GAO

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

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EMBEDDED COMPUTER SYSTEMS

Software Development Problems Delay the Army's Fire Direction Data Manager

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

Dear Mr. Chairman:

At your request, and as part of our overall evaluation of the Department of
Defense's development of embedded computers, we are providing this
report on the Army's development of the Multiple Launch Rocket System's
(MLRS) Fire Direction Data Manager (FDDM). FDDM is being developed to
provide communications, data processing, and fire direction capabilities
for a group of munitions fired from the MLRS launcher. Our objectives in
this review were to determine the types and causes of software
development problems and examine the program's status and current
Army efforts to address the problems. A detailed discussion of our
objectives, scope, and methodology is contained in appendix I.

Results in Brief

Due to software development problems, FDDM software is not complete,
the prime contractor's development costs have tripled from $8 million to
over $24 million, and the program is more than 2 years behind schedule.
Existing software problems that need to be corrected before FDDM is
deployed could push costs and completion dates even further from original
projections.

FDDM has experienced development problems largely because the Army did
not adequately define initial requirements for the system or promptly
enforce the Defense software standard for technical reviews of software. In
addition, the Army's contractor did not develop and use a software
development plan, and some of its testing was unrealistic and superficial,
which added to software development delays.

The Army plans to integrate FDDM's functions into a new Army command
and control system. However, the Army has just begun to coordinate this
integration effort and does not yet have a detailed strategy for
accomplishing this goal. Such a strategy is needed so that (1) optimal use
can be made of FDDM software during the integration process; (2) effective
coordination procedures can be established among responsible Army

Army's plan is to integrate the completed FDDM software with AFATDS software to the extent possible; when this effort is completed, AFATDS will replace FDDM.

FDDM is comprised of two major computers, auxiliary hardware items, and associated software. The communications and data processing functions are implemented on one computer that will provide (1) automated communications with other battlefield systems such as radar and data distribution systems, and (2) data-processing capabilities to perform such functions as tracking weapons inventories, scheduling missions, and other battlefield tasks. The other major FDDM computer is the fire direction computer, which will be used to provide an operator interface and maintain data on fire unit status and assignments. FDDM's auxiliary components include a power unit, software program loading unit, printer, and secure communication device. Figure 1 shows the FDDM configured in an M-577 tracked vehicle. Figure 2 shows how FDDM fits into Army battlefield command and control.

Figure 2: FDDM Battlefield Orientation
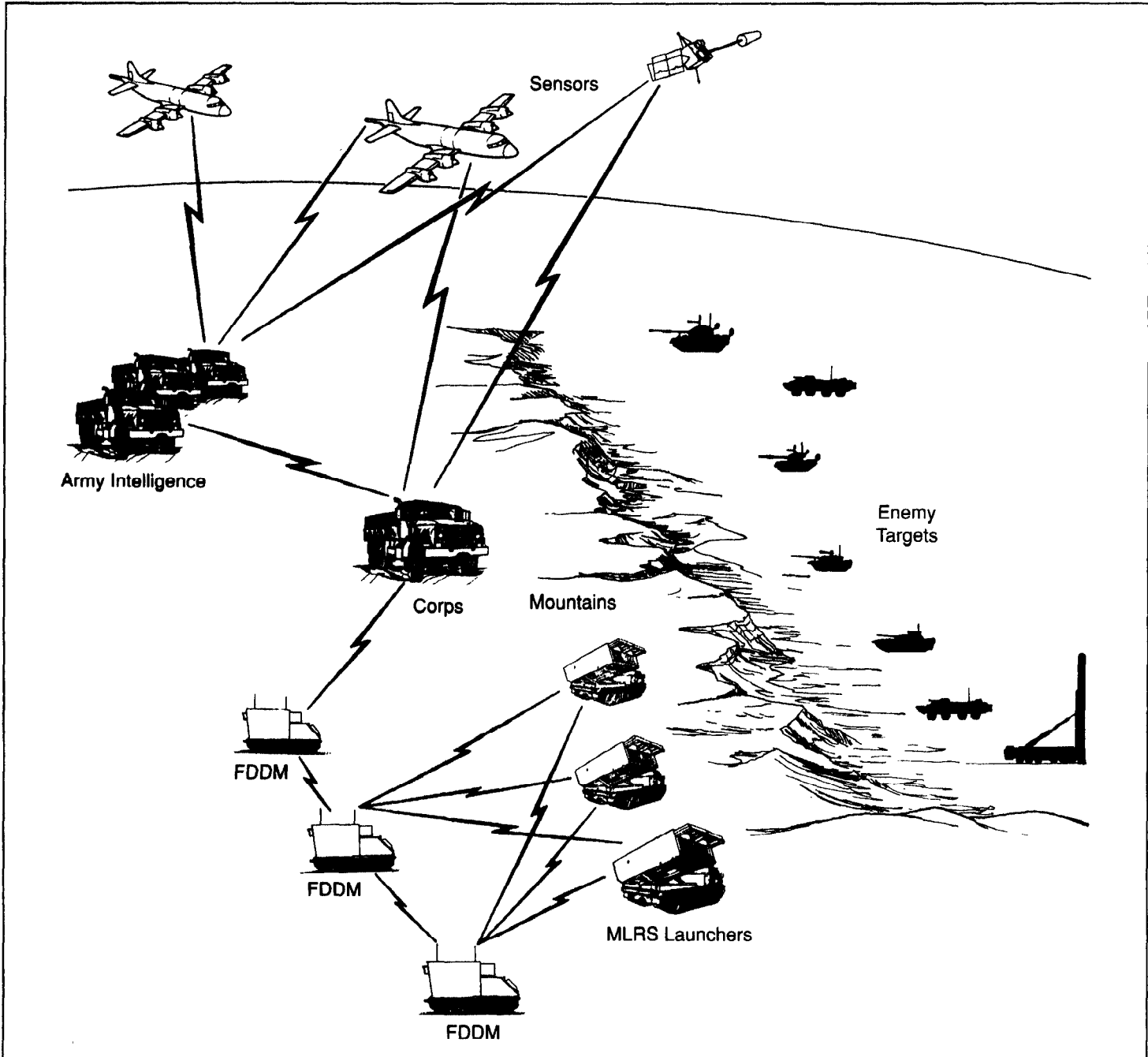
Note: The Army obtains data on enemy targets from sensors such as aircraft and satellites. This information is sent to Army intelligence and corps units, that in turn transmit it to FDDMs located in the field. The FDDMs then provide targeting and firing information on these targets to the MLRS launchers.
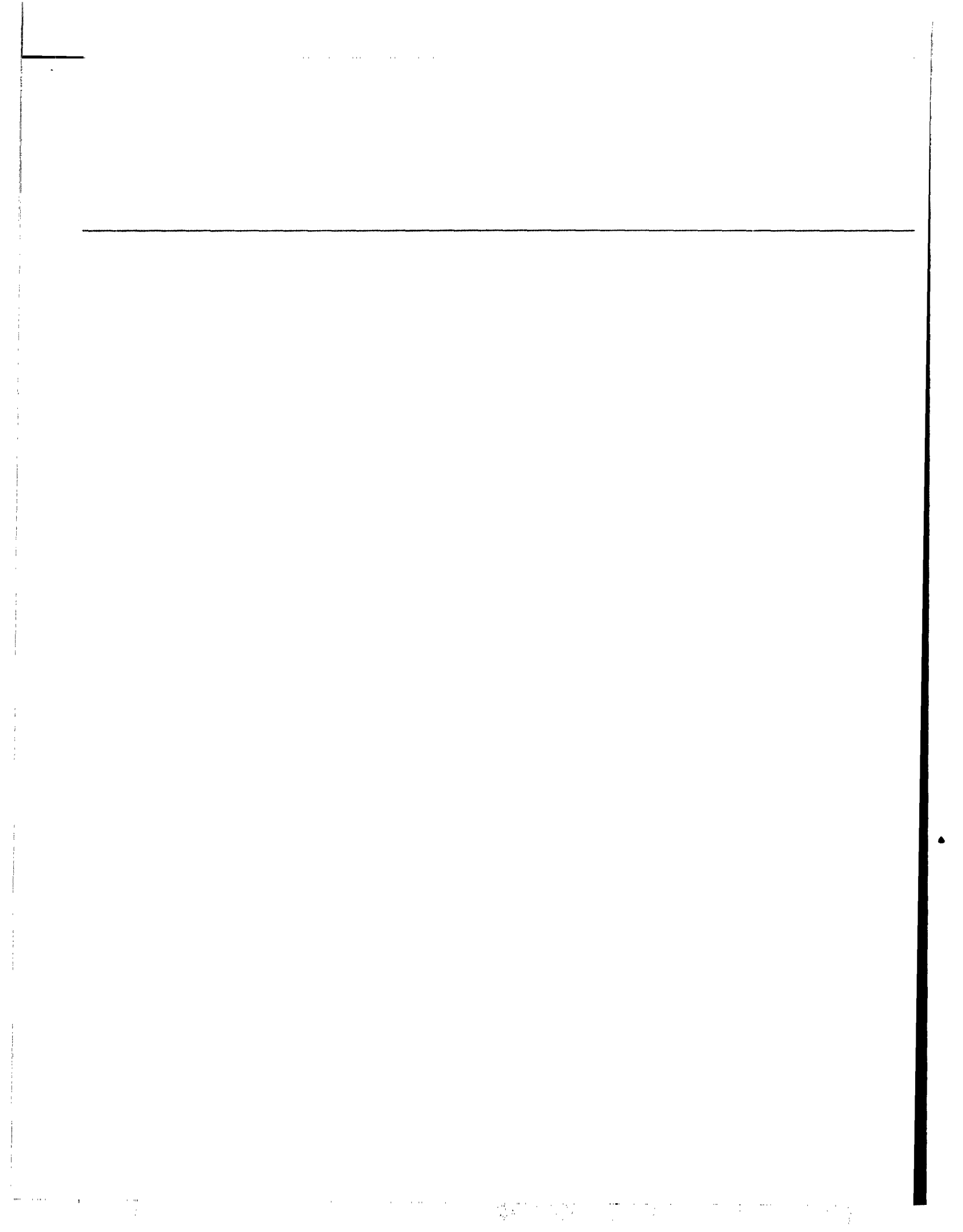
offices; and (3) specific time frames for the integration effort can be developed.

Background

MLRS was originally designed as a self-propelled launcher capable of firing up to 12 rockets in air defense and artillery-defeating roles. In 1985 the Army decided to increase the MLRS' utility by firing missiles as well as rockets. The Army Tactical Missile System, which was then under development, was intended to be the first missile to use the MLRS launcher. However, the existing MLRS fire direction system could not provide the additional communications and data processing capabilities that the missile required. The Army decided to provide those capabilities through a new system already under development, the Advanced Field Artillery Tactical Data System (AFATDS), scheduled to be ready when the Army Tactical Missile was deployed in 1990. The Army expects to use AFATDS as its new automated command and control system for Army fire support functions, including automated support for tactical air, naval gunfire, mortars, attack helicopters, air defense, and tanks. However, AFATDS was not going to be ready in time to support the Army Tactical Missile operational testing, scheduled to begin in 1989. Consequently, the Army decided to develop FDDM as a test device to provide the capabilities needed for the operational tests and then use AFATDS to support the missile system when it was deployed.

The Army contracted in March 1986 for development of the hardware and associated software needed for FDDM. However, in 1987 the Army delayed the AFATDS deployment date until 1993,[1] which meant that AFATDS would not be ready to support deployment of the Army Tactical Missile. As a result, the Deputy Chief of Staff for Operations directed the Army to plan to deploy a limited number of FDDMs to support the Tactical Missile deployment, thereby changing FDDM from a test device to a fielded system.

Current plans are for FDDM to serve as the command and control system only for the Army's MLRS. The Army is continuing to develop and test FDDM and through 1991 has spent about $50 million on FDDM development. FDDM is scheduled to be deployed in 1993, and the Army plans to incorporate its capabilities into AFATDS beginning in fiscal year 1994. The

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[1]According to Army plans, AFATDS will be deployed in several versions. The first version of AFATDS is expected to be deployed in 1994, and will provide communications and command support for several weapons systems, but not MLRS. AFATDS will support MLRS when FDDM is integrated into the system that is expected to be deployed in 1997.

Figure 1: FDDM In M577

Major Components

Auxiliary Components
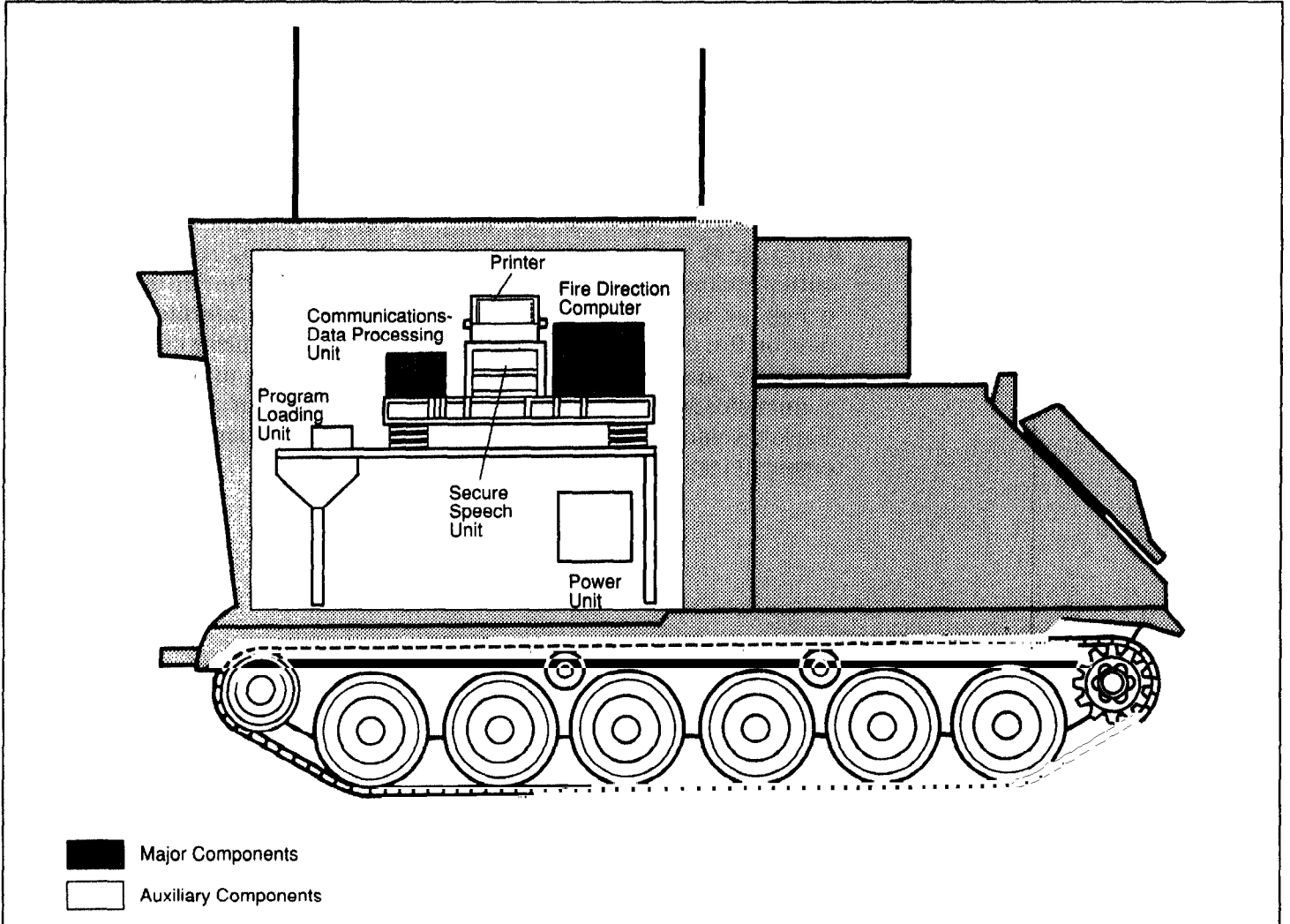
FDDM Experiencing Software Development Problems, Cost Increases, and Schedule Delays

The Army's FDDM development effort has encountered a number of problems since 1986 and still has software problems that must be corrected before the system is deployed. The prime contractor's costs have tripled from about $8 million to about $24.5 million; the Army has also spent $25 million on other contracts for services such as testing and engineering assistance. FDDM's deployment schedule has also slipped several times, and was recently moved from January 1993 to June 1993.

Software Development Problems

FDDM has had a history of software development problems. FDDM was originally developed to support the Army Tactical Missile operational tests. However, it failed a critical field test in 1989—its communications software would not work and had to be rewritten and its data-processing software was not completed in time to be used in the field test—and it was unable to support the missile's operational tests held later that year. As a result, the Army modified the operational tests to exclude FDDM and instead tested the Army Tactical Missile using the existing MLRS fire direction system and manual support.

In March 1991, preliminary integration testing was performed on updated data-processing software. However, the software was still incomplete. It could not run the approved test procedures and had to be modified before testing could be resumed. In July 1991, the Army had to cancel this testing because the fire direction system did not have the capacity to handle high volumes of messages, and the system would therefore shut down.

Another problem was the system's inability to keep its fire direction and data-processing data bases synchronized. The fire direction data base contains some of the same information as the data base in the communications-data processing computer. It is essential that all updates to the fire direction data base be automatically communicated to the communications-data processing data base so it keeps current and accurate data. Without data base consistency, the system does not have accurate data on necessary items such as launcher status and assignments.

In February 1992, the FDDM product manager told us that a December 1991 Army software integration test indicated that most of FDDM's software problems had been corrected and that remaining FDDM tests could continue. We reviewed the test report, and it showed that FDDM still experienced significant problems during this test. For example, problems with the data processing unit caused the system to shut down on a number of occasions. Another problem was that during periods when high firing

rates were required, FDDM experienced communications bottlenecks due to the large number of messages being transmitted. During these situations, FDDM could not function as rapidly as required. According to the current FDDM product manager, the Army is currently trying to correct the remaining software problems.

Project Costs Have Risen

Costs to develop FDDM have increased from an original estimate of about $8 million in 1986 to a current estimate of about $50 million. Because the original FDDM contract did not require separate identification of software development costs, it is difficult to estimate exact costs or cost growth. However, the Army estimates that original contract costs have increased from $8 million to about $24.5 million, with most of these increases due to added requirements. In addition, the Army has spent another $25 million beyond its original estimate to contract for services such as engineering assistance, and independent verification and validation.

Schedule Has Been Delayed and Deployment Is Uncertain

The Army began developing hardware and software for FDDM in 1986. FDDM was expected to be ready by 1989 to support operational tests for the Army Tactical Missile System. Because FDDM was behind schedule, the Army could not use it to support these tests. Consequently, the missile system was fielded in 1990 without FDDM. The missile system can function without FDDM, but lacks processing capacity when the missile must be fired rapidly. By 1990, FDDM's planned deployment had been delayed until January 1993. The contractor delivered communications software in May 1991, but due to software problems the Army postponed the delivery date for the data-processing software until May 1992. Without the data-processing software, FDDM is not functional. As of April 1992, FDDM was still undergoing development and testing, and the Army had delayed FDDM deployment from January 1993 to June 1993.

In August 1991, the FDDM product office, which is responsible for developing FDDM, directed another Army organization, the Ft. Sill Center for Software Engineering, to manage the effort to resolve FDDM's remaining software problems. This organization, however, is not using the original FDDM contractor and has brought in another contractor. The new contractor is familiar with some of the FDDM system but will have to learn how all the FDDM components work together before solving FDDM's software problems. Learning how the complete system works, correcting existing problems, and completing FDDM testing may affect FDDM's deployment schedule.

FDDM Software Development Effort Poorly Managed

Many of FDDM's problems have occurred because the Army did not effectively manage the FDDM software development effort. Specifically, it did not provide detailed requirements in the original 1986 contract or promptly enforce Defense standards for software development, and it continued to add functional requirements that further delayed development. The contractor added to these development problems with poor testing in some areas.

Functional Requirements Not Well-Defined or Controlled

The Army did not provide detailed functional requirements in the original 1986 contract. These requirements should be defined very early in the development process and in sufficient detail to (1) ensure that the military service and contractor know what the system is supposed to do, and (2) prevent unnecessary and unstructured changes. According to the contractor software development manager, this lack of specific requirements has been the major problem with FDDM development. The initial requirements were so brief and vague that the Army had to redefine the functions it wanted FDDM to perform before software could be developed. It took almost 14 months after the contract was awarded to finalize the functional requirements.

Between 1986 and 1991, the Army added more requirements, which led to the need for additional software to be designed and developed, principally to allow FDDM to support additional weapons systems. Even after the contractor began the initial system testing in late 1991, the Army has continued to add FDDM requirements. These new requirements include changing software and increasing data base sizes so FDDM can handle more messages and schedule different missions.

Adding requirements this late in a development effort can complicate and delay delivery of the software. The first FDDM product manager agreed that the additional requirements caused delays in the development schedule.

Defense Standards Not Enforced

The Army required the contractor to follow Defense Standard 1521 during the FDDM software development effort,[2] but did not promptly enforce its provisions. The standard requires a contractor to define, from the

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[2]"Technical Reviews and Audits for Systems, Equipments, and Computer Software," June 4, 1985.

functional requirements, a software requirements baseline[3] early in the development effort so the Army can determine, during the software specification review, whether the contractor understands the system software requirements. Failure to establish a stable requirements baseline early increases the risk of unnecessary rework, i.e., if the contractor does not understand the requirements or if requirements changes are not controlled, additional effort will be spent continually changing the software. However, the Army did not hold a specification review for FDDM and did not approve a baseline of system software requirements until 1989, about 3 years after work began. This allowed the Army to increase requirements without the controls established by an approved baseline.

Guidance on development of military software is also provided in Defense Standard 2167.[4] Among other things, it requires creation of a detailed software development plan to guide software development. A software development plan establishes the complete process that the contractor will use in developing the software. The process includes a methodology for building quality into the software and its documentation, as well as guidance for sustaining quality throughout the software's life cycle. Without the discipline provided by a detailed software development plan, it is more difficult to develop software-intensive systems effectively. Without a plan it is also difficult to ensure that requirements growth is controlled, that software designs are approved before coding begins, that software standards are identified and adhered to, that comprehensive tests are conducted, and that documentation is complete.

However, the Army's contractor did not develop or use a detailed software development plan as a guide to develop the software. The contractor did produce a computer program development plan that the FDDM product office believes served the same purpose as a software development plan. However, the brief portion of this document relative to FDDM does not provide sufficient guidance on matters such as determining when system design and development are mature enough to proceed to the next phase, which tests need to be conducted and when, and how to evaluate test results.

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[3]A baseline is a set of documents that formally identifies the technical requirements for hardware or software at a point in time. A baseline, plus changes to the baseline, provides a method of documenting changes in requirements.

[4]"Defense System Software Development," June 4, 1985.

Contractor Testing Deficiencies	The contractor's initial communications testing was inadequate and, as a result, development was delayed because a number of problems were not detected until later in the development process. For example, the contractor did not include tests that realistically represented the environment in which the system would be used. The communications software was tested using only cable links between system components, even though the system, when deployed, will use radio communications, not cables. Consequently, the testing did not disclose problems that occurred when radio links, which are subject to interference, were used. The problems caused a test failure, and consequently FDDM was not able to support the Army Tactical Missile System operational tests. The contractor's test manager agreed that the test procedures were unrealistic.

In addition, in 1991 the independent verification and validation agent evaluated the contractor's test procedures and concluded that they would not thoroughly test FDDM communications software. The contractor initially refused to change its test procedures and conducted the tests as planned. As a result of the independent agent's complaints about the test procedures, the Army subsequently required the contractor to conduct more extensive and thorough tests. These tests found 89 software problems that the earlier limited testing had not detected and proved, according to the verification and validation agent, that the contractor's initial testing had been inadequate.

FDDM-AFATDS Integration Effort

The Army is still developing and testing FDDM software, and is also planning the integration of FDDM into AFATDS. The Army expects to deploy FDDM in 1993, start the integration in 1994, and complete integration in 1997. However, the Army has not yet begun developing a detailed strategy for accomplishing this transition. Such a strategy is needed to determine how much FDDM software will be compatible with AFATDS and how much new software will have to be written.

The FDDM product office and Field Artillery Tactical Data System (FATDS) project office agreed in 1990 to jointly develop policies to ensure a smooth transition from FDDM to AFATDS and to coordinate program plans, budgets, and schedules. The 1990 agreement established broad guidelines and responsibilities but did not provide details on how to resolve potential disagreements or accomplish the integration. The agreement also noted that the integration would only utilize FDDM software to the extent that it is cost-efficient to do so. However, it was not until January 1992 that FDDM product office personnel began meeting with FATDS project office

personnel to discuss the integration effort. The two offices have since established working groups to begin exploring how FDDM functionality could be used in AFATDS.

Conclusions

The Army's failure to follow required software development procedures has resulted in cost increases and schedule delays. Further, the Army's December 1991 software integration test report showed that FDDM still has software problems. In addition to these problems, a change in software developers and new FDDM requirements may affect the planned June 1993 deployment of FDDM. Since AFATDS will replace FDDM in 1997, any further delays will limit FDDM's useful life. Meanwhile, the Army has just begun to coordinate the integration of FDDM functions into AFATDS and does not yet have a detailed strategy to accomplish this task.
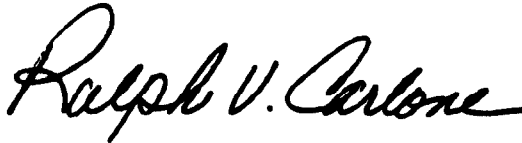
Recommendations

We recommend that the Secretary of the Army ensure that the FATDS project office develop a detailed strategy for incorporating FDDM into AFATDS. In developing its strategy, the Army should assess the impact of any further software development delays on FDDM's usefulness, considering its limited life cycle. The strategy should at a minimum (1) provide direction for determining how much, if any, of the FDDM software can be used in AFATDS; (2) establish clear lines of authority and accountability between the FDDM and FATDS offices for making decisions and resolving problems; and (3) provide specific milestones for actions to accomplish the transition.

We conducted our review in accordance with generally accepted government auditing standards, between October 1990 and April 1992. As requested, we did not provide a draft of this report to the Department of Defense for its review and comment. Instead, we discussed the report's facts with representatives from the Army and the Office of the Secretary of Defense, including the FDDM Product Manager, the lead FDDM software engineer, and the AFATDS Product Manager, and have incorporated their views as appropriate. These representatives provided information to support their view that while the FDDM program has experienced problems, the Army has taken action to overcome these problems. We have evaluated this information and agree that while the Army has taken steps to solve FDDM's problems, these steps have not sufficiently resolved the issues discussed 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 and the Army; and the Director, Office of Management and Budget. We will also make copies available to others upon request. This report was prepared under the direction of Samuel W. Bowlin, Director, Defense and Security Information Systems, who can be reached at (202) 512-6240. Other major contributors are listed in appendix II.

Sincerely yours,

Ralph V. Carlone
Assistant Comptroller General

Objectives, Scope, and Methodology

In its report on Defense's fiscal year 1991 authorization bill, the House Armed Services Committee requested that GAO review computer systems that are embedded in Defense weapons systems. This report responds to the January 1991 request by the Subcommittee on Research and Development to review the Army's development of software embedded in the FDDM command and control system and associated MLRS components. Our objectives were to determine the types and causes of software development problems being encountered in FDDM, and examine the program's status and current Army efforts to address these problems.

We performed our work at the U. S. Army Missile Command, Redstone Arsenal, Alabama; U. S. Army Communications-Electronics Command, Fort Sill, Oklahoma; U. S. Army Communications-Electronics Command, Fort Monmouth, New Jersey; Program Executive Office, Command and Control Systems, Fort Monmouth, New Jersey; LTV Corporation, Grand Prairie, Texas; Operational Test and Evaluation, Office of the Secretary of Defense, Washington, D.C.; and the U. S. Army Field Artillery Fire Support Office, Deputy Chief of Staff, Washington, D.C. For most locations visited, we interviewed program officials and reviewed relevant program documents and records. The views of program management officials have been incorporated, where appropriate, throughout this report.
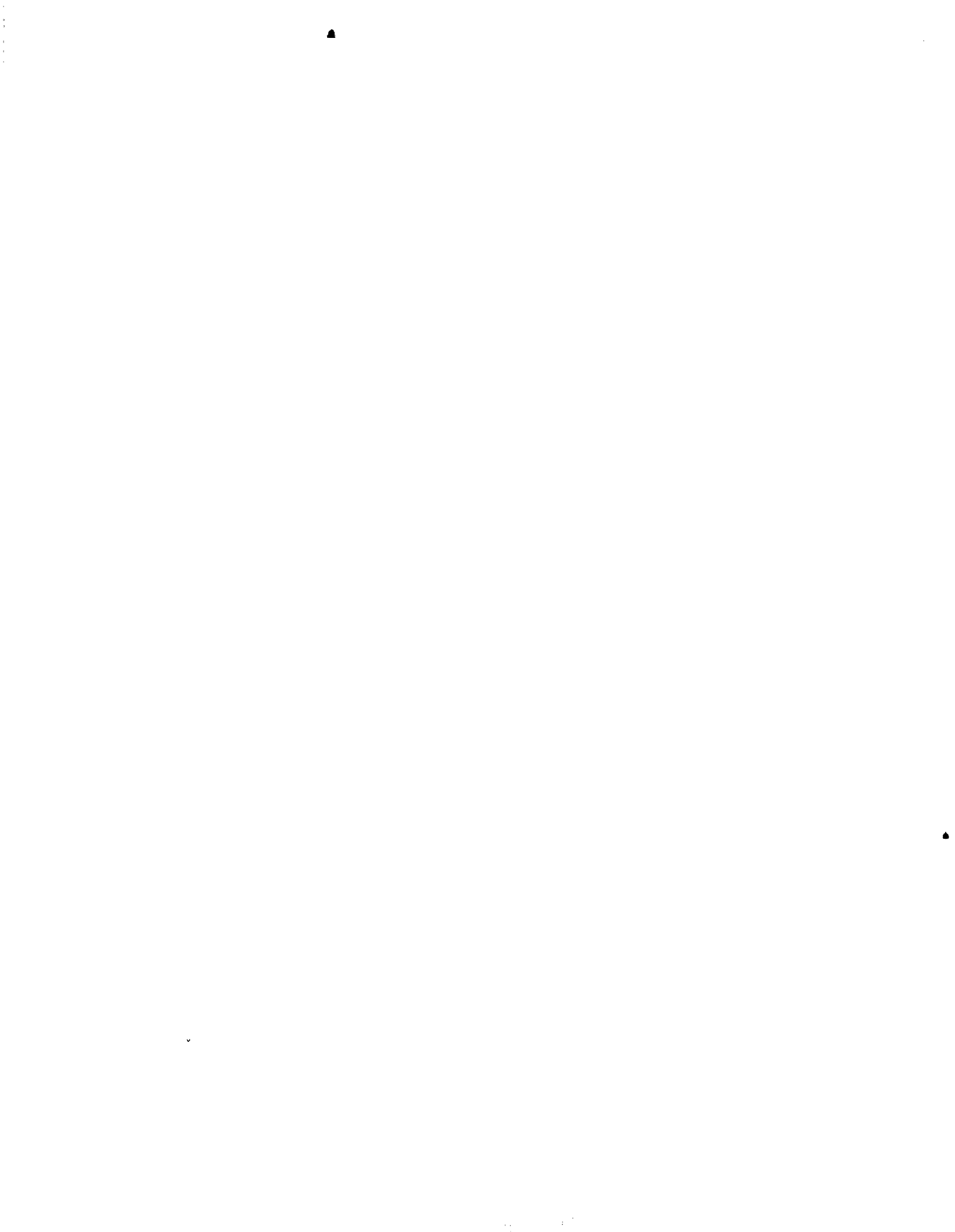
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