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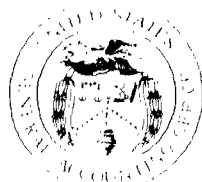
GAO

Briefing Report to the Chairman,  
Subcommittee on Research and  
Development, Committee on Armed  
Services, House of Representatives

July 1992

# EMBEDDED COMPUTER SYSTEMS

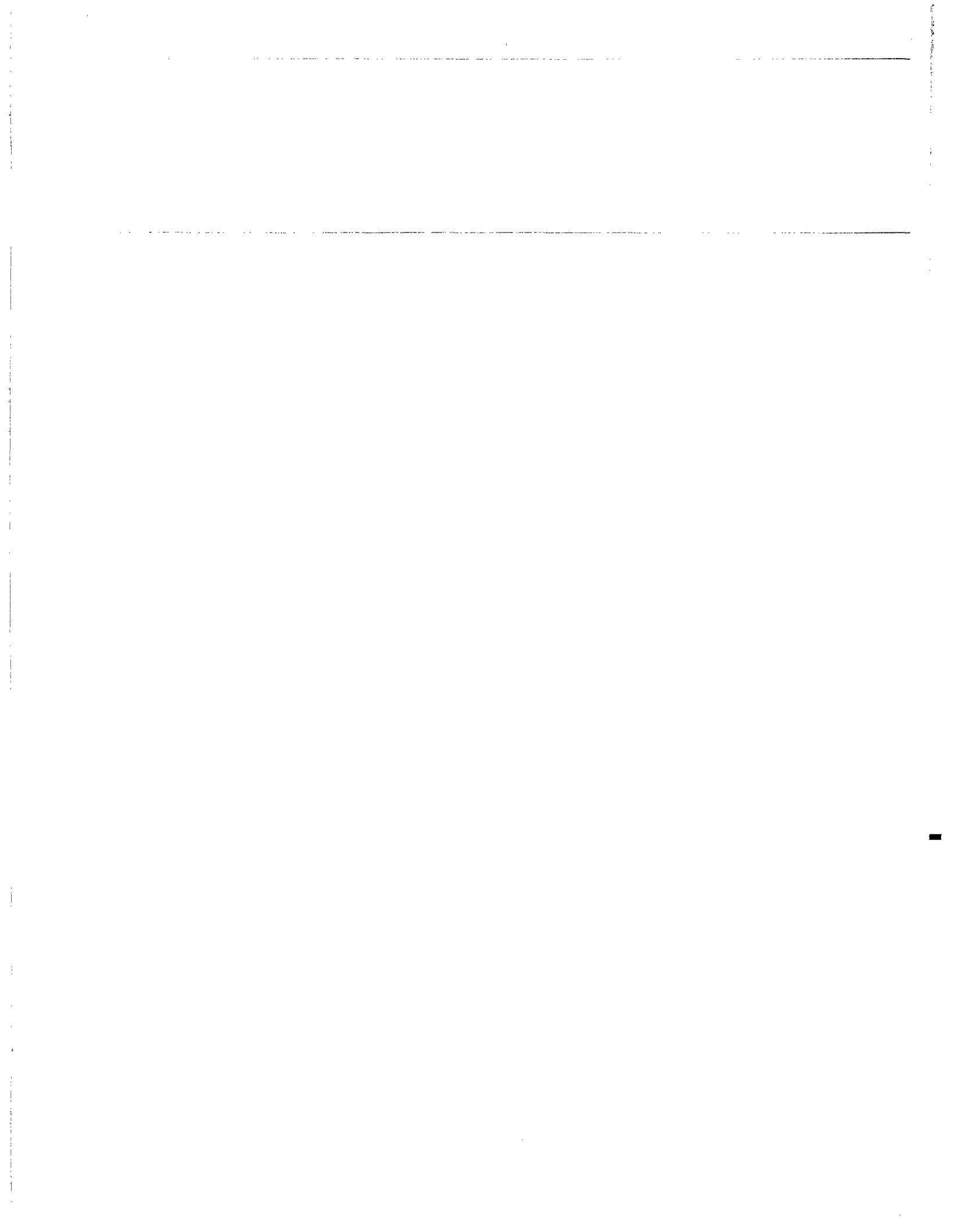
## Defense Does Not Know How Much It Spends on Software



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United States  
General Accounting Office  
Washington, D.C. 20548

Information Management and  
Technology Division

B-248235

July 6, 1992

The Honorable Ronald V. Dellums  
Chairman, Subcommittee on  
Research and Development  
Committee on Armed Services  
House of Representatives

Dear Mr. Chairman:

Today's complex weapons systems cannot work without reliable software. As such, the importance and cost of this software has increased tremendously in recent years. This report responds to discussions initiated on December 2, 1991, with staff of the full committee and subsequent discussions with your office, requesting that we (1) determine if the Department of Defense knows how much it spends on software embedded in weapons systems, and (2) examine what Defense is doing to track and reduce embedded software costs.

We briefed your office earlier this year on the results of our work to that time. As agreed, this report documents the results presented at that briefing, and provides additional information concerning Defense's tracking of weapons systems software costs. The briefing charts are included in appendix I.

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## Results in Brief

Defense weapons systems capabilities are increasingly dependent on software, which is rapidly becoming a very costly and technically challenging component. However, Defense does not know how much it spends on this critical technology. Estimates of software costs range from \$24 billion to \$32 billion annually—about 8 to 11 percent of Defense's total budget. However, these estimates are rough at best because Defense has not identified or tracked software costs as a discrete item in its weapons systems development programs. Recognizing the importance of tracking software costs, Defense has recently taken action to require new weapons programs to separately identify and report software costs. Defense is also exploring ways to reduce the cost of software. Collecting more complete embedded software cost information could enable Defense to more effectively manage its weapons programs.

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## Background

Software is critical to a modern weapons system's ability to perform key functions, such as communications, detecting and tracking enemies, and targeting and firing weapons. Failure to perform these functions correctly and in a timely manner can endanger lives and equipment and threaten national security.

In addition to performing critical functions, software offers increased flexibility and can replace costly manpower. For instance, updated software gave the Patriot missile added capability to defend against SCUD missiles in the Persian Gulf. The Patriot was originally designed to target cruise missiles and aircraft, but modifications to its software made it adaptable to intercept SCUD missiles. In addition, as our military forces are reduced, software will be increasingly relied upon to perform roles once reserved for trained personnel. For example, software for the C-17 aircraft is expected to eliminate the need for a navigator and a flight engineer. However, any new software must be appropriately designed and developed to ensure that weapons systems effectively perform their missions.

Because of software's critical role in weapons systems, Defense's demand for software is continuously increasing. For example, the Air Force's F-4 fighter of the Vietnam war era had practically no software, while today's F-14D fighter relies upon over 1 million lines of computer code to perform its mission. The next generation fighter aircraft, the Advanced Tactical Fighter, is expected to rely upon 7 million lines of code. According to some estimates, the ballistic missile defense system, known as the Strategic Defense Initiative, could have 40 million to 100 million lines of code.

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## Defense Has Not Tracked Embedded Software Costs

Despite its increasing importance, Defense has not tracked embedded software costs and therefore does not know how much it spends on this critical technology. Estimates of total 1992 software expenditures range from \$24 billion to \$32 billion, or approximately 8 to 11 percent of Defense's budget. However, these estimated costs are for developing and maintaining software for all Defense systems, including embedded, command and control, and automated information systems. Estimates also indicate that total annual software costs could increase to about \$50 billion in the next 15 years, eventually accounting for almost 20 percent of Defense's overall budget. While these estimated software costs are significant by themselves, they are dwarfed by the billions of dollars being invested by Defense in the weapons systems that depend so heavily upon the software.

This estimate of annual software costs is not, however, well-supported. The cost estimates were not generated by Defense statistics, but rather by external sources, such as trade associations and defense media. According to both senior Defense information technology officials and these external sources, the estimates were not developed using actual software cost data. For example, information used to develop the software cost estimates was generally drawn from budget projections and trend analyses, which were often based on insufficient or incomplete information. In addition, these total software cost estimates do not separate embedded software costs from total weapon system costs.

It is important that Defense track its software costs because of the billions of dollars involved. Good cost data are needed to assess and help manage software expenditures, as well as to help develop more effective software metrics<sup>1</sup> for future software cost estimating. Moreover, Defense's prediction that software costs will increase dramatically over the next 15 years underscores the need to obtain as much reliable data as possible.

Defense has not tracked embedded software costs in the past because, in most cases, software has not been managed as a discrete item. Weapons systems programs and contractors have not been required to separately identify and report software costs because the work breakdown structure<sup>2</sup> and cost accounting for weapons systems make it difficult to separately identify software costs. Furthermore, Defense does not have a focal point to plan and manage software issues including costs. Consequently, there is no Defense repository for collecting and analyzing overall embedded software costs. According to Defense officials, software cost information has generally been (1) reported as part of the total system or subsystem in which the software is embedded and (2) available only at the contractor level.

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<sup>1</sup>Software metrics are tools for monitoring and managing software projects. These tools use mathematical models to measure elements of the development process, such as time, cost, and resources. This information allows organizations to better understand and manage the relationships among resource decisions, development schedules, and the cost of software projects.

<sup>2</sup>A work breakdown structure is a description of work tasks that describes the required product, as well as any work that needs to be accomplished to develop the required product.

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## Defense Is Now Acting to Track and Reduce Software Costs

In recognition of the importance of tracking software costs to improve software management, Defense recently revised its policy guidance for acquiring weapons systems. Defense Instruction 5000.2, "Defense Acquisition Management Policies and Procedures," was changed to require that any weapons systems begun after February 23, 1991, should identify and report software costs separate from other costs. The effect of this revision is that embedded software costs will be more visible, since weapons systems contractors will have to provide software cost information as part of the work breakdown structure. The software-intensive Advanced Tactical Fighter program is one of the first weapons systems to require software cost reporting under this guidance.

Defense also recently prepared its "Software Technology Strategy," a long-term strategy intended to cut software costs, reduce software development problems, and use software to increase the capability of mission-critical systems by the year 2000. In its strategy, Defense proposes to take actions to reuse software, avoid expensive rework during development, make software easier to modify once developed, leverage commercial technology, and explore new software engineering techniques. Defense predicts that implementing this plan will cut software life-cycle costs in half, thereby providing savings as well as the means to obtain additional software capability. Defense is currently obtaining public comments on its strategy and hopes to issue a final version by the end of 1992.

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## Observations

Software has become one of the most critical and expensive elements of today's weapons systems, yet Defense has only recently begun to track these software costs. We believe Defense cannot effectively manage its weapons programs unless it separately identifies, tracks, and manages software as a discrete item. Defense's new requirement that weapons programs report software costs separately is a step in the right direction. However, most weapons system programs do not report software costs because they began prior to implementation of the new policy.

Until more complete embedded software cost information is collected, Defense will not accurately know how much it is spending on this critical technology area. More importantly, greater visibility of software costs is essential for effective management of expensive weapons systems development programs. As Defense improves its collection of basic embedded cost data, it should be able to use these data to more effectively estimate and control software costs. In addition, reliable software cost

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information should support better decision-making, software risk control, and improve management of weapons systems development programs.

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We performed our work in accordance with generally accepted government auditing standards between February 1992 and June 1992. We did not provide a draft of this report to the Department of Defense for its review and comment. Instead, we discussed the draft report's contents with senior Defense information technology officials and have incorporated their views as appropriate. These officials generally agreed with the facts and observations in this report.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the Chairmen of the Senate and House Appropriations Committees; the Chairman of the Senate Armed Services Committee; the Secretaries of Defense, the Air Force, the Army, and the Navy; and the Director, Office of Management and Budget. We will also make copies available to others upon request.

If you have any questions about this report, please contact me at (202) 512-6240. Other major contributors are listed in appendix II.

Sincerely yours,



Samuel W. Bowlin  
Director, Defense and Security  
Information Systems

# Briefing Charts

GAO Information Management  
and Technology Division

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## **Embedded Computer Systems: Defense Does Not Know How Much It Spends on Software**

Presented to the  
Subcommittee on Research  
and Development, House Armed  
Services Committee



## GAO Objectives

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- Determine if Defense knows how much it spends on embedded software
- Examine what Defense is doing to track/reduce software costs

## GAO Points for Discussion

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- Embedded software is critical to weapons systems
- Defense demand for software continues to grow
- Embedded software costs are not tracked
- Actions being taken to track/reduce software costs
- Observations

## GAO Embedded Software Is Critical to Weapons Systems

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- Performs critical functions such as
  - Navigation
  - Enemy detection
- Offers flexibility to change weapon capability, e.g., Patriot
- Can replace costly manpower

## GAO Defense Demand for Software Continues to Grow

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- 1960s F-4: almost no computer code
- 1970s F-14: 32K lines
- 1980s C-17: 1.3M lines
- 1990s ATF: 7M lines
- 1990s SDI: 40-100M lines

## GAO Embedded Software Costs Are Not Tracked

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- No reliable embedded software costs
- No one responsible for collecting software costs
- Rough estimates place total annual software costs at \$24 billion to \$32 billion

## GAO Embedded Software Costs Are Not Tracked (cont.)

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- Total software costs are about 8-11% of Defense budget; may reach 20% by 2008
- Embedded software not managed as a discrete item

**GAO** Embedded Software Costs  
Are Not Tracked (cont.)

- Defense needs good software cost data to
  - Assess and help control software expenditures to avoid costly overruns
  - Help develop effective software metrics for future estimates

## GAO Actions Being Taken To Track/Reduce Software Costs

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- New Instruction 5000.2 requires reporting of software costs
- Defense Software Technology Strategy aims to reduce cost
- ATF is one of the first weapon systems to require software cost reporting



## GAO Observations

- Defense does not know how much it spends on software
- Difficult to manage what cannot be measured
- Defense needs reliable software cost data to effectively manage weapons programs

# Major Contributors to This Report

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