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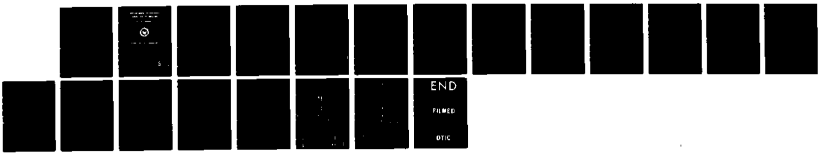

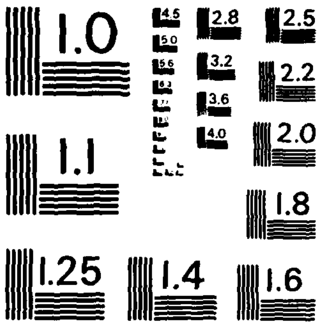

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DEPARTMENT OF DEFENSE COMPUTER TECHNOLOGY

(STUDY ANNEX)

A REPORT TO CONGRESS

JANUARY 1984

OFFICE OF THE UNDER SECRETARY OF DEFENSE
RESEARCH AND ENGINEERING
WASHINGTON, D.C.

REPRODUCED AT GOVERNMENT EXPENSE

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FOREWORD

This report addresses concerns of the Congress expressed in the Authorization and Appropriations Acts of 1983 and 1984 regarding the Department's plans for the management of mission-critical computer resources. The Congress requested the Department to address acceleration of the Ada® language, advanced microelectronic and chip set computers, instruction set architecture, the reduction of unproductive proliferation of different types of military computers, schedules for current computer programs, and the plan for the software technology (STARS) program.

The Department's Ada policy and plans are provided in Section I of this report, as is an Introduction to the STARS Program. (The detailed strategy for STARS will be forwarded to the Congress in February 1984.) The Department's strategy covering the use of advanced microelectronic and chip set computers in weapons systems is presented in Section II, however, specific program segments that effect this strategy are included in each section of the report.

A revised approach to instruction set architecture has been developed. It is detailed in Section III in the larger context of computer system interfaces. Plans for current generation military computer programs are contained in Section IV. Finally, a plan for next-generation mission-critical computers is presented in Section V.

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I. MISSION-CRITICAL SOFTWARE INITIATIVES

The Ada language is receiving wide United States and international acceptance. The military standard for Ada was adopted as an American National Standard on February 17, 1983. International standardization of Ada is being addressed by a working group of the International Organization for Standardization. Ada standardization milestones are shown in Figure 1.

Government, industry, and academic organizations are currently sponsoring over forty developments of Ada compiler systems throughout the free world. The Department intends to capitalize on these efforts and to accelerate its use of Ada as described herein.

Included in the Authorization Act for 1983 is the following statement:

> "The Department of Defense should accelerate the implementation of the Ada higher order language and constrain to the maximum extent feasible service variations on Ada to ensure the utmost commonality of systems support software."

The Department is moving vigorously toward Ada. On June 10, 1983, a policy was promulgated that mandates the use of Ada, consistent with approved introduction plans, in all mission-critical defense systems that enter advanced development status after January 1, 1984 or that enter full-scale engineering development status after July 1, 1984.

It is also the Department's policy that all Ada compilers used in the development and support of mission-critical systems comply fully with the Ada standard. This policy prevents Service variations on the language itself and thereby facilitates the maximum degree of commonality afforded by the standard. Compliance with the standard will be assured through Ada compiler validation facilities at the Language Control Facility at Wright Patterson Air Force Base, Ohio, and at the GSA Federal Software Testing Center in Washington, D.C.

The Department has Ada compilers under development with code generators for specific military computers (See Figure 1). The Army has been developing the "Ada Language System" (ALS) which includes a code generator and an associated run-time support subsystem for the Military Computer Family (AN/UYK-41 and AN/UYK-49). It is hosted on, and also targeted to, the Digital Equipment Corporation VAX 11/780 computer.

The Navy is building on the Army's ALS to support the AN/UYK-43, AN/UYK-44, and AN/AYK-14 computers (See Figure 1). The Navy also has under separate development a compiler hosted on the IBM

S/370 and targeted for the S/370, the Motorola MC68000, and the AN/UYK-44 to support the Submarine Advanced Combat System (SUBACS) program. This will accelerate the introduction of Ada into Navy systems. Applications software produced under this development will then be phased into the Navy's Ada Language System, "ALS/N, to achieve an integrated system for Navy-wide use.

The Air Force has been developing the "Ada Integrated Environment" (AIE) including a code generator for IBM S/370 computers for use in command and control and intelligence applications. In FY 1984, the Air Force will, via competitive procurement, also initiate development of a code generator and associated run-time support subsystem for MIL-STD-1750 computers for avionics applications as an augmentation of one of the existing Ada compiler efforts. Milestones for Air Force Ada activities are provided in Figure 1.

The Department has been working on a joint effort, in cooperation with industry, to develop interface standards for Ada compilers that will facilitate the transportability of software "tools", for example, an Ada-oriented text editor, across Ada compilers/programming support environments produced by different companies. These interface standards are called the "Common Ada Programming Support Environment Interface Set" abbreviated to "CAIS". The schedule for these standards is shown in Figure 1. When they are developed and compilers/environments are modified to accommodate them, it will be possible to transport software tools produced by different organizations to any given compiler/environment with only a minimum of effort.

Most of the developments of Ada compiler systems are sponsored by industry. Maximum use of such systems is encouraged by the Department as the technical capabilities and innovations in software concepts, methodologies, and automated tools contained in such systems may facilitate significant increases in software productivity and reductions of software errors. (See discussion of the STARS "Automated Software Factory" concept in this Section.) The Department's long range policy for this area is to allow contractors to employ the Ada environments of their choice for the development of mission-critical defense software so long as they comply with the CAIS interface standards and they do not cause the government to become permanently locked into company-owned and protected software environments. This approach will facilitate the transition of software developed on one Ada environment over to another Ada environment, when required, at any point in the evolutionary software life cycle.

During the period of development of the CAIS interface standards, however, the government will not be able to afford the consequences of unconstrained proliferation of Ada environments. Therefore, the Department's interim policy is to allow industry use of company-owned environments where such use offers benefits to the government in terms of cost, schedule, or increases in software productivity and quality with respect to government environments and the means are provided to transition such capabilities to government environments. During this interim period, as over the long term, the Department will avoid approaches that will lock the government permanently into company-owned and protected software environments.

To establish criteria and procedures for evaluating different Ada programming support environments in various contexts, the Ada Joint Program Office has established a Joint Service Environments Evaluation and Validation Working Group under Air Force leadership. This work will be an extension of the current compiler validation efforts and will include industry inputs on criteria and tests. The schedule for this effort is shown in Figure 1.

In addition to the transportability of Ada-oriented software tools across different Ada environments (which is addressed by the CAIS), there is also a need to provide transportability of run-time (applications) software modules from one military computer to another where the second computer may use a different instruction set architecture. This level of transportability will provide the ability to reuse applications software modules. To address this situation, the Department will develop an Ada Transportability Handbook containing rules to be followed in the use of Ada that will enhance the potential for transportability of Ada applications software to different computers or microprocessors. Examples of reusable encapsulated software modules, called "packages" in Ada, are navigation programs and I/O handlers. Version 1 of the Ada Transportability Handbook will be distributed for use in the development of mission-critical defense systems by 30 December 1984. The schedule for this effort is shown in Figure 1.

Thirty systems that will use Ada in the near term (next three years) have been identified. Beyond this transition period it is intended that all new systems and major upgrades to existing systems will use Ada. (Use of artificial intelligence languages, e.g., LISP, and other special-purpose languages will be allowed on a waiver-basis.)

The following Army systems will begin use of Ada in the near term: Advanced Field Artillery Tactical Data System, Joint Tactical Fusion, PLRS/JTIDS Hybrid, Mobile Protected Gun System, MLRS Terminally Guided Warhead, Anti-Tactical Missile, Air Defense Electronic Warfare System, Joint Tactical Missile System, Maneuver Control System Evolutionary Development, Regency Net, and Lightweight Air Defense System.

The following Navy systems will begin use of Ada in the near term: Tactical Data Information Exchange System, Submarine Advanced Combat System, Tactical Flag Command Center, Ocean Surveillance Information System Baseline Upgrade, Anti-Submarine Warfare Operations Center Upgrade, Replacement for Force High Level Terminal at Shore ASW Command Center, Replacement for Shore Targeting Terminal at Submarine Operational Control Centers, MK 50 Advanced

Lightweight Torpedo, and the Advanced Combat Direction System.

The following Air Force systems will use Ada in the near term: Peace Keeper Test Support System, Minimum Essential Emergency Communications Network, WWMCCS Information System Upgrade, Joint Operational Interface Simulation and Training System, Communications System Segment-Replacement, Command Center Processing/Display System-Replacement, Data System Modernization, Consolidated Space Operations Center, Defense Support Program, and Space Defense Operations Center.

The Department expects the Ada initiative to result in significant software cost avoidance. Economies will accrue first through DoD-wide language commonality, and second through the excellent technical capabilities inherent in Ada for mission-critical computing compared to other high order languages. Ada's influence, however, will be limited primarily to the implementation or coding of software which currently represents about 15% of mission-critical computer software costs. With software providing an increasingly higher percentage of the functionality of modern weapon systems, and with software costs continuing to skyrocket, there are opportunities to reap even greater benefits.

Other software activities are very much in need of solutions analogous to that being provided by Ada for the coding function. Unlike coding, which is now strongly supported by compilers and other automated labor-reducing and error-reducing aids, other activities, such as software requirements definition, software architectural design, software detailed design, software integration, and software testing, are now largely manual and extremely labor-intensive.

This fiscal year, the Department initiated a new program, called "STARS" (Software Technology for Adaptable, Reliable Systems) to address this opportunity. STARS will create the "Automated Software Factory", a coherent and integrated system of computerized software tools and reusable software parts and building blocks. Through the Automated Software Factory concept, orders-of-magnitude increases in software productivity will be achieved as will comparable reductions in the number of software defects latent in fielded weapon systems.

The Automated Software Factory concept will address all of the dimensions of software activities including technical (software engineering), project management, software acquisition, and also will build reusable libraries of software modules applicable across the wide range of functional areas addressed by mission-critical defense systems, e.g., navigation, intelligence, and communications. Versions of the Automated Software Factory will be used throughout the Services, Defense Agencies, and industry.

STARS addresses Defense needs which are are now pushing the software capability of the United States beyond its present limit. STARS also will provide a much needed national focus to retain world leadership in this critical technology, a leadership that is now being seriously threatened by at least four similar projects outside of the United States (Japan, Great Britain, The European Economic Community, and France), each of which is now more mature than the U.S. STARS effort.

STARS is being managed by a Joint Program Office in the Office of the Secretary of Defense. The OSD Program Office is complemented by corresponding STARS Offices in the DoD components. Also, a Software Engineering Institute is being planned with the mission to accelerate the transition of emerging software technology into practice on mission-critical computer systems.

The STARS Automated Software Factory will evolve over time to improve current methods as well as introduce new software engineering concepts and methods. Forming the basis of the latter are the artificial intelligence and advanced architecture work being pursued under DARPA's Strategic Computing project as well as DoD-sponsored work in formal software verification and rapid prototyping.

The major STARS efforts in FY 1984 will concentrate on definition of the Department's requirements for the Automated Software Factory. Plans for the STARS program will be forwarded to the Congress in February 1984 in response to the request from the Appropriations Conference Committee.

II. USE OF COMMERCIALLY-AVAILABLE MICROPROCESSORS IN MISSION-CRITICAL DEFENSE SYSTEMS

In this section, a distinction is made between commercially-available, single-chip microprocessors and associated chip sets, e.g., the Intel 8086 and the Motorola MC68000, and stand-alone mission-critical computers such as the Navy's AN/UYK-44 and the Army's AN/UYK-41. A strategy covering the use of commercial microprocessor chips is presented in this section. This strategy differs from that for more powerful, stand-alone military computers. Programs covering the latter are discussed in Section IV.

The Department recognizes the rapid rate of progress and the tremendous growth in the area of commercial microprocessor chips. The semiconductor industry now produces entire central processing units (CPUs-the central portions of microcomputers) on single microelectronic chips and the speeds and gate densities of such chips have been increasing dramatically each year. Furthermore, the increases in performance and functional capabilities of such chips are available at no additional cost and, in many cases, at lower prices.

The Department has embedded single chip microprocessor CPUs and associated chips for memory, input, output, and special features, in many mission-critical systems for operation in military environments by mounting such "chip sets" on circuit boards which are then installed in chassis that perform several system functions, only one of which may be computing. In such uses, there is no identifiable stand-alone computer. Computational needs that exceed the capabilities offered by microprocessor chip sets are met by more powerful stand-alone computers in self-contained chassis.

From both business and technical viewpoints, there are important differences between these two types of computing capabilities, beyond differences in computing power. These differences are: (1) several competing suppliers usually exist for each chip in microprocessor chip sets thereby preventing lock-in to a single supplier; (2) very high production levels for microprocessor chip sets make prices extremely attractive; (3) the usual placement of microprocessor chip sets on circuit boards that tend to be system-unique does not permit the logistics commonality normally associated with stand-alone computers; and (4) in comparison with stand-alone, higher capacity computers, the software for which tends to be highly evolutionary over the life cycle, microprocessor applications tend not to be as "software-intense". With regard to the last point, with Ada as the common high order language, transportability of software to another microcomputer having a different instruction set would be, in most cases, less severe a problem than transportability of software across larger computers with dissimilar instruction sets. The Ada Transportability Handbook discussed in Section I is expected to greatly facilitate the transportability of applications software across different microprocessors.

These differences provide the basis for an acquisition strategy for microprocessor that is different from that for stand-alone computers. The Department strategy for this area is to encourage use of commercially available advanced microprocessors in Defense systems so long as (1) they can be programmed using Ada; (2) they are cost-effective from a life cycle viewpoint; (3) they have been qualified to function in the military environments to be encountered in operational use; and (4) multiple competing suppliers for each chip exist.

In Section III, an approach to the long-term management of computer system interfaces is presented. This approach involves coordinated efforts of government and industry working groups. In the long-term, advanced microprocessors used in Defense systems will be required to comply with the interface approach deemed appropriate for microprocessors through this working group effort.

III. MANAGEMENT OF MISSION-CRITICAL COMPUTER SYSTEM INTERFACES

The initial report provides a discussion of computer system interfaces, including instruction set architectures (ISAs) and operating systems, and concludes that the Department cannot afford uncontrolled proliferation in this area. This section presents a strategy for the management of such interfaces.

The initial report describes how the use of different instruction set architectures impedes the transportability of run-time software, even where Ada is employed as the common language. The software transportability handbook effort discussed in Section I will ameliorate but not totally eliminate the difficulty of transporting large-scale Ada software systems across different instruction sets. Until this difficulty is eliminated, instruction set architecture will continue to be an important software interface.

The Department's initial plan for the long-term management of this area was to promulgate DoD Instruction 5000.5x. However, this approach has been abandoned in favor of a more attractive long-term alternative which is described in the following paragraphs.

At the present time, the computer community has not established a clear direction for future instruction set architectures. One segment of this community believes that the direction should be toward higher level ISAs (more compound instructions) while another segment believes that next generation ISAs should be even simpler than those currently employed. There is also a considerable amount of work underway on approaches to highly parallel ISAs. Perhaps the only thing universally agreed upon at this point is the need to distill a future direction from among the various approaches now being investigated.

In order to facilitate interoperability and reuse of equipments and software produced for different programs and different manufacturers, the Department will establish, a "Computer Systems Interface Working Group." Comprised of Service, OSD, and Defense Agency members, the group will work very closely with industry and industry standards groups to develop a long-term approach to all of the interfaces important in mission-critical systems, including ISAs, operating systems, computer peripheral interfaces, system buses (e.g., MIL-STD-1553), interfaces for local and wide-area networks of computers, and interfaces associated with the STARS Automated Software Factory. The working group will also coordinate computer system interfaces of Department computer programs including military computers, VHSIC, Ada, and STARS.

The Department encourages industry to establish a similar working group under the aegis of an existing voluntary industry association representing multiple industry organizations (e.g., CODSIA) to address this area in parallel with and in coordination with the Department's working group. The industry group should have a close link with national standards organizations.

The Computer Systems Interface Working Group will be established in March 1984. Its first tasks will be to define defense requirements for the hardware/software interface and for external computer interfaces. It should be noted that there is no intent at this time to establish a single standard instruction set or operating system for Tri-Service use. There is also no intent to develop a new Government ISA. There may be many possible long-term opportunities, e.g., standardization at a more intermediate level, development of mechanisms for working within a range of commercial ISAs, etc. The work of this group will be completed in preparations for next generation mission-critical computer acquisitions which are planned for the 1990s (See Section V).

The Ada Joint Program Office will chair a Run-Time Software Interface Panel of the Computer Systems Working Group that will coordinate interfaces with respect to mission-critical real-time executives/operating systems. The purpose of this coordination is to insure consistency in run-time interfaces in order to achieve high levels of transportability and reusability of applications software. Interfaces of the Army's MCF operating systems project, the Navy's future standard run-time executives, and other similar efforts will be coordinated by this panel. This effort will commence in June 1984, and a first version of a military standard for mission-critical run-time interfaces will be prepared by December 1985. A final standard will be published by December 1986.

IV. CURRENT GENERATION MISSION-CRITICAL COMPUTERS

Many mission-critical needs can be satisfied by commercially-available microprocessors. The Department's approach to the use of microprocessor chip sets has been presented in Section II. This Section addresses Defense needs not satisfied by such chip sets.

All of the programs discussed below will fully support Ada. Details on Ada compilers and environments for these military computers have been presented in Section I.

The following discussion, including milestone schedules, supplements the material presented in the basic study.

All three Services will use the Air Force 16-bit instruction set architecture standard, MIL-STD-1750. The Air Force requires MIL-STD-1750 for all 16-bit avionics applications and will also apply the standard to aerospace applications where appropriate. The Army will permit the use of MIL-STD-1750 computers for 16-bit mission-critical applications, but will tightly control the number of different hardware types of 1750 computers employed. The Army will only use off-the-shelf 1750 computers (modified as necessary to meet Army environmental requirements) and will not embark on any new 1750 computer developments. The Navy will permit the use of commercially-available MIL-STD-1750 VLSI and VHSIC chip sets in applications where embedded AN/UYK-44 or AN/AYK-14 card sets would be computational overkill.

All three Services will use the joint Army and Air Force 32-bit instruction set architecture standard, MIL-STD-1862 (NEBULA). The Army is using 1862 in all members of its Military Computer Family. The Air Force will use MIL-STD-1862 computers, when they become available, in applications where a 32-bit computer is required. In order to satisfy VHSIC-level, high performance, 32-bit requirements that cannot be met by commercially available chip sets, the Navy is working with the Army to take advantage of the 32-bit VSHIC technology chip sets implementing MIL-STD-1862 that will be available through the Military Computer Family program. The Army's development will result in a 6"x9" board from each supplier. The Navy intends to derive from the Army's development a family of boards having capacities, form factors, and interfaces compatible with Navy requirements. The schedule for this effort, called "Advanced Multi-Platform Embeddable Computer (AMEC)" is shown in Figure 2.

The Army currently employs over 65 different types of comput in its battlefield and airborne systems, all of which must be supported by its common logistics system. Such unbounded proliferation of types has become extremely expensive, both in hardware and software, and will be a serious impediment to effect logistics support.

The Army's solution to this problem is its Military Computer Family (AN/UYK-41 and AN/UYK-49), details of which are contained : the initial report. Since the submittal of that document, the Ar has made a significant change in the acquisition strategy for the MCF. The original strategy was to converge to a single producer from two competitors in full-scale engineering development (FSED) which derived from four original advanced development contracts.

The revised strategy is to establish a minimum of two competi companies (and associated competing technologies and designs) as qualified producers. Units produced by one competitor will be interchangeable with those produced by another competitor on a for fit-function basis. Thus, the Army will be able to qualify units made by different manufacturers to operate interchangeably in a given weapons system. In addition, the Army will permit the introduction of additional competitors during production so long a it does not have to assume development costs and risks, and if use of such products is justifiable based on superior capabilities or life cycle cost benefits. A schedule for this program is provided in Figure 2.

Navy standard shipboard computers are rapidly becoming obsolescent. The Navy has competitively developed technologically current computers (AN/UYK-43 and AN/UYK-44) to replace the AN/UYK- and AN/ UYK-20 computers now in use while at the same time avoidin the high cost of redoing existing software. Both the AN/UYK-43 an the AN/ UYK-44 are in the final phases of production acceptance testing; the embeddable card set of the AN/UYK-44 has commenced full-scale production. In each case, five-year commitments for fi fixed prices for production units have been obtained. Milestone schedules for these computers are shown in Figure 2.

The AN/AYK-14 Navy standard airborne computer was competitivel selected for development in 1975, and production commenced in 1979. At least fifteen Navy programs will acquire in excess of 10,000 AN/ AYK-14 computers through 1990. Due to this large requirement, a second source, build-to-print competition was conducted. A second source supplier was selected in December 1983. The schedule for th AN/AYK-14 is shown in Figure 2.

As discussed in the initial report, the Air Force does not hav a computer hardware development program. Air Force computer acquisitions will continue to be made on a system-by-system basis following compliance with the Department of Defense's Ada policy, and with the interface standards defined by MIL-STD-1750, MIL-STD-1553, and MIL-STD-1862 (when available in hardware). Microprocessors will be employed as appropriate as discussed in Section II.

V. NEXT GENERATION MISSION-CRITICAL COMPUTERS

Progress in microelectronics is expected to continue unabated. It is anticipated that the next five years will see the single chip CPUs discussed in Section II replaced in the marketplace by entire microcomputers on a single chip. With respect to tomorrow's low-performance microcomputer-on-a-chip and more powerful stand-alone computers, the Department also expects the four differences unrelated to computing power to be the same as those listed in Section II. Thus, the Department sees no reason not to use such microcomputers in mission-critical defense systems under the same conditions listed in Section II.

Further, the Department looks forward to commonality in computer system interfaces through the efforts of the government/industry working group activities discussed in Section III. This commonality is expected to have a positive impact at all computer performance levels, microcomputer through stand-alone. The Department will encourage industry to produce competitive military computers meeting jointly developed form-fit-function specifications (hardware and software) derived from the computer system interface working group activities, and will not pursue the development of stand-alone computers for the 1990s unless industry developments to meet defense needs do not materialize. (Funds will be put into the Defense budget to cover this possibility and to cover interface efforts.) The Department will continue its science and technology efforts relevant to computers in order to maintain U.S. strength and leadership in this important area.

Through this approach, multiple companies would become qualified as certified suppliers for each type of form-fit-function equivalent military computer. Next generation computers will be needed starting in 1992 for Navy and Army systems consistent with the planned cessation of acquisition of current-generation computers for new starts.

In order for industry to be responsive to defense needs for computers, the efforts on their interfaces will be completed prior to Mid-1987 in order to afford industry the necessary development lead time. The Department, at that time, will seek assurances that there will be an adequate industry thrust to produce the required computers in a technological and price competitive market. In the event of an inadequate response, the Department will proceed with sponsored development at that time. A schedule for next generation activities is given in Figure 2.

FIGURE 1.

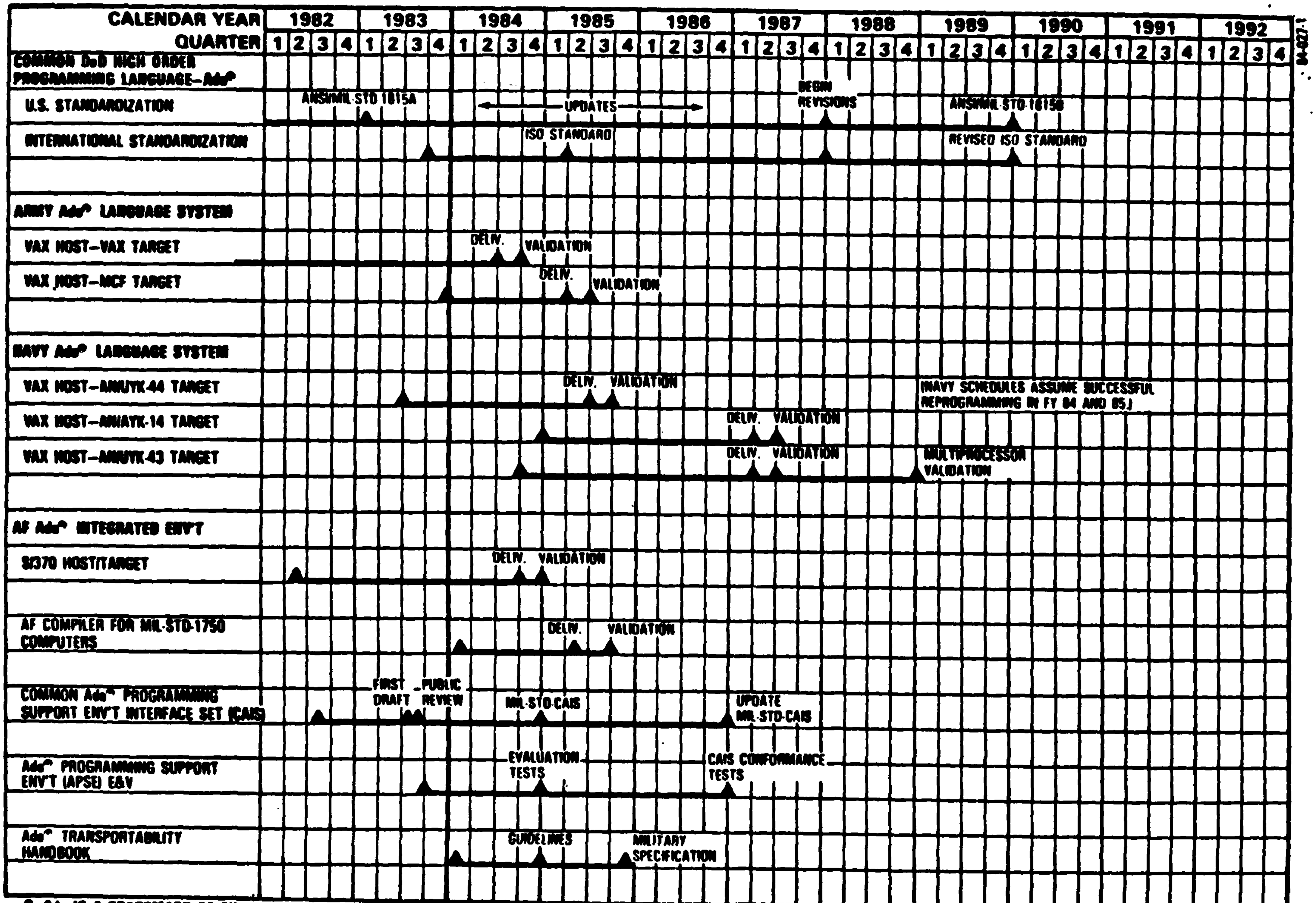

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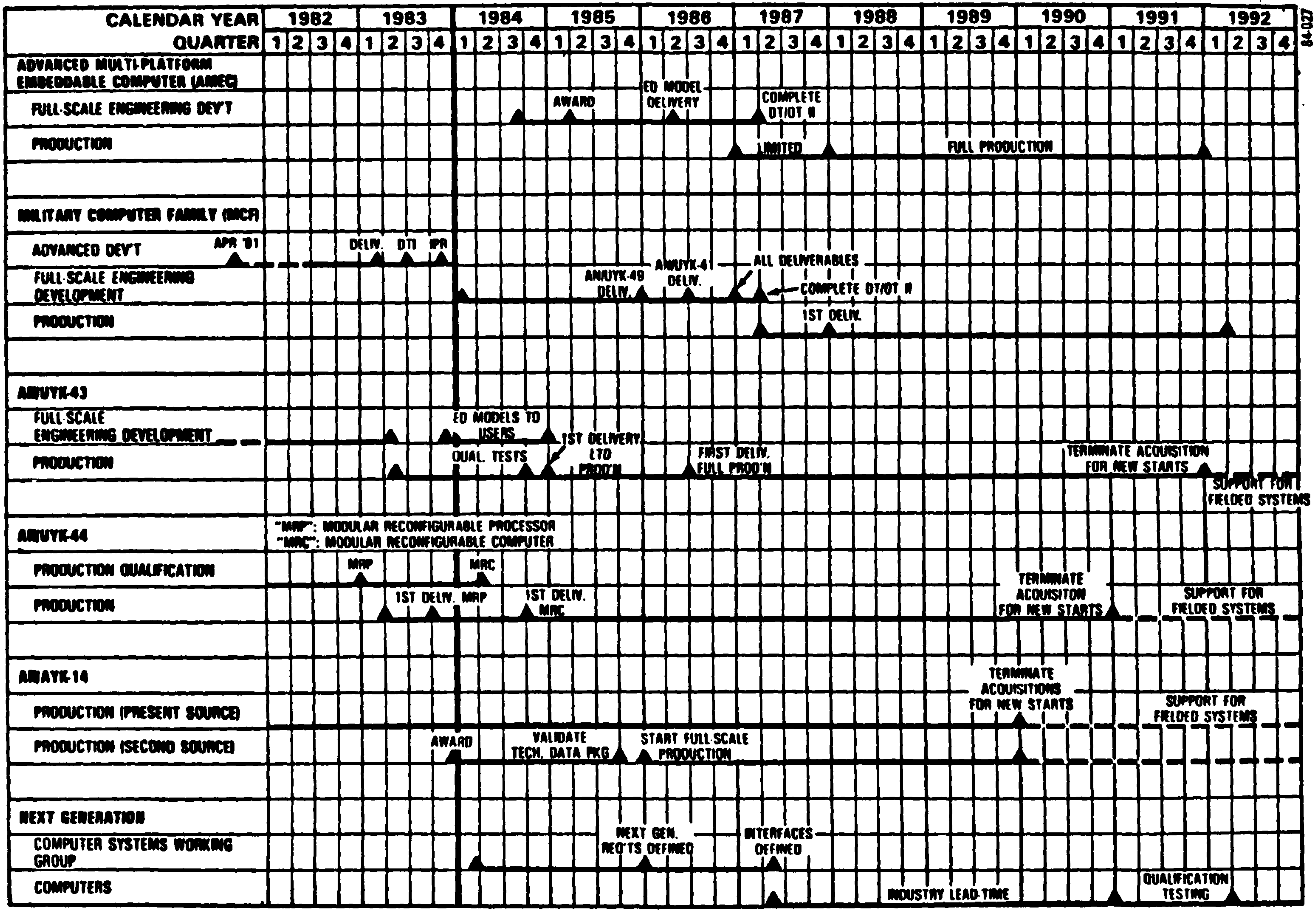
FIGURE 2.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CALENDAR YEAR
QUARTER
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ADVANCED MULTI-PLATFORM EMBEDDABLE COMPUTER (AMEC)
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AWARD
ED MODEL DELIVERY
COMPLETE DT/OT II
PRODUCTION
LIMITED
FULL PRODUCTION
MILITARY COMPUTER FAMILY (MCF)
ADVANCED DEV'T
APR '81
DELIV.
DTI
IPR
FULL-SCALE ENGINEERING DEVELOPMENT
AN/UYK-49 DELIV.
AN/UYK-41 DELIV.
ALL DELIVERABLES
COMPLETE DT/OT II
PRODUCTION
1ST DELIV.
AN/UYK-43
FULL-SCALE ENGINEERING DEVELOPMENT
ED MODELS TO USERS
1ST DELIVERY LTD PROD'N
PRODUCTION
QUAL. TESTS
FIRST DELIV. FULL PROD'N
TERMINATE ACQUISITION FOR NEW STARTS
SUPPORT FOR FIELDED SYSTEMS
AN/UYK-44
"MRP": MODULAR RECONFIGURABLE PROCESSOR
"MRC": MODULAR RECONFIGURABLE COMPUTER
PRODUCTION QUALIFICATION
MRP
MRC
PRODUCTION
1ST DELIV. MRP
1ST DELIV. MRC
TERMINATE ACQUISITON FOR NEW STARTS
SUPPORT FOR FIELDED SYSTEMS
AN/AYK-14
PRODUCTION (PRESENT SOURCE)
TERMINATE ACQUISITIONS FOR NEW STARTS
SUPPORT FOR FIELDED SYSTEMS
PRODUCTION (SECOND SOURCE)
AWARD
VALIDATE TECH. DATA PKG
START FULL-SCALE PRODUCTION
NEXT GENERATION
COMPUTER SYSTEMS WORKING GROUP
NEXT GEN. REQ'TS DEFINED
INTERFACES DEFINED
COMPUTERS
INDUSTRY LEAD-TIME
QUALIFICATION TESTING

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