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# THE AIR FORCE COMPUTER PROGRAM ACQUISITION CONCEPT

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## FOREWORD

The information contained in this document was originally prepared for presentation by the author at the 1967 Spring Joint Computer Conference, April 1967, Atlantic City, New Jersey.

## REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

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## ABSTRACT

An extensive series of design control techniques for the acquisition of "systems" and "hardware" has been developed by the Air Force over the past five years. The control of computer program (software) designs, the verification and validation of the computer program products, and the integration of "software" and hardware has not been as aggressively investigated. This paper describes the overall Air Force project that has been established to evolve a series of techniques for the acquisition and design control of computer programs and computer program data.

The Air Force 375 System Management Concept proved to be the best model about which to structure and develop the technology and management process for computer program acquisition and development. To date, certain standards and techniques have been developed; namely, the concept of uniform specifications, design baseline management, design change controls, specification maintenance, and design accounting. Current studies are in progress to evolve computer program testing and validation standards, the systems engineering integration aspects, and the detailing of the generalized procedures and events as related to computer-oriented systems and programs.

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SECTION I

# INTRODUCTION

The classic approach to the development of Air Force operational computer programs has been to award separate contracts for the hardware and for the "software" aspects of an electronic system. The integration of the hardware and the "software" into a homogenous total system has not always been a planned certainty, primarily due to the lack of definitive management procedures and contractor guidance and control techniques for the area popularly known as "software." It was with this history in mind that a study[1] was initiated to evolve a technique which would permit the following:

a. Development of contractual requirements standards to provide positive control over the contractor's effort in the development of computer programs.

b. Development of a series of principles and procedures which would be applied to the configuration management of computer programs.

c. Development of a series of design standards and specifications for use during computer program design and development.

d. And most important of all, to develop an orderly process of "software" production that would assure full compatibility and timeliness with hardware production.

The acquisition of computer programs, as discussed in this paper, has been broadly categorized to two areas:

a. Those early events, activities and steps involved in INITIALLY acquiring the computer hardware and the related computer programs. Here is the arena for activities and problems from the viewpoint of the system manager, the system designer, and the system acquisition agency.

b. Those events and activities by the military user and implementor to maintain and constantly update the computer programs and the computer program data AFTER the initial acquisition. In this instance, the activity is primarily with the "software" implementation process from the point of view of the "software" implementor's problems within his own environment.

This paper and the series of papers to follow, address themselves to area "a", that series of events and activities which involve the initial design and acquisition of computer programs and the integration of the resultant efforts into the overall system. Those activities

identified in the second category "b", are the user's activities after the system is declared operational and turned over to the user. The "b" activities involve the updating and maintenance of existing operational computer programs and the evolvement of a limited number of new and additional programs. Management procedures for the "b" activities are in the process of evolvement by the Electronic Systems Division for the U. S. Air Force and will be presented at a later date.

The objective of this paper is threefold:

1. To introduce the Air Force developed procedures for the acquisition and control of command system computer programs based on the concept of the computer program as the end item of a definable process;

2. To suggest that the developed process is general enough to cover a wide variety of users outside the military domain; and

3. In terms of this process and the Air Force system management philosophy, set the stage for the papers [2,3,4] that follow.

## SECTION II

## THE COMPUTER PROGRAM AS AN "END ITEM"

### A. Classical Definition of "Software"

The term "software" is being removed from official Air Force terminology because of the diversity of its entrenched definitions; some of the more popular definitions of "software" are as follows:

1. Computer programs, together with associated data, training materials, and the operational personnel.

2. All computer programs, including the hardware of the computer system itself.

3. All computer programs, excluding hardware.

4. Special utility computer programs which are supplied by the digital computer manufacturer as part of a computer.

5. Deliverable contractor data associated with the development and operation of system equipment.

6. System personnel, as contrasted with system hardware.

### B. "Software" as an End Item

In order to adapt the Air Force 375 concept of system management to "software," it was first necessary to define "software" precisely and, more specifically, to attempt to describe it in engineering and hardware terminology. It was determined that it was more reasonable to adapt "software" to the "375 hardware acquisition techniques," than to develop a separate "software" management process, which in turn would require a third or higher level management process to integrate "software" and hardware into a total system.

Fundamental to the management of "hardware" is the readiness with which it is possible to identify an item of hardware as an End Item (a Contract End Item[5]) and the various paper products (Drawings, Manuals, Specifications) as Data Items. It is this philosophy which was adapted to "software," and as depicted in Figure 1, "The Computer Program as an End Item," permitted the identification of "software" products into the more precise categories of:

1. Computer Program Contract End Items (CPCEI), and

2. Computer Program Data

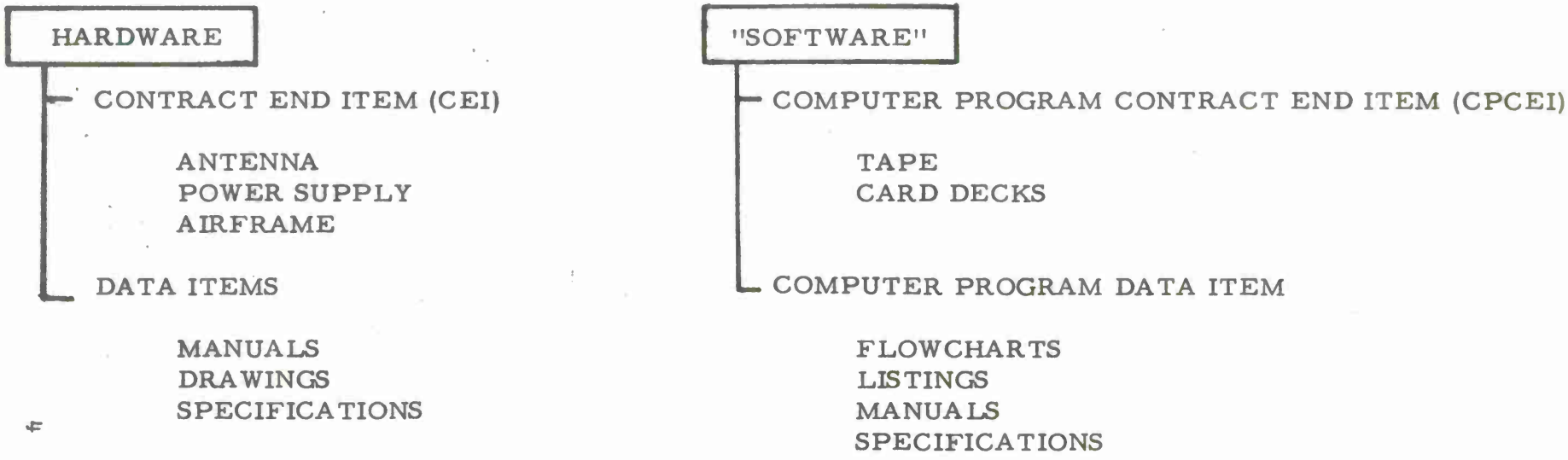


FIGURE 1. "THE COMPUTER PROGRAM AS AN END ITEM"

It will be noted from Figure 1 that, as is the case with hardware, the computer program is now a designated, deliverable, and contractually-controlled product. The Data Items for both hardware and for computer programs are those paper products which "describe" the deliverable "end item" or describe how to use, test, or update the end item. Card Decks, although physically "paper" are essentially integral to the direct operation of the computer itself, and are not considered a Data Item per se. Both the hardware and the computer program data items have standards for their preparation, however, the format and content for computer programs is recognized in that there are separate "standards" for hardware and separate "standards"[6] for computer program data items.

C. Definition of Contract End Item (CEI)

The term "contract end item" (CEI) has been selected to identify individual design packages. A contract end item has become a very useful and common reference for program management, i.e., alignment of design responsibilities, contracts, schedules, budgets, etc. The CEIs, thus, represent a computer program or a level of assembly of equipment selected as the basis for management. Once the "design package" has been identified as a contract end item (CEI), this end item is then described in an individual specification[2].

Experience to date with electronic command systems contracts[7], has indicated that there is indeed a common basis for management when computer programs are designated as CEIs; management by the government of the contractor's efforts and management by the contractor of his own or subcontractor's efforts. An understanding by both the government and the contractor of what is to be delivered is an important step toward developing an orderly process for the production of computer programs.

D. Computer Programs and the 375 System Management Process

The basic decision that a computer program could be defined as a Computer Program Contract End Item (CPCEI) permitted adaptation of virtually all the Air Force 375 System Management concepts to the management of computer programs. Specifically, the concepts of uniform specifications, baseline management, change control, specification maintenance, design reviews, and a test program became all as pertinent to computer programs as they are to hardware acquisition. More importantly, however, a common definition and acquisition process now assures a full integration and in a timely manner of both the equipment and the computer programs into an integrated and homogenous military system.

There were sufficient, substantive differences between hardware end items and computer program end items to warrant the development of separate but companion procedures and standards for computer programs, and these will be described at opportune moments during this and the next three (3) papers [2,3,4]. However, it was possible, in the real live world situations that the Electronic Systems Division is constantly exposed, to adapt the "end item" philosophy of management to computer programs, and yet retain full technical integrity and full technical identity for all disciplines concerned.

E. Comparison of Computer Program End Items with Hardware End Items

Figure 2, "Some Commonalities between Computer Program End Items and Hardware End Items," portrays in a capsule form that the major technical events and milestones, which pertain to hardware, are also applicable directly to computer programs. Under the Contract End Item (CEI) concept, there is a common and understood method for specifying the technical requirements prior to computer program design, for specifying the interfaces between computer programs/hardware/personnel, and for the development of sufficient computer program documentation to assure that the user can operate the system effectively.

The basic premise is that it is equally important to specify the system requirements for computer programs as it is for hardware, thus the initial common ground for both is in the System Specification. In the normal design process for military or for commercial computer programs, both the hardware designer and the computer program designer require a document identified as a Specification, in which the performance/design and test requirements and/or parameters can be detailed. Likewise, design reviews, testing, change procedures, manuals, technical descriptions of the product are equally common to both areas. The discussion on the system management process that follows attempts to point out that it is primarily due to the "commonality of approach" by the computer program designer and the hardware designer, that it was possible to adapt the 375 process to computer program development.

Just as it was possible to identify common activities, it became quickly apparent that substantial differences existed too. These are listed in Figure 3, "Differences between Hardware and Computer Program End Items." Unlike hardware, computer program instructions do not "wear out." Further, it is not necessary to build and to maintain an elaborate special production facility to produce each computer program in quantity since, regardless of its configuration, any number of copies can be normally duplicated on standard

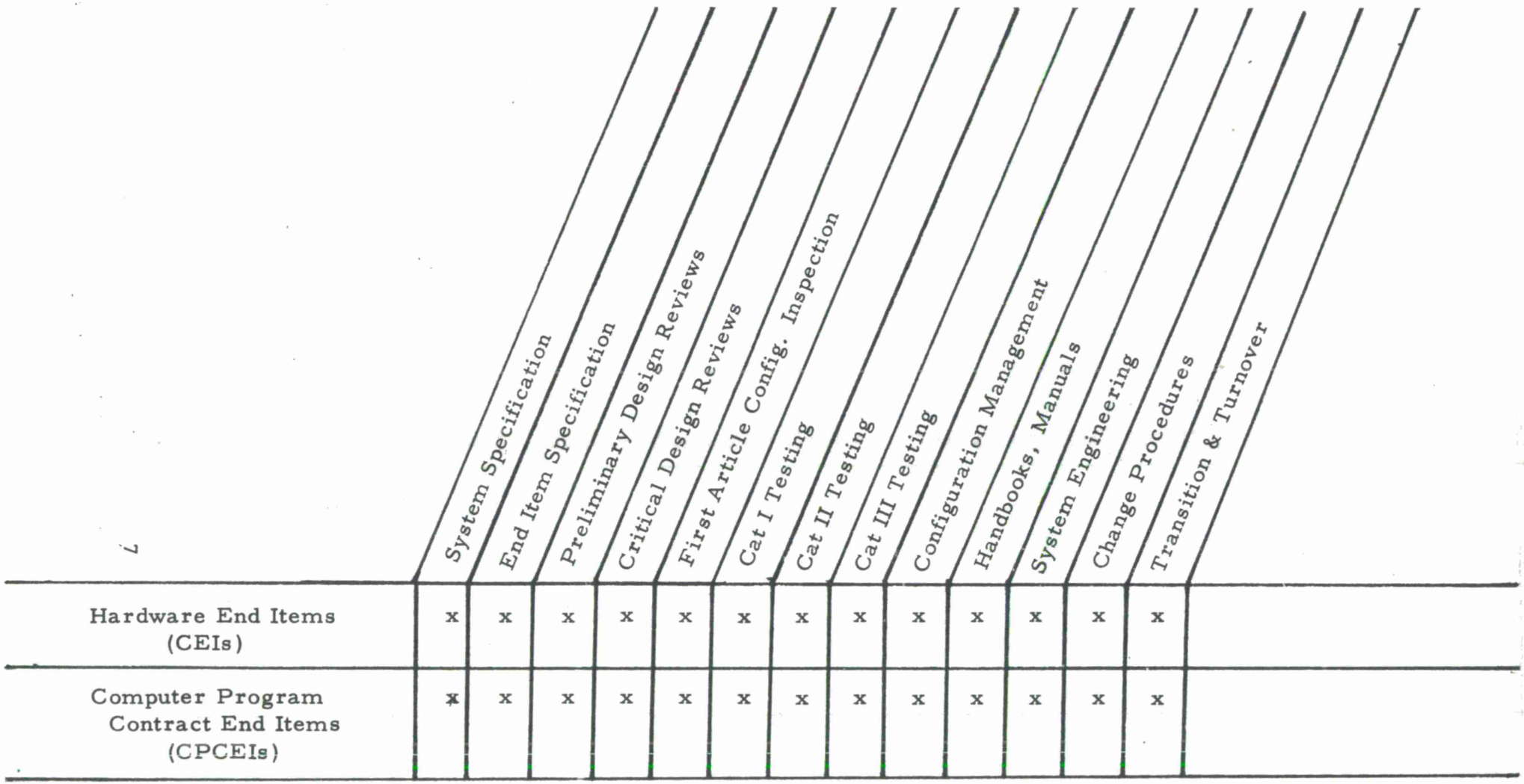


FIGURE 2. "SOME COMMONALITIES BETWEEN COMPUTER PROGRAM END ITEMS AND HARDWARE END ITEMS"

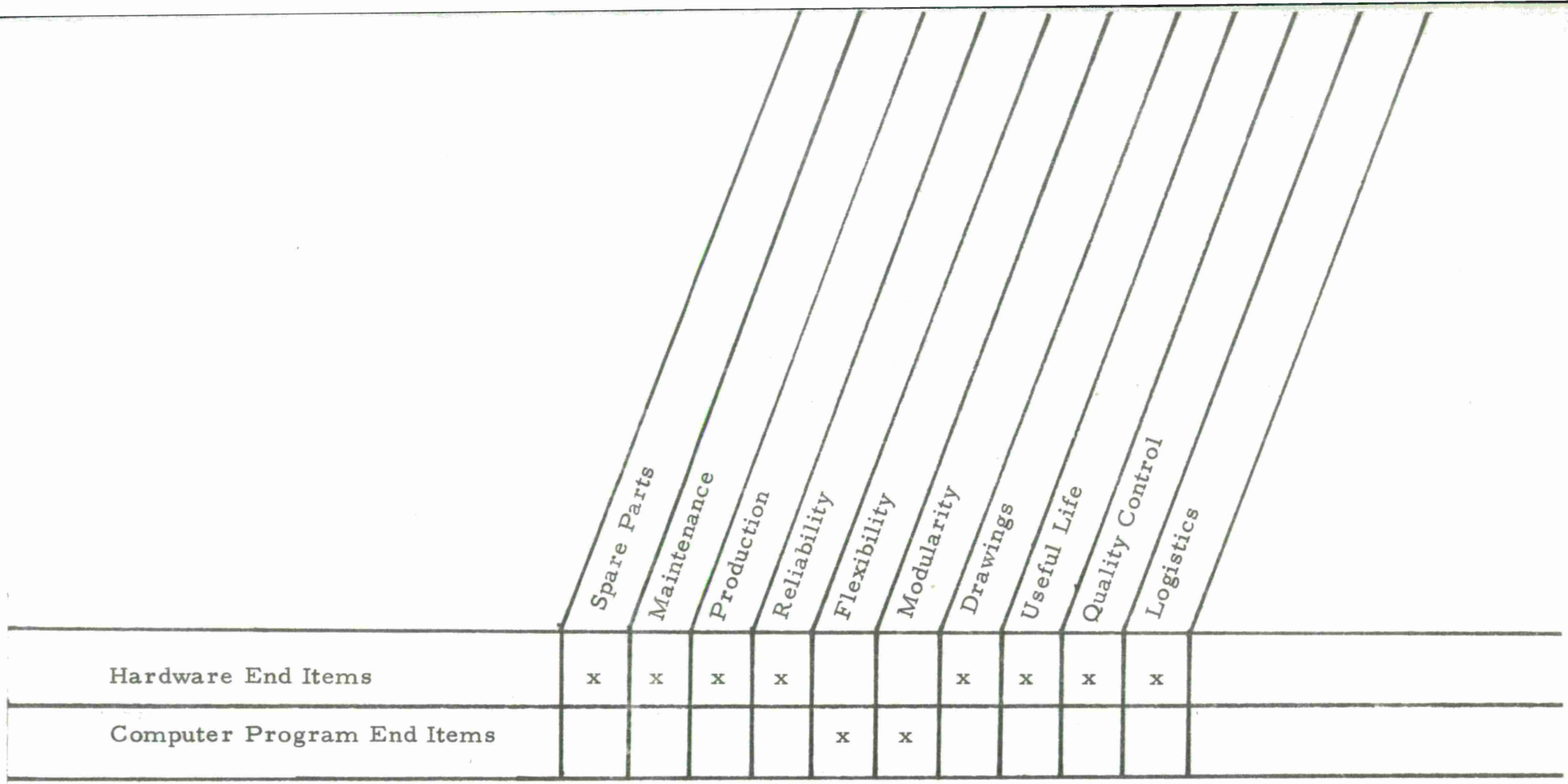


FIGURE 3. "DIFFERENCES BETWEEN HARDWARE AND COMPUTER PROGRAM END ITEMS"

machines at small cost. Therefore, the elimination of concepts, such as, reliability, spare parts, quality control, useful life, etc., required careful tailoring of the hardware oriented management procedures to computer programs. It is felt that this goal was substantially achieved, and the following discussion on the pertinence and relative compatibility of the Air Force 375 System Management Process to computer program development is an attempt to demonstrate that, with modified procedures, the basic 375 process can readily be accepted by the computer program community.

## SECTION III

## CONCEPT OF SYSTEMS MANAGEMENT

The contemporary Air Force 375 series regulations and the AF Systems Command manuals establish the procedures of acquiring a new military capability in a finite and structured manner. These documents were intended to include all the activities and all the events necessary to assure a complete military system, however, the emphasis in the current AFSC manuals is on hardware acquisition and does not adequately identify the inherent peculiarities of computer program acquisition. The "375" technique, nevertheless, can be applied and the computer program activities readily associated with the 375 life cycle. This is the objective of the discussion following. (NOTE: The applicability of the AF System Command Management Manuals is discussed in more detail in the Appendix to this report).

The system life cycle is divided into four phases: Conceptual, Definition, Acquisition, and Operational, as shown in Figure 4.

### A. An Overview of the Air Force System Management Process

System management of large-scale military systems is a complex team effort, in which many government agencies and the contractors pool their resources to balance technology, cost, time and other factors to achieve the best performing product for the military inventory. One of the most important points to understand about the 375 process is that it is not a new way of life, nor is it an entirely new approach to the development of a system. As stated by General B. A. Schriever[8], the Air Force is taking advantage of the lessons learned over past years, and has formalized and standardized on a "typical" way of doing business. This is not to say that every program or project was or is intended to follow all the 375 procedures or all the processes, but that it is a "road map" of events, activities, and milestones that make sense, can save the taxpayers' dollars, and the military time. The emphasis in the Air Force always has been on the "selective use" and on the "discreet application" of these formal and standard procedures.

The final portion of this paper is essentially an introduction of a management concept for computer programming and is intended to set the stage for the papers [2,3,4] that follow. The significant activities of the programming process, in terms of the four phases of a system's life cycle, with an emphasis on key milestones and key outputs, are summarized on a phase by phase basis.

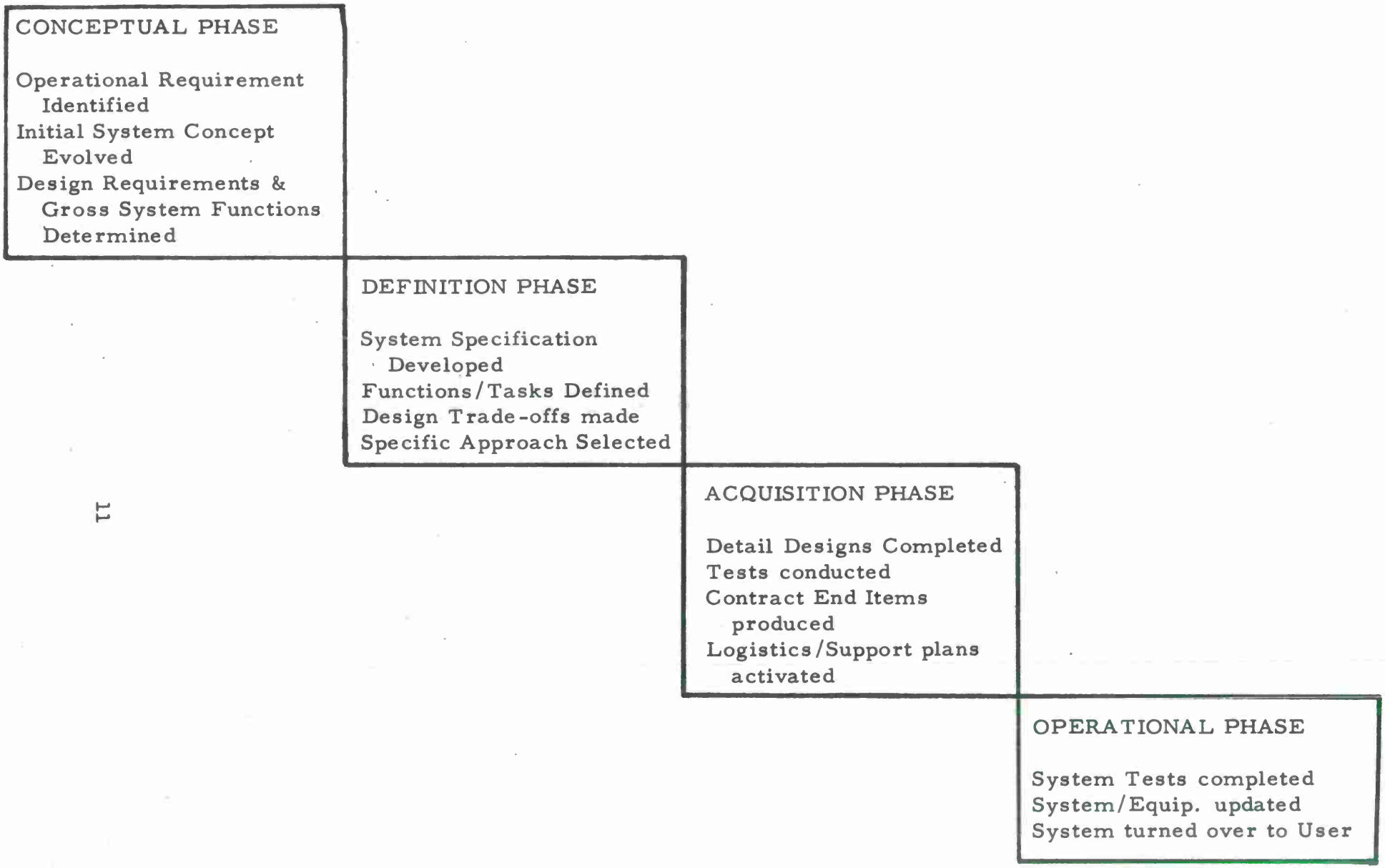


FIGURE 4. AIR FORCE SYSTEM LIFE CYCLE

## B. The Conceptual Phase for a Computer Program

This is the period during which new inventions, technological advances, user requirements, time and money, and other considerations are traded off to define a valid requirement.

Of particular interest to computer program development is a firm delineation of the system mission, the operational environment, interfaces, and doctrine of operational employment. For information management and handling systems, the analyses of the system information processing functions should begin during the Conceptual Phase. These analyses will typically include the detailing of system functional flows, the identification of design requirements, and the performance of trade-off studies based on estimates of cost effectiveness.

Figure 5 depicts typical key events/activities that would be important to insure early and adequate consideration for the computer programming aspects of an information processing system.

Block 1, "Identify Operational Requirement"

For computer-based systems/subsystems, this is the initiation of the information processing analysis. Mission requirements are analyzed, the operating concept is defined as are the modes, environment and constraints. The responsibilities, geographic locations and the levels of the user are identified. A preliminary estimate of personnel requirements is made. Depending on whether the requirement is to satisfy a military or a non-military user, the information processing requirements are included in the appropriate planning documentation, in order to identify the total system operational requirements.

Block 2, "Define Initial System Concept"

This step is concerned with developing qualitative requirements of sufficient potential value as to warrant further effort and definition in specific terms. The qualitative requirements should recognize the status of the pertinent state-of-the-art and should conceive those concepts which will satisfy the basic mission and plans. The initial operational functions and concepts are developed at this time, as would be the identification and nature of the sources and the destinations of data elements. The requirements for data collection, generation and/or transmission are initially defined. It is often pertinent to evolve several information processing concepts, in order that various approaches can be assessed, particularly from the major time and money trade-off viewpoints.

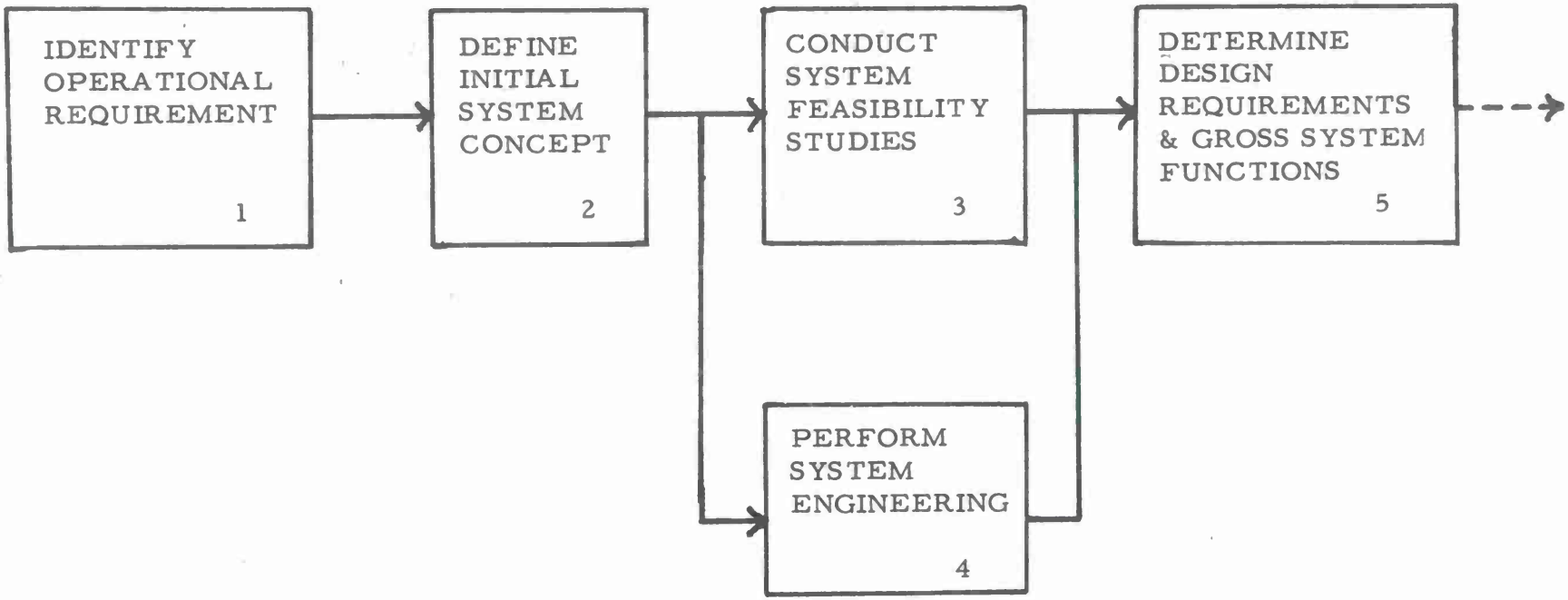


FIGURE 5. THE CONCEPTUAL PHASE FOR A COMPUTER PROGRAM

Block 3, "Conduct System Feasibility Studies"

This step represents the initial effort toward the formulation of a specific operational requirement for a system. For computer-based systems, this involves the translation of a qualitative requirement into system concepts by the assignment of functional and operational capabilities to specific areas of equipments, procedures, and man/machine relationships on a trial basis. This is the first point at which the considerations of timeliness, technological and economic feasibility, and capability are explored in any detail.

Block 4, "Perform System Engineering"

A specific concurrent and prime technical activity at this point in time is the system engineering activity. In the case of military systems, this activity will be performed more and more by in-house government agencies and less and less by contractor-industry activities. For the Air Force, captive contractors, such as the MITRE Corporation and the Aerospace Corporation, and in-house engineering agencies, such as the System Engineering Group and the Rome Air Development Center, perform the bulk of the initial system engineering studies.

System engineering studies are conducted to the level of detail necessary to establish that the system selected will meet the operational performance capabilities and will be technically attainable within the required time period. Basic technical data should essentially be complete in the following areas:

1. Information Processing. This will at least include: a description of the mission requirements, including deployment requirements and integration with other systems; concept of operation associated with each mission/environment; the system information flows; the allocation of functions between man and computer; a description of the system data base including processing and storage requirements; a description of selected techniques of computer programming; a description of the command organization with preliminary estimates of personnel requirements; a description of requirements for system exercising; and a description of interfaces with other information systems.

2. Computer and Associated Equipment. The performance characteristics of the computer, the operational consoles, the other Input/Output units, and the special equipments for system exercising are derived from the analysis of system information processing functions, in parallel with the determination of functions to be performed

by personnel and computer programs. Both off-the-shelf and state-of-the-art equipments are considered. Additionally, custom-configured or significantly modified existing equipment are included in the cost-effectiveness studies, in order that technical feasibility, cost and schedule estimates, and interfacing characteristics with the computer program system, communications, and facilities are firm enough to warrant the development of a System Performance Specification. Factors, such as general, logical and physical equipment configuration; data processing speeds, storage requirements, input-output interfaces; peripheral requirements for magnetic tape units and card machines; operator consoles; special equipments; and growth potential, are identified preliminarily at this point in time in order to assure feasibility of the system to meet the mission requirements.

Block 5, "Determine Design Requirements & Gross System Functions"

This step signifies that sufficient system concept studies, system feasibility studies, exploratory development, and/or system engineering have been performed to satisfy decision makers that the system costs are realistic, estimated schedules realizable, the high risk areas identified, and that this is the system which should be funded and resources allocated with which to proceed to the next phases, the Definition/Acquisition Phases.

C. The Definition Phase for a Computer Program

This phase, which came into being under Secretary McNamara, sees the entire system defined and identified down to the level of contract end item specifications. During this phase, the systems analysis activities are carried out, considering such factors as total system cost/schedule/performance, identification of interfaces and high-risk areas. The definition Phase culminates with the preparation of a definitized development contract setting forth the results of the Definition Phase as the Design Requirements Baseline.

For electronic systems, the information processing aspects are identified as a system segment. Technical studies and alternative approaches are made at this time in the areas of computer programming, equipment, communications, facilities, personnel, procedural data, and training, including considerations of development lead times, system testing criteria. The direct objectives of these technical studies are to establish the total spectrum of design requirements and design constraints firmly, both for hardware and software, at the levels required for the System Specification and other documents which must be prepared.

Figure 6 identifies some of the major events, activities, and output products that would normally be expected to occur whenever a system goes through the Definition Phase.

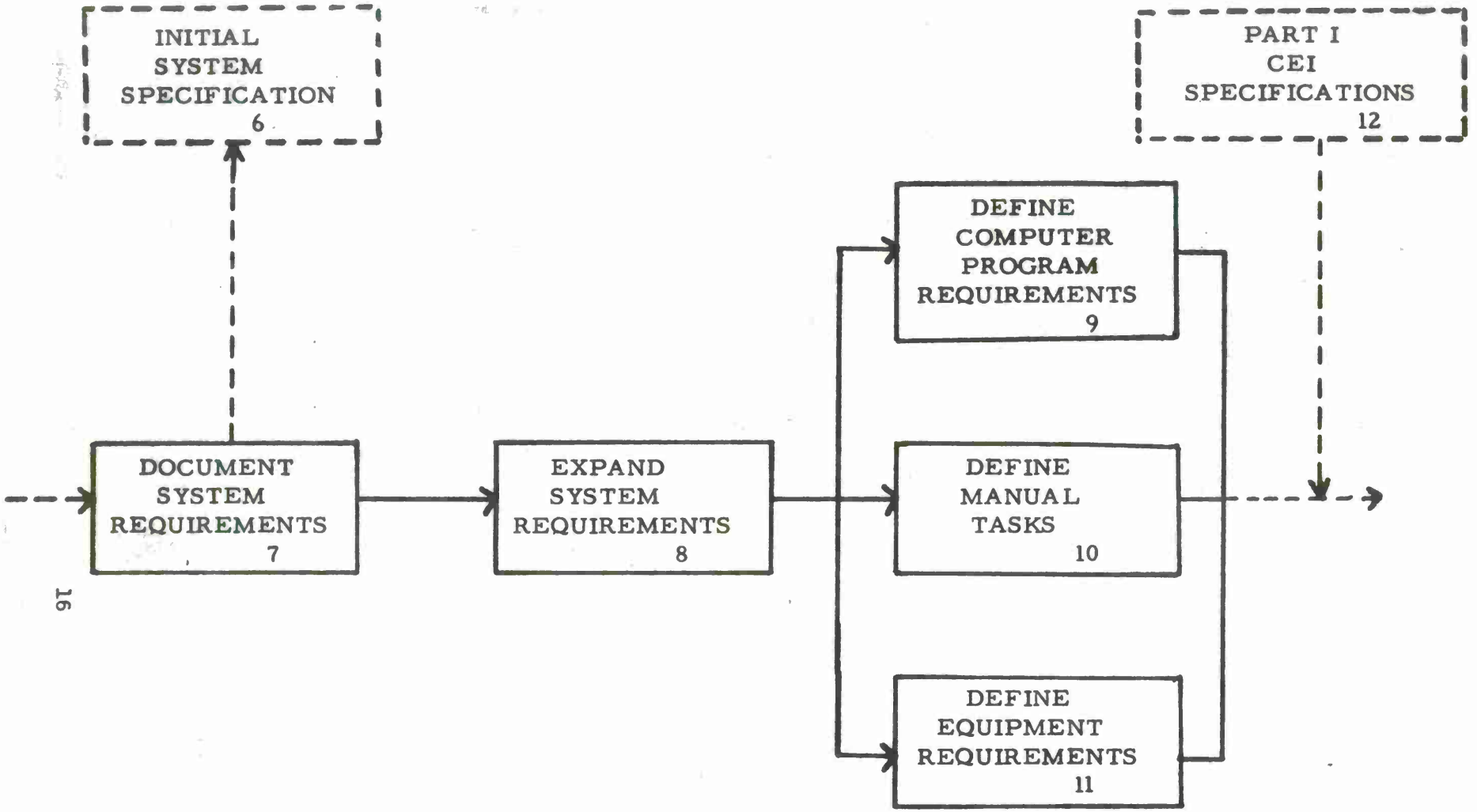


FIGURE 6. THE DEFINITION PHASE FOR A COMPUTER PROGRAM

Block 6, "Initial System Specification"

This step represents the technical effort that is applied to preparing a specific document upon which many subsequent steps and processes are dependent. The initial system specification is largely oriented to the operational requirements and allows considerable latitude in the system design, except in those areas wherein gross design considerations are specified or obvious. In some instances, expediency does not permit more than a cursory refinement of previous concepts and tentative performance requirements in the formulation of this document.

The preparation of the initial System Specification generally first requires that trade-off studies are identified and performed and that technical studies, consisting of reviews, verification, and expansion or alteration of technical concepts and data resulting from the activities from the Conceptual Phase are accomplished. If time precludes in-house accomplishment of these studies, this activity may be tasked upon the Definition Phase contractor(s). In this case, the Definition Phase contractor(s) would be required to evolve a fully defined System Performance Specification as one of his end products. For computer-based systems, information processing functions are re-examined and verified in relation to the user's organization, mission, and operating doctrines. Alternative approaches in the areas of computer programming, equipment, communications, facilities, personnel, procedural data, and training are assessed. The direct objective of these studies is to establish the total spectrum of design requirements and design constraints at the levels required for a System Specification.

Block 7, "Document System Requirements"

Under the 375 system management concept, the entire technical control of the system is based on the establishment of three (3) baselines/specifications. The first of these is the Program Requirements Baseline, the technical requirements of which are defined in the System Specification described earlier. The Program Requirements Baseline consists of documents which provide a conceptual technical description of the system, a description of the Definition Phase inputs/events/expected outputs and the estimated cost. This is the document that is evolved prior to initiation of the Definition Phase. From the total system approach, it is critical that the entire man/machine concept be sufficiently detailed particularly from the time, money and integration aspects.

Block 8, "Expand System Requirements"

The Definition Phase contractors first technical activity is to conduct a comprehensive and critical review of the functions, the performance, and the design requirements contained in the System Specification. Objectives are to verify, expand, and/or alter on the basis of the contractors approach and technical experience. Selected trade-off studies would be performed, interface requirements of the major hardware and computer program end items would be expanded.

Block 9, "Define Computer Program Requirements" and
Block 11, "Define Equipment Requirements"

The nature of the technical efforts will typically begin to diverge at this point in time with respect to their direct concern with system operational functions. This effort will define the requirements for the detailed tasks to be performed by the operational computer programs and the system equipment. It is predicated on the basis that the interfacing equipment characteristics have been defined at a level which will permit the analysis and specification of functions to be performed by the computer programs and equipment contract end items.

Block 10, "Define Manual Tasks"

A concurrent activity is the definition of manual tasks. The technical effort during this phase encompasses the analysis of manual and man/machine tasks. This leads to the definition of:

1. Manual tasks and procedures

2. Console operator procedures and decisions

3. Design requirements for console controls and displays

Block 12, "Part I CEI Specifications"

One of the most important products of the Definition Phase is the development of all the necessary "design-to" specifications for the Computer Program Contract End Items. In Air Force terminology these are called Part I - Performance and Design Requirements Specifications[2]. This part of the CPCEI specification is used to specify requirements peculiar to the design, development, test and qualification of the contract end items (CEIs). The Part II - Product Configuration and Detailed Technical Description Specifications[5] are not prepared until well into the Acquisition Phase. An important section of every computer program Part I specification is the detailing of

the requirements imposed on the design of a computer program and because of its relationship to other equipment/computer programs. Interfaces defined in this section of the specification shall include at least all relevant characteristics of the computer, such as memory size, word size, access and operation times, interrupt capabilities, and special hardware capabilities. The Part I specification permits the first opportunity for initiating configuration management procedures[5] for the control of design requirements changes. Part I specifications permit competition for the Acquisition Phase contract(s).

D. The Acquisition Phase for a Computer Program

The contractor designs, produces and tests the system hardware and computer programs during this phase. This phase continues until the last article is delivered to the operational user and all system development test and evaluation has been accomplished.

Figure 7 identifies many of the important activities in the design and validation process that would normally be initiated during an Acquisition Phase.

Block 13, "Part I Specification"

Now that the initial end item performance specifications have been developed, the test requirements detailed, and all the necessary man-machine trade-offs made, it is necessary that the System Specification be updated and approved for contractual use in the Acquisition Phase contract(s). For hardware, it is usually possible to have defined in detail the functional interfaces, however, for computer programs this is normally not possible unless a firm selection and approval of specific hardware, computer programs, and communications has been made. Thus, the system specification will normally not be fully updated, insofar as computer program requirements are concerned at this point in time, but rather, after some of the Design Review activities in the Acquisition Phase.

Blocks 9, 10, 11 and 12 constitute the technical substance of Design Requirements Baseline. This baseline represents the technical requirements for the Acquisition Phase contractor(s).

Block 14, "Preliminary Computer Program Design"

The fundamental purpose of the Acquisition Phase is to acquire and test the system elements required to satisfy the user's requirements. Upon award of the Acquisition Phase contract(s), the design of all contract end items begins. The Part I (design-to) specifications developed earlier, plus the System Specification, will be the

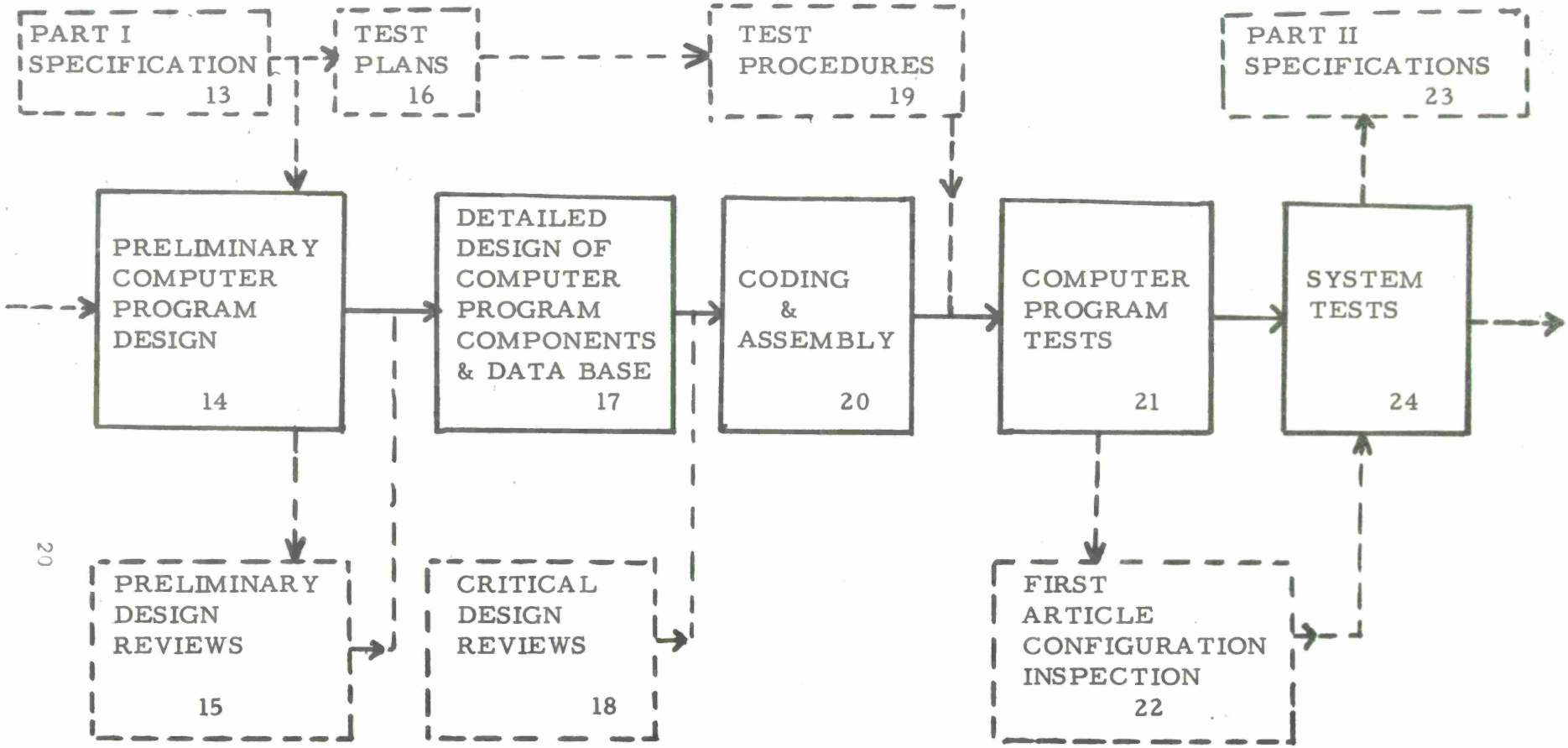


FIGURE 7. THE ACQUISITION PHASE FOR A COMPUTER PROGRAM

contractors technical baseline and, essentially, are a start on the design of the end items. For computer program end items, this activity consists of finalizing the analysis of system inputs/outputs/functions, allocation and grouping of computer programming tasks into individual computer programs or program packages. Additionally, individual programs will be described and the inter-program interface requirements detailed. All this, plus the development of functional flows, the accomplishment of trade-offs, etc., will be the basis of the detailed design that will be described in the Part II specification.

Block 15, "Preliminary Design Reviews"
Block 18, "Critical Design Reviews" and
Block 22, "First Article Configuration Inspection"

During the Acquisition Phase, a series of technical reviews and inspections are held to provide discrete milestones for an exchange of technical information between the Air Force and the contractor. Two of these, the Preliminary Design Review and Critical Design Review, are analyses of the design of the contract end items at various stages of development. The third milestone, the First Article Configuration Inspection, is an audit of the documentation that describes the contract end item. A more detailed discussion of these milestones is contained in the paper by Piligian[3].

Block 16, "Test Plans" and
Block 19, "Test Procedures"

A parallel effort to the computer program end item design is the development of a Category I qualification test program. Draft of the test plan and associated test procedures for the validation and evaluation of computer program end items are written for submission to the procuring/engineering agency for approval.

Block 17, "Detailed Design of Computer Program Components & Data Base"

The detailed design of the computer program is accomplished based on the approved Part I Specification and the results of the Preliminary Design Review.

The detailed flowcharts logic diagrams, narrative description, etc., will provide the basis for actual coding of the computer program(s). The design of the data base is developed at this time resulting in the number, type and structure of tables, as well as description of the items within the table. The detailed design forms the basis for the Critical Design Reviews[3] discussed previously.

Block 20, "Coding & Assembly" and
Block 21, "Computer Program Tests"

Immediately following the Critical Design Review, coding of the individual components of the computer program end items takes place and the process of checkout and testing of the components begins. Computer Programs are generally first tested during the Category $I^3$ test program. Cat I demonstrates that the CPCEI, as produced, satisfies or does not satisfy the design/performance requirements of the Part I CPCEI specification.

Block 23, "Part II Specifications"

The Part II Specification is a detailed technical description of the CPCEI. Essentially, it consists of elements which have appeared as computer program documentation in the past in a variety of forms and combinations--e.g., functional allocations, timing and sequencing, data base characteristics and organization, flowcharts, etc. The Part II Specification organizes these into a single, comprehensive description which includes the data base and listings. It is an "as-built" description, which the procuring agency accepts only after its completeness and accuracy have been formally verified, and normally after the computer program performance has been qualified in relation to the Part I Specification. Like the Part I, it does not contain operating instructions, test procedures, or other non-specification materials. Its subsequent technical uses are as an aid in correcting errors and designing changes. Following formal verification of its completeness and accuracy, it defines the Product Configuration Baseline.

Block 24, "System Tests"

The objective of Category II system tests is to demonstrate that the system will satisfy the system performance/design requirements of the System Specification. For computer programs, Cat II testing will assure the overall systems engineer that the computer programs are fully compatible with the hardware in an integrated performance environment, and that they meet the total system requirements, including personnel, communications, man-machine relationships, etc.

## E. The Operational Phase for a Computer Program

The Operational Phase permits the transfer and turnover of a systems/equipments from the design and acquisition agency to the using (customer) agency. This phase begins when the operational user accepts the first article, when all the elements of the system have been accepted by the user, and ends when the user disposes of the last item from the operational inventory.

Most Air Force systems are turned over to the user on an incremental basis; squadron by squadron for missiles; site by site for electronic systems; or system element by system element. In the case of computer-oriented systems (command/control systems), there is an evolutionary aspect present, which seldom permits the completion of specific Operational Phase. In this instance, it might be stated that there may be many Operational Phases for any one System, as a requirement for system-updating occurs and as this requirement is satisfied.

As the development agency acquires end items, and satisfies the user that a group of end items meets the user's operational requirement, a formal release of both the physical entities, as well as the engineering responsibility, is made by the development/acquisition agency. For computer programs, the transfer of engineering responsibility would not normally be to the Air Force Logistics Command (as is true for hardware), but rather would more likely be to the user. There are instances, however, where certain utility and/or maintenance-diagnostic computer programs furnished with, or as parts of, the computer equipment are engineering-transferred to the Logistics Command, rather than the user.

As elements or end items are turned over to the user, the configuration management responsibility also becomes the responsibility of that agency. For purposes of configuration management of computer programs, the updated System Specification and the Part I Computer Program End Item Detail Specification function as the design requirements baseline throughout the Operational Phase.

Figure 8 identifies many of the specific activities that pertain to a process that permits the design and acquisition agency to turn over to the user those completed elements of a system, as the operational requirements are met.

Block 25, "Turnover to User"

Under current Air Force concepts, equipment, facilities and computer programs can be incrementally "turned-over" to the user on an operating unit by operating unit basis. The standards for computer program turnovers is in the process of evolvement, however, it is general practice to "turn-over" both the hardware as well as the applicable computer programs on a concurrent basis. Under any circumstance, turnover implies that the minimum operational capability has been satisfied for the total system or for some element thereof, and that the industry and government design agencies consider the primary design/engineering activities as completed.

Block 26, "Updating Changes on Contract"

As with hardware, computer programs are subject to follow-on development tests which normally result in updating change requirements. As the user exercises his system, or some element of a system, deficiencies and/or improvements become suggested. Updating changes are most practical to contracts which have not been completed, and can be broadly categorized as those which are (1) the contractor's responsibility and essentially under contract "guarantee," and (2) improvements and performance updating initiated by the user, which requires a new contractual understanding and new design effort. In essence, the "design-updating" changes that are necessary are now placed on contract, system tested and recorded.

Block 27, "Transfer of Engineering & Logistic Responsibilities"

There is no formalized Air Force policy on the logistics and engineering responsibilities for computer programs once they have been turned over to the user, however, an unofficial process is in effect. Several large electronic systems have been officially turned over to using commands. The "engineering" responsibility for controlling corrective actions and incremental improvements of operational capabilities through changes in the computer programs has in all cases, to date, been assigned to and assumed by the using command. In some instances, this responsibility extends to the maintenance of handbooks, user manuals, and other documents which are directly dependent upon the computer program end item configuration. The "logistics" and the so-called "engineering" aspects of computer programs are being studied and debated at appropriate levels, and a decision issued, particularly with reference to certain utility and/or maintenance-diagnostic programs furnished with, or as parts of, the computer equipment.

Block 28, "User Operational System Tests"

Upon the completion of Category II system tests and the incremental transfer of computer programs, computer equipments, handbooks, user manuals, etc., to the user, the using command may elect to conduct Category III type tests. Category III tests are system tests similar to Category II and for computer programs may either be unnecessary, or may be conducted concurrently with Cat II. At this point in time, the system is fully operational, all live environment, and is conducted by the user, generally with the assistance of contract services from the automated data industry. As during Category II testing, deficiencies and/or improvements are revealed, and system modifications made dependent on significance to mission and budgets.

Block 29, "System Updating"

One of the final technical functions is to document and record the precise system/equipment configuration and to update all manuals, handbooks, etc. Beginning back in the latter part of the Definition Phase, a "configuration management" procedure would have been defined, agreed upon by the contractor(s), and would at this point in time be thoroughly updated and turned over to the user. The user would continue to use the system specification and the Part I detailed "design to" specification, as the design requirements baseline for the purposes of configuration management and for a design updating standard. The system itself is also updated to incorporate updating changes and modifications resulting from the users operational testing and system usage.

Block 30, "Mission Performance"

This event represents the continued operation of the system by the user until such time as the system is phased out of the operational inventory.

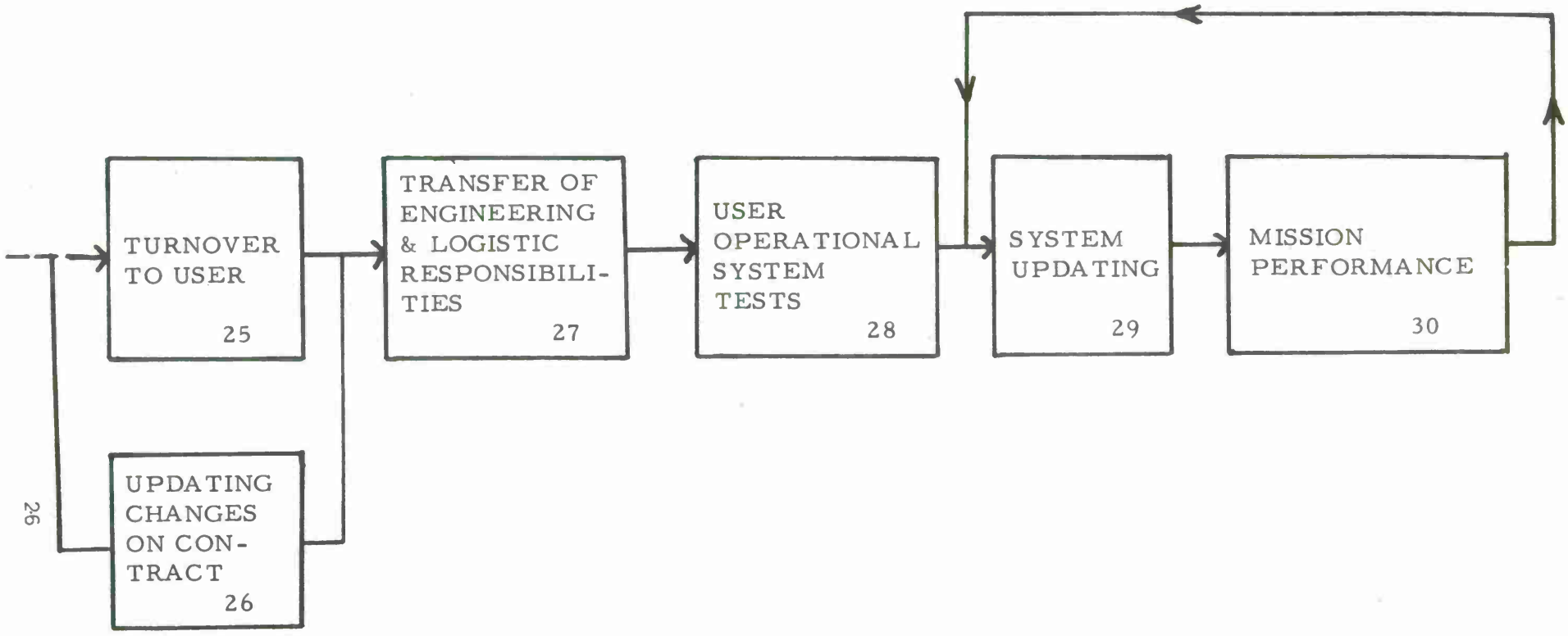


FIGURE 8. THE OPERATIONAL PHASE FOR A COMPUTER PROGRAM

## SECTION IV

## SUMMARY AND CONCLUSION

The management framework established by the 375 series Air Force regulations and manuals is applicable to electronic systems, as well as to aircraft and missiles. This management concept is exemplified by electronic computer-based systems, such as 412L, 416L, 425L and 465L; namely, operational military systems which provide information processing assistance to command personnel who are responsible for planning, decision-making, and control of resources and forces. A major impact of considering this type of system is to emphasize information processing and associated technologies as the lead items in system concept and design. This emphasis is needed in order to assure that the specification and procurement of hardware and facilities will be based upon adequate consideration of the user's information processing procedures and requirements.

The modification of the current hardware-oriented 375 system management process to include "software" activities places primary emphasis on events associated with:

1. Analysis of system information processing functions.

2. Allocation of functions to operational personnel and the computer hardware.

3. Definition of the functions to be performed by computer programs.

4. Development of operating procedures.

5. Design, development, and testing of computer programs.

6. Development of provisions for operational training and other personnel subsystem products.

The implications of the concept described in this paper can be summarized as follows:

1. The normally hardware-oriented System Program Director is now provided with a management tool with which to evolve requirements and assess the total system's progress by the establishment of computer program key events, milestones and activities during the system's life cycle. The "visibility" aspects of computer program intricacies will be more evident to the System managers.

2. Computer program requirements documented in a technical specification provide a standard by which the performance of the contractor and the performance of the resultant computer program can be evaluated.

3. The design documentation and specifications developed during a normal Definition Phase activity will provide for the first time an opportunity for the government to acquire computer programs on a true price competition and open-bid, fixed-price basis, rather than the current predominant sole-source, cost-plus situation.

4. The computer program management techniques evolved will significantly reduce the excessive cost-overruns and will reduce the overall system costs that were uncontrollable without a finite management control process.

5. The eventual user and operator of the electronic system will be provided with sufficient data and documentation which will permit the user to operate, maintain and update the system much more effectively and efficiently.

6. The concept described is considered to be applicable to any system, military, business, or industry and to any programming exercise that warrants the use of computer program management techniques.

## SECTION V

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7. System 416-M: BUIC-Back-Up Interceptor Control. Electronic Systems Division, U. S. Air Force.

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## APPENDIX

## THE AIR FORCE SYSTEM MANAGEMENT MANUALS

The AF Systems Command Manuals are the medium through which Air Force directives, regulations, dictums and requirements are put into practice. There is a master scheme and a specific usage for each manual, in that some are intended for Air Force usage only while others are supplied selectively as a requirement on specific contracts. Figure No. 9 summarizes those of prime interest to industry. The manuals are cross-referenced extensively in order to eliminate conflicts and double standards. The following discussion describes the applicability of these manuals to Computer Program acquisition.

### AFSCM 375-3, System Program Office Manual

AFSCM 375-3 describes what a System Program Office (SPO) is, how it is organized, how the overall job is done, the general responsibilities, the relationships with other government agencies, and the functional duties and responsibilities of all the members of a SPO. AFSCM 375-3 is introductory and indoctrinational in nature and will never be applied on a contract as a requirement, but is of useful interest to contractors. AFSCM 375-3 requires modification in order to introduce new SPO personnel to the complexities and intricacies of managing computer-based systems.

### AFSCM 375-4, System Program Management Procedures

AFSCM 375-4 establishes the requirements, policies, and procedures for the Conceptual, Definition, Acquisition, and Operational Phases of a system program. It prescribes the significant management activities for integrating and fulfilling the responsibilities of the organizational elements involved in managing a total system program. It is the mandatory management standard for all future Systems Command system programs and projects. AFSCM 375-4 will never be placed on contract as a contractual requirement; however, it is vital for contractors to be familiar with 375-4, since this is the "roadmap" of management and technical milestones and events that a SPO will follow on all future contracts. AFSCM 375-4 is the "overall" AF systems management manual and references 375-1 and 375-5.

As currently written, 375-4 does not detail nor address itself to computer programs. The Electronic Systems Division has, in conjunction with the System Development Corporation, evolved ESD Exhibit EST-2, which does tentatively describe computer program

| DOCUMENT | SPO/ PROJECT OFFICE | CONTRACTOR |
|---|---|---|
| DOD 5010.14 DIRECTIVE | X | |
| AFR 375 SERIES REGULATIONS | X | |
| AFSCR 375 SERIES REGULATIONS | X | |
| AFSCM 375-1, "CONFIG. MGMT MANUAL" | X | X |
| AFSCM 375-3, "SPO MANUAL" | X | |
| AFSCM 375-4, "SYS PROG. MGMT PROCEDURES" | X | |
| AFSCM 375-5, "SYSTEM ENG. MGMT MANUAL" | X | |
| AFSCM 375-6, "DEV. ENG. MANUAL" | X | |
| AFSCM 50-3, "SYS. TNG. EQUIP." | X | |
| AFSCM 310-1, "DATA MANAGEMENT MANUAL" | X | X |

FIGURE 9. CONTRACTUAL APPLICATION OF "375"

events and milestones. This Exhibit is being expanded and will describe in detail all the activities, milestones and events relating to Computer Programs, and in particular relating the hardware events with the computer program events.

AFSCM 375-1, Configuration Management Manual

AFSCM 375-1 establishes the policy, guidance and the responsibilities for system/equipment in the management of the configuration of systems/equipments. It prescribes the format and the details for preparation and maintenance of specifications and drawings. It provides for the control and approval of engineering and design changes and for implementing these decisions. It describes the various engineering inspections and compliance reviews. AFSCM 375-1 is placed on contracts as a contractual requirement on a selective Exhibit by Exhibit basis.

AFSCM 375-1 does not currently provide for procedures peculiar to the area of computer programs. The Electronic Systems Division and the System Development Corporation have developed an extensive and detailed configuration process that complements the existing AFSCM 375-1 process. Currently, this is available as ESD Exhibit EST-1. The revised AFSCM 375-1 will fully take into account and will describe in detail the configuration management procedures for computer programs.

AFSCM 310-1, Data Management Manual

Describes the overall data (drawings, manuals, specifications, reports, etc.) management approach, data control procedures and data standards. AFSCM 310-1 also is a "catalog" of approved data (documentation) items. Air Force organizations ordering data from contractors must choose their documentation requirements from this approved list. AFSCM 310-1 is intended to be primarily a contractual requirement type of manual.

To date, the following Data Items, suitable for contractual acquisition of computer program data, have been developed:

1. Positional Handbook -- Information System Operational Personnel

2. Contract End Item Detail Specification (Computer Program) Part I

3. Contract End Item Detail Specification (Computer Program) Part II

4. Category I Test Plan (Computer Programs)

5. Category I Test Procedure (Computer Programs)

6. Category I Test Report (Computer Programs)

7. Exercise Conduct Manual (U)

8. Synthetic Inputs Operator Guide (U)

9. Evaluation Manual (Information System Exercising Personnel (U)

10. Human Operator Task Analysis for Information Systems (U)

11. Training Needs/Exercise Requirements Analysis (U)

12. Evaluation Needs/Exercise Requirements Analysis (U)

13. Exercising Capability Implementation Plan (U)

14. Minutes of Formal Reviews and Inspections

15. (Computer Program) Users Manual

16. Version Description Document (Computer Program)

17. Change Status Report (Computer Program)

18. Configuration Index (Computer Program)

19. System Exercising Problem Package (U)

20. System Exercising Problem Agreements Documents

AFSCM 375-5, System Engineering Management Manual

The 375-5 manual establishes and describes in detail the Air Force methodology for accomplishing the system engineering management process. The main body of the manual provides guidance and policy for Air Force organizations and also is very useful to contractors for general information, and an understanding of how system elements are laid out in advance so that they are understood, not only by the contractor with respect to the job, but the customer as well. It is essentially an agreement between the two parties who have engaged in the contract as to what they expect to get, in considerable detail, at a fairly early point in time. This agreement -- and its controls -- is progressively

definitized as the system is defined. Then there is a demonstration, as the equipment evolves, to show that the contractor has in fact achieved what was agreed upon. It will then be possible to look at the dollars, to look at the schedule, and by proper testing determine whether the contractor has been successful in producing the product that was intended. With some of the past systems programs, this was done, but not in the same formalized manner. One reason, in part, was that the contractor was delving in an area where he was not certain of the end results, and the customer was never too certain of the operational use of the device after he received it. The customer frequently did not establish the specific philosophy of operation and maintenance until after the system was developed. Consequently, many changes occurred in order to satisfy the basic operational requirements. In the past several years, both contractors and customers alike have gained considerable experience and this experience is now being reflected in Air Force regulations and manuals.

AFSCM 375-5 does recognize and identifies the basic relationships and interactions between computer programs and hardware; however, as with all the other AFSC Manuals discussed to this point, AFSCM 375-5 is primarily hardware oriented. The System Development Corporation, under a study contract with the Electronic Systems Division, is currently developing in conjunction with in-house Air Force effort, a detailed exposition of the system engineering process for computer programs. The ultimate goal is to eventually develop one manual for system engineering, to include equipment as well as the computer program processes.

AFSCM 50-3, System Training Equipment Management Manual

This manual is intended to serve as a management tool by providing the procedures, requirements, and responsibilities for the identification, design, development, documentation, acquisition, test, and evaluation of all training equipment required in support of the system. As currently in force, the manual is intended for both computer hardware and all other equipment hardware.

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13 ABSTRACT

An extensive series of design control techniques for the acquisition of "systems" and "hardware" has been developed by the Air Force over the past five years. The control of computer program (software) designs, the verification and validation of the computer program products, and the integration of "software" and hardware has not been as aggressively investigated. This paper describes the overall Air Force project that has been established to evolve a series of techniques for the acquisition and design control of computer programs and computer program data.

The Air Force 375 System Management Concept proved to be the best model about which to structure and develop the technology and management process for computer program acquisition and development. To date, certain standards and techniques have been developed; namely, the concept of uniform specifications, design baseline management, design change controls, specification maintenance, and design accounting. Current studies are in progress to evolve computer program testing and validation standards, the systems engineering integration aspects, and the detailing of the generalized procedures and events as related to computer-oriented systems and programs.

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| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Computer Program Management<br>Design Control of Computer Programs<br>Computer Program Data Products Development<br>Acquisition Techniques for Computer Programs<br>Software Management<br>Acquisition of Software<br>Software Design Controls<br>Design & Development Process for Command Systems<br>Software and the Air Force 375 System Management Process<br>Design Integration of Hardware and Software | | | | | | |

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