112594

BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Secretary Of Defense

The Department Of Defense's Standardization Program For Military Computers-- A More Unified Effort Is Needed

The continued proliferation of many different kinds of military computers in combat support and weapon systems is a major contributor to increased logistical support costs and operational difficulties. Standardization can help reduce these problems.

The Department of Defense recognizes the benefits of standardization but has not promoted an effective and unified standardization effort among the services. Certain fundamental actions are necessary to unify individual service standardization programs to ensure that maximum Defense-wide standardization can be achieved. These actions need to be accelerated to conform the unilateral service efforts to the new policies before long-term commitments are made.

112594

010756

LCD-80-69
JUNE 18, 1980

Single copies of GAO reports are available free of charge. Requests (except by Members of Congress) for additional quantities should be accompanied by payment of $1.00 per copy. (Do not send cash).

Requests for free single copies should be sent to:

U.S. General Accounting Office
Distribution Section, Room 1518
441 G Street, NW
Washington, DC 20548

Requests for multiple copies should be sent with checks or money orders to.

U.S. General Accounting Office
Distribution Section
P.O. Box 1020
Washington, DC 20013

Checks or money orders should be made payable to the U.S. General Accounting Office.

To expedite placing your order, call (202) 275-6241. When ordering by phone or mail, use the report number and date in the lower right corner of the front cover.

GAO reports are now available on microfiche. If such copies will meet your needs, be sure to specify that you want microfiche copies.

GAO

United States General Accounting Office
Washington, DC 20548

Logistics and
Communications
Division

B-199008

The Honorable Harold Brown
The Secretary of Defense

Dear Mr. Secretary:

This report presents the results of our review of the Department of Defense's efforts to standardize military computers and software used in combat support and weapon systems. Our findings, conclusions, and recommendations are summarized below. A detailed discussion of the results of of our review is provided in appendix I.

The Department increasingly has become dependent on automation to assist in accomplishing its mission. Today's military combat support and weapon systems, for example, use computers and software to perform command and control, communications, navigation, surveillance, target detection, intelligence, and other functions critical to strategic and tactical missions. Oftentimes, these computers are embedded directly in various military equipment and are specially configured and ruggedized to operate in a military environment. While the quantities and costs of these military computers are not known, their use and associated costs are growing. Through the 1980s, the Army, Air Force, and Navy estimate they will have deployed over 13,000, 40,000, and 33,000 computers, respectively.

Associated with this huge computer growth has been a proliferation of many different kinds of computers with wide ranges of speed, size, power, and weight. An Army study of 20 computer-based systems, for example, disclosed the systems use 18 different computers. Further, one Air Force command has at least 61 different computers in its

inventory, while the Navy uses at least 20 different computer models. Most of these computers were acquired on a project-by-project basis in which military project officers and contractors were given the flexibility to independently select the computers for their particular tactical systems.

This widespread proliferation has adversely affected the Department in terms of increased logistical support costs and operational difficulties. The overall cost to develop, operate, and maintain automated systems has increased dramatically because systems using different computers require unique system interfaces, logistics support, software development, maintenance, and training. Moreover, as the requirements for automated systems increase, problems and costs continue to grow.

As a result, the Department has been forced to examine different techniques to lessen these adverse impacts so that it can deploy and maintain more cost affordable and operable automated systems in the future.

Each military service has placed increased emphasis on computer standardization and is pursuing its own program to provide for standardization in future tactical systems. The Army's efforts are contained in its Military Computer Family program, intended to satisfy long-term automated battlefield requirements. The Navy's efforts are directed toward deploying a standard avionics computer and, in its Navy Embedded Computer System program, deploying standard shipboard computers. The Air Force's efforts are directed to avionics computer standardization, which has grown out of its Digital Avionics Information System program.

Although the services have many common functional requirements, they continue to spend funds on separate standardization programs. We question the need for separate programs, especially in view of studies which indicate that a Defense-wide standardization base could be the most cost advantageous for the Department.

We believe that the Department has an opportunity to maximize standardization of military computers and software for combat support and weapon system use. We further believe that to increase the chances for achieving maximum Defense-wide standardization, the Department should establish

--a standard high-order programming language for military applications,

--a standard computer architecture or the minimum number of common architectures that may be necessary to meet common functional requirements,

--the extent or appropriate level of standardization to be achieved, and

--an effective decisionmaking management organization to oversee Defense-wide standardization efforts.

The Department has recognized that the lack of a standard programming language is a major contributor to the high cost of developing and maintaining software for military applications. The Department is to be commended for its initiative to fill that void by developing a common high-order programming language--called Ada--which is expected to be ready for use in 1983. The Department must, however, provide for Ada's mandatory use in all suitable applications; otherwise, its beneficial impact could be severely curtailed. While the Army and Air Force appear to be strong advocates of Ada, the Navy has taken a "wait-and-see" attitude and is basing its standardization efforts on the continued use of CMS-2, the Navy's interim standard language. By establishing Ada as the Defense-wide standard language, the Department can ensure its appropriate implementation and form a sound basis for further standardization efforts.

The Department has not established adequate policies which dictate which computer architecture(s) should be used for military applications. Without this central guidance, the services have based long-term standardization efforts on different computer architectures, despite studies which indicate that a single standard can achieve the most Defense-wide life cycle cost savings. The Department needs to resolve this architecture issue by issuing policy guidance which clearly establishes the most appropriate architecture(s) as a basis for continued automation usage and future standardization efforts.

The military services do not have central direction as to the level of computer standardization to be achieved. The Air Force is standardizing at the computer architecture level, while the Army and Navy are standardizing at the equipment level. The services are using different standardization philosophies and concepts, although a unified

approach may accommodate most of their automation requirements. The Department must decide on the level or levels of standardization that can maximize benefits Defense-wide and use that as a basis for establishing policy to guide its standardization efforts.

Finally, the Department is aware of the need to provide the military services with central direction; however, it does not have an effective management organization to provide it. It currently manages standardization efforts through the Management Steering Committee for Embedded Computer Resources. This committee has no decisionmaking authority or funding control. It functions only with the cooperation of the Defense components, consensus voting by its Executive Board, and recommendations to the Office of the Secretary of Defense. This management arrangement has not been effective, as demonstrated by the lack of standardization policies and the services' continuing separate standardization programs.

CONCLUSIONS

We believe that the Department is rapidly losing an opportunity to achieve maximum Defense-wide standardization of military computers and software used for combat support and weapon systems automation. Although the Department has taken some positive action, it needs to do more to achieve standardization in a manner that can reduce the adverse impacts of widespread computer and software proliferation. Failure to do so means continued high costs, operational problems, and a probable inability to deploy and support cost affordable and operable automated systems in the future.

Our concern is that economic and operational benefits of standardization will be lost unless the Department controls the standardization program. Control should be centralized, and most important, carried out with periodic reviews to ensure the effective use of standard architectures to meet the services' common functional needs.

We view the need for architecture standardization as a function, in part, of the availability of Ada as the standard computer programming language. Because Ada is being developed to be a machine-transportable language with a relatively low life cycle maintenance cost, the need for standard architectures may be diminished when it is available. In the long term, Ada could become the standard computer architecture when computers that can directly execute

the language are developed. However, in the short term, standard computer architectures are needed to reduce life cycle costs. We believe that those architectures should be common across service lines, compatible with Ada and the minimum number required to meet common functional requirements and to retain the older languages, such as CMS-2 and JOVIAL, until they are phased out. These measures are necessary to minimize life cycle costs and to facilitate the transition to Ada.

RECOMMENDATIONS TO THE SECRETARY OF DEFENSE

We recommend that you establish a high-level steering committee with decisionmaking authority and a triservice program office with responsibility for maximizing standardization of military computers and software in a manner that will promote and ensure the use of new technology, reduce software and acquisition costs, simplify logistics, and realize economies of scale. This responsibility--to be carried out under the steering committee's direction--should include implementing Ada as the standard programming language and managing its implementation and use, determining with the military services the computer architecture(s) that should be standardized and the level of standardization to be achieved, and establishing the appropriate standardization policies. The triservice program office should be responsible to the steering committee for planning and controlling the implementation of those policies and the Department's standardization efforts.

We recommend, also, that you expedite these actions so the various independent efforts can be conformed to the new policies before long-term commitments are made.

AGENCY COMMENTS AND OUR EVALUATION

We discussed our report with the Assistant for Defense Systems, Computer Resources and Electronics, Office of the Under Secretary of Defense for Research and Engineering, and with cognizant officials of the Army, Navy, and Air Force. 1/ They generally agreed that program management improvements were needed and were receptive to our recommendations. Their comments and our evaluation of them follow.

1/On May 15, 1980, the Under Secretary of Defense for Research and Engineering provided us with written comments to supplement this discussion after our report was finalized. His letter is included in the report as app. II.

The Assistant for Defense Systems agreed that Ada, when it is ready for use in 1983, should be established as the standard programming language for all new military applications and major program modifications when appropriate. He advised us that the Department was planning to establish a central office to complete testing and validation of Ada and that the office would be given the responsibility for establishing Ada as the standard language. This action is in consonance with our recommendation and should ensure proper implementation of Ada with Defense-wide benefits.

Regarding standardizing computer architectures, the officials informed us that a draft instruction was being staffed through the Department which would establish Defense-wide policy on architecture. According to the officials, the policy would restrict the military services to using Government-owned architectures or to those to which the Government had clear rights, and would require the military services to select their standard architectures and control them. The policy would also allow waivers in those cases where the service standard architecture(s) was not suitable.

In our opinion, the policy, as proposed, will allow each service to continue with its separate standardization efforts, using its preferred architecture(s), rather than directing the services toward a unified program. We believe that the proposed policy should be modified to require the services to use common architectures for common functional requirements, such as command and control, that are to be automated in new systems with Ada. This modification is needed to promote maximum Defense-wide standardization, to foster the use of modern architectures, and to restrict the number of compilers that will be needed for Ada.

The officials noted that different support environments dictated the level of standardization to be achieved. They indicated that the Air Force was limiting standardization to the computer architecture level because it operated at fixed bases, which were usually easily accessible and where maintenance and logistics support were readily available. On the other hand, the Army and Navy are standardizing at the equipment or box level because they operate at mobile and remote bases. These operations make support more difficult. In the Army's and Navy's mode of operation, a higher level of standardization is necessary to minimize

the quantity of different spares and spare parts needed and maintenance skills required. The officials indicated that the level of standardization was not an issue.

We recognize that differences in modes of operation among the military services affect logistical support of computer equipment. We believe, however, that technology is significantly changing the support requirements by increasing computer equipment reliability and decreasing its size, weight, and cost. Also, some computer manufacturers are already designing computers with modern architectures that will have Ada compilers available. These or other manufacturers will probably offer follow-on computers that will directly carry out Ada instructions and substantially improve performance reliability. Because these changes provide better support options, such as building more redundancy into systems, they should compel the Department to further evaluate the level of standardization to be achieved before allowing the Army and Navy to commit themselves to standard form, fit, and function specifications for the long term.

The Assistant for Defense Systems advised us that the work of the Management Steering Committee for Embedded Computer Resources had become more effective with the recent appointment of higher level officials to the committee. He also told us that, as the committee's chairman, he was making decisions without a consensus vote, although the committee's charter requires one. Since these changes are occurring on a de facto basis, we believe they should be formalized by amending the charter to specify the grade level or position of committee members and to endow the chairman with appropriate decisionmaking authority. This would satisfy our recommendation to establish a high-level steering committee with decisionmaking authority.

Regarding establishing a triservice program office with responsibility for maximizing standardization of military computers and software Defense-wide, the officials recognized that such an office would be useful. They agreed that it would provide better planning, coordination, and control of standardization and facilitate presenting a consolidated program to the Congress for funding in place of separate programs as currently done. The Assistant for Defense Systems agreed that the planned Ada project office could be expanded to include the computer standardization responsibility, but he stated that the Department needed to further analyze our recommendation before adopting it.

As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report. We would appreciate being informed of the actions you plan to take in response to our recommendations.

We are sending copies of this report to the Director, Office of Management and Budget; the Chairmen, Senate and House Committees on Appropriations and on Armed Services, House Committee on Government Operations, and Senate Committee on Governmental Affairs; and the Secretaries of the Army, Navy, and Air Force.

Sincerely yours,

Donald J. Horan

for R. W. Gutmann
Director

THE DEPARTMENT OF DEFENSE'S STANDARDIZATION PROGRAM FOR MILITARY COMPUTERS--A MORE UNIFIED EFFORT IS NEEDED

THE SERVICES ARE PROCEEDING IN DIFFERENT DIRECTIONS TO STANDARDIZE MILITARY COMPUTERS

In today's military environment, the Department of Defense has found it necessary to depend increasingly on automation to assist in accomplishing its mission. Modern combat support and weapon systems use military computers to perform command and control, communications, navigation, surveillance, target detection, intelligence, and other functions critical to strategic and tactical missions. These computers are custom-designed for military applications with wide ranges of speed, power, weight, and size. They are configured and ruggedized for use in track and wheeled vehicles, and ships, airplanes, and weapons.

The quantities and costs of military computers acquired by the individual services are not known because complete inventories are not maintained. However, they are large and growing. The Army, Air Force, and Navy estimate that in the 1980s they will have about 13,000, 40,000, and 33,000 computers, respectively. Acquiring these computers, associated equipment, and software consumes a large portion of the estimated $6 billion the Department spends annually for automated data processing systems. Software alone costs over $3 billion annually.

Acquisition of military computers has occurred under practices that, through the years, have allowed military project officers and contractor system developers to independently select computers on a project-by-project basis from a multitude of related computer types available off-the-shelf or through special design. Invariably, the choices have differed from project to project because of contractual considerations or heavy pressures to optimize costs and schedules of individual projects at the expense of long-term life cycle costs.

Acquisition practices have resulted in a proliferation of many different makes and types of computers of varying ages. For example, an Army study of 20 computer-based systems representing over 2,250 computers disclosed that the systems use 18 different computers. One Air Force command has at least 61 different computers in its inventory,

while the Navy uses at least 20 different kinds. This proliferation has increased the cost to develop, operate, and maintain systems because each different type of computer added to the inventory has required unique system interfaces, logistics support, software development, maintenance, and training. To stem rising logistics costs and operational problems, the services have begun looking to standardization techniques based on computer architectures.

Standardization based on a selected computer architecture is a concept used by computer manufacturers to develop families of compatible computers. In this concept, the architecture remains constant while it is physically implemented in different ways with different electrical and physical layouts. Architecture, in this sense, means the conceptual structure and functional behavior of a computer. It includes the instruction set, instruction formats, operating codes, addressing modes, input/output initiation and interrupt modes, and the manner of use of all registers and memory locations. Two comparable computer systems with the same architecture but implemented differently in design can carry out the same computer language program with identical results.

This type of standardization is being considered because traditional standardization based on specified computers is no longer practical in today's environment. Rapidly advancing computer technology and the long time required to develop combat support and weapon systems make traditionally standardized computers obsolete before the system using them is deployed or during the system's early life. This has happened to the Navy's standard AN/UYK-7 and AN/UYK-20 computers which were acquired in 1969 and 1973, respectively, and the Army's AN/GYK-12 computer which was designed in the 1960s.

Standardization based on a selected computer architecture can accommodate technology since the architecture can be physically implemented into newer computers as they are developed. Also, this type of standardization is a safe, proven, and accepted approach that may be the only near-term answer to software transferability to a wide range of computers. It has stood the test of time in industry-wide applications and its success and practicality have been demonstrated by major computer manufacturers which use it to build families of upward-compatible computers.

Within the services, computer standardization is limited and varies according to actual military applications. In the past, the Department has not stressed standardization. Instead, it has allowed service project managers, for the most part, the flexibility to select various computers for their tactical systems. However, each service increasingly is emphasizing standardization and pursuing its own standardization program.

The Army's standardization program

The Army believes that computer standardization is essential to battlefield mission effectiveness, particularly in view of the increasing use of complex automation on the battlefield. As a result, the Army plans to deploy more than 70 combat support and weapon systems in the 1980s.

According to the Army, standardization is needed to resolve a major problem of nonstandard computer proliferation that causes a lack of commonality in equipment, software languages, architectures, support systems, training, and development. This impedes the achievement of interoperability and continuity of operations, security, reliability, availability, and maintainability. Unless standardization is achieved, the Army believes that the continuing proliferation will make the costs of designing, developing, operating, and maintaining automated systems prohibitive and will create a network of systems that will not operate effectively under realistic post-1980 battle conditions.

Faced with the problem of computer proliferation and of replacing its older computers (while protecting its investment in computer software development and providing standard computers for the long term), the Army adopted the Military Computer Family (MCF) program, a computer family approach to standardization.

In MCF, the Army planned to develop a software compatible family of standard computers, terminals, and other peripheral devices suitable for a wide range of military land, sea, and air applications. This equipment was to be plug-to-plug compatible and modularly constructed according to form, fit, and function specifications so that the modules could be configured into computer systems with ranges of capabilities and performance levels to suit particular needs. The computers were to be designed to support multiple computer architectures. Initially, the computers were to carry out a selected commercial architecture as the

standard for the long term and emulate 1/ the AN/GYK-12 computer. This emulation was to allow the Army to transport software already developed for the AN/GYK-12 to the new computers when the AN/GYK-12s were replaced. The Army planned to emulate other architectures later.

The Army had planned to deploy the MCF computers by 1983 and had anticipated costs over $100 million to develop the computer equipment, support software, and support facilities. However, in late 1979--after about 5 years of analyses and limited testing--the Army abandoned its original concept for a more conservative approach because of high technical risks in developing plug-to-plug compatible modules, legal impediments to using a commercial architecture, and timing limitations for the proposed emulation of existing architectures.

Currently, the Army plans to use a newly developed, Government-owned architecture that will be implemented into computer equipment developed according to form, fit, and function specifications. The computer equipment will be competitively acquired through periodic buys from single suppliers rather than by modules from multiple suppliers as initially planned. This change has delayed the initial deployment of MCF computers to about 1986.

The Navy's standardization program

Of all the military services, the Navy has achieved the greatest degree of military computer standardization, especially for its shipboard applications. In the early 1970s, the Navy standardized primarily on two computers, the AN/UYK-7 and AN/UYK-20, to satisfy its shipboard requirements. The effort was begun in an attempt to control the proliferation of computers which had occurred earlier and which was creating inefficiencies in Navy logistics, training, interoperability, and software support. For its avionics systems, the Navy, in 1975, started plans to acquire a standard avionics computer, designated the AN/AYK-14, to resolve similar issues in the avionics arena. Up to that time, aircraft computers had been purchased on a "total system concept" basis, thus resulting in 19 different computer architectures in the Navy avionics inventory.

1/Emulation is circuit board technology which allows one type of computer to operate like another.

Although the standard shipboard computers have served the Navy well, they are rapidly approaching obsolescence in the face of increasing requirements and advancing technology. In 1977 the Navy presented a plan to the Congress to acquire new standard computers as replacements for the existing standards and to upgrade the AN/UYK-20s for the interim time period. The Congress, however, denied the upgrade request and encouraged the Navy to proceed as rapidly as was reasonably possible with developing and deploying the new computers. The Navy's program, commonly referred to as the Navy Embedded Computer System, along with the separate continued development of the standard avionics computer, constitutes the Navy's current standardization effort.

Currently, the Navy Embedded Computer System is in the engineering development stage and is a large-scale program intended primarily to satisfy shipboard requirements well into the 1990s. The Navy expects to spend over $2 billion over the system's life cycle of which $50 million is for research, development, tests, and evaluations; $660 million is for procurement over the system's projected 15-year production period; and $1.3 billion is for operational and maintenance costs. Under the latest milestone schedule available, the first standard computer produced from the program acceptable for Navy use will be available during fiscal year 1986.

The Air Force's standardization program

The Air Force, like the Army and Navy, is pursuing standardization, particulary in the avionics arena, because its acquisition practices have led to a widespread proliferation of nonstandard computers to the extent that the Air Force now has over 230 different makes and types in its inventories. The Air Force recognizes that this proliferation has created software, maintenance, logistical, training, and operational problems, similar to those faced by the Army and Navy. As a result, the Air Force has initiated a standardization effort to resolve them.

The Air Force standardization effort grew out of its Digital Avionics Information System program which started in June 1973. In this program, the Air Force is developing specifications for a family of software compatible computers using a selected computer architecture, commonly called the Military Standard 1750, which was specially designed for avionics. This computer equipment, along with other avionics equipment, will be modularly constructed with standardized

interfaces and software so that it can be configured to support a broad range of avionics and mission requirements for many different aircraft.

The program is in the full-scale engineering development stage in which the Air Force has awarded parallel contracts to develop four models for testing and validation. The Air Force does not yet have an acquisition plan for long-term purchases.

The Air Force has other computer requirements for such functions as command and control, air traffic control, communications, and intelligence that are not part of its standardization efforts. These requirements are evidenced by the Joint Tactical Information Distribution System, the Tactical Information Processing and Interpretation System, and other computer-based systems that the Air Force is developing. However, the Air Force does not have a program to standardize computers for them.

JOINT EFFORTS TO DEVELOP A COMMON PROGRAMMING LANGUAGE

In addition to the standardization programs discussed above, the military services are jointly developing a common, high-order programming language--called Ada--for military applications. This program began in May 1975 when the Department of Defense established the High-Order Language Working Group composed of members from the Army, Navy, Air Force, and other Defense components to investigate programming languages and to recommend adoption or implementation of a common language or languages. After studying the functions and specialized needs of military applications, the working group developed technical requirements through a feedback process involving the Institute of Defense Analysis, many commands and offices within the military departments, Defense contractors, and other potential users.

In the process, requirements were analyzed and interpreted and conflicts were resolved to produce a trial set of technical requirements. These requirements were further refined through four interactions with potential users to produce a preliminary set of requirements that the military departments approved in January 1976. In conjunction with the requirements determination, the working group also analyzed the existing languages to determine whether any of

them could satisfy the emerging requirements. From many languages considered, 23 were formally studied, including the Navy's CMS-2, the Air Force's JOVIAL, and the Army's TACPOL languages.

By this analysis, the working group unanimously concluded that the development of a single language was needed. Not one of the existing languages studied satisfied the requirements so that it could be adopted as the standard language. This conclusion led to the award of contracts in 1977 to four contractors for developing competitive prototype language designs based on the technical requirements. These designs were evaluated in the spring of 1978 by 80 volunteer review teams chosen on the basis of interest from industry, Government, the academic community, and technical communities of other countries. The designs were narrowed to two. In April 1979 the CII-Honeywell Bull-designed language, now called Ada, was selected after 4 intensive years of study. Ada is now being validated and is expected to be ready for use in 1983 on a voluntary basis.

FUNDAMENTAL ACTIONS NEEDED TO UNIFY DEFENSE STANDARDIZATION EFFORTS

The Department of Defense has an opportunity to achieve maximum standardization of military computers and software used in combat support and weapon systems by unifying the military services' standardization programs. Currently, each service is pursuing its own program, despite the services' many common functional requirements and despite studies which indicate large potential economies can be obtained through a triservice standardization effort. However, certain fundamental program decisions are necessary before progress can be made. We believe that to achieve maximum standardization Defense-wide, the Department needs to establish

- --Ada as the standard programming language for military applications,
- --a standard computer architecture or the minimum number of common architectures that may be necessary to meet common functional requirements,
- --the extent or appropriate level of standardization to be achieved, and
- --an effective decisionmaking and management organization.

Standard language
for military applications needed

At present, the Department expects the military services to use Ada voluntarily when it is ready in 1983, rather than to make its use mandatory. While the Army and the Air Force have based their computer standardization efforts on Ada, the Navy has taken a "wait-and-see" attitude. The Navy's computer standardization efforts are based on the continuing use of CMS-2, despite its inadequacies. By establishing Ada as the standard language for all suitable military applications, the Department can ensure its appropriate implementation by all of the services while providing a sound basis for Defense-wide standardization.

Ada is needed as the standard language because the proliferation of languages is a major contributor to the high cost of developing and maintaining software for military computer applications and to the poor quality of software. None of the more than 500 different programming languages being used by the military services, including the Navy's CMS-2, the Air Force's JOVIAL, and the Army's TACPOL, which have been established as interim standard languages, are suitable as standard languages for military applications (see p. 7). Also, Ada, as the standard language, will allow the Department the opportunity to achieve substantial cost savings Defense-wide through software commonality, improved programmer productivity, and new technical features incorporated into its design.

Studies conducted in 1977 indicated that nearly $24 billion could be saved from 1983 to 1999 if Ada was implemented Defense-wide. The savings, together with Ada providing a means to stop the language proliferation problem, and most of all, a common foundation for Defense-wide standardization of software and military computers, warrant the establishment of Ada as the standard language.

With the acceptance and implementation of Ada as the Department's standard programming language for military applications, the Department can expect computer manufacturers to use the latest technology to develop computers that can be provided with Ada compilers. Also, follow-on computers probably will be available that will directly carry out Ada instructions with substantial improvements in performance and reliability. This should diminish the need for standard computers and architectures provided

that computer equipment reliability is increased as promised by technology. However, until this occurs, effective military computer standardization will be needed to reduce life cycle costs of combat support and weapon systems.

Standardization architectures needed

Although architecture studies indicate that a standard single architecture can achieve the most life cycle cost savings, the Army, Navy, and Air Force are using different computer architectures for standardization. The services do not have sufficient central guidance needed to direct them toward adopting a common architecture. Nor do they have the minimum number of common architectures that may be necessary to satisfy common functional requirements and to implement Ada.

Computer architecture studies

A series of studies sponsored primarily by the Army from 1975 through 1979 strongly indicate that a single computer architecture is most desirable for standardization. The initial study was conducted in 1975 by a joint Army/Navy computer architecture selection committee composed of representatives from 10 Army and 17 Navy organizations. This committee evaluated three military and six commercial computer architectures using representative performance criteria for military computers and conducted life cycle cost analyses of those architectures over a 10-month period. On the basis of its evaluation, the committee concluded the following:

--The need for selecting a single architecture was more important than the particular architecture which was chosen.

--Unique military requirements did not preclude using a general-purpose commercial architecture. In fact, the military architectures were deficient compared to commercial architectures in terms of those characteristics believed to be most important in tactical military applications.

--The PDP-11/70 was voted the most advantageous architecture for a military computer family. The extensive commercial support software base for the architecture was noted as a factor in this study.

APPENDIX I

Several Army-sponsored analyses have been performed to evaluate the life cycle cost effectiveness of architecture standardization. A July 1978 University of California study compared costs of 78 Army/Navy computer-based weapon systems assuming a single versus multiple architecture scenario of four designs. The study concluded that using a single standard architecture resulted in an average savings of about $3 billion over a 22-year period, or about half the life cycle costs of using four different ones.

In October 1978 the study was updated to reflect changes in the analysis model and to evaluate costs using a different mix of weapon systems, including the addition of 12 Air Force systems. Further, the candidate architectures were changed and the study was geared to comparing the costs of commercial versus military architectures. The study concluded that it was cheaper to use commercial architectures because the commercial support software was readily available and Government funds were not required for its development. Further, the savings for each of the candidate architectures were comparable to the savings in the July 1978 analysis.

Army computer architecture

Although the Army has studied and analyzed many computer architectures, it has been uncertain as to which one should be used. Initially, it had selected the PDP-11/70 architecture as the prime candidate, but the Draper Laboratory criticized this selection in its evaluation of MCF. In its report to the Army in August 1979, Draper recommended that the Army adopt the PDP-11/780 as the standard.

The PDP-11/780 is a more powerful architecture of recent design. In benchmark testing, completed by the Carnegie-Mellon University in July 1978, it scored higher in efficiency in carrying out programs and using memory than nine other architectures tested, including the AN/GYK-12 (Army), AN/UYK-7 (Navy), and the Military Standard 1750 (Air Force). Carnegie-Mellon noted that the PDP-11/780 was more technically advanced than the 1960's vintage PDP-11/70 and believed it would be cheaper to adopt a modern architecture now rather than convert to one later.

The selection of the PDP-11/70 and/or PDP-11/780 architectures as the standard(s) required the resolution of legal issues concerning the uses of those architectures since they were proprietary. After negotiating for 3 years with the computer manufacturer, the Army was not able to

obtain the right to use the architectures. Because of this problem, the Army decided in March 1980 to adopt a new Government-owned architecture called Nebula that was developed under contract by Carnegie-Mellon. Currently, the Army is giving broad exposure of Nebula to industry and other Government agencies before soliciting industry for development of MCF later this year.

Navy computer architectures

Although the Navy agrees with the Army that standardization on a particular computer architecture is highly desirable, the Navy, in its program, is using the basic architectures of its obsolescent AN/UYK-7 and AN/UYK-20 computers, and its AN/AYK-14 avionics computer which emulates an extended version of the AN/UYK-20 architecture. The Navy is using these architectures to maximize software transferability and to utilize the support software developed for the older computers at a cost of about $90 million.

The AN/UYK-7 and AN/UYK-20 architectures have not fared well in the various architectural studies. For example, in the Army/Navy computer family architecture selection committee study (see p. 9), the AN/UYK-7 and AN/UYK-20 scored the lowest among the nine architectures evaluated. In the Carnegie-Mellon study completed in July 1978, the AN/UYK-7 finished last, while the AN/UYK-20 scored lower than the PDP-11/780 and the PDP-11/70. However, the Navy architectures are Government-owned, which permits their unrestricted use within the Department of Defense. In addition, the Navy plans to improve the architectures as part of its standardization efforts.

Air Force computer architecture

The Air Force also agrees that standardization of a particular architecture is desirable. However, it too has selected a different architecture for standardizing avionics computers. The architecture, known as Military Standard 1750, was developed by the Air Force and private industry especially for avionics. The architecture is modern and has fared well in various architectural studies. For example, in a Carnegie-Mellon study made in March 1979, the Military Standard 1750 outscored both the AN/AYK-14 and PDP-11/70 architectures.

Office of the Secretary of Defense initiatives

The Department of Defense recognizes the need to standardize computer architectures. During 1978 the Office of the Secretary of Defense considered whether a policy directive should be issued to (1) prescribe an interim list of approved architectures as a step to reduce their proliferation and (2) provide a formal mechanism for assimilating more advanced architectures as they are developed and validated. The proposed directive caused considerable controversy among the services and private industry. Therefore, in November 1978, the Under Secretary of Defense for Research and Engineering directed that a triservice panel be formed to resolve the issues.

The panel first met in April 1979. It was tasked to determine (1) whether it was appropriate to issue a policy directive in view of the questions which had been raised and (2) which architectures should be included in the directive. The panel has determined that a policy is needed but has not yet finalized a directive nor determined what architectures should be included.

Appropriate level of computer standardization to be achieved

At present, the military services do not have central direction as to the level of standardization to be achieved. They are using different standardization philosophies and concepts, although a unified approach may accommodate most of their automation requirements.

Air Force standardization concept

The Air Force is standardizing at the computer architecture level by adopting its own architecture--the Military Standard 1750--for avionics. In this approach, the Air Force will standardize software, using a standard programming language--initially JOVIAL, then Ada when it is ready--and write computer programs to fit the architecture without regard to its physical implementation into equipment. Under this approach, the computer manufacturers, on a case-by-case basis, will build the architecture into computer equipment in a manner best suited by their manufacturing techniques and technology.

The Air Force believes that this approach will reduce life cycle costs of its systems through software standardization; reduce proliferation of military computer types by using a standard architecture; and promote interchangeability, technological advances, and competition.

Army and Navy standardization concepts

While the Air Force is limiting its standardization to the computer architecture, the Army and Navy are going a step further by standardizing the computer equipment that will implement their selected computer architectures.

The Army initially planned to standardize equipment modularly so that plug-to-plug compatible modules, such as central processing unit modules and memory modules, could be configured and reconfigured into computer systems of varying sizes and capabilities suitable for varying needs. These modules were to be competitively acquired according to form, fit, and function specifications from multiple qualified suppliers for use by program managers and system developers.

The Army believed that this approach would provide software transportability, meaningful competition, multiple suppliers, graceful technology insertion through modularization, and reduced life cycle costs. However, the approach was deemed risky because of the difficulty and uncertainty of integrating and interchanging the modules within a computer system composed of equipment from different suppliers. Because of this risk, the Army has changed its approach similar to the Navy's so that now the primary difference between the programs is the architectures being used.

The Navy is also standardizing equipment modularly to permit computer systems to be configured according to needs. However, its approach differs from the Army's initial approach because the modules will be interchangeable only within the product line. They will be competitively acquired through periodic buys from single suppliers based upon form, fit, and function specifications. The Navy believes that this approach is less risky than the Army's initial concept while providing for software transportability, competition, technology insertion, and reduced life cycle costs.

The military services have explored the various standardization alternatives and know their advantages and disadvanvantages. The Department of Defense must now decide

on the standardization method that can best maximize benefits Defense-wide and establish that method as departmental standardization policy to guide its standardization efforts.

More effective decisionmaking and management organization needed

The Department of Defense is aware of the need to provide the military services with central direction, as indicated by its efforts to establish standard computer architectures (see p. 12) and its June 1979 Defense Computer Resources Plan, in which it acknowledged the need for better coordination among the services. However, the Department does not have an effective management organization to provide that direction.

At present, the Department is managing the standardization efforts through the Management Steering Committee for Embedded Computer Resources which was established in 1974 under the auspices of the Office of the Under Secretary of Defense for Research and Engineering. This committee, which is composed of a 5-member Executive Board and an 18-member Management Advisory Board, has neither decisionmaking authority nor control over funding. It functions only with the cooperation of the Defense components, consensus voting by the Executive Board, and recommendations to the Office of the Secretary of Defense.

This management arrangement has not been effective as demonstrated by the lack of adequate standardization policies and the military services' continuing programs to standardize military computers for intraservice use even though they have common functional requirements that warrant Defense-wide standardization.

Need for separate programs questionable

The need for separate standardization programs is questionable. Both the Army and Navy are developing standard computers for command and control type functions. Further, they have separate programs, although they had agreed to work together with the Air Force in a triservice program to develop a family of standard computers for all types of military applications. After signing an agreement to participate, the Navy dropped out of the program to pursue its own standardization efforts because of planning differences with the Army and the need to protect its investment in software that it had developed for its older computers. This situation occurred even though the Army

was willing to accommodate the Navy's requirements in a manner that would have protected the Navy's investment and despite the Navy's awareness of the significant values of triservice cooperation.

A similar situation exists with the Air Force and the Navy. Both are standardizing computers for avionics even though they have similar avionics requirements, as evidenced by the Department of Defense's efforts to standardize electronic equipment among the military services. 1/ Also, the Air Force and Navy agree that it is feasible to develop a standard avionics computer for both services using a single computer architecture and had jointly participated in the Military Standard 1750 effort--to the extent of altering the architecture to accommodate Navy requirements--before the Navy completed developing its AN/AYK-14 avionics computer.

The Navy has justified its actions on the grounds that (1) its large investment of support software was not usable with the Military Standard 1750, (2) it was improving that software and CMS-2 for long-term use, and (3) it did not want to develop new software that would be needed for the Military Standard 1750. This position, however, does not consider Ada becoming a common language that will replace CMS-2, nor the does it consider that the Air Force is developing compilers to make the Military Standard 1750 compatible with Ada.

To maximize standardization, we believe the Department of Defense needs to establish more effective management control over the services' programs. This could be accomplished by forming a steering committee with authority to decide how standardization should be achieved and to provide top level management control over the Department's standardization efforts and by designating a project manager who can plan and direct the standardization efforts in a manner that will maximize standardization Defense-wide.

1/See our report to the Secretary of Defense concerning standardization of avionics equipment (B-163058, dated May 12, 1978).

APPENDIX I

SCOPE OF REVIEW

In reviewing the Department of Defense's standardization efforts, we studied each military service's standardization program within the context of the Department's planning and management of its computer resources. We established that the Army, Navy, and Air Force have similar functional requirements, use the same types of military computers for those requirements, and are faced with the same problems caused by the proliferation of different makes of computers and programming languages. Using these facts as a baseline, we studied the various standardization concepts and approaches being used in the services. We then used this information to identify the similarities and differences among the programs and to assess the need for separate programs in view of the services' common needs and problems.

Our evaluation included reviewing planning and program documentation; requirements analyses; various computer architecture studies; evaluations and analyses; cost/benefit studies; program critiques; computer industry reports and evaluations; military regulations, instructions, and directives; and other pertinent documents.

We also discussed the programs and concepts with Army, Navy, Air Force, and Office of the Secretary of Defense officials. We made our review at the following locations:

Office of the Under Secretary of Defense for Research and Engineering, Washington, D.C.

Defense Advanced Research Projects Agency, Arlington, Virginia

U.S. Army Communications Research and Development Command, Fort Monmouth, New Jersey

U.S. Naval Material Command, Crystal City, Virginia

U.S. Naval Sea Systems Command, Crystal City, Virginia

U.S. Naval Air Systems Command, Crystal City, Virginia

U.S. Air Force Systems Command, Andrews Air Force Base, Camp Springs, Maryland

APPENDIX I

U.S. Air Force Avionics Laboratory,
Wright-Patterson Air Force Base, Dayton, Ohio

U.S. Air Force Headquarters,
Aeronautical Systems Division,
Wright-Patterson Air Force Base, Dayton, Ohio

APPENDIX II

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D C 20301

RESEARCH AND
ENGINEERING

May 15, 1980

Mr. Donald L. Eirich
Associate Director
Logistics and Communications
Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Eirich:

This is in reply to your letter dated March 21, 1980 to the Secretary of Defense regarding your draft report on The Department of Defense's Standardization Program for Military Computers--A More Unified Effort is Needed," OSD Case #5403, Code 941175.

This letter supplements the informal meeting held between you and members of your staff and representatives of the Department of Defense on April 7, 1980.

In your report you conclude that: The Department of Defense has become increasingly dependent upon automation to assist in the accomplishment of our mission; that there has been a proliferation of kinds of (embedded) computers in the Department; that this proliferation has had an adverse impact in terms of cost, operational and logistic support difficulties; and, as a result, that the Department has been forced to examine numerous techniques to alleviate these adverse impacts. You state your belief that the Department has an opportunity to achieve improved standardization of military computers and software for combat support and weapon system use and recommend that the Department:

-- Establish Ada as the standard programming language for military applications.

-- Establish standard Instruction Set Architectures (ISAs) to be used in various military applications.

-- Establish the extent or appropriate level of computer standardization to be achieved beyond ISA.

-- Strengthen the decision-making management organization to oversee defense-wide standardization efforts.

You concluded that, although the Department has taken positive action in this area, more needs to be done to achieve more effective standardization of

APPENDIX II

(systems or embedded) computers and software. You further note your belief that present individual standardization programs of the Services should be curtailed until the Department establishes the appropriate standardization policies and has strengthened the management organization needed to plan and control the Department's standardization program.

During the tenure of your study, the Department has been actively evaluating the embedded computer area and, in fact has moved generally in the directions you recommended. The report's discussion of some of the specific programs has become overcome by events in that these programs have been altered as a result of close scrutiny of their requirements, in response to reaction from industry and because of our own analyses of the acquisition strategies involved. This progress was discussed during the April 7 meeting and will be covered later in this reply.

We concur that the Department is increasingly dependent upon the embedded digital computer and upon software in accomplishment of our national defense mission. This parallels our dependence upon ADPE for the administration and operation of the Department, per se. Two specific cases come to mind: award of the Air-Launched Cruise Missile Contract (ALCM) was pivoted on the guidance system software design, all other technical factors being basically equal. The performance of the F-16 radar, the AN/APG-66, was significantly improved for operation in the European environment, principally via software changes.

We concur that Ada should be the standard programming language for military application across DoD. Because the impact of this decision goes far beyond what would be implied from the modest $5-6 million annual investment required, we are taking steps to manage the implementation, introduction and support phases via a DoD Ada Joint Program Office (AJPO). Establishment of this office is in the final stages of coordination. In addition, DoD Instruction 5000.31, "Interim List of DoD Approved High Order Languages (HOLs)" is being revised to include Ada and to remove two interim languages which we wish not to use for new systems. This Instruction together with the AJPO Charter, will give DoD Components central direction and clear guidance on this matter.

We concur that a policy on Instruction Set Architecture (ISA) standardization is required. USD(R&E) memorandum dated November 21, 1978 provided interim standardization policy and established an Instruction Set Architecture Panel (ISAP) reporting to the Management Steering Committee for Embedded Computer Resources (MSC-ECR) to develop and recommend a DoD position in this area. The panel has reported out a draft DoD Instruction 5000.5X, "Instruction Set Architecture (ISA) Standardization Policy for Embedded Computers," which is being reviewed by the MSC-ECR prior to formal coordination and issuance. The extent of standardization beyond the ISA is still being considered. It is at this point that we must bring the aspects of performance, supportability and business strategy into an integrated acquisition policy. We wish to assure ourselves that the level of standardization chosen will allow for continued injection of new technology, maintain proper competition and fairness and simultaneously reduce our total hardware and software costs.

We concur that a clarification and strengthening of the embedded computer management organization is appropriate. The Joint Logistics Commanders requested modification to DoD Directive 5000.29, "Management of Computer Resources in Major Defense Systems" to clarify acquisition and management policy in this area. This review was completed April 18, 1980 and the

APPENDIX II

recommendation will provide a basis for revision of the directive. The MSC-ECR is the oversight mechanism established by DoD Directive 5000.29. The original Executive Board of the MSC was comprised only of representatives of key OSD staff elements. The Chairman has added the senior Service representatives to the MSC and representatives from OASD(Intelligence) and OASD (Manpower, Reserve Affairs and Logistics) by administrative action. This assures that ASD and Service secretariat levels are adequately represented in the decisions of the MSC. They are in positions to implement the decisions, as appropriate, in the individual Components and to promulgate policy at the OSD staff level. This reconstitution of the MSC will be included in the charter when DoD Directive 5000.29 is revised. The decision making role will be clarified. We prefer this approach of strengthening an existing body to the establishment of a new high-level steering committee as you recommended. The impact of the MSC has been significant in its deliberative and advisory role and it is well accepted by the affected DoD Components. Further, the MSC Executive Board is identified as the Executive Committee for the AJPO. In this role they will operate in a manner analogous to the Defense System Acquisition Review Council (DSARC) with respect to the implementation and introduction of Ada. We anticipate a similar role with respect to potential future Tri-Service or DoD ISA implementation efforts. We believe this evolutionary increase in responsibility and authority meets the intent of your recommendation.

We do not concur in your recommendation that the present standardization programs of the Services should be curtailed. They each meet a set of needs which have been thoroughly justified by the Services and, further, they provide a living laboratory to arrive at the best answer to your concern over the appropriate level of standardization beyond the ISA. To halt these programs--the Army's Military Computer Family (MCF), the Navy Embedded Computer System (NECS) and the Air Force MIL-STD-1750--would force a hiatus in controlled introduction of present and next generation technology. This would lead either to a further proliferation of types of computer hardware or to less than open competition for a mandated, but not well rationalized, standard. You will note that the MCF has chosen to develop and introduce a new government-owned, non-proprietary 32-bit architecture, principally for ground-based command and control (C^2) systems. The Navy is attempting to inject the most modern technology as replacements for the AN/UYK-7, AN/UYK-20 and, to a lesser extent the AN/AYK-14. The principal rationale for holding to these ISAs is conservation of the existing software investment mainly in CMS-2, the Navy standard. The Air Force MIL-STD-1750 is a 16-bit architecture suitable for airborne, missile and ground-based real-time systems. Recent growth to 1750A as a result of broad industry and user-group input will add extended memory management and hence render 1750A germane to a range of C^2 application as well. We intend that MCF and 1750A be multiple Service programs; if necessary to assure that this happens, we will set up a DoD program office parallel to the AJPO. The materialization of 1750A and MCF should provide the next generation 16-bit and 32-bit architectures for broad use across all DoD Components. We intend that they both be included as proof of principle demonstrations within the Very High Speed Integrated Circuits (VHSIC) Program. Therefore, multiple sources for the hardware will be assured as will the injection of the very latest advanced technology. As you can see, the strategy which has developed through the MSC-ECR process has led toward a marked reduction proliferation in both architectures and languages from the

APPENDIX II

uncountable to a manageable few toward a practical minimum. Now by coupling the Ada Program, the ISA policies and later, the VHSIC Program we believe we have demonstrated an effective and efficient degree of management in a very rapidly changing technical and business environment.

Gerald P. Dinneen

(941175)

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. GENERAL ACCOUNTING OFFICE

THIRD CLASS