination of data on earth satellite vehicles.

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COMBAT GRANDE - Semi-Automated Spanish Air Defense System

Under a 1970 Agreement of Friendship and Cooperation between Spain and the United States, the COMBAT GRANDE program was established to modernize and partially automate the existing Spanish Aircraft Control and Warning system. The planned air defense network provides for centralized data processing and command and control functions, including netting of radar and radio sites and a significantly upgraded microwave communications system, all built around the existing Aircraft Control and Warning system. COMBAT GRANDE will also interface digitally with the French Air Defense System.

CONUS OTH-B PRS - Continental United States Over-the-Horizon Backscatter Prototype Radar System

The CONUS OTH-B PRS program is developing a prototype radar system to provide radar surveillance, tracking and identification of aircraft at extended ranges from a site located in the Northeast continental United States. As each aircraft is detected by the prototype radar system and its track established, a comparison of flight characteristics (heading, speed, position, etc.) will be made with available flight plan and positional data to achieve track correlation and aircraft identification.

JSS - Joint Surveillance System

The JSS program was established to provide surveillance and peacetime control of designated airspace, including the CONUS, Alaska and Canada. The system is to replace existing SAGE and BUIC surveillance systems. Although intended for peacetime surveillance, JSS would serve in a transitional role during wartime until E-3A's took over. The Alaska system will have some tactical and Electronic Counter Counter Measures (ECCM) capability. The Canadian system will have a limited war capability, including ECCM and automatic interceptor vectoring.

JTIDS/ASIT - Joint Tactical Information Distribution System/Adaptable Surface Interface Terminal

JTIDS is an advanced communications system that will provide integrated communications, navigation and identification for the Army, Navy, Air Force, and Marine Corps. Surface subscribers (e.g., mobile ground and ship) and aircraft elements will be supplied with JTIDS terminals and will transfer combat data over a high capacity, jam resistant, secure information distribution network. ASIT will incorporate the JTIDS capability into existing surface tactical surveillance and command and control systems by adding a terminal that provides a "transparent" interface to the surface subscriber systems.

MACIMS - Military Airlift Command Integrated Management System

MACIMS provides both operational and management information processing support for the Military Airlift Command (MAC) airlift missions. The present system consists of approximately 16 subsystems which support:

- Mission management
- Transportation management
- Airframe management
- Airlift services industrial fund management
- Aircrew management
- Planning management

NCMC Improvement Program (427M)

The NCMC Improvement Program, 427M, interfaces the NCMC with worldwide command, control, and communication elements.

PAVE PAWS - Phased Array Warning System

PAVE PAWS is a system that will employ two long-range coastal radars to detect and track submarine launched ballistic missiles, and to support the USAF spacetrack system with earth satellite vehicle surveillance, tracking, and radar space object identification.

SATIN IV - SAC Automated Total Information Network

SATIN IV will provide data communications to support the worldwide record data command, control, and communication requirements of the National Command Authority and SAC. The system will replace the hardware of the SAC Automated Command Control System and the command and control functions of SATIN I. It will be a SAC subsystem of WWMCCS.

TACC AUTOMATION - Tactical Air Control Center Automation (485L)

The initial TACC Automation Program consists of additions and modifications of equipment and facilities developed for the Tactical Air Control System under the 407L program. The objective of these additions and modifications is to improve operational force management, planning, and control of tactical air operations.

TRI-TAC - Tactical Communication Control Facilities (TCCF)

The TRI-TAC Tactical Communication Control Facilities program is developing a "family" of tactical facilities to perform such functions as technical control of communications facilities, dynamic control of communications systems, and automated support for broad system level planning and engineering.

APPENDIX B

AIR FORCE SOFTWARE DEVELOPMENT AND MAINTENANCE FACILITY SURVEY DATA

E-4 (AABNCP) Facilities

Boeing has established a SDF at their plant for development of the application software. Another SDF has been set up by Burroughs to aid in debugging communication processor firmware and diagnostic software. Neither facility is deliverable, but the Government has use of available software through special data rights. Plans for software maintenance following system turnover have not been finalized. The SDF at Burroughs will be phased out after delivery of the communications processor system. System tests will be performed using an operational E-4 aircraft configuration.

The support software that Burroughs supplied for the Boeing SDF includes:

- Operating system
- Assembler
- Link editor
- Text editor
- Library editor
- Maintenance and diagnostic support

Boeing built support software includes:

- System test operational program
- Journal tape print program
- System tape generation program
- Tape duplication program
- AUTODIN simulator program

A specialized product from Burroughs with the "D machine" architecture is used as the Central Processing Unit (CPU). The CPU can be used to emulate the architecture of the other computers. It runs as a stack-oriented machine for software development and emulates the E-4 communications processor for software checkout. The mode is selected by loading the appropriate microprogram into the control memory.

AFSATCOM I Facilities

Collins Radio Group was awarded the develoment contract for terminal hardware and software. They chose the Rolm 1601 as the terminal processor. The terminal embodies a dual processor and considerable special hardware, including encryption devices, special input and output interfaces, and modems. Collins developed the operational software on an in-plant UNIVAC 1108, using a NOVA cross-assembler. An executive plus application programs were tested on in-

plant developmental terminal equipment. Collins has completed initial operational tests of Model I software.

An AFSATCOM SMF is planned at CCPC, Tinker AFB, with capability for maintaining and testing AFSATCOM operational software. Specification and procurement of this SMF are the responsibility of ESD. The procurement action will begin in January 1977.

The SMF development contract is expected to be completed by January 1979, at which time the SMF will be physically moved to Tinker AFB and run by the Air Force Communications Service (AFCS). The CCPC is to be responsible for all application software maintenance during the operational phase.

Among the requirements stated in the Prime Item Development Specification for AFSATCOM Software Maintenance Facility [21] are:

- "The SMF shall provide assembly, load, edit, debug and IPL build capabilities."

- "The SMF shall provide the capability to assemble source code software modules input via punched cards, punched paper tape, nine-track magnetic tape or magnetic disk file. The resultant object code modules shall be stored in magnetic disk files or on punched paper tape. The capability to printout assembly listings as well as a cross-reference list of all program labels shall be provided."

- "The SMF shall provide the capability to perform an edit function controlled via inputs from a CRT terminal. This function shall allow the manipulation of data (source or object, etc.) in magnetic disk files."

- "The SMF shall provide access to magnetic disk files for the purposes of storage and retrieval. Data to be stored in disk files shall be input via punched cards, nine-track magnetic tape, CRT or punched paper tape. Data retrieved from disk files shall be output to nine-track magnetic tape, punched paper tape, printer, CRT, or transferred to another disk file."

- "The SMF shall provide the capability of on-line access to core memory permitting the modification or read-out of the contents of discrete program addresses (both data and instructions) via the external control panel."

- "The SMF shall provide the capability to perform the IPL build function to generate the necessary four-track magnetic tape (for the magnetic tape memory unit) containing the AFSATCOM operating program in the required initial program load format. This function shall be utilized to generate all new magnetic tapes required for the AFSATCOM system."

- "The SMF shall provide the capability of executing program modules under the control of the standard ROLM DEBUG utility program. Interactive control and on-line program examination and modification shall be accomplished via a CRT terminal."

- "For its software testing function, the SMF shall be capable of simulating the operation of any AFSATCOM MPU-terminal, airborne or ground...."

- "The SMF shall be capable of loading any or all data inputs to the AFSATCOM message processor and of monitoring all data outputs of the message processor."

- "Furthermore, the SMF shall be capable of simulating device failures for any of the modems, cryptos, and I/O's which interface with the AFSATCOM message processor."

- "The SMF shall be comprised of the following functional subsystems: Message Processor Subsystem, Black Interface Simulator Subsystem, Red Interface Simulator Subsystem, Program Maintenance Peripherals Subsystem, and the Control Software Subsystem."

- "The Program Maintenance Peripheral Subsystem shall consist of the peripheral devices for the message processor which are required to perform the program maintenance function."

- "The Control Software Subsystem shall consist of disk operating system (DOS) software to be used in either the RED or BLACK Processor in conjunction with the Program Maintenance Peripherals and...."

- "The DOS software shall provide comprehensive file system capabilities (load, assemble, debug, and edit) as well as diagnostics on either processor and the maintenance peripherals."

COBRA DANE Facilities

The primary development contract for COBRA DANE was awarded to Raytheon Company, Wayland, Mass. in June of 1973. Raytheon selected and acquired the data processing equipment including a CDC CYBER 74-18 as the main processor. Raytheon subcontracted the development of mission and off-line software for the CYBER 74-18 to SDC. SDC began software development at Raytheon's Wayland, Mass. plant where Raytheon was assembling the operational system hardware. The system has since been deployed at Sheyma AFB, Alaska where SDC continued to develop the mission programs.

A CDC CYBER 74-14 has been acquired to handle the post mission processing and data reduction programs since these programs cannot be run concurrently with the primary mission programs. CDOS, a slightly

modified version of SCOPE 3.4, is used as the CYBER 74-18 operating system.

The contract with Raytheon carries a built-in one-year maintenance period beyond the Initial Operational Capability (IOC). This maintenance will be accomplished using both the operational system on-site and a CDC 6600 (functionally equivalent to a CYBER 74-18) located at the Air Force Geophysics Laboratory at Hanscom AFB. Beyond the one-year contract, continued development and maintenance will be the responsibility of ADCOM.

COMBAT GRANDE Facilities

In February of 1974, the prime system contract was awarded to COMCO Electronics Corporation of Fullerton, California. COMCO has been responsible for acquisition of all computer hardware and development of almost all application software (i.e., part of the applications has been subcontracted to Sylvania). For approximately the first nine months of the contract, COMCO used a Hughes H-4118 computer at Hughes Aircraft Company's computer center. An IBM System 370 connected to remote terminals at COMCO provided a capability to check out operational Hughes H5118M programs through use of an interactive simulator.

By the tenth month COMCO had established its COMBAT GRANDE Fullerton Test Facility and had acquired its own Hughes H5118M. During the first year and a half, COMCO assembled at the Fullerton Test Facility the full complement of computer resources that will be deployed in Spain, including a second H5118M with peripherals, displays, controllers, etc.

The Fullerton Test Facility is dedicated to the development of COMBAT GRANDE software. COMCO has used the Fullerton Test Facility for development of the operational computer program, other application programs, diagnostic programs, utility programs, simulation program, and data reduction programs. The programs are coded in JOVIAL and assembly language.

The Central Computer Utility Program which operates on the H5118M is used to produce and maintain parts of the Operational Computer Program and utilities that operate on the H5118M. It includes a JOVIAL compiler, data assemblers, master tape generator, magnetic tape operations, adaptation calculator and miscellaneous program maintenance tools. Some of these programs are newly developed.

A set of support programs also exist for producing and maintaining application and utilities that execute in the controller computers. They include assemblers, tape generators, and miscellaneous program check-out tools (off-the-shelf and commercially available) and execute on the PDP 11/05 and TI-980A computers.

The Sector Operations Center data processing equipment will be moved to Torrejon, Spain where system testing will be performed. COMCO

will continue as prime contractor until the end of system testing. Because of the complete duality of equipment at the Sector Operations Center, the backup equipment will comprise an SMF for continued software modification, test and maintenance.

CONUS OTH-B PRS Facilities

In March of 1975, the General Electric Company of Syracuse, New York was chosen as the prime contractor. The computer hardware selected for the PRS by General Electric includes:

- A UNIVAC 1110 computer to be located at the Operations Site as the central data processor.
- Two UNIVAC 1616 computers, one to be located at the Transmit Site and one to be located at the Receive Site as radar control and monitor equipment. (The Receive and Operations Sites will be collocated.)
- A programmable Modular Processing System (MPS) built by General Electric, to be located at the Receive Site as a signal processor.

General Electric has subcontracted the majority of the software development for computer programs which will be executed on the UNIVAC 1110, to TRW Systems, Inc., of Redondo Beach, California. General Electric will develop the remainder of the software required for the PRS.

The PRS will have two SDF's. The Central Data Processor SDF at TRW, Redondo Beach and the OTH Integrated Test Facility at General Electric, Syracuse. A combined General Electric and TRW team will use the Central Data Processor SDF for developing most of the functional and application computer programs. TRW will be responsible for overall process integration and in-plant testing for the computer programs developed at this SDF.

The OTH Integrated Test Facility will be used by General Electric as the SDF for the computer programs which will be executed on the UNIVAC 1616's, as well as the computer programs which will be executed on the Signal Processor. The computer hardware configuration of this SDF is identical to the configuration that will be used at the Receive Site. Using this SDF, General Electric will develop the radar control and monitor programs, the data recording programs and the maintenance and diagnostic programs for the Transmit and Receive Site computers. General Electric will also use this SDF and diagnostic programs which will be executed on the Signal Processor. These computer programs will be developed using assemblers, simulators, and debug utilities which are executed on the UNIVAC 1616.

The components from these SDF's will not be assembled and tested as a complete system until they are delivered to the PRS sites in Maine.

The Receive Site and the Operations Site will be collocated, and the facility will function as an operational prototype as well as a SDF and a SMF for the life of the PRS.

JSS Facilities

The JSS RFP package was released in October 1976. Two contractors will be initially selected and will compete in a "fly-off" - a parallel validation phase during which each contractor will concentrate on designated high risk areas (e.g., operating system, tracking, displays). After 15 months, a single contractor will be chosen for the full-scale development and production phases.

It is expected that software development will be accomplished in-plant by the contractor. The first Regional Operations Control Center (ROCC) to be installed is the CONUS Southeast (SE) quadrant. At the same time, the contractor is to install what is called a ROCC System Support Facility (RSSF) to be collocated with the SE quadrant ROCC. A System Support Element specification defines the RSSF requirements. The RSSF tasks will include:

- System software support
  - Modification
  - Redesign
  - Test
  - Documentation
  - Program support library
  - Generation of exercise files
- Displaced SE ROCC operations
- Training

The system is to be acquired, where possible, using "off-the-shelf" components. No hardware research and development is anticipated with the possible exception of displays. The RSSF equipment configuration is undetermined, but it will closely approximate a ROCC.

Before system Final Operational Capability (FOC), the RSSF will be used to train operational personnel and to familiarize the using organizations with the software. After FOC, the RSSF will support design and maintenance of all ROCC software as well as generation of system exercise tapes. Testing of new versions of ROCC software will be performed using the SE ROCC resources with the RSSF temporarily assuming the operational mission.

JTIDS/ASIT Facilities

The JTIDS/ASIT system is one of the JTIDS system procurements and was in source selection as of August 1976.

According to the SOW [22],

"support software for development of the Operational Computer Program (OCP) shall operate on a contractor defined computer system, identified in the CPDP, subject to procuring activity approval."

The Operational Computer Program, auxiliary programs (i.e., Data Reduction Program and Exercise Preparation Program), and Information Distribution Network software (if proposed), will be developed on contractor provided facilities. Certain parts of the development may require a secure facility (classified). The auxiliary programs need not be developed on the same facility as the Operational Computer Program. The support hardware need not be deliverable.

According to the SOW [22],

"deliverable support software shall include all programs required to maintain, update and modify all operational and support programs delivered under this contract, with the support computer(s) (i.e., standard operating system, file system, ANSI compatible compilers, loaders)."

It is anticipated that the contractor will perform program maintenance. There are presently no plans for Government maintenance of this software.

According to the SOW [22]:

- "The support software shall support all phases of the contract including software development, in-plant testing and field testing through IOT&E."
- "No development of support software or development aids shall be done, except for development described in CPDP as reviewed by the procuring activity."

In regards to Operational Computer Program support software:

- "All support software shall be capable of being executed on any installation of the support computer using a standard operating system."
- "The support software shall include, but not be limited to: assembler, compiler, binder, loader and microprocessor software."

The assembler and compiler are to be "off-the-shelf". Detailed requirements for the assembler, binder and compiler are also specified in the SOW.

The SOW also requires that a program support library be implemented and maintained throughout the software development phases of the contract. The library functions required include source data

maintenance, output processing, programming language support and library system maintenance. If microprocessors are proposed, the contractor is to provide the "support software needed to develop, produce, operate, test, modify, and maintain the microprocessor software." The ASIT RFP also requires full data rights to all firmware and firmware development tools.

MACIMS Facilities

MAC developed the IOC subsystems in-house at Headquarters MAC using basically standard WWMCCS hardware and software. Application software was developed on the same facilities presently used for operation. Computer Systems 1 and 2 are used for continued development and maintenance of application software in addition to operations. System 1 supports other processing besides MACIMS (e.g., Major Command programs). Systems 4 and 5 are dedicated to operation of the cargo and passenger subsystems, but are occasionally used for testing program changes.

System 1 is a WWMCCS Force Control system with dual processor H6080's. System 2 is a WWMCCS Force Control system with a single processor H6080, and Systems 4 and 5 are WWMCCS General Staff Support Medium H6050 systems. Each system includes WWMCCS DATANET 355 front-end communication processors. The support software used on these systems is the standard WWMCCS GCOS and its associated compilers, assembler, and utilities. A number of performance monitoring tools were obtained through other Air Force agencies.

A Honeywell System 700 minicomputer was installed at Headquarters MAC and used to modify the minicomputer software and test the remote interfaces. This system was an expansion of the operational cargo port configuration and included additional peripherals and core to support application program development. A batch operating system was used for software development. Special test packages were also developed internally by MAC to check out minicomputer systems.

PAVE PAWS Facilities

The contract for one system (Otis AFB) was awarded in April 1976 to Raytheon Company, Wayland, Mass. Raytheon selected the computer hardware including the CDC CYBER 174-12 as the main processor and the MODCOMP IV/25 as the radar controller. Raytheon subcontracted development of the CYBER 174-12 operating system (an adaptation of CDC's Network Operating System) to CDC. CDC will also supply various off-the-shelf support software. IBM was subcontracted to develop all other software for the CYBER 174-12. Raytheon will develop software for the MODCOMP IV/25 and for their own signal processor.

The following CPCI's will be developed:

CDC	- (CPCI.1)	PPOS (PAVE PAWS Operating System)
IBM	- (CPCI.2)	Tactical Applications Software
	- (CPCI.3)	Simulation Software

- (CPCI.4) Structured Programming Development Tools
- (CPCI.5) Data Reduction Tools

Raytheon
- (CPCI.6) Radar Controller Software
- (CPCI.7) Signal Processor Software

The SDF is at Raytheon and includes two CYBER 174 computers, one radar controller, display consoles and peripheral devices. The Structured Programming Development Tools (CPCI.4) include a JOVIAL preprocessor, COMPASS preprocessor, program support library, and report generator programs.

The SDF at Raytheon will be delivered to Otis AFB (Site 1). Raytheon may keep Beale AFB (Site 2) hardware in-plant for some time after Site 1 deployment, but eventually the SDF functions are to be assumed by the Site 1 system. The SDF hardware is being acquired entirely by Raytheon. The SDF will be managed by Raytheon while it is at their facility. After IOC and turnover, on-site development and maintenance will be the responsibility of ADCOM.

The site SDF will be used for:

- System operations
- Program development
- Program modification
- Program debugging and test
- System maintenance and documentation
- Hardware testing
- Simulation exercises

TRI-TAC Facilities

In December of 1974, the performance specification for the Communications System Control Element (CSCE) and Communications Nodal Control Element (CNCE) of the TCCF were completed. In May 1975, a contract was awarded to Martin-Marietta for development and delivery of two CSCE's and six CNCE's. Martin-Marietta subcontracted all data processing hardware and software to UNIVAC.

The Defense Systems Division of UNIVAC in St. Paul, Minnesota is building or purchasing the data processing hardware. Hardware development is required for the UNIVAC U-1600 and Data Bus Controller. UNIVAC will also supply the support software, including off-the-shelf or adapted operating systems, data management systems, compilers, assemblers, etc.

The SDF for application software was established at the UNIVAC Technical Services Division in Houston. The SDF will be moved to Martin-Marietta's Orlando, Florida facility, but will still be operated by UNIVAC. This will be a dedicated facility and the Houston facility will be phased out.

A CSCE and one or more CNCE's are to be moved to the Fort Huachuca Test Bed, where a joint Army, Navy, and Air Force team will begin an estimated two-year period of testing. Martin-Marietta and UNIVAC are expected to be heavily involved throughout this period of testing. A second CSCE and at least two CNCE's will most likely remain in the Orlando facility, so it is probable that the primary SDF will continue to be in Orlando even after testing is under way. However, some software modification and testing may be conducted at the test site.

APPENDIX C

TYPES OF SUPPORT SOFTWARE

The types of support software discussed below are representative of those types encountered in the surveyed systems. The list is not intended to be all encompassing, but it includes the most important types of support.

Operating Systems

According to one definition, an

> "operating system is a collection of programs (algorithms) designed to manage system resources; namely, memory, processors, devices, and information (programs and data)" [23].

Application or support software (e.g., compilers) generally request use of system resources through an operating system. In some cases support software may operate in a stand-alone mode with no operating system. Examples of operating systems are IBM's System 370 Virtual Storage 1, IBM's System 360 Operating System, UNIVAC's 1108 EXEC 8, and Data General's Real Time Disk Operating System.

Compilers

According to one source, a compiler is a program

> "which translates a source program written in a particular programming language to an object program which is capable of being run on a particular computer" [24].

Compilers exist for such computer languages as FORTRAN, COBOL and JOVIAL. A cross-compiler is a compiler that operates on a host machine with an instruction set different from the one on which the compiled program is executed. For example, a FORTRAN program may be compiled on an IBM System 370 and executed on a Data General NOVA.

Interpreters

An interpreter differs from a compiler in that it is

> "a program which executes a source program, usually on a step-by-step, line-by-line, or unit-by-unit basis" [24].

Interpreters exist for such languages as BASIC, APL, and SNOBOL.

Assemblers

An assembler is a program which translates assembly-level code (symbolic code) to machine code that is executable by the computer. A

cross-assembler is an assembler that executes on a host machine with an instruction set different from that on which the assembled program is run. Some assemblers have macro capabilities. Macros provide a capability to define a sequence of instructions with alternative types of expansion using macro parameters. Macro calls are coded in-line with assembly statements. Each macro call is expanded into assembly statements according to the parameters supplied.

Linkage Editors and Loaders

A linkage editor is a program that binds the object modules generated by an assembler or compiler into a unit ready for loading. It resolves external program references. A loader loads the resulting program into memory. In some cases, the linking and loading functions are performed by one program. A link editor or loader may operate in a stand-alone mode or under control of an operating system.

Utilities

Utilities are support programs used to create, edit, sort, merge and maintain system or user program libraries and files; to configure the operating system; and to debug or test application programs. Utilities may operate in a batch or interactive mode. Some typical examples of these support programs are:

- Library Maintenance Routines - used to create program and data libraries (directories), to add or delete directory items, to reorganize libraries (e.g., purge and reorder items) and to dump/restore libraries from disk and tape.

- File Maintenance Routines - used to copy, sort, and merge files on several types of media (e.g., tape, disk, card).

- Text Editors - used to edit program source code or data.

- Software Diagnostic and Debug Aids - include compile and execution time debug aids that help identify and isolate program errors. These capabilities may include commands such as DUMP, TRACE, MODIFY, and BREAKPOINT. The aids may provide static (batch) or dynamic (real-time) debug capabilities.

Interpretive Simulators

Interpretive simulators are programs that interpretively execute each instruction of a user program in a simulated environment. The simulator may optionally provide execution statistics. In some cases, debugging aids are incorporated in the simulator (e.g., breakpoints, dumps).

Design Aids

Examples of automated design aids are design languages and their associated processors. An operational program can be described in a high level design language and the description "executed" to verify the design logic. In some design languages, as each module of the program is coded, the code can replace the design language description and be executed with the other modules. A system can be thus propagated from "design code" to operational code by this process. Decision tables are another example of an automated design aid. Once validated these tables may be manually coded or automatically translated into program code.

Language Translators

Language translators are programs that translate statements in one language (e.g., FORTRAN) to statements of another language (e.g., PL/I).

Language Preprocessors

A language preprocessor is a program that preprocesses source code prior to its input to another processor (e.g., compiler). For example, a program described in structured FORTRAN may be translated to standard American National Standards Institute (ANSI) FORTRAN prior to input to an ANSI FORTRAN Compiler.

Automated Test Tools

Automated test tools are programs which generate test data and evaluate program test cases. An example of a test case generator is a program that automatically prepares a sequence of input data based on input parameters; hence, various combinations or time-ordered sequences of input data can be easily prepared.

Documentation Aids

Documentation aids are programs that automatically generate program documentation from source code or library descriptions. An automatic flowcharter is one example. Another example is a program that produces a "picture" of the program structure (e.g., hierarchical top-down description) based on the program library directory.

Report Generators

Report generators are programs used to produce reports from formatted computer files. They are not generally considered compilers in the sense that the language processed is not a programming language. IBM's System 360 Report Program Generator (RPG) and SDC's DS/2 are examples of report generators.

Modelling Tools

Included among these tools are languages such as GPSS and SIMSCRIPT which facilitate the writing of system simulation programs.

External Emulators

These tools include a combination of hardware and software used to emulate external input data to a system. For example, an emulator may generate peripheral, terminal, or intercomputer input.

Hardware Monitors

Hardware monitors are collections of equipment (probes, cables, logic boards, counters, and data recorders) directly attached to a computer's circuitry, which sample pulses representing data flowing through the computer. A computer keeps track of the number of occurrences or duration of particular signals and records the accumulated data on a recording device (e.g., magnetic tape). These data are reduced (e.g., using data reduction and analysis programs) to obtain information, for example, about CPU and channel utilization. Based on this information, inefficiencies may be located and remedied.

Software Monitors

A software monitor is a program that resides in computer memory and gathers data about the system's performance. It may operate as a high priority application program or as part of the operating system. The monitor gathers data about the changing status of the system by reading operating system internal tables, control blocks, registers, and memory maps. As in the case of hardware monitors, these data can be recorded and analyzed.

Hardware Diagnostics

Hardware diagnostics are on-line or off-line computer programs, or firmware, used to detect and isolate processor, memory, peripheral, communication, and other types of hardware malfunctions.

Microprogramming Development Tools

These tools are a combination of hardware and software resources used to generate and test microprograms. Examples of such support include the INTEL 8080 PL/M, assembler, and loader. In many facilities, a special microprogramming laboratory is set up to develop microprograms. In most cases, the support is host-resident.

Data Reduction and Analysis Tools

These tools are statistical packages used to analyze system data. An example of such a tool is a program that reduces input data previously recorded by a hardware or a software monitor and derives

utilization statistics, allocation statistics, and performance indicators.

Requirements Analysis Aids

Examples of these aids are problem statement languages and their associated processors. System requirements, including functional processes, interfaces, input, and output, can be stated as problem language statements. These statements can be stored in a data base, updated as required, analyzed for consistency, and accessed for report generation.

LIST OF ABBREVIATIONS

Abbreviation	Definition
AABNCP	Advanced Airborne Command Post
ADCOM	Aerospace Defense Command
ADP	Automatic Data Processing
AFCS	Air Force Communications Service
AFGL	Air Force Geophysics Laboratory
AFLC	Air Force Logistics Command
AFSATCOM	Air Force Satellite Communications
ALC	Air Logistics Center
ANSI	American National Standards Institute
ASIT	Adaptable Surface Interface Terminal
ASPR	Armed Services Procurement Regulations
ATC	Air Training Command
AWACS	Airborne Warning and Control System
CCPC	Communications Computer Programming Center
CDC	Control Data Corporation
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CI	Configuration Item
CNCE	Communications Nodal Control Element
CONUS	Continental United States
CP	Card Punch
CPCI	Computer Program Configuration Item
CPDP	Computer Program Development Plan
CPPF	Computer Programming Production Facility
CPS	Core Processing System
CPU	Central Processing Unit
CR	Card Reader
CRISP	Computer Resources Integrated Support Plan
CRT	Cathode Ray Tube
CRWG	Computer Resources Working Group
CSC	Computer Sciences Corporation
CSCE	Communications System Control Element
CSS	Communications System Segment
DoD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DOS	Disk Operating System
DT&E	Development, Test and Evaluation
ECCM	Electronic Counter Counter Measures
ESD	Electronic Systems Division
FOC	Final Operational Capability
FQT	Formal Qualification Test
GCOS	General Comprehensive Operating System
GE	General Electric
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GMAP	General Macro Assembly Program
IOC	Initial Operational Capability

LIST OF ABBREVIATIONS (Concluded)

Abbreviation	Definition
IOT&E	Initial OT&E
IPL	Initial Program Load
JSS	Joint Surveillance System
JTIDS	Joint Tactical Information Distribution System
MAC	Military Airlift Command
MACIMS	Military Airlift Command Integrated Management System
MDS	Modular Display System
MPS	Modular Processing System
NCMC	NORAD Cheyenne Mountain Complex
NCS	NORAD Computer System
NORAD	North American Air Defense Command
O/S CMP	Operational/Support Configuration Management Procedures
OS	Operating System
OT&E	Operational Test and Evaluation
OTH-B	Over-the-Horizon Backscatter
PAWS	Phased Array Warning System
PDR	Preliminary Design Review
PMD	Program Management Directive
PMP	Program Management Plan
PQT	Preliminary Qualification Test
PROM	Programmable Read-Only Memory
PRS	Prototype Radar System
RFP	Request for Proposal
ROCC	Regional Operations Control Center
RPG	Report Program Generator
RSSF	ROCC System Support Facility
S/370	IBM System 370
SAC	Strategic Air Command
SATIN IV	SAC Automated Total Information Network
SCC	Space Computational Center
SDC	System Development Corporation
SDF	Software Development Facility
SE	Southeast
SMF	Software Maintenance Facility
SOW	Statement of Work
SSF	Software Support Facility
STATF	Staging and Test Facility
TAC	Tactical Air Command
TACC	Tactical Air Control Center
TCCF	Tactical Communications Control Facilities
TDMA	Time Division Multiple Access
WWMCCS	World Wide Military Command and Control System

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