SOME MANAGEMENT INITIATIVES TO IMPROVE EMBEDDED COMMERCIAL COMPUTER AND TRAINING DEVICE LIFE CYCLE SUPPORT

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ABSTRACT

This paper discusses some of the problems associated with the use of commercial off-the-shelf computer systems in aircrew training devices and offers some suggestions for improving the life cycle management of commercial computer systems in such military training devices. The impacts of commercial practices and computer capacity limitations are addressed as well as acquisition and logistics management considerations. Improved planning and management effectiveness will be needed in the 1980s to ensure that computer systems are supportable and/or replaced during the life cycle of training devices systems. Both acquisition and logistics support agencies will need to recognize that the life cycle of commercial computer systems may be limited by the lack of computer and peripheral vendor support and by the lack of expansion capability. Accordingly, training devices will need to be designed and developed to accommodate computer expansion or replacement. Computer system expansion or replacement will need to be anticipated to minimize training device to weapon system configuration differences caused by a lack of computer system supportability or capacity. *This process could be termed "Pre-Planned Product Preservation (P^4)".*

INTRODUCTION

Life Cycle support of commercial off-the-shelf computers embedded in training devices has traditionally been a challenge to military training device managers. Logistics supportability problems and computer capacity limitations have plagued simulator managers since digital computers were first embedded in simulators. Commercial practices, acquisition management practices, and logistics management practices have all contributed to life cycle support problems.

While advancing technology and improved management practices have lessened the impact in some areas, the overall life cycle supportability problem remains.

LOGISTICS SUPPORTABILITY PROBLEMS

On older generation computer systems, logistics supportability could be prolonged because base level maintenance had the capability for piece/part repair of the single-layer, discrete-component technology (core memory was the exception). With new technology computer systems (multi-layer, high density boards), base repair capability has become more limited with increased dependence on depot level (contractor) repair. This evolution in maintenance concept has occurred with commercial users (airlines) as well as the military. With increased dependence upon contract depot level repair, the supportability problem has changed from that of providing piece/part components for base level repair to that of finding contractors, either original manufacturers or third parties, for depot level repair and spares.

Because of rapidly advancing technology and the highly competitive environment, commercial computer companies are announcing a new product series of computers with increasing frequency (every three to five years). As new products become mature and accepted, production of the previous series is terminated. Most commercial computer manufacturers will then guarantee support of their products for five years following termination of production of a particular computer model. Some companies provide support for a longer time depending on availability of spares and components, availability of company skills, and the total computer population supported. There are indications that computer companies who are predominant suppliers of training device computer systems are recognizing the simulator user's need for longer support. Most companies, however, particularly those who do not have a large share of the simulation market, appear to be staying with the five-year support policy.

The availability and cost of depot level repair and spares from original manufacturers and/or third party repair contractors are highly dependent upon the overall demand for such services. Factors affecting *demand include:*

Effect of Production Status

Support is available while the product is in production and normally for at least five years following production termination. The availability of spares and repair from original manufacturers varies with company policies. Some will bid on spares and repairs so long as their products are in service, though the cost is likely to increase. Others simply refuse to bid repairs after they have discontinued guaranteed support of a product. Also, computer manufacturers may or may not maintain an in-house repair capability for their vendor-supplied peripherals. Thus, repair for peripherals may be subject to another level of availability. It has been suggested that long term computer support commitments be made a requirement in all simulator acquisitions. While this would be highly desirable, there is some question whether it could be enforced since such a commitment is dependent upon the integrity and continuity of the prime, the computer vendor, and second tier peripheral vendors.

Manufacturing Rights and Data Availability

The availability of repairs from third party repair sources is frequently dependent upon the availability of technical data. One computer manufacturer claims that the documentation furnished with each delivered system is adequate to establish and maintain a depot level repair capability. Others, however, furnish limited documentation with their equipment and consider depot level technical data as proprietary information. Most computer manufacturers contacted during this study indicated that they would consider selling proprietary data or manufacturing rights on their older systems if they could not offer repair services. It was noted during the study that third party repair is becoming more readily available for older technology systems. However, there is some question whether it will be economical for third party repair sources to develop the expertise and more sophisticated resources necessary to repair newer technology equipment.

Total Production Quantity

Larger total production quantities of an item increase the probability that enough units remain in service to economically justify retention of a repair capability for a longer period. Commercial users tend to depreciate computer systems over about five to seven years and then replace them, while the military embeds computers in equipment that is intended to be used for 15-25 years. Frequently, then, the military becomes the sole user of commercial computer repair services as commercial applications are phased out.

Equipment Reliability and Sparing

Computers are inherently reliable and are becoming more so with new technologies. Thus, the basic repair and spare demand for computer circuit boards is low compared to electro-mechanical devices such as peripherals. This inherent reliability of computer circuit boards makes the choice in sparing philosophy more difficult. Although at least one of each kind of board is spared in most commercial and military simulator applications, long term support choices involves either: (a) dependence upon contractor repair and spare support; (b) provisioning a life-time supply of spare boards; or (c) a combination of these. All three choices involve some risk. As indicated above, dependence upon contractor support is subject to limited commercial life support policies. Life-of-type sparing involves high front-end costs and less-than-perfect predictions of failure rates . A combination of contractor dependence until termination of guaranteed support, then procuring life-of-type spares is subject to planning, programming and budgeting lead time which exceeds the one year termination-of-support notice provided by some computer vendors.

Base Level Self-Sufficiency

The capability of base (organizational and intermediate) maintenance personnel to repair computer components can have a significant impact on the demand for depot repair. With older technologies (single-layer discrete component boards), both military and commercial maintenance personnel could maintain computers with a high degree of self-sufficiency. However, with newer technologies (multi-layered, high density boards), both military and commercial users lack the skills and support equipment for a repair capability.

As the older technology hardware is phased out, an increased demand for depot repair can be expected. In this respect, computer companies are limiting their field engineers to troubleshooting and board removal-and-replacement, with board repairs accomplished at centralized depot level repair facilities.

As the demand for computer spares and repairs diminishes, it understandably becomes more costly for repair contractors, whether original manufacturers or third party, to retain the skills, parts and test equipment for a support capability. The current Air Force policy of competing most computer repairs tends to discourage the commercial retention of support capability because a sustained business base is not assured. The relative cost of depot repair during a computer's life cycle is depicted in Figure 1. A similar depiction could be made to illustrate spares costs.

EXPANSION CAPABILITY LIMITATIONS

The lack of expansion capability (computational timing and memory requirements) to incorporate trainer changes has, in the past, frequently been more of a driving factor in computer replacements than logistics supportability. Trainer changes, generated by weapon system changes and by increased training requirements, place additional demands on the originally delivered computational system. Solutions to this eventual computer system saturation include: (1) expanding existing systems; (2) adding another computer system; or (3) replacing the existing system. Pertinent aspects of this problem are contained in the following discussion:

The Developers' Challenge

With a few exceptions (e.g., Singer GP-4), older generation computer systems used in simulators were not specifically designed for real-time simulation. In order to meet simulation requirements as well as government imposed spare timing and sizing requirements, simulator developers were faced with the challenge of extracting the maximum capability from the then state-of-the-art machines. Techniques used to accomplish this were (a) modification or replacement of the computer vendor's software and/or hardware, (b) use of machine or assembly language and/or more efficient software programming, and (c) designing interfaces for multiple CPUs. Even with these efforts, simulator developers sometimes had to add CPUs during development and frequently delivered less than the contractually-specified spare time and memory capacity. It may be noted that changing requirements imposed by acquisition agencies sometimes contributed to this problem.

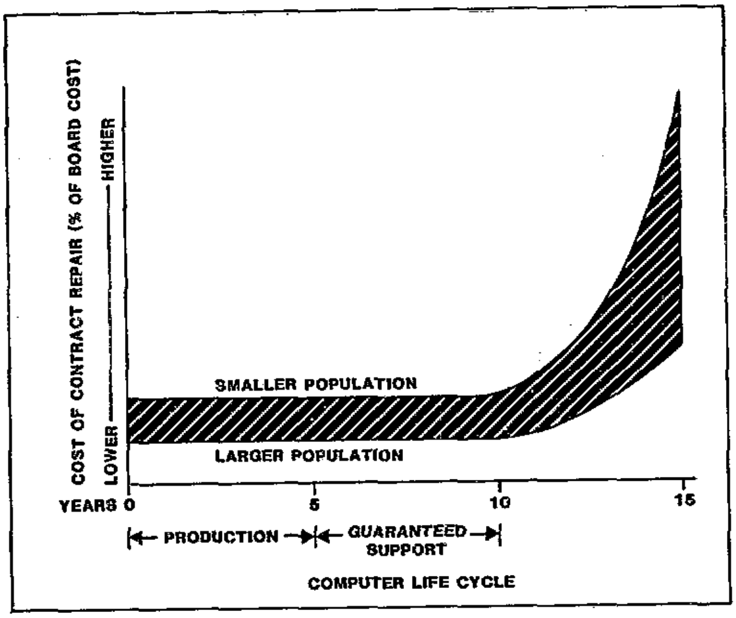
Spare Time and Size Requirements

Acquisition agencies generally plan and contractually specify spare time and size to accommodate change activity during simulator development and for delivery to the using command. Frequently, however, spare time and size is used by change activity and other factors by the time the system is delivered.

Hindrances to Computer Expansions

Attempts to expand computer capacity have been affected by the following:

a. Older generation computer systems had limited expansion capability.



RELATIVE COST OF REPAIR DURING COMPUTER LIFE CYCLE

FIGURE 1

b. Because of the Air Force's practice of "freezing" configurations, computer systems had to be updated to the latest configuration in order to add capability. Sometimes it was determined to be less expensive to replace than to update.

c. Because the computer system was obsolete (out of production), expansion kits were not available.

d. Because simulator developers had modified the computer vendor's software and/or hardware, vendor updates might not be compatible. Also, compatibility with the vendor's next generation of computer systems was diminished, making applications software less transportable and more costly in the computer replacement. More often than not, simulator-unique designs led to sole source procurement of the computer replacement with the simulator developer because of his unique design.

Technology Impact

Recent and current technology computer systems are being designed with increased capability for real-time simulation. In addition, these systems are more easily expanded by adding such things as a cache memory, a high speed floating point processor, additional CPUs , or extra memory.

COMMERCIAL PRACTICE CONSIDERATIONS

A number of practices employed by computer and simulator manufacturers contribute to the overall management problem. Some of the underlying causes of these problems are being overcome by advancing technology and improved management procedures. Other practices, however, particularly those employed by commercial computer vendors, are not likely to change.

Revision Procedures

Computer manufacturers issue service bulletins, Product Improvement Notices (PINs), Field Change Notices, Design Change Notices, or otherwise designated revision levels to a particular item of equipment and/or software. Each manufacturer has his own system of issuing revision levels; these differ (sometimes significantly) in cost, description of change, inclusion of kits, method of implementation, etc. Some manufacturers issue a revision that consists only of a drawing correction. Some affect hardware only; some affect software only; and some affect both.

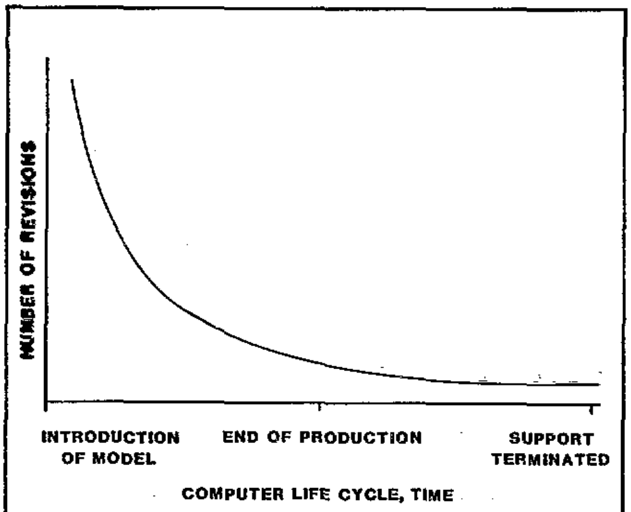
Revisions may be issued for the purpose of:

a. Improving computer system capability.
b. Improving reliability.
c. Reflecting manufacturing changes.
d. Correcting design defects or field reported problems.
e. Reflecting component or material changes or substitutions.

In turn, these revisions may or may not:

a. Affect form, fit and function.
b. Require prior incorporation of a lower level revision.
c. Be upward or downward compatible with other revisions.
d. Be fully de-bugged for a particular application.

Typical numbers of revisions versus computer life-cycle are illustrated in Figure 2, from which it can be seen that commercial computers have a very dynamic configuration baseline.



TYPICAL NUMBER OF REVISION NOTICES DURING A COMPUTER MODEL'S LIFE CYCLE

FIGURE 2

Configuration Control in Acquisition

Simulator developers have not always delivered computer systems, spares, and technical data for a given trainer type/model in a common or current configuration. Computers or spares delivered at different times could include different revision levels. In recent acquisitions, the Air Force has required that computer systems for a given trainer type/model be updated to the configuration of the last delivered trainer.

Software and Hardware Modifications

Both simulator developers and computer manufacturers advised Veda that until just recently simulator developers have modified or replaced the computer vendors' operating systems (O/S) and/or hardware in order to improve the "real-time" computational capability of the vendors' systems. This fact alone has had significant impacts on simulator management:

a. If vendor operating systems and/or hardware are modified or replaced, computer vendors cannot guarantee that their hardware updates (revisions) will not affect the simulator operation.

b. Vendors' operating system revisions, upon which some hardware revisions are dependent, may not be compatible with a modified operating system.

c. Even though computer manufacturers attempt to design for compatibility from one computer model or generation to the next, modification or replacement of the operating system and/or hardware make the applications software less transportable. Thus, software costs during computer replacements are significantly increased.

d. It is also possible for simulator developers to use the vendor's operating system intact, but supplement the O/S by using portions of the computer not used by the then current O/S, such as reserved memory words. A subsequent computer vendor revision to the O/S utilizing that portion of the computer is then not usable in the simulator application.

e. In the past, most simulator developers made at least minor hardware changes to vendor-supplied equipment. This was accomplished in one of two ways:

(1) The simulator developer would physically modify the vendor's part, making it simulator-unique and no longer an off-the-shelf item. If handled properly, a simulator manufacturer part number would be assigned to the resulting assembly and a source control drawing produced and delivered.

(2) The simulator developer would provide a modified design and/or specification to the computer vendor, who would produce and deliver the assembly with a vendor part number. Although the assembly was vendor supplied, it most likely became a vendor's "specialized product" (versus a "standard product") and thus simulator-unique.

Peripheral Equipment Modification

A related problem exists with respect to modification of peripheral equipment. Some computer manufacturers modify peripheral equipment or specify modifications to the peripheral vendor. In either case, peripheral equipment procured directly from the peripheral vendor may not always perform satisfactorily in the delivered computer systems. Some simulator developers procure peripherals through the computer manufacturer in order to preclude the above and to hold the computer vendor responsible for total computer system performance.

The Outlook

It should be noted that the problem associated with manufacturer-modified hardware and software may not be as severe in future systems. This is because currently available computer systems have been designed for real-time operations and have considerably more capability and expansion potential than previous generations. Both computer vendors and simulator developers have stated to Veda that the newer technology computer systems can be used in simulation applications without modification of hardware or software. One simulator developer, while believing this possible, suggested that modification would still be required because of cost competitiveness and the customer's desire to "push technology".

ACQUISITION MANAGEMENT CONSIDERATIONS

Some of the acquisition practices contributing to computer system management problems have been corrected in recent acquisitions. However, because of acquisition lead times, the effectiveness of these improved practices is yet to be demonstrated. Particular aspects of current versus past practices are identified in the following discussions.

The Computer Selection Process

Traditionally, computer systems in training devices have been selected by the simulator developer during the acquisition process based upon general computational system requirements specified by the acquisition agency. Generally, a commercial off-the-shelf computer system is selected either by the simulator developer's choice or because a commercial system is specified by the government. The government, however, does not normally specify a commercial brand or model. The basic rationale for selection and/or specification of commercial systems for simulation has been as follows:

a. Real-time performance and memory capacity requirements for simulation applications have required state-of-the-art computer systems designs; generally, only commercially available computer systems could meet these requirements.

b. The quantity of computers required in any one simulator system type/model has not justified the development of a military computer system that could meet computational requirements.

c. The simulation market is highly competitive; thus, cost is a prime consideration of the simulator developer. If left to the developer, then, a least-cost system meeting performance requirements will be selected.

d. Rapidly advancing technology in a highly competitive commercial computer market has made available low cost-to-performance ratio commercial systems, thus eliminating the need for high government development costs.

This method of computer system selection has, in the past, tended to proliferate the types and models of computer systems in training devices and thus aggravate the logistics support effort. More recently, however, the increased use of simulators, and more significantly, the increased use of digital computers in simulation have lead to recognition of simulation as a computer industry market. Because of this market recognition, computer manufacturers who specialize in real-time systems are designing them with a consideration for simulation requirements. This evolution has led to the present situation wherein it is likely that computer systems of the minicomputer or super-minicomputer category from one of four manufacturers are selected. Specifically, manufacturers whose systems are being selected today as mainframe computers for both commercial and military simulator applications are: Digital Equipment Corporation (PDP or VAX series); Gould SEL (32/77 or 32/87 series); Harris (800 series); or Perkin-Elmer (8/32 or 3200 series). While the current selection process has essentially reduced proliferation of mainframe computer systems to four manufacturers, there are other factors that affect, or may affect, the commercial computer selection process:

a. No single computer model within a manufacturer's product line is suitable for all simulator applications whereas a single computer of the same model could have excessive performance (and cost) in other applications.

b. Technology innovations, seemingly being introduced with increased frequency, may make the current training device computation system concept obsolete. While most simulator developers contacted believe that a mainframe computer will continue to be used in simulations, they suggested that there would be increased use of microprocessors in a distributed mode, and that the physical size of the mainframe will decrease. The management of microprocessors presents yet another challenge to simulator managers.

c. In spite of inflation, the cost-to-performance ratio has continued to decrease with the introduction of new technologies. This trend can be expected to continue for the foreseeable future. Accordingly, computational system cost (excluding applications-unique software) will continue to become a smaller percentage of the overall simulator system cost.

The Simulator Development Process

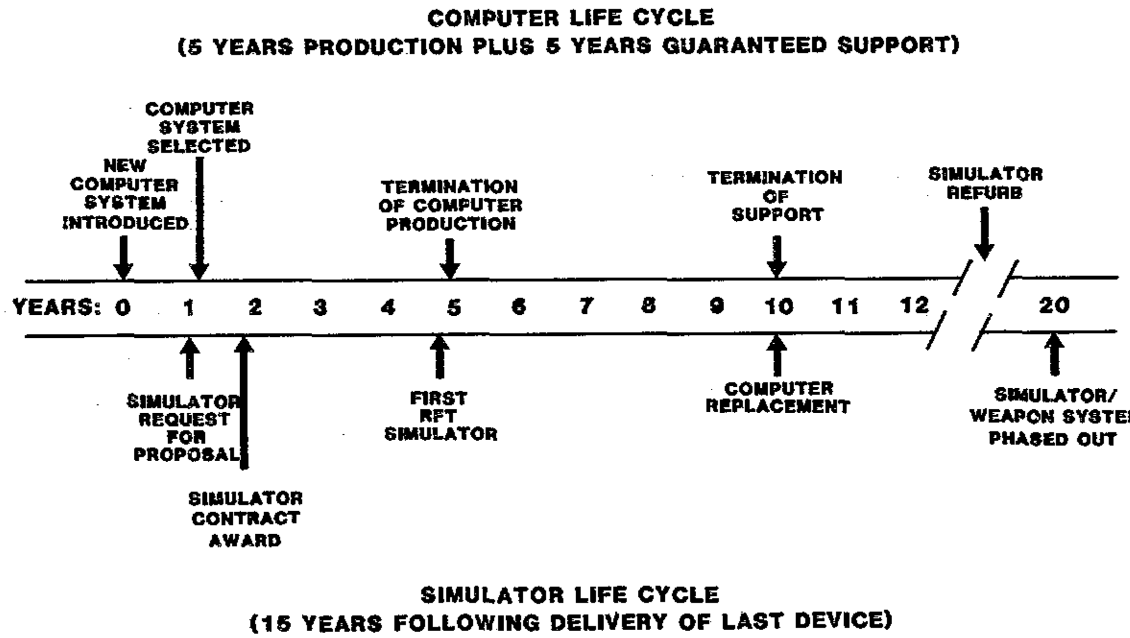
During simulator acquisition, simulator developers select computer systems during the proposal phase. In order to minimize risks to both the government and the developers, a reasonably mature computer (one to two years into production) is selected. Based upon statistics from the Air Force, a simulator development requires, on the average, 34 months from contract award to delivery of the first ready-for-training (RFT) simulator. Therefore, as illustrated in Figure 3, computer systems are four to five years into production , or perhaps already out of production, when simulators are deployed. Thus, logistics managers can expect to experience supportability problems within five years of deployment of the first training device.

For new simulator acquisitions, the Deputy for Simulators prepares a Type BI, Prime Item Development (Part I) Specification and requires a Part II Product Specification from the simulator developer. The training device is procured as a single Configuration Item. The computational system is specified by incorporating, or referencing, portions of MIL-D-83468, Digital Computational Systems for Real-Time Training Simulators. No specification per se is required for the computer system, nor are interface specifications or interface control documents required. Thus, there is no clear distinction between the off-the-shelf computer system and the applications (simulator-unique) hardware and software.

As indicated in previous discussions, simulator developers in the past were not required to deliver computers and spares in a common or current configuration; however, this has been imposed in recent acquisition contracts. Also, acquisition agencies have not maintained visibility and control over modifications to computer vendor's hardware and software. The Air Force has recognized this and is currently intensifying efforts to control and minimize these modifications. Finally, contractually specified spare time and size is frequently used up by change activity during development. This problem should become less of a concern with the expandability of newer technology computer systems.

Acquisition Management Initiatives

The provisions of an acquisition, of course, strongly influence the supportability of a training device. Thus, computer life cycle planning must begin with the acquisition process. If it is recognized that computer replacements are inevitable, then training devices should be designed to facilitate such computer replacement. It is suggested that preservation of the off-the-shelf nature of computer systems is essential. This translates into the following requirements:



COMPARISON OF TYPICAL COMPUTER AND SIMULATOR LIFE CYCLES

FIGURE 3

a. Commercial off-the-shelf hardware and software must be used without modification. Any deviation should be fully documented and justified to the acquisition agency. It is also assumed that applications software is programmed in a higher order language such as FORTRAN or Ada.

b. The hardware and software interface between the commercial off-the-shelf computer system and the simulator must be defined and maintained through interface control documents or other comparable means.

c. A configuration description is needed to define the commercial configuration baseline. Such a configuration description is normally delivered by the computer vendor with each system, and describes the hardware, software, and documentation as delivered. The computer vendor's current configuration of hardware, software, and documentation should be maintained during development and be reflected in the configuration description delivered with the simulator.

d. A technique that can be used to encourage simulator contractors to consider life cycle supportability is to require a Post Production Support Plan as a part of acquisition contracts. The Post Production Support Plan is described in MIL-STD-1388-1A, Logistics Support Analysis, and Data Item Description DI-P-7119. This plan requires the prime contractor to: (1) identify items that will present potential problems due to inadequate sources of supply after termination of production; and (2) prepare alternatives to satisfy support problems for the system/equipment's expected useful life.

If the above requirements can be fulfilled, a current, fully documented and unmodified commercial off-the-shelf computer system will be delivered with the simulator. Maintaining the off-the-shelf integrity of commercial systems should facilitate computer replacements since computer manufacturers try to design their next generation computer systems to be compatible with their previous generation systems. Thus, the cost and complexity of computer system replacements should be minimized. Requiring a Post Production Support Plan should greatly enhance Air Force's planning for life cycle supportability of commercial computer systems including peripherals.

LOGISTICS MANAGEMENT CONSIDERATIONS

Although there are many ramifications to the logistics management of computer systems, there are two overriding considerations: configuration management of computer systems and recognizing the limited life cycle of commercial systems.

Configuration Management

Effective logistics management of embedded computer systems following deployment of simulators has been hindered by a lack of positive configuration management. Failure to maintain computer systems at the manufacturers' current configuration levels has created mixed configurations of spares, data, and installed hardware and software within specific simulator types and also among different types of simulators. As a design goal, computer manufacturers try to make next generation computer systems compatible with their previous generation systems. This compatibility, however, is based upon the latest configuration of the older generation system. Thus, failure to update computer systems makes logistics support and replacement of computer systems more difficult and costly.

Computer Replacements

The need for computer system replacements one or more times during a simulator life cycle is not yet established as a recognized requirement. In the past, computer replacements have been driven more by lack of capacity (time and/or size) to accept simulator modifications rather than by a lack of supportability. The cost of replacing computers has been substantial because software was programmed in machine or assembly language, computer systems had not been updated, and modifications had been made to off-the-shelf software and/or hardware. In some simulator systems, this replacement cost has contributed to a significant simulator modification backlog, and thus, to degraded training because of weapon system-trainer configuration differences.

Logistics Management Initiatives

Based upon the above considerations, there are logically two logistics management initiatives to be considered: maintaining positive configuration management of computer systems and periodically reviewing supportability of computer systems.

a. Maintaining positive configuration management of computer systems includes preserving their commercial off-the-shelf nature and maintaining the systems and documentation to the manufacturers' dynamic configuration baseline. To accomplish this, more flexible procedures will have to be developed to accommodate the manufacturers' dynamic configuration baselines.

b. In order to provide adequate funding lead times, computer system supportability must be periodically reviewed. Using the Post Production Support Plan, if acquired, this review should include:

- Parent weapon system inventory plans
- Weapon system modernization plans
- Trainer modernization plans
- Computer spare time and size
- Expandability of the computer system
- Availability of expansion kits
- Vendor support policy and plans
- Availability and cost of support from vendor or third party
- Reliability
- Maintainability
- Any modifications made to off-the-shelf hardware and software
- Applications software program language
- Compatibility with currently available replacement systems

Because of the rapidly changing commercial computer market, it is suggested that a supportability review should be made on at least a biennial basis, and probably annually for older systems and peripherals.

This increased management attention to embedded computer systems should contribute to improved logistics supportability during the life cycle of the computer system and to improved training effectiveness during the life cycle of the simulator.

SUMMARY

There are many factors contributing to the problems of commercial off-the-shelf computer system life cycle support. Some of the problems are being overcome by technology while others are being corrected by management initiatives. However, full recognition of the limited commercial computer life cycle is needed, along with acceptance of computer replacement requirements.

The cost and mission impact of computer system replacements can be minimized if: (1) simulator developers can deliver off-the-shelf commercial computer systems without modification; (2) computer systems are maintained to the vendor's current configuration; and (3) supportability of computer systems is periodically reviewed to anticipate replacement requirements. This entire process could be termed "Pre-Planned Product Preservation (P^4)".

ABOUT THE AUTHOR

Mr. Wayne W. Gamble is a Senior Engineer and Project Manager at the Dayton Division of Veda Incorporated. His projects have encompassed a wide range of logistics support studies pertaining to training devices. This paper was based upon a simulator computer support study performed by Veda Incorporated for Headquarters Air Force Logistics Command. Mr. Gamble is a former Air Force Officer with over 25 years diversified experience in operations, maintenance, acquisition, and logistics. He holds a B.S. degree in Aerospace Engineering and an M.S. in Aerospace-Mechanical Engineering.