OFFICE OF THE INSPECTOR GENERAL

EFFECTIVENESS OF PROTOTYPING ACQUISITION STRATEGIES FOR MAJOR DEFENSE ACQUISITION PROGRAMS

Report No. 94-181 September 2, 1994

Department of Defense

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Acronyms

API	Acquisition Program Integration
ARPA	Advanced Research Projects Agency
BAT	Brilliant Anti-Armor Submunition
EMD	Engineering and Manufacturing Development
EOA	Early Operational Assessment
FDS	Fixed Distributed System
IDA	Institute for Defense Analysis
JSOW	Joint Standoff Weapon System
LRIP	Low-Rate Initial Production
MDAP	Major Defense Acquisition Program
OPTEVFOR	Operational Test and Evaluation Force
OSD	Office of the Secretary of Defense
TEMP	Test and Evaluation Master Plan
USD(A&T)	Under Secretary of Defense for Acquisition and Technology
UTTMDS	Upper Tier Theater Missile Defense System

INSPECTOR GENERAL
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September 2, 1994

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION AND TECHNOLOGY
DIRECTOR, PROGRAM ANALYSIS AND EVALUATION
DIRECTOR, DEFENSE PROCUREMENT

SUBJECT: The Effectiveness of Prototyping Acquisition Strategies for Major Defense Acquisition Programs (Report No. 94-181)

We are providing this final audit report for your review and comments. It discusses the use of prototyping in the acquisition strategies for major Defense acquisition programs. Comments on a draft of this report were considered in preparing the final report.

DoD Directive 7650.3 requires that all recommendations be resolved promptly. Therefore, we request that the Under Secretary of Defense for Acquisition and Technology and the Director, Program Analysis and Evaluation, provide comments on the unresolved recommendations and internal control weaknesses by November 1, 1994.

We appreciate the courtesies extended to our audit staff. If you have questions on this audit, please contact Mr. John Meling, Program Director, at (703) 604-9090 (DSN 664-9090) or Mr. Harold James, Project Manager, at (703) 604-9093 (DSN 664-9093). Appendix L lists the distribution of this report. The audit team members are listed inside the back cover.

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Report No. 94-181 **September 2, 1994**
(Project No. 2AE-0051)

THE EFFECTIVENESS OF PROTOTYPING ACQUISITION STRATEGIES FOR MAJOR DEFENSE ACQUISITION PROGRAMS

EXECUTIVE SUMMARY

Introduction. A prototype has traditionally been defined as a model upon which a later item is formed or based and which provides a basis to test new types of equipment before large-scale use of resources. Prototypes are developed and tested to reduce technical risk in weapons system development by providing information on the feasibility of planned system concept and design, as well as expected operational effectiveness and suitability. Prototypes should be used early in the acquisition process, with a prototyping strategy established at the Milestone I, Concept Demonstration Approval, and executed during Phase I, Demonstration and Validation. Use of prototypes allows the Government to delay major funding commitments until system design is more advanced and risk is reduced. A prototype is not normally a complete system but is designed to focus on the areas of highest technical risk. Numerous reviews of the DoD acquisition process have advocated prototyping.

Objectives. The primary objective of the audit was to evaluate the effectiveness of DoD's use of prototyping acquisition strategies for major Defense acquisition systems and critical subsystems. We also evaluated the internal controls associated with the prototyping process.

Audit Results. The use of prototyping for major Defense acquisition programs has increased over the last 7 years. Noteworthy examples of prototyping included the Upper Tier Theater Missile Defense System and the Air Force F-22 Aircraft Program. However, further improvement was needed. Prototyping could be used more effectively in the acquisition strategies for major Defense acquisition programs to identify and reduce risk and to assess whether the most promising design approaches will operate in the intended operational environment before proceeding with Phase II, Engineering and Manufacturing Development. The effectiveness of prototyping acquisition strategies for five of the six programs reviewed was impeded by a lack of a properly structured planning and decisionmaking process for balancing cost, schedule, and technical risk and by noncompliance with existing regulations. As a result, DoD incurred increased risk of committing system designs to engineering and manufacturing development when feasibility of the designs and their ability to meet mission needs had not been sufficiently demonstrated.

Internal Controls. Internal controls and the implementation of the DoD Internal Management Control Program were not effective to identify material internal control weaknesses. Office of the Secretary of Defense and Military Department directives and instructions provided only limited guidance regarding the use of prototyping. Guidance was needed for formulation and execution of effective prototyping strategies. These internal control weaknesses are discussed in Part I of this report.

Potential Benefits of the Audit. Implementing the recommendations in this report will ensure that programs progress to Phase II, Engineering and Manufacturing Development, only when prototyping and demonstration processes provide reasonable

assurance that the technologies and processes critical to success are attainable and affordable. Monetary benefits to be realized by implementing the recommendations should occur from reduced future program growth. However, the benefits were not readily quantifiable since they impact future programs transitioning from Phase I, Demonstration and Validation, to Phase II, Engineering and Manufacturing Development. Appendix J notes the potential benefits to be derived from implementing the recommendations.

Summary of Recommendations. We recommend that the Under Secretary of Defense for Acquisition and Technology improve the planning process for use of prototyping in acquisition strategies and the management of prototyping programs to ensure readiness for the transition into Engineering and Manufacturing Development. We also recommend that the Director, Program Analysis and Evaluation, determine whether proposed prototyping plans will adequately support analyses of operational efficiency and costs.

Management Comments. The Director, Acquisition Program Integration, provided management comments to the draft report for the Under Secretary of Defense for Acquisition and Technology. The Director concurred with our finding but nonconcurred with the majority of our recommendations involving revisions of existing policy related to the use of prototyping. The Director, Program Analysis and Evaluation, nonconcurred with the finding but did not provide specific comments to our recommendation for him. The Director, Defense Procurement, nonconcurred with our recommended revision of the Defense Federal Acquisition Regulation Supplement to provide for contractor input to prototyping plans. However, she proposed alternative corrective actions that would require implementation by the Under Secretary of Defense for Acquisition and Technology. Part II contains a discussion of management's comments to the report. Part IV contains the complete texts of comments from the Director, Acquisition Program Integration; the Director, Program Analysis and Evaluation; and the Director, Defense Procurement.

Audit Response. We revised five recommendations in response to comments provided by the Director, Acquisition Program Integration. Additionally, we revised and redirected a recommendation concerning contractor input to proposed prototyping plans to the Under Secretary of Defense for Acquisition and Technology rather than the Director, Defense Procurement, based on management comments. We stand by all other recommendations as written. We believe the general comments provided by both the Director, Acquisition Program Integration, and the Director, Program Analysis and Evaluation, as well as the comments to many individual recommendations show a misunderstanding of both the content and intent of our draft report. In our audit responses, we provided additional information and clarification. We request that the Under Secretary of Defense for Acquisition and Technology and the Director, Program Analysis and Evaluation, reconsider their positions on the nonconcurrences and provide additional comments to the final report by November 1, 1994.

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This report was prepared by the Acquisition Management Directorate, Office of the Assistant Inspector General for Auditing, Department of Defense.

Part I - Introduction

Background

Prototyping. A prototype has traditionally been defined as a model on which a later item is formed or based that is used to test new types of equipment. Prototyping helps to reduce technical risk in developing weapon systems by answering three questions:

- o Is the concept feasible?
- o Does the design work the way it is supposed to work?
- o Does the system provide a useful military capability?

A prototype is not normally a complete system in the sense of being deployable to operational forces. Rather, prototypes should be designed to focus on the areas of highest risk that are essential to mission success.

While prototyping requires initial time and money, the Government can delay major funding commitments until design and development are more advanced and risk is reduced. In recent years, prototyping has received increased attention due to decreasing DoD budgets.

Acquisition Regulations. DoD Instruction 5000.2, "Defense Acquisition Policies and Procedures," February 23, 1991, identifies prototyping as a major element of Phase I, Demonstration and Validation, to use in assessing and reducing the risks from integrating available and emerging technologies to satisfy a valid mission. The Instruction provides the following guidance:

- o Requirements for prototyping are established at Milestone I, Concept Demonstration Approval.
- o Prototyped technologies include hardware, software, and manufacturing processes.
- o Prototyping is differentiated from the advanced technology demonstrations that may occur before Milestone I, Concept Approval, on a major Defense acquisition program (MDAP):
  - o Advanced technology demonstrations assess the military utility of innovative technologies and focus on validating the viability, utility, and producibility of a technology.
  - o Prototyping involves the development and demonstration of a system or a subsystem or component of that system to meet a specified mission requirement.

- DoD Instruction 5000.2 requires competitive prototyping of systems or critical subsystems unless the milestone decision authority issues a specific waiver.

Objectives

Our overall objective was to evaluate the effectiveness of DoD use of prototyping acquisition strategies for major Defense acquisition systems and critical subsystems. We also evaluated the internal controls associated with prototyping. The audit is one of a series of reviews to assess implementation of recommendations in the Packard Commission Report that the Secretary of Defense submitted to the President in June 1986.

Scope and Methodology

To satisfy our objectives, we evaluated the use of prototyping for six MDAPs that were in either in Phase I, Demonstration and Validation, or had completed Demonstration and Validation and began Phase II, Engineering and Manufacturing Development (EMD), since September 1989. Those programs were judgmentally selected from the universe of programs meeting the criteria for MDAPs established in DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures." Programs were selected from the Office of the Secretary of Defense (OSD) as well from the Army, Navy, and Air Force:

- OSD:

  Upper Tier Theater Missile Defense System (UTTMDS)

- Army:

  Comanche Helicopter

  Brilliant Anti-Armor Submunition (BAT)

- Navy:

  Joint Standoff Weapon System (JSOW)

  Fixed Distributed System (FDS)

- Air Force:

  F-22 Aircraft

We also performed limited examinations of three other programs: Army Tactical Missile, Navy F/A-18 E/F Aircraft, and Air Force Joint Surveillance and Target Attack Radar System. Audit work on the Army Tactical Missile and the Joint Surveillance and Target Attack Radar System, both of which had began Phase II, EMD, by February 1986, only evaluated the role of the Advanced Research Projects Agency (ARPA) in prototyping. Those programs were selected because they were latest examples of ARPA involvement in a MDAP during Phase I, Demonstration and Validation. Audit work on the F/A-18 E/F Aircraft program was limited to a review that validated the Navy's decision not to use prototypes because the program was not high risk in terms of concept, design, performance, or operational suitability.

We examined information in acquisition plans, operational requirements documents, contract files, test and evaluation master plans, developmental and operational test assessments and reports, and technical reviews and audits performed to support start and progression through Phase I, Demonstration and Validation, and transition to Phase II, EMD. We interviewed personnel responsible for program management, procurement, testing, and contract administration, as well as contractor personnel, to determine and evaluate the policies and procedures followed in the prototyping process. We examined the program information provided to senior acquisition management in the Defense Acquisition Executive Summary Report and other reports. We also assessed support for waiving programs from the requirements for competitive prototyping, risk reduction efforts in programs where prototyping was not used or planned, and use of test and evaluation of prototypes to support program transition to Phase II, EMD.

As a supplement to our audit coverage, we surveyed 15 program offices for MDAPs that started after January 1987 to determine the extent to which prototyping has been planned or used since the issuance of the Packard Commission Report in 1986 (Appendix B). To obtain industry perspectives on use of prototypes, we surveyed six contractors who had participated as prime contractors in the development of prototypes of MDAPs during Phase I, Demonstration and Validation. We obtained their input concerning how prototyping can be used most effectively (Appendix C).

The audit began in June 1992 and was suspended in October 1992. Audit work resumed in March 1993 and was completed in February 1994. The audit work included a review of information relating to prototyping dated from December 1984 through February 1994. This program results audit was made in accordance with auditing standards issued by the Comptroller General of the United States, as implemented by the Inspector General, DoD, and included

necessary tests of internal controls. We did not place material reliance on computer-processed data to support the finding and recommendations in this audit report. Appendix K lists the organizations visited or contacted.

Internal Controls

We assessed the internal controls related to the prototyping process. Those controls are specified in DoD Directive 5000.1, "Defense Acquisition," February 23, 1991, and DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures," February 23, 1991. We also assessed implementation of DoD Directive 5010.38, "DoD Internal Management Control Program," April 14, 1987. As part of our evaluation, we assessed:

- o Statutory and DoD regulatory guidance on the use prototyping;
- o Military Department implementing procedures and compliance with regulations; and
- o OSD and DoD Component oversight of the use of prototypes in program acquisition strategies.

The audit identified material internal control weaknesses, as defined by DoD Directive 5010.38, "Internal Management Control Program," April 14, 1987. Guidance for the prototyping process needed improvement to ensure that prototypes were used more effectively in reducing technical, cost, and schedule risk when transitioning from Phase I, Demonstration and Validation, to Phase II, EMD. The Internal Management Control Program failed to detect the internal control weakness because it did not include the prototyping process as an assessable unit. Moreover, the management comments on the draft report indicate that management would not have considered the process to have internal control weaknesses even if a vulnerability assessment had been done.

Implementation of the recommendations in this report will correct those weaknesses. The monetary benefits of implementing those recommendations were undeterminable because the recommendations will impact future programs entering Phase I, Demonstration and Validation, and transitioning to Phase II, EMD. A copy of the report will be provided to the senior officials responsible for internal controls within the Offices of the Secretary of Defense and the Military Departments.

Prior Audits and Other Reviews

Since 1989, the Inspector General, DoD, and the General Accounting Office have each issued three reports addressing issues that relate to the use of prototyping. We identified six other reviews performed by Federally Funded Research and Development Centers and within DoD that made recommendations involving prototyping policies and procedures. Appendix D synopsizes those audits and other reviews.

Part II - Finding and Recommendations

Use of Prototyping in Acquisition Strategies

Prototyping had not been used effectively in the acquisition strategies for major Defense acquisition programs to identify and reduce risk and to assess whether the most promising design approaches will operate in the intended operational environment before proceeding with EMD. The effectiveness of prototyping was impeded because a properly structured acquisition planning and decisionmaking process for balancing cost, schedule, and technical risks at Milestone I, Concept Development Approval, did not exist to determine how prototypes should be used during Phase I, Demonstration and Validation. Effectiveness of prototyping was also impeded by noncompliance with existing regulations and guidance. As a result, the Government incurred the increased risk of committing to EMD before system designs, including critical technologies and manufacturing processes, have sufficiently demonstrated the potential to affordably satisfy mission needs and achieve acceptable operational performance.

Background

Use of prototyping is a critical element in meeting the objectives provided by DoD Instruction 5000.2 for Phase I, Demonstration and Validation, of the acquisition process for MDAPs. Those objectives include supporting Milestone II, Development Approval, through:

o Better defining the critical design characteristics and expected capabilities of the system concept;

o Demonstrating that critical technologies can be incorporated into system designs with confidence; and

o Proving the processes critical to the most promising system concepts are understood and attainable.

DoD Instruction 5000.2 further provides that a program may not enter Phase II, EMD, unless the milestone decision authority confirms, before the Milestone II, Development Approval, that prototyping and demonstration results to date provide reasonable assurance that the technologies and processes critical to success are attainable. DoD Instruction 5000.2 requires that hardware, software, and manufacturing processes be included within the scope of prototyping efforts.

One of the most difficult aspects of planning a prototyping acquisition strategy is determining what should be prototyped. While full system or process prototypes are not warranted in all cases, some level of prototyping would be

beneficial in every MDAP requiring development through the Demonstration and Validation and EMD phases, especially if electronic simulation and design analysis is considered part of the total prototyping effort.

The results of prototyping efforts impact virtually every required document and analysis specified to support a Milestone II, Development Approval, decision. For example, the Cost and Operational Effectiveness Analysis, one cornerstone to acquisition milestone decisions, should be heavily dependent on prototyping results to compare various alternatives for meeting military requirements. DoD Instruction 5000.2 requires that Cost and Operational Effectiveness Analysis be prepared and considered at milestone decision reviews of major Defense acquisition programs, beginning with the Milestone I, Concept Demonstration Approval. At the Milestone II, Development Approval, the Instruction states that the Analysis should typically establish performance floor and cost ceiling objective or acceptable bands for possible combinations of cost and performance. Performance of a Cost and Operational Effectiveness Analysis without the benefit of prototyping results unduly restricts the analysis to stated versus demonstrated system capabilities. Knowledge gained through use of prototyping increases the realism and, thus, the usefulness of the Analysis. The usefulness of other documentation required by DoD Instruction 5000.2 to support Milestone II, such as the Developmental Test and Evaluation Report, the Early Operational Assessment, and Program Life-Cycle Cost Estimate (program manager's estimate of the total cost to the Government for acquisition and ownership of a system over its useful life) would also be enhanced by prototyping experience.

Prototyping efforts require a careful balance of cost, schedule, and technical factors. The knowledge and understanding gained through prototyping experience during Demonstration and Validation provides the foundation necessary for a program to successfully progress through EMD and subsequently to meet prerequisites for transitioning into production provided by DoD Instruction 5000.2; Military Standard 1521B, "Technical Reviews and Audits for Systems, Equipments, and Computer Software"; DoD Standard 2167A, "Defense System Software Development"; and DoD 4245-7-M, "Transition from Development to Production." Appendix E shows how those guidance documents support the transition from development to production. Additional recommended prerequisites are discussed in Inspector General, DoD, Report No. 94-014, "Low-Rate Initial Production in Major Defense Acquisition Programs," November 9, 1993. Because of the relevance of the Low-Rate Initial Production Report, the report recommendations are listed in Appendix D. The recommendations provided by Report No. 94-014 and this draft report, along with existing policies and procedures, constitute a defined process to plan and execute risk-reduction efforts, including the use of prototyping, as programs progress from Milestone I, Concept Demonstration Approval, through the end of low-rate initial production. Appendix F shows the impact of the recommendations in these two reports on the DoD acquisition process as defined by DoD Instruction 5000.2.

Planning and Executing Prototyping Strategies

DoD could improve the planning and execution of prototyping acquisition strategies to assess and reduce program risk. Shortfalls in prototyping strategies critical to support entry into EMD included:

o Prototyping of hardware, software, or manufacturing processes not adequately planned or executed to reduce risk and provide opportunity for early operational assessment.

o Inadequate provision for competitive design, manufacture, and testing of prototype systems under Demonstration and Validation contracts.

o Insufficient early operational assessments of prototyping efforts to confirm the feasibility of a design approach to satisfy mission need and meet minimum acceptable operational performance requirements.

o No significant program events relating to the use of prototypes in acquisition program baseline parameters for measuring program progress during Demonstration and Validation.

Appendix G summarizes deficiencies relating to the planning and execution of prototyping strategies in the six MDAPs reviewed.

Prototyping of Hardware, Software, and Manufacturing Processes. Our review of prototyping strategies and related documentation required by DoD Instruction 5000.2 and DoD Standard 2167A, "Defense System Software Development," February 29, 1988, showed that programs had deficiencies in planning and executing prototyping of hardware, software, and manufacturing processes. Those deficiencies did or will significantly reduce the quantity and quality of information available to program managers for identifying and addressing technical problems before entry into EMD and for supporting Milestone II, Development Approval.

Hardware. Four of the six programs reviewed, including the Army BAT and Comanche programs and the Navy FDS and JSOW programs, had limitations in planning or execution of hardware prototyping strategies.

Army BAT Program. The Army BAT Program provides an example of the programs having limitations in planning or execution of hardware prototyping strategies. The BAT program had no formal Milestone I, Concept Demonstration Approval. In lieu of a formal Milestone I review, the program had a "Blue Ribbon Panel" review in December 1984 that included technical and acquisition experts from Government and academia. The "Blue Ribbon Panel" provided a recommended acquisition strategy for the program to follow to the Milestone II, Development Approval, decision point. The BAT Program Office followed the guidance provided by the Blue Ribbon Panel with one major exception. The Panel had stated that, before the program progressed to Milestone II, the complete prototype BAT vehicle should be drop tested.

Drop testing involves release of the BAT from an aircraft to determine whether it can glide to an assigned target. Although drop testing did occur before Milestone II, the BAT vehicle used had the following limitations relating to key subsystems:

- o no integrated Central Electronics Unit,
- o no integrated warhead, and
- o incomplete Inertial Measurement Unit.

The Central Electronics Unit is composed of an autonomous processor, autopilot, and interface electronics. According to program office personnel, the Central Electronics Unit was not integrated into the BAT because of delays experienced by the contractor in completing a design that could be accommodated within the available space. The space limitations resulted from a change to the Required Operational Capabilities on December 8, 1987, which led to a modification to the warhead that increased the space that it required, thus limiting the space available for other subsystems. During drop testing, functions to be performed by the Central Electronics Unit were done through telemetry using a receiver aboard the BAT and a ground-based Central Electronics Unit breadboard system.

The warhead or munition is composed of a precursor charge, main charge, and an electronic safe and arm device. Although test firings of the warhead were completed before Milestone II, it was not integrated into the BAT submunition and used as part of the drop testing exercises. Development of the warhead, as discussed above, was impacted by the need for modifications during Demonstration and Validation to increase its capabilities.

The Inertial Measurement Unit is part of the guidance system for the BAT that is used to measure movement and acceleration. Like the Central Electronics Unit, the design of this measurement unit lagged behind due to packaging difficulties resulting from the increased space required for the warhead. As a result, only a partial Inertial Measurement Unit capability was available for testing before Milestone II, Development Approval.

Limitations in the availability of BAT prototype hardware for testing during Demonstration and Validation increased the level of developmental risk carried over into EMD in May 1991. A briefing prepared September 20, 1993, by the BAT Program Office personnel for our audit team stated that the major risk areas for Phase II, EMD, included design, testing, and development of the Central Electronics Unit, subsystem integration, and effectiveness of terminal homing. Progressing to EMD when risk-reduction strategy for Demonstration and Validation was incomplete is an example of a schedule-driven versus event-driven acquisition strategy.

Navy JSOW Program. The Navy JSOW Program provides another example of a system that had significant limitations in the planning and execution of prototyping. The statement of work for contract N00019-89-C-0076, issued to Texas Instruments on June 29, 1989, to support Demonstration and Validation for the program, did not require the design, fabrication, and testing of prototype hardware. Required risk reduction under this statement of work was limited to wind tunnel testing and various systems engineering activities that involved analyses, modeling, and simulation rather than hardware prototyping. Contractors were "encouraged" to use prototype hardware in testing but this effort was not funded under the original contract. The same statement of work was included in Demonstration and Validation contracts issued to two additional contractors who competed with Texas Instruments during Demonstration and Validation.

When USD(A&T) approved the JSOW acquisition strategy for Demonstration and Validation, USD(A&T) assumed that a Recoverable Test Vehicle being developed in a separate Navy program would be used to support captive flight testing of airframe hardware approximating the planned JSOW configuration. This test support never occurred because the Recoverable Test Vehicle Program encountered technical and financial difficulties and the vehicle was not available to support the JSOW effort. Subsequently, the competing contractors each decided to pursue prototyping activities outside of the contracts. The JSOW Program Office then modified the Demonstration and Validation contracts in September 1990 to provide for receipt of test data from the contractors, allow use of Government facilities for testing dispenser (launch and release mechanisms), and fund testing and analysis of composite materials for the nose and fins of the JSOW vehicle.

Although the competing contractors built and flew JSOW prototypes, performing the vast majority of prototyping activity outside of the scope of the contract seriously impacted the risk reduction accomplishments that could be carried over into Phase II, EMD. Factors contributing to the negative impact on risk reduction included:

o Greatly reduced opportunity for interface between the JSOW Program Office and the contractors concerning how prototyping could be used most effectively and efficiently. Management personnel at all three competing contractors agreed that, to be most effective as a risk reduction tool, prototyping should be planned and funded before beginning Demonstration and Validation. Personnel at two of the three contractors stated, without preliminary planning and funding, prototyping becomes more of a media event than a risk-reduction exercise. They stated that prototype hardware produced under those conditions often has little resemblance to what will be developed during EMD.

o The lack of test approval authority by the JSOW Program Office over contractor testing of prototype hardware. Since the testing was done outside the scope the awarded contracts, the Program Office

could not provide input to the focus of the testing process and could not ensure that the title 10, United States Code, section 2438 requirement for competitive "side by side" prototyping was met.

o The lack of exit criteria involving events or achievements using prototypes to support Milestone II, Development Approval, and award of the EMD contract. Exit criteria directed by USD(A&T) and required by DoD 5000.2 were a means to reduce program risk by tying progression to the next acquisition phase to specific events or achievements. All exit criteria established in the Milestone I, Acquisition Decision Memorandum, June 29, 1988, were of an administrative nature such as establishing a Memorandum of Understanding with the Air Force concerning joint Service interoperability and cooperation and did not involve performance-related accomplishments.

Program Office personnel stated that an extra 2 years were needed to get funding and negotiate contract modifications and the program Demonstration and Validation would cost an additional $34 million if the contracts had been modified to require competitive prototyping for JSOW. This position does not consider the benefits of system and process demonstration in support of source selection and that limiting effort during Demonstration and Validation means additional effort will be required in EMD. Additionally, we believe that the time impact would have been reduced if prototyping had been planned and made part of the original Demonstration and Validation contracts in June 1989.

Software. For two of the six programs, the Navy JSOW and FDS, we found significant limitations in the effectiveness of software prototyping done during Demonstration and Validation. Additionally, planning for the test and evaluation of system software had been insufficiently documented as three of the six programs, Army BAT, Navy JSOW, and Air Force F-22 Aircraft, transitioned from Demonstration and Validation into EMD.

Effectiveness of Software Prototyping. The effectiveness of software prototyping for the JSOW was limited because, as discussed earlier under "hardware," the contractors did the majority of prototyping effort outside the scope of the Demonstration and Validation contracts, limiting planning interface between the JSOW Program Office and the contractor and precluding test approval authority. Effectiveness of software prototyping efforts were further limited because a thorough allocation of the software requirements between the JSOW and the F/A-18 Aircraft, the planned user platform for launching the weapon, was not made until after the JSOW program progressed to Phase II, EMD. The Integrated Program Summary approved for JSOW on April 1, 1992, by the Assistant Secretary of the Navy (Research, Development and Acquisition) stated that the requirements allocation would be made early in EMD. Because of the uncertainty concerning the allocation of software requirements, it was not clear during Demonstration and Validation what software capabilities would have to be developed by the JSOW program rather than by the F/A-18 program.

Prototype software was not developed and tested during Phase I, Demonstration and Validation, for the shore segment of the FDS. FDS, which will be used to detect movements of enemy submarines, is composed of two segments: the underwater segment and the shore segment. The system software will reside in the shore segment, known as the Shore Signal Information Processing Segment. Shore segment software was not available to support testing of underwater system segment hardware because of the 29-month difference in the development schedule for the two segments. The underwater segment was approved to enter Phase II, EMD, in September 1989 while the shore segment did not enter EMD until February 1992. During Demonstration and Validation for the underwater segment, previously existing shore processing equipment and software from the Sound Surveillance System (the predecessor to FDS) was used for early evaluation of underwater segment system concepts. At the time of the Demonstration and Validation for the underwater segment, an estimated 50 percent (approximately 800,000 lines of code) of the software for the shore segment would have to be developed while the other 50 percent could be procured "off-the-shelf." A lower risk approach to the development of the FDS would have involved developing prototype shore segment software in conjunction with the development of the undersea hardware since the two segments must work together to allow the FDS to meet mission needs. If delays or failures occur in the EMD of the shore segment, operational capability of the overall system will be delayed.

Planning Software Test and Evaluation. The imposition of documentation requirements that were not appropriate for Demonstration and Validation hampered the effectiveness of software development and testing on the Navy JSOW. Insufficient documentation of software test planning also hampered planning effectiveness on the JSOW, Army BAT, and Air Force F-22 programs.

The effectiveness of the software prototyping done under the Demonstration and Validation contracts for JSOW was reduced because the contracts did not provide for tailored application of DoD Standard 2167A, "Defense System Software Development." The DoD Standard requires that its provisions be tailored for each application so that only cost-effective provisions are implemented. The Demonstration and Validation contracts for JSOW included blanket application of all provisions of the DoD Standard. The Standard includes provisions for extensive documentation of software packages, which are helpful to the Government when programs are in EMD or production but are counterproductive when prototyping software. This application of the Standard should be tailored because, during Demonstration and Validation, the primary focus of software effort should be on determining whether critical algorithms or sections of the software can be successfully programmed. Requiring formal software documentation to an extent appropriate for the later phases of the acquisition takes time and money from the primary objective of determining whether necessary capabilities can be programmed.

Planning for the test and evaluation of system software for the BAT, JSOW, and F-22 had been insufficiently documented as the programs transitioned from Demonstration and Validation into EMD. All three programs had completed

Demonstration and Validation before July 1992. We compared the Test and Evaluation Master Plans (TEMPs) used during Demonstration and Validation for the programs with those to be followed during EMD and found that the software test and evaluation plans were no longer a separate annex in the later versions of the TEMP. Instead, only abbreviated summaries of software test planning were provided. By allowing the removal of the annexes providing software test and evaluation plans from the TEMP, we believe the Military Departments have deemphasized planning for the development and testing of software when software development and integration are becoming increasingly important to system success. While planning for software test and evaluation is in the Computer Resources Life-Cycle Management Plan, this document has neither the visibility or the organizational coordination involved with the TEMP, which DoD Instruction 5000.2 requires as part of the documentation for each acquisition milestone review. The Computer Resources Life-Cycle Management Plan is not part of the milestone documentation requirements established by the Instruction. Program office personnel for the BAT stated that the annex for software test and evaluation was dropped to meet DoD Manual 5000.2-M requirements to keep the TEMP under 30 pages. The 30-page limit does not apply to annexes, however, since the Instruction states they may be used as needed.

Continued inclusion of a software test and evaluation plan as an annex to the TEMP is important to the successful planning and execution of Demonstration and Validation as well as for successfully building on Demonstration and Validation accomplishments during EMD. The Institute for Defense Analysis Document D-1097, "Prototyping Defense Systems," prepared for USD(A&T) in December 1991, states that software has historically caused difficulty and that software integration has become more complicated. Additionally, the document states that software is becoming a major part of overall system costs, adding to technical risk and increasing the importance of prototyping.

Manufacturing. We determined that two of the six programs reviewed, the Army BAT and the Navy FDS, did not prototype critical manufacturing processes during Phase I, Demonstration and Validation. The requirement to include manufacturing as part of the Demonstration and Validation effort has been required since 1984 under DoD regulations relating to acquisition. DoD Directive 4245.6, "Defense Production Management," January 19, 1984, (cancelled in 1991 by DoD Instruction 5000.2) required that manufacturing voids and deficiencies be addressed during Demonstration and Validation through manufacturing technology projects. Those projects were to involve the development or improvement of manufacturing processes, techniques, and equipment to help bridge the gap between system feasibility and production. DoD Instruction 5000.2 retained the requirement for including manufacturing processes as one focus for prototyping efforts.

Representatives from the Army BAT Program Office stated that manufacturing processes were not prototyped during Demonstration and Validation because they believed that critical manufacturing processes refer to producibility risk and do not relate to technical risk. Additionally, they did not believe they could prototype manufacturing processes until system design was firm. The BAT

program entered Phase II, EMD, in May 1991 and the system contractor is currently studying producibility to identify what manufacturing processes will be critical. The most critical processes we identified were those relating to the acoustic sensor. Based on guidance in DoD 4245.7-M, "Transition from Development to Production," September 1985, we believe critical manufacturing processes should have been identified and prototyped with the hardware during Demonstration and Validation. The DoD 4245.7-M states that the manufacturing process required to produce an item significantly influences the design approach and product configuration. The guidance calls for early involvement of production and manufacturing personnel while system design is still fluid.

Prototyping of manufacturing processes for the underwater segment of the Navy FDS Program was limited because the Demonstration and Validation effort focused on proving out the system concept rather than the system technology. Under the acquisition strategy for the system, hardware from the predecessor to FDS, the Sound Surveillance System, was used during Demonstration and Validation to verify the feasibility of a new pattern for distributing listening devices. Development of hardware for the FDS was largely planned for Phase II, EMD. As a result, there was no opportunity to prototype manufacturing processes related to FDS hardware during Demonstration and Validation. Although the prime contractor for the underwater segment of the program had experience with commercial and military underwater systems, FDS required new levels of miniaturization and durability of design. Because technical and manufacturing risks were not adequately assessed and reduced during Demonstration and Validation, the program was projecting a significant cost overrun on contract NOOO39-90-C-0077 with American Telephone and Telegraph Technologies Incorporated for the EMD of the underwater segment. As of December 8, 1993, the FDS Program Manager was projecting cost overruns between $91 million and $105 million on this cost-plus-incentive-fee contract that was originally negotiated for $389 million. The negative cost variance primarily involves fiber optic cable production delays and technical issues.

Competitive Prototyping. The program documentation concerning provisions for competitive prototyping showed that one of the six programs reviewed, the Navy JSOW, had not met provisions for waiver of the requirement to perform competitive prototyping as required by United States Code and DoD Instruction 5000.2. Additionally, we determined that another program, the OSD UTTMDS, could have increased the potential for benefits accruing from competitive prototyping at the subcontractor level.

Waiver of Competitive Prototyping Requirement. The Navy JSOW program did not follow the provisions of title 10, United States Code, section 2365, which requires use of a competitive prototype acquisition strategy in the development of a major weapon system (or a subsystem of such system) unless the Secretary of Defense submits a written notification explaining why the use of competitive prototyping is not practicable.

Acquisition Plan AIR 88-21, approved for the JSOW on July 1, 1988, by the Commander, Naval Air Systems Command, describes an acquisition approach that includes competition but clearly precludes the use of prototypes. The Acquisition Plan describes a competitive Demonstration and Validation that was to culminate in the delivery of a "paper concept and a level 1 data package." This plan was followed by the Milestone I, Concept Demonstration/Validation, decision (now Concept Demonstration Approval) in June 1989 and the issuance of contracts to three competing contractors. The statement of work for contract N00019-89-C-0076, issued to Texas Instruments, Incorporated, on June 29, 1989, stated that "This statement of work stops short of requiring Prototype or Advanced Development Model design, fabrication, and test." The statement of work provides that risk reduction efforts were limited due to limitations in funding. The same statement of work was used for contracts with the other two competing contractors. Although it was evident in the Acquisition Plan released almost a year before Milestone I approval that the Navy did not plan to use competitive prototyping for JSOW, notification and justification through a waiver request was not forwarded through the Secretary of Defense to Congress as required by title 10, United States Code, section 2365. Section 2365 expired September 30, 1991, more than 2 years after the Milestone I approval for JSOW. In October 1992, the competitive prototyping requirement was reinstated in title 10, United States Code, section 2438, "Major Programs: Competitive Prototyping." In section 2438, the USD(A&T) was given authority to approve competitive prototyping waiver requests submitted by the Military Departments.

Competitive Prototyping by Subcontractors. Our review of program acquisition strategies showed that two programs reviewed, the Army BAT and the OSD UTTMDS programs, planned to limit competitive prototyping to the subcontractor level. While restricting competitive prototyping to the subcontractor level focuses the competitive effort on key subsystems, thus reducing program cost, the winning subcontractor must be selected based on the best interest of the Government. While the Army BAT program was establishing the necessary provisions to control the selection of the winning subcontractors, the OSD UTTMDS Program had not.

The acquisition strategy for the UTTMDS, as presented in the Integrated Program Summary dated November 12, 1991, states that the cost of carrying more than one contractor through Demonstration and Validation would be prohibitive. To reduce program risk, on November 23, 1992, the UTTMDS Program Manager inserted provisions into Change 2 to the Scope of Work SW-K-50-90 to contract DASG 60-92-C-0101 for the Theater High Altitude Area Defense portion of the system to require the contractor to include dual sourcing of critical components as part of the contractor's risk management plan. Change 2 to the contract's scope of work was then followed on May 18, 1993, by Change 5, which stated that the contractor should select sources for components based on which source had the most cost-effective and technically acceptable product. While money was saved by limiting the competitive prototyping effort, the choice of the winning subcontractor and the relative weights given to cost versus technical considerations in making the choice will be outside the control of the Government.

The Army BAT program provides a positive example of how the Government can maintain control over the source-selection process while using competitive prototyping among subcontractors under a single prime contract. The BAT Program Office planned to use competitive prototyping at the subcontract level as part of the Phase I, Demonstration and Validation, of a pre-planned product improvement effort. The goals of the pre-planned product improvement are to increase the lethality, countermeasure resistance, and sensor capability and selective target attack features of the basic BAT system.

Four contractors will competitively build prototypes of the terminal seeker for the BAT Pre-planned Product Improvement to determine which subcontractor will be the source for the seeker. Competition will be reduced to two subcontractors after a design review 9 months into Demonstration and Validation. Final selection will be made after the 36-month effort involving drop testing of prototype seekers. To maintain control over subcontractor competition, the BAT Program Office has provisions in the Request for Proposals for the Pre-planned Product Improvement, which the BAT Program Manager stated will allow the Government to establish the selection criteria for choosing the subcontractors. The provisions also provide that no authorization can be given to proceed with a subcontract until the Government has approved the subcontractor selection. We believe that the actions planned for the BAT Pre-planned Product Improvement effort meet the intent of DoD 4245.7-M, "Transition From Development to Production," September 1985, which states that the effective management of subcontractors needs more emphasis within industry and in the Government's management of prime contractors if there is to be a smooth transition to production.

Early Operational Assessments of Prototyping Efforts. Program Early Operational Assessments (EOAs) showed that assessments for three of the six programs evaluated, the Army BAT and the Navy JSOW and FDS, were not adequately supported by test and evaluation of prototypes. The EOAs are evaluations of operational effectiveness and suitability made during Demonstration and Validation by the independent test and evaluation organizations of the Military Departments. DoD Instruction 5000.2 defines operational effectiveness as the overall degree of mission accomplishment of a system. Operational suitability is defined as the degree to which a system can be satisfactorily placed in field use with consideration of availability, compatibility, reliability, maintainability, and manpower and logistic supportability. DoD Instruction 5000.2 requires that prototypes confirm the feasibility of a specific design approach to satisfy the mission need and to achieve minimum acceptable operational performance requirements before progressing to Phase II, EMD. The EOA is the means to determine whether acceptable performance is achievable based on the recommended design approach.

The EOA performed by the Navy's Operational Test and Evaluation Force (OPTEVFOR) for the JSOW was primarily based on the results of modeling and simulation. While modeling and simulation is valuable in determining how a weapon will work against various threat defenses and in estimating lethality, its use assumes that the system will work at some given level of efficiency.

Specifically, the EOA of the Baseline Advanced Interdiction Weapon System (now JSOW), October 3, 1991, listed the following limitations that precluded resolution of critical operational issues and affected the ability to draw conclusions regarding the operational effectiveness and suitability of the system:

- o No hardware was available for actual flight testing. Testing consisted chiefly of a computer modeling and simulation assessment.

- o One model used in testing was produced by one of the three competing contractors and may not have adequately represented the performance characteristics of actual system hardware.

- o Terrain data were not used in scenario modeling.

- o Anti-aircraft artillery was not used in threat simulation; only surface-to-air missiles were simulated as attacking the system.

Additionally, the simulation and assessment exercises done by OPTEVFOR were primarily limited to operational effectiveness issues and did not include the system suitability issues. During the EOA, the assessment of JSOW's compatibility with current and proposed mission-planning systems and with the A-6 and F/A-18 aircraft were qualitative. Mission-planning systems and planned aircraft platforms were not compatible with JSOW at the time of the EOA, but operator experience indicated they could be if properly modified. OPTEVFOR did not assess the results of the contractors' testing because the EOA was performed when contractor testing was ongoing. The Developmental Test and Evaluation Report summarizing the results of contractor testing was not prepared until December 1991, 2 months after issuance of the EOA. Also, OPTEVFOR personnel stated that the independent test organization had not historically been involved with the assessment of aviation-related programs such as JSOW until Phase II, EMD.

The EOA performed for FDS did not include an adequate assessment of system technology (hardware and software). The EOA, like the overall acquisition strategy used for the program during Demonstration and Validation, focused instead on the assessment of the system concept. The FDS test bed was first laid out in October 1985, and the OPTEVFOR completed the EOA in July 1989. The early operational testing done during Demonstration and Validation was designed to demonstrate the concept for a new pattern for distributing listening devices on the ocean floor. Hardware from the existing Sound Surveillance System was used to support the testing and the EOA. The following hardware items critical to the success of the FDS were not prototyped and assessed during Demonstration and Validation: FDS hydrophones (listening devices), multiplexer, and fiber optic cable. The effectiveness of the EOA was further limited since operational suitability was not assessed and a summary report of developmental test and evaluation was not available for OPTEVFOR personnel. In addition to limiting the scope of operational testing, the FDS acquisition strategy did not allow for adequate assessment and reduction of

technical risk during Demonstration and Validation. As a result, the underwater segment of the program during Phase II, EMD, experienced a significant cost overrun as discussed under "Manufacturing."

Program Baseline Parameters. We found that the Acquisition Program Baselines for the OSD UTTMDS and Army BAT, two of the three programs reviewed that were still involved in Phase I, Demonstration and Validation, did not establish baseline schedule milestones necessary for measuring program progress related to the use of prototypes.

The baseline established January 28, 1992, for UTTMDS did not include the following schedule milestone relating to use of prototypes:

- o date for completion of technical testing and
- o start and complete dates for the Early Operational Assessment.

The baseline established for the BAT program on May 13, 1993, provided schedule milestones for the basic BAT program, which is in Phase II, EMD, and also for the Pre-planned Product Improvement effort, which is in Phase I, Demonstration and Validation. The shortfalls in the baseline information relating to the Demonstration and Validation effort included neither a date for completion of prototype development nor start or complete dates for technical testing or for EOA.

The Pre-planned Product Improvement Effort is scheduled to reach Milestone II, Development Approval, in March 1997.

Program progress against Acquisition Program Baselines is reported quarterly in the Defense Acquisition Executive Summary Report. DoD Instruction 5000.2 and DoD Manual 5000.2-M require this progress report to give the Defense Acquisition Executive early warning of problems in meeting interim schedule milestones in the Acquisition Program Baselines. If problems are reported, the Defense Acquisition Executive can direct corrective action before the program reaches a major milestone review such as Milestone II, Development Approval. When schedule milestones are not established for delivery of all or key parts of prototype hardware or for start and finish of both technical testing and operational assessment, the baseline reporting process cannot completely fulfill its purpose as an early warning system.

Issues With the Prototyping Process

The primary causes of the deficiencies identified in the prototyping efforts for the systems reviewed included:

- lack of a properly structured acquisition planning and decision-making process for balancing cost, schedule, and technical risks at the Milestone I decision point to derive the prototyping strategy for Demonstration and Validation;

- need for greater involvement of ARPA in formulation of prototyping strategies; and

- noncompliance with regulations and guidance for planning and conducting test and evaluation, tracking the status of program implementation, and tailoring implementation of regulations to meet individual program needs.

Acquisition Planning and Decisionmaking Process. DoD Instruction 5000.2 and DoD 5000-2-M, "Defense Acquisition Management Documentation and Reports," do not adequately define a planning and decisionmaking process for determining how prototyping will be used for individual MDAPs. The need for improved planning and decisionmaking relating to prototyping was emphasized in the "Defense Management Report to the President," June 12, 1989, and the RAND Report R-4161-ACQ, "The Nature and Role of Prototyping in Weapon Systems Development," 1992.

The Defense Management Report stated that "Decisions made during the early phases of systems development -- including those that involve funds and schedules for prototyping and testing -- often have dramatic consequences for operational performance and life-cycle cost." This report charged the Under Secretary of Defense for Acquisition (now USD[A&T]) with developing and ensuring rigorous application of policies that support sound decisions on major programs through Full-Scale Engineering Development (now Phase II, EMD).

The 1992 RAND Report, which was prepared under sponsorship of USD(A&T), concluded that "there is no single approach to prototyping; effective practice involves considerable flexibility, both in tailoring a particular strategy to the needs of a development effort and in using the resulting information." The report recommended that prototyping be explicitly considered as part of the strategy for development of weapon systems, but that the acquisition policy should provide broad guidelines on prototyping rather than specifying detailed prototyping strategies. The RAND Report advocated including the full range of prototyping considerations in a rational decision process.

The DoD Instruction 5000.2 and the DoD Manual 5000.2-M do not meet intentions of the Defense Management Report and RAND recommendations because the Instruction and the Manual do not adequately define a decisionmaking process for tailoring prototyping strategies for meeting the unique risk reduction needs of individual programs. Both the February 1991 and February 1993 updates of the DoD Instruction 5000.2 state that the prototyping requirements established at Milestone I, Concept Demonstration Approval, will be based on an assessment of the technical, manufacturing, and cost risks associated with the proposed concept and the result of technology

demonstrations. The Instruction, however, neither defines prototyping nor provides a process for determining and justifying the level and scope of prototyping deemed to be appropriate to a particular program.

Defining Prototyping. Although DoD Instruction 5000.2 states that prototyping "will be a major element of Phase I Demonstration and Validation," the Instruction does not define what constitutes a prototype. We believe that an agreed-on definition is necessary for effective policy implementation. The RAND Report defined a prototype as a:

> tangible product (hardware and/or software) that allows hands-on testing in a realistic environment .... In scope and scale, it represents a concept, subsystem, or production article with potential for utility .... It is not necessarily a complete system, but rather focuses on those high risk areas critical to system success.

This definition should be expanded to include use of electronic simulation as well as hardware and software. In this context, electronic simulation would involve using electronic work stations to demonstrate the performance of potential system or subsystem designs.

The RAND Report also discussed the use of prototyping at various levels: full system, partial system, and subsystem levels. Full system includes all key subsystems, partial system would include only one or two subsystems integrated into a platform (such as an engine airframe combination), and subsystem would involve subsystems prototyped independent of a platform. Scope of prototyping refers to whether the use of prototyping involves hardware, software, manufacturing processes, or some combination of the three. Appendix H shows the level and scope of prototyping in systems we evaluated.

Determining Appropriate Prototyping Strategy. The DoD Instruction 5000.2 does not provide a decisionmaking process for determining and justifying the level and scope of prototyping planned for a particular program. The Instruction only requires that information on planned use of competitive prototyping be presented in the Acquisition Strategy Report, which is an annex to the Integrated Program Summary at Milestone I. If use of competitive prototyping is not planned, the Instruction requires preparation of a waiver presenting the reasons it is impractical to comply with this requirement. Use of competition is only one decision that must be made with regard to prototypes. The choices concerning the level and scope of prototyping in a program are of greater importance.

Impediments to the Use of Prototyping. Major impediments to expanded use of prototyping acquisition strategies during Phase I, Demonstration and Validation, are the preliminary costs, funding requirements, and schedule impact. Those preliminary costs must be weighed relative to the potential benefit of ensuring that the best alternatives are selected for entry into Phase II, EMD. Premature entry into EMD before essential prerequisites in design, testing, and production processes are demonstrated significantly increases program risk. Tight funding limitations during Demonstration and Validation resulted in key events that should support the Milestone II decision

being deferred until after the Milestone II decision is made. In essence, underfunding Demonstration and Validation merely transfers the cost and risk to EMD where problems receive considerably more attention due to the level of DoD's financial commitment. Prototyping acquisition strategies during the Demonstration and Validation phase will likely impact program schedules. We could not quantify this impact because we could not assess the schedule impact of the absence of prototyping on the EMD phase. Performing prototyping before the Milestone II decision could reduce the effort required during EMD; however, too many variables are in program management to evaluate this impact. The RAND Corporation concluded prototyping appeared to increase the time from Milestone I, Concept Demonstration Approval, to first operational delivery by about 12 months.

Existing Guidance. Limitations in the DoD Instruction 5000.2 guidance relating to planning the use of prototyping were identified based on our review of the Instruction, conclusions reached in the RAND Report regarding prototyping policy, and the deficiencies in the use of prototyping observed in five of the six systems evaluated. The RAND Report concluded that while the conceptual framework provided by DoD Instruction 5000.2 for decisionmaking on competitive prototyping was adequate, similar guidance should be applied to decisionmaking on level and scope of prototyping as well. The Report stated that some form of prototyping is almost always appropriate and that the "burden of proof" should be on those who argue that a prototyping activity is unnecessary or impractical. In cases where full-scale articles are too expensive or technically impractical, subsystem prototyping may still be appropriate. The RAND Report also concluded that policy should provide for including the full range of prototyping considerations in the decisionmaking process. When prototyping was not deemed necessary, the decisionmaking process suggested would allow for explicit rationalization as to why prototyping was deemed inappropriate.

The RAND Report was based on the February 1991 versions of the DoD Instruction 5000.2 and DoD Manual 5000.2-M. Changes made in the February 1993 update of the Instruction did not include the RAND recommendations for expanding the policy guidance to provide a decisionmaking framework and documentation requirements to support planning the level and scope of all prototyping efforts similar to that required for use of competition. In addition, Part 4 of the DoD Manual 5000.2-M still contains confusing language regarding the justification for not using competitive prototyping. Change 1 to DoD Manual 5000.2-M promulgated under a DoD Publication System Change Transmittal, issued March 5, 1993, states that the following language was deleted from the manual: "Prepare a request for a competitive prototype strategy waiver for milestone decision authority approval, under authority delegated by the Secretary of Defense, specifying the basis for the waiver (see Part 12 for competitive prototype strategy waiver)." The last portion of the above language, the reference to Part 12, was never deleted so the Manual's discussion on justification for not using competitive prototyping now refers the reader to Part 12 which, after Change 1, states "Reserved for Future Use."

Revising Prototyping Guidance. Prototyping can be made a more effective risk-reduction tool by revising DoD Instruction 5000.2 and DoD Manual 5000.2-M to:

- Outline a decisionmaking process for tailoring a prototyping strategy to meet the risk-reduction needs of specific programs.

- Require a prototyping plan to be prepared before Milestone I that will specify the level and scope of planned prototyping as well as provide explicit explanation of those areas where prototyping was deemed inappropriate.

Additional changes to guidance and regulation to support the recommended revisions to DoD Instruction 5000.2 and DoD Manual 5000.2-M would include the development of a handbook to provide guidance for preparation of prototyping plans.

Decisionmaking Process. The Instruction and the Manual should be modified to provide a conceptual framework for decisionmaking concerning planned prototyping strategies. While we recognize that no single prototyping strategy fits all programs, basic guidelines are needed to determine when prototyping is appropriate and what types of prototypes would be effective and efficient in reducing risk in a particular program. At a minimum, policy should provide:

- general definitions of system level, partial system level, and subsystem level prototyping and

- considerations for determining the appropriate level of prototyping (system, partial system, or subsystem) for hardware, software, and manufacturing processes.

The RAND Report advocated a costs versus benefits approach to making prototyping decisions. RAND stated that the benefits of prototyping must be weighed against the costs of prototyping. According to RAND, those benefits include reduced technical risk; identification of critical system integration issues; increased accuracy of cost, schedule, and performance estimates; and allowing necessary design changes to be made early. RAND stated that costs of prototyping include increased preliminary cost and a slightly longer time needed (about 12 months average) to reach first operational delivery. We could not confirm the schedule impact of prototyping because of the numerous variables that affect program outcome and the many differences between individual programs. This type of cost versus benefits analysis can be applied at the system, partial system, and subsystem levels for hardware, software, and manufacturing processes.

The Institute for Defense Analysis (IDA) in IDA Document D-1097, "Prototyping Defense Systems," December 1991, provided additional guidance on when and how to prototype. This document was prepared for the Under Secretary of Defense for Acquisition (now USD[A&T]). The IDA Document states that prototyping should be done for systems (or subsystems) that involve:

- o new performance and manufacturing technology for the contractor(s),
- o high cost per unit and large quantity, and
- o long lead time or high cost to correct potential unforeseen problems.

Prototyping Plan. To provide milestone decision authorities the rationale behind the proposed prototyping strategy for each MDAP, DoD Instruction 5000.2 should require that the program manager prepare a prototyping plan as part of the documentation for the Milestone I decision. The prototyping plan should be based on the knowledge gained during Phase 0, Concept Exploration, and the best judgment of experienced engineers and managers applied within the framework of the amended policy guidance as discussed. The prototyping plan should document how prototyping will be used to reduce the technical, cost, and schedule risks of transitioning from Demonstration and Validation to EMD. The plan should specifically require justification for <u>not</u> pursuing a prototyping acquisition strategy. Documentation should describe:

- o the extent of planned development of system, partial system, or subsystem prototypes of hardware, software, and manufacturing processes;
- o use of competitive prototyping at the prime and subcontractor levels;
- o developmental test and evaluation of prototypes to be completed before EMD;
- o the operational effectiveness and suitability demonstrations to be completed using prototypes to support the Early Operational Assessment;
- o system engineering events defined in Military Standards 499-A and 1521-B that will be based on prototypes and their design documentation (for example, the extent of planned design reviews on prototypes);
- o how modeling, simulation (sometimes known as electronic prototyping), and producibility analyses will supplement and enhance the use of prototypes;
- o how requirements of DoD Standard 2167A, "Defense System Software Development," February 1988, will be tailored to provide for software prototyping; and
- o the trade-off analysis to support decisions not to use prototyping or to limit its use to the partial system or subsystem levels.

Contractor Input to Prototyping Plans. We found input from potential Demonstration and Validation contractors to be essential for planning the prototyping activities to be in the formal acquisition strategy approved by the milestone decision authority at Milestone I. The first version of the plan should be prepared before issuance of the Request for Proposals for the Demonstration and Validation contract. Program managers should ensure that solicitations for Demonstration and Validation contracts request that contractor proposals identify where prototyping will be used. Revisions to the prototyping plan should be based on contractor input provided in response to the Request for Proposals. To accomplish these objectives, the DoD Instruction 5000.2 should be revised to include language on prototyping stating that solicitation proposals should include a complete description of the prototyping plan required to be submitted with contractor proposals. Additionally, a Data Item Description should be used to describe the contents of the contractor prototyping plan. Program managers can use these methods to solicit contractor prototyping approaches and assess the most beneficial uses of prototyping as part of the evaluation process leading to contract award.

Prototyping Handbook. A handbook should be developed to provide guidance to program managers for preparation of prototyping plans for programs approaching Milestone I, Concept Demonstration Approval. The handbook guidance should address cost versus benefits consideration of system, partial system, or subsystem prototyping for hardware, software, and manufacturing processes, as well as competitive prototyping, and the use of modeling and simulation to enhance prototyping effort. The handbook would act as a supplement to the revised guidance discussed for DoD Instruction 5000.2 and DoD Manual 5000.2-M.

ARPA Involvement in Formulating Prototyping Strategies. Another factor contributing to the deficiencies observed in prototyping strategies is that ARPA has not assumed an expanded role in prototyping as intended by the Packard Commission. ARPA, under the authority, direction, and control of the Director for Defense Research and Engineering, serves as the central research and development organization of the DoD with a primary responsibility to maintain U.S. technological superiority over potential adversaries. The Packard Commission Report recommended that the role of Defense Advanced Research Projects Agency (now ARPA) be expanded to include the mission of stimulating greater emphasis on prototyping Defense systems. ARPA was to accomplish this expanded role by actually conducting prototype projects that embody technology that might be incorporated in joint or selected programs and, on request, assist the Military Departments in their prototyping programs. Dr. David Packard, Chairman of the Commission, clarified those recommendations in a letter to the Secretary of Defense in April 1989. The letter was also signed by Dr. William J. Perry, then a member of the Ad Hoc Advisory Group on Defense Advanced Research Project Agency's Role in Prototyping and now Secretary of Defense. The importance the Packard Commission attached to prototyping as part of the acquisition process is documented by three quotations from the April 1989 letter:

> We believe you [Secretary of Defense] have an unparalleled opportunity to make a major improvement in the defense acquisition system by supporting prototyping throughout the department.
>
> . . . . . .
>
> The use of prototyping is fundamental to the success of this process, for only by building and testing prototypes can real performance be demonstrated and actual costs be established.
>
> . . . . . .
>
> [P]rototyping can save substantial time because only general performance specifications are required, the benefits of competition can be used to minimize costs and encourage creativity, and a sound base for the next Phase can be established by testing real hardware.

The letter discussed the use of prototyping during two Phases: Phase I, Demonstration of System Feasibility and Military Worth (equivalent to current Phase I, Demonstration and Validation), and Phase II, Full-Scale Development Through Low-Rate Initial Production (equivalent to current Phase II, EMD). The letter stated that ARPA should play a substantial role in Phase I prototyping, particularly in extension of its own system developments.

ARPA began initiatives in the late 1980s to increase ARPA involvement in prototyping in response to the Packard Commission recommendations. However, the Military Departments contested ARPA involvement and the Agency never received the appropriate funding to allow it to become involved in prototyping. The only notable exceptions were the ARPA assistance in the prototyping efforts for the Army Tactical Missile System and the Air Force Joint Surveillance and Target Attack Radar System. Current ARPA work is focused primarily on technology-based projects and advanced technology demonstrations.

Those efforts are precursors to the prototyping efforts that occur during Demonstration and Validation and in which the Packard Commission recommended ARPA involvement.

ARPA's present work in advanced technologies provides the Agency with the ability to provide independent, technology-driven input to the planning of prototyping strategies for major systems. To meet the intention of the Packard Commission that ARPA "should have the additional mission of stimulating a greater emphasis on prototyping Defense systems," DoD Instruction 5000.2 should require ARPA to review and report on the Acquisition Strategy Reports, with emphasis on prototyping plans, for all Acquisition Categories I and II programs before Milestone I, Concept Demonstration Approval. The Instruction should also require ARPA to review and report to the Milestone Decision Authority concerning the need for prototyping as a risk-reduction method for major modifications or upgrades of Acquisition Categories I and II programs approaching Milestone IV, Major Modification Approval.

Compliance With Regulation and Guidance. We believe that the third major contributing factor to deficiencies observed in prototyping strategies was compliance with existing regulations and guidance. Military Departments have not fully complied with existing regulations and guidance for planning and conducting test and evaluation, tracking the status of program implementation, and tailoring implementation of regulations to meet individual program needs.

Planning and Conducting Test and Evaluation. The deficiencies relating to the test and evaluation of prototypes occurred because operational testing was not planned and executed to fully support early operational assessments and comply with the requirements established in DoD Instruction 5000.2. Demonstration of operational capabilities of weapon systems during Demonstration and Validation has long been a part of the acquisition process as defined by DoD Instruction 5000.2. The September 1987 version required that operational effectiveness and suitability goals and thresholds be "met and reviewed" before Milestone II, Full-Scale Development decision (now called Development Approval). This requirement supported the Defense Acquisition Board's Milestone II deliberations concerning system cost and affordability versus system effectiveness meeting operational requirements. The February 1993 update of the Instruction requires that prototyping include the opportunity for an assessment of operational effectiveness and suitability by the operational test organization.

The July 1989 Defense Management Report to the President also emphasized the importance of using prototypes to evaluate operational capabilities of systems. The Report stated that schedules and plans should provide for early test and evaluation of prototype hardware to prove concept, performance, and suitability in a realistic operational environment.

Maximizing the effectiveness of operational test and evaluation and increasing the meaningfulness of early operational assessments require close and continuous interface between the program office developing a system and the Military Department's operational test organizations. The F-22 Aircraft Program provides a positive example of effective interface between the program manager and the operational test organization. The program's April 1991 TEMP documented that the Air Force Operational Test and Evaluation Center conducted a continuing operational assessment of the program from November 1986 until the June 1991 EOA was issued to support Milestone II, Development Approval. During this 5-year assessment process, the operational test organization evaluated progress in many phases of the Demonstration and Validation activities. Specifically, the assessment included:

- o review of contractor's avionics prototype capabilities and
- o participation in contractor's flight test program, contractor and program office working groups, mission simulation efforts, and relevant maintenance demonstrations.

The June 1991 EOA, which supported the Milestone II, Development Approval, was not a one-time review but the product of continued effective interface between the operational test organization and the program office.

Tracking the Status of Program Implementation. OSD UTTMDS and Army BAT, the two programs having acquisition program baselines that did not include program schedule events necessary for measuring program progress relating to prototyping, did not comply with the DoD Manual 5000.2-M requirement for establishing baseline schedule information adequate to describe the program. DoD Manual 5000.2-M provides the formats for preparing acquisition program baselines, which include performance, schedule, and cost parameters. For the schedule parameters to be established at Milestone I, the Manual requires that baseline entries be established for "date of Demonstration and Validation contract award [and] early operational assessment (start - complete)." The Manual further states that "the minimum dates [are] required in each baseline but are rarely sufficient to describe the program." To fill the void in the program schedule descriptions, the Manual suggests dates for "prototype development complete [and] technical test (start - complete)" also be established in the baseline.

Because prototyping is a major element of Phase I, Demonstration and Validation, the DoD Manual 5000.2-M should be modified to require those dates as part of the Milestone I Concept Baselines whenever prototyping is planned. This change to DoD Manual 5000.2-M will ensure that acquisition managers have an adequate reference point for measuring and reporting the status of program implementation and that baseline schedule information includes dates necessary to describe the program adequately, as required by DoD Manual 5000.2-M.

Tailoring Regulations. Not consistently applying this requirement contributed to the shortfalls noted in software prototyping. DoD Standard 2167A, Defense System Software Development, requires tailoring the Standard to meet specific program requirements. Most contractors we surveyed believed that prototyping software during Phase I, Demonstration and Validation, should be focused on critical software algorithms. The contractors believed that imposing the full software documentation and reporting requirements described in the Standard can be counterproductive during Demonstration and Validation.

Impact of Prototyping

Increased program risk is the primary impact of the deficiencies noted in the prototyping process. When full execution of a prototyping strategy that has been matched to the particular needs of a program does not occur in Phase I, Demonstration and Validation, then Milestone II, Development Approval, may occur when it has not been sufficiently demonstrated that critical technologies can be incorporated into the design or proven that processes critical to the system concept are at an acceptable level of risk. Milestone II, Development

Approval, represents a commitment to translate the design approach developed during Demonstration and Validation into a stable, producible, and cost-effective design that can satisfy mission need and meet operational performance requirements. When misconceptions concerning the expected capabilities of a system concept and the ability to understand and incorporate the critical technologies exist at Milestone II, then program risk increases the likelihood of:

- large additional expenditures during Phase II, EMD, to overcome unforeseen technical problems;
- cancellation of systems for engineering and development due to poor performance;
- difficulties in transitioning into production; and
- accepting systems that do not fully meet mission requirements.

Execution of an appropriate prototyping strategy during Demonstration and Validation improves the accuracy of cost and schedule estimates for both EMD and production of a system. The information gained from prototyping organizations allows program managers to make more educated estimates of the costs and the time needed to engineer and produce a system. In the same manner, prototyping provides program managers the technical information to more accurately predict technical performance of a program.

The benefits of prototyping were documented in the IDA report, prepared for USD(A&T) in December 1991. D-1097, "Prototyping Defense Systems," stated that both development and production cost growth were significantly lower for prototyped programs than for non-prototyped programs. IDA examined 52 major acquisition programs over 32 years, ending December 31, 1987. The examination included aircraft, tactical munitions, satellites, and helicopters and reported the following differences in percentage of cost growth between the 17 programs that prototyped and the 35 that did not:

Growth Area	Prototyped (in percent)	Non-Prototyped (in percent)
Development Cost Growth	17	62
Production Cost Growth	29	55

Percentage cost growth was derived by comparing the cost estimates for each program at Milestone II with the latest estimates provided in the December 1987 Selected Acquisition Report. Cost growth was adjusted for changes in production quantity and inflation. We could not independently confirm the percentages of cost growth on programs that used and did not use prototyping. In particular, we could not confirm that the reported differences in cost growth had a direct causal relationship to prototyping efforts. Nevertheless, prototyping efforts should provide the information necessary to develop more accurate cost, schedule, and performance forecasts.

The IDA Report also discussed possible negative effects prototyping can have on programs. Those effects included:

o Extra time required. According to the Report, prototyped programs took about 2 years longer to progress from Milestone I, Concept Demonstration Approval, to Initial Operational Capability than programs that did not use prototyping.

o Increases preliminary costs of programs.

o Delays major funding commitment. The large scale commitment of funding at the Milestone II, Development Approval, is viewed as necessary to "lock-in" support for the program.

Revising the DoD Instruction 5000.2 and DoD Manual 5000.2-M to provide cost/benefit consideration for determining the appropriate level of prototyping (system, partial system, or subsystem) for hardware, software and manufacturing processes will maintain or enhance the documented benefits of prototyping while minimizing the negative impacts. The result of this systematic approach should be a prototyping strategy, documented in an approved prototyping plan that focuses prototyping on those areas where additional technical information is most needed to reduce program risk and effectively integrates prototyping with other development techniques such as modeling and simulation. Increased emphasis on choosing the most appropriate prototyping strategy will ensure that time and money spent on prototyping will be limited to what has been determined as necessary to reduce technical risk to an appropriate level. Additionally, delaying funding commitment allows the Government to keep its options open as suggested in the IDA report.

Conclusions

Effective prototyping to reduce program risk in transitioning from Demonstration and Validation to EMD can only occur through the development and implementation of a structured decisionmaking process that will result in a documented and executable prototyping plan. This prototyping plan should incorporate the best judgment of:

o experienced program managers and engineers within Government and industry,

o research scientists at ARPA who are familiar with critical technologies associated with the planned weapon system, and

o test personnel at the operational test organizations of the Military Departments who must ensure that planned prototyping will provide opportunity for early operational assessment of operational effectiveness and suitability.

The designation of ARPA for a leadership role in prototyping decisions at the Milestone I decision point is consistent with the Agency mission as described under "ARPA Involvement in Formulating Prototyping Strategies." Expanding the ARPA role will ensure that decisions regarding prototyping are based on sound technical information. ARPA has cognizance for advanced technology demonstrations that should be transitioned to development programs.

We recognize that no single approach or application of prototyping can be used for all programs. Therefore, the prototyping plan should be developed to fit the unique needs of a particular program. To support effective planning of prototyping efforts, DoD Instruction 5000.2 should be modified to provide for determining, through systematic costs versus benefits analysis, whether prototyping should be used at the system, partial system, or subsystem level, and for specific decisions on the subsystems to be prototyped. The determination process should be applied to the hardware, software, and critical manufacturing processes involved in the acquisition. The prototyping plan should also describe the planned use of modeling and simulation to supplement prototyping effort. A handbook containing detailed guidance for formulating the prototyping plan should be developed to supplement the general guidance in the DoD Instruction 5000.2. In all cases, as stated in the RAND study, the burden of proof should be on those who believe that prototyping is unnecessary or impractical.

Once the prototyping plan is developed, we believe the following controls and procedures will promote effective execution of Phase I, Demonstration and Validation:

o Establish specific, quantifiable exit criteria to define events or achievements using prototypes that should occur before the program transitions to Phase II, EMD.

o Tailor requirements of DoD Standard 2167A, Defense System Software Development, or applicable commercial standards to include those provisions that are cost-effective to the development of prototype software.

o Close and continuous interface among the program offices and the operational test organizations of the Military Departments.

o Effective tracking of the status of program implementation through program office reporting against acquisition program baselines, approved by the Defense Acquisition Executive, which provides schedule milestones relating to the development of prototypes and the starting and completion of technical tests.

Further, the use of prototyping fully supports DoD initiatives to expand the use of performance specifications in the acquisition of weapon systems. Performance specifications permit contractors to more thoroughly examine alternatives for affordably meeting military requirements by not mandating a particular design. The specifications are particularly important during

Demonstration and Validation and entirely consistent with a prototyping acquisition strategy to assess the potential for technological approaches to meet performance objectives.

Our recommendations, if fully implemented, will significantly elevate the significance of the Milestone I, Demonstration Approval, decision and provide for a more gradual transition from Demonstration and Validation into EMD. An expanded Demonstration and Validation phase that includes significant prototyping will permit funding to be committed more incrementally and based on demonstrated program progress instead of the more traditional entry into EMD accompanied by a single major increment in funding. Further, use of prototypes facilitates the preparation of more accurate cost and operational effectiveness analyses and life-cycle cost estimates.

Many programs have encountered significant developmental problems during EMD. Those programs had Milestone II decisions when greater developmental risk was justified based on the urgency to respond to potential threats. In general, DoD has stated that higher levels of risk are no longer justifiable. Under those circumstances, expanded use of prototyping to reduce program risk and improve the quality of Milestone II decisions is both logical and essential. Prototyping enhances the quality of the Milestone II decision by providing the basis for more accurate forecasts of program cost, schedule, and performance.

Although we recognize the need to avoid unnecessary regulatory guidance, the present guidance for planning and implementing prototyping strategies must be expanded. Prototyping, along with related activities accomplished during Phase I, Demonstration and Validation, provides the knowledge and experience that enhances likelihood of program success in all subsequent and much more expensive acquisition phases. Therefore, DoD acquisition management must overcome impediments to expanded use of prototyping by placing the burden of proof on program managers who do not recommend prototyping. Implementing the processes and procedures discussed will facilitate effective and informed decisionmaking for the initial and critical phases of the system acquisition process.

Recommendations, Management Comments, and Audit Response

1. We recommend that the Under Secretary of Defense for Acquisition and Technology:

a. Revise DoD Instruction 5000.2 to:

(1) Provide a definition of prototyping as it applies to Phase I, Demonstration and Validation, that encompasses prototyping done

at the system, partial system, and subsystem levels; involves hardware, software, manufacturing processes; and includes electronic simulation and design analysis.

Director, Acquisition Program Integration (API), Comments. The Director nonconcurred, stating that prototyping was a well-known concept. The full text of management's comments is in Part IV.

Audit Response. We disagree with management's assertion that prototyping is a well-known concept. We believe a definition is needed now more than ever. The summary section of RAND Report R-4161-ACQ, "The Nature and Role of Prototyping in Weapon System Development," 1992, stated that confusion regarding terms, including prototyping, has historically led to inconsistencies in acquisition policy. The Report further stated that evidence suggested that lack of a clear definition of prototyping has contributed to a lack of consensus on prototyping policy.

A compounding factor in defining prototyping is the development of modeling and simulation methods that may supplement or be in lieu of more traditional hardware prototypes. During our review, the Director of Product Integrity in the Office of the Assistant of the Navy (Research, Development and Acquisition) agreed that there is no adequate definition of prototyping. He also stated that any prototyping definition should include the use of electronic simulation (or electronic prototyping) as well as the more traditional use of hardware. We, therefore, ask management to reconsider its position in response to the final report.

(2) Require program managers to submit a prototyping plan as part of the Acquisition Strategy Report for the Milestone I, Concept Demonstration Approval. The plan must be based on cost, schedule, and technical risks; describe the intended use of prototypes in risk-reduction efforts at the system, subsystem, or component levels; and include consideration of prototyping hardware, software, and manufacturing processes as well as the use of competitive prototyping at contractor and subcontractor levels.

Director, API, Comments. The Director nonconcurred, stating that this plan is already an inherent part of the Acquisition Strategy Report and the TEMP. He believed that additional oversight was not justified by the findings and are counter to the acquisition streamlining required by Executive Order 12861. He also believed that adding to program manager workload is contrary to National Performance Review efforts. Finally, the Director stated that before accepting far-reaching recommendations, the findings of the Acquisition Task Force on Modeling and Simulation, which is examining the feasibility of using computer-generated models in lieu of prototypes, should be considered. The Director stated that the Task Force effort should be complete within 90 days (from June 3, 1994).

Audit Response. We recognize that the Acquisition Strategy Report and the TEMP contain some elements that could be integrated into a prototyping plan.

However, neither document provides complete and consolidated documentation describing the extent of planned development and use of system, partial system or subsystem prototypes of hardware, software, or manufacturing processes. Specifically the Acquisition Strategy Plan and the TEMP are not required to document:

o a trade-off analysis made to support decisions not to use prototyping or to limit its use to the partial system or subsystem levels;

o how requirements of DoD Standard 2167A, "Defense System Software Development," or similar commercial standards will be tailored to provide for software prototyping; and

o system engineering events defined in Military Standards 499-A and 1521-B that will be based on prototypes and their design documentation.

With regard to management's contention that our recommendation runs counter to Executive Order 12861 and the National Performance Review, we do not believe those initiatives prohibit or discourage thorough planning. Improving the quality of information provided at the Milestone I decision will reduce the need for additional and unscheduled oversight during Demonstration and Validation and better position programs for achieving Milestone II, Development, approval. We agree with management that implementation of our recommendation would be best accomplished after the Task Force on Modeling and Simulation completes its efforts. We, therefore, ask that management reconsider its position in response to the final report.

(3) Require the Advanced Research Projects Agency to report to the milestone decision authority on its review of Acquisition Strategy Reports, with primary emphasis on prototyping plans, for all Acquisition Categories I and II acquisition programs before Milestone I, Concept Demonstration Approval.

Director, API, Comments. The Director nonconcurred, stating that the report did not provide strong rationale, other than the 1986 Packard Commission Report, for the recommendation. He further stated that although ARPA is technology based, it does not have the knowledge or expertise that is resident in the Military Departments and is not resourced or staffed to be the single DoD focal point for prototyping.

Audit Response. We believe that ARPA is capable and can provide critical input into the formulation of prototyping strategies at the Milestone I decision, especially in those cases where ARPA was involved in pre-Milestone I research and development effort. DoD Directive 5105.41, Defense Advanced Research Projects Agency, January 25, 1989, states that ARPA serves as the central research and development organization of the Department of Defense and is to stimulate a greater emphasis on prototyping in Defense systems by conducting prototype projects (designated as advanced technology demonstrations in DoD Instruction 5000.2) that embody technology that might be incorporated in Military Department programs.

In terms of knowledge of Military Department programs, an ARPA official estimated that ARPA has historically performed some level of technology demonstration work on about 40 percent of the acquisition programs going to Milestone I. He stated that the degree of ARPA involvement has ranged from system-level demonstrations of the technologies that later became the Army Tactical Missile System and the Air Force Joint Target Attack Radar System to demonstrations of technology to be used at the subsystem or component levels. In cases where ARPA has done significant pre-Milestone I work, ARPA personnel would have as much or more expertise concerning technologies critical to system development as Military Department personnel and would be able to provide valuable and independent input to the milestone decision authority concerning the adequacy of planned usage of prototypes for risk reduction during Phase I, Demonstration and Validation.

Similarly, we believe ARPA could provide valuable input to Milestone I decisions in cases where ARPA has not been directly involved in technical demonstrations. In these instances ARPA could, within limitations of available staffing and with priority given to Acquisition Category I programs, serve as a focal point to eliminate duplicative or unnecessary developmental effort during Phase I, Demonstration and Validation. ARPA's input would also help identify the need for prototyping and for developing an acceptable prototyping strategy. These benefits could accrue from ARPA's wide knowledge of technical efforts completed or ongoing within the Military Departments, private business entities, educational institutions, and foreign nations.

In respect to the Acquisition Strategy Report, we recommend that ARPA's review be focused on the prototyping plans rather than the entire Acquisition Strategy Report. We, therefore, request that management reconsider its position in response to the final report.

(4) Require the Advanced Research Projects Agency to report to the milestone decision authority concerning the need for prototyping as a risk-reduction method for major modifications or upgrades of Acquisition Categories I and II programs before Milestone IV, Major Modification Approval.

Director, API, Comments. The Director nonconcurred with this recommendation for the same reasons given in response to Recommendation 1.a.(3). Additionally, he questioned whether ARPA is the correct organization to review producibility, a very important issue at Milestone IV.

Audit Response. As in our audit response for Recommendation 1.a.(3), we believe that ARPA can provide valuable input to the milestone decision authority in support of the Milestone IV decision. Producibility is a major issue at Milestone IV and incorporation of technological advances, as part of system modifications or upgrades, is a key component of the producibility determination. At Milestone IV, the milestone decision authority is to determine which acquisition phase should be entered based on level of risk, the adequacy of risk management planning, and the level of resources to be committed. In this respect, ARPA has the ability to provide the milestone

decision authority with independent input concerning the need for prototyping as a risk reduction method for major modifications or upgrades of Acquisition Categories I and II programs. We, therefore, request that management reconsider its position in response to the final report.

(5) Require the Directors of Military Departments' operational test and evaluation organizations to report specifically at Milestone I on system and subsystem-level prototyping requirements needed for optimal operational assessments of systems suitability and effectiveness during Demonstration and Validation.

Director, API, Comments. The Director partially concurred, stating that the Director, Operational Test and Evaluation, sees benefit in the recommendation but that the Army and the Navy question how this plan would be implemented.

Audit Response. The recommendation can be implemented by requiring the directors of the Military Department's operational test and evaluation organizations to submit a separate assessment of prototyping requirements to the Director, Operational Test and Evaluation. This assessement would address the system or subsystem level prototyping needed for optimal operational assessments of systems' suitability and effectiveness during Demonstration and Validation. We request that management consider our suggestion for implementing the recommendation in responding to the final report.

(6) When prototyping is used, require "Prototype Development Complete" and "Technical Test (Start - Complete)" to be part of the minimum required schedule dates for Defense Acquisition Executive Concept Baselines for programs in Phase I, Demonstration and Validation.

Director, API, Comments. The Director concurred with the recommendation but did not provide an estimated completion date for revising DoD Instruction 5000.2.

Audit Response. In response to the final report, we ask that management provide an estimated completion date for revision of the Instruction.

(7) Require specific, quantifiable exit criteria for programs involving the use of prototyping during Phase I, Demonstration and Validation.

Director, API, Comments. The Director nonconcurred, stating that requiring exit criteria regardless of program particulars would not allow the program manager and the Milestone Decision Authority enough leeway to run programs in a manner reflecting good business practice. He further stated that the recommendation presupposes that all programs are prototyped, which he believes is unlikely.

Audit Response. DoD Instruction 5000.2 states that exit criteria are intended to benefit both the milestone decision authority and the program manager. For the milestone decision authority, the use of exit criteria offers the flexibility to

set execution boundaries for each phase of the program and to regulate the amount of oversight to be applied during the phase. For the program manager, the use of exit criteria offers the freedom to execute key events during a phase without the formality of milestone decision authority and staff reviews except at milestone decisions.

We recognize that individual exit criteria must be carefully and selectively applied but also believe that establishing some type of specific, quantifiable exit criteria for programs involving the use of prototypes in the acquisition strategy is a logical supplement to the general decision criteria established by DoD Instruction 5000.2 for the Milestone II, Development Approval, decision. These general decision criteria include the requirement that prototyping and demonstration efforts to date provide reasonable assurance that the technologies and processes critical to success are attainable. The exit criteria would support the general decision criteria by requiring specific, measurable accomplishments relating to performance, technology, or events involving prototypes that can be used to assess program readiness to move to EMD. We have clarified the recommendation in the final report to specify that exit criteria should be required for those programs involving the use of prototyping acquisition strategies during Demonstration and Validation. We, therefore, request that management reconsider its position in response to the final report.

(8) Require an initial design review to be completed before Milestone II, Development Approval, based in part on the results of prototyping for programs involving prototyping acquisition strategies.

Director, API, Comments. The Director nonconcurred, stating that the existing decision criteria specified in DoD Instruction 5000.2 for Milestone II make the recommended change unnecessary. He stated that the current version of the Instruction requires that the decision authority confirm that "Prototyping and Demonstration results to date provide reasonable assurance that the technologies and processes critical to success are attainable." Further, the Director stated that the recommendation presupposes that all programs are prototyped.

Audit Response. Before Milestone II, DoD Instruction 5000.2 does require that the milestone decision authority confirm that prototyping and demonstration results to date provide reasonable assurance that technologies and processes critical to success are attainable. DoD Instruction 5000.2 decision criterion also supports the need to implement our recommendation. How can the milestone decision authority confirm the general criterion of "reasonable assurance" without some specific criteria for measuring the attainability of critical manufacturing technologies and process? Through performance of an initial design review, the milestone decision authority would be made aware of known limitations or shortfalls in the system design, along with contractor-proposed solutions for overcoming design problems. We clarified the recommendation in the final report to specify its applicability to only those programs involving a prototyping acquisition strategy. We, therefore, ask management to reconsider its position in response to the final report.

(9) Require a producibility analysis to be prepared based on prototypes for programs involving prototyping acquisition strategies.

Director, API, Comments. The Director nonconcurred, stating that not all programs will be prototyped. Further, he stated that a producibility analysis is normally prepared during EMD to support Production Readiness Reviews and the analysis is based on the EMD model. He stated that prototypes can also be used for input into the analysis.

Audit Response. DoD Instruction 5000.2 requires that the focus of prototyping be on assessing and reducing the risks associated with integrating available and emerging technologies into a system design approach to satisfy a validated mission need. In defining this requirement, the Instruction states that technologies will include hardware, software, and manufacturing processes. For Milestone II, the decision criteria includes the requirement that prototyping and demonstration results to date provide reasonable assurance that the technologies (including manufacturing) and processes critical to success are attainable. The producibility analysis, like the initial design review discussed in our response to management comments on Recommendation 1.a.(8), would provide the milestone decision authority at Milestone II with reasonable assurance that technologies and processes critical to success are attainable. The product of this analysis would identify known and potential production problems along with contractor's proposed approaches for solving the problems. We have clarified the recommendation in the final report to specify applicability to only those programs involving a prototyping acquisition strategy. We, therefore, ask management to reconsider its position in response to the final report.

(10) Require Requests for Proposals for Demonstration and Validation contracts to include a provision for proposing the level of software documentation and reporting, under DoD Standard 2167A, "Defense System Software Development," or applicable commercial standards, that contractors deem most appropriate through applying the principles as provided in DoD Handbook 248, "Guide for Application and Tailoring of Requirements for Defense Material Acquisitions." The proposal documentation from each contractor should provide the cost and benefit justification for the level for the type of documentation proposed.

Director, API, Comments. The Director partially concurred with draft Recommendation 1.a.(11) (renumbered Recommendation 1.a.[10]). He stated that it is inappropriate to require the use of a DoD Standard when commercial standards are preferable in accordance with Deputy Secretary of Defense guidance.

Audit Response. Management comments were responsive to the intent of the Recommendation 1.a.(10). Based on management's comments, we revised the recommendation to provide a wider focus. Our revision provides for proposing tailoring to the DoD Standard or commercial standards for software documentation and reporting as contractors deem most appropriate. In the proposal documentation, each contractor should provide the cost and

benefit justification for the tailored documentation proposed. We, therefore, request management to provide comments on our revised recommendation in response to the final report.

(11) Revise language on prototyping to state that solicitation proposals for Phase I, Demonstration and Validation, contracts should include a complete description of the prototyping plan required to be submitted with the contractor proposals.

We added Recommendation 1.a.(11) as a result of comments provided by the Director, Defense Procurement, and the Director, Acquisition Program Integration, on Recommendation 3. in the draft report. We request the Under Secretary of Defense for Acquisition and Technology to provide comments on Recommendation 1.a.(11) in response to the final report.

b. Issue a handbook providing guidance for formulation of prototyping plans for programs approaching Milestone I, Concept Demonstration Approval. Handbook guidance should cover costs and benefits consideration of system, subsystem, or component prototyping for hardware, software, and manufacturing processes; competitive prototyping; and the use of modeling and simulation to substitute for or refine prototyping effort.

Director, API, Comments. The Director nonconcurred, stating that it was not clear that a handbook was necessary and that it certainly was not necessary to revise DoD Instruction 5000.2 to issue a handbook.

Audit Response. We do not agree with management's assertion that a clear need does not exist for a prototyping handbook. A handbook is needed because existing DoD guidance does not provide program managers enough assistance to determine the level and scope of prototyping warranted on each program. The handbook would help program managers to effectively perform the cost versus benefits consideration of system, partial system, or subsystem prototyping options for hardware, software, and manufacturing processes. Also, the handbook would help program managers understand how to consider the use of competitive prototyping and determine how modeling and simulation could be integrated into the prototyping process. To be useful, the handbook should include a discussion of the possible benefit and cost factors that can enter a prototyping decision and discuss the possible methodologies to weigh these factors. The handbook should not give specific weights to the benefit and cost factors or to mandate how each factor should enter the decision process. In summary, a handbook would be a needed supplement to existing guidance in DoD Instruction 5000.2. We request that management reconsider its position in response to the final report.

c. Revise DoD Manual 5000.2-M to:

(1) Delete the language in Part 4 that cites Part 12 as an example of the competitive prototyping strategy waiver.

Director, API, Comments. The Director nonconcurred with draft Recommendation 1.c., (renumbered Recommendation 1.c.[1]), stating that Change 1 incorporated the requirement to include the rationale for not using prototyping strategy as part of the Acquisition Strategy Report.

Audit Response. Management was correct in asserting that Change 1 to DoD Manual 5000.2-M incorporated the requirement to include the rationale in the acquisition strategy report when it is not practicable to use a competitive prototyping strategy. However, Part 4 of the DoD Manual 5000.2-M still contains confusing language regarding the justification for not prototyping. DoD Publication System Change Transmittal, issued March 5, 1993, that transmitted Change 1, states that the following language was deleted: "Prepare a request for a competitive prototype strategy waiver for milestone decision authority approval, under authority delegated by the Secretary of Defense, specifying the basis for the waiver (see Part 12 for competitive prototype strategy waiver)." The last portion of the above language, the reference to Part 12, was never actually deleted so the Manual's discussion on justification for not using competitive prototyping still refers the reader to Part 12 that, after Change 1, states "Reserved for Future Use." We revised the Recommendation to require only that the faulty reference be removed at the next update of the manual. We, therefore, request management to provide comments on the revised recommendation in response to the final report.

(2) Require a software test and evaluation plan to be included as an annex to the Test and Evaluation Master Plan in support of all milestone decisions in all cases where software is determined to be a moderate or high risk area in the Annex D, Risk Assessment, of the Integrated Program Summary.

Director, API, Comments. The Director nonconcurred with the draft Recommendation 1.a.(10) (renumbered Recommendation 1.c.[2]). He stated that software test and evaluation is currently a required integral part of the TEMP.

Audit Response. We agree with management's statement that the current version of DoD Instruction 5000.2 requires software test and evaluation to be a part of the TEMP. However, we still believe additional guidance is needed concerning how the software test and evaluation planning should be documented in the TEMP. As a result, we revised the recommendation to recommend that DoD Manual 5000.2-M be revised to provide guidance for addressing software test and evaluation in the TEMP. Precedence validates our recommended policy change. Before its cancellation in 1991, DoD Manual 5000.3-M-3, "Software Test and Evaluation Manual," November 1987, provided guidance identifying specific portions of the TEMP that should include software aspects in the planning for system test and evaluation. Specifically, the DoD Manual 5000.3-M-3 required that:

o software test and evaluation planning address mission, system, and software requirements and their associated support requirements and interrelationships;

o the TEMP include provisions for software test and evaluation throughout the life-cycle of the system;

o each phase of evaluation be structured to provide a clear understanding of software maturity, to form the basis for future evaluations, and to establish traceability with previous evaluations; and

o system-level testing be designed and conducted to demonstrate the extent of fault-free or fault-tolerant software performance and determine the level of achieved mission requirements.

In addition, the DoD Manual 5000.3-M-3 referenced guidelines on how to evaluate TEMPs to ensure that software was adequately addressed and gave examples of software test programs.

Although software is more critical to system success than ever, DoD Manual 5000.2-M does not provide the type of guidance described above for integrating and documenting planned software test and evaluation into the TEMP. The cancelled DoD Manual 5000.3-M-3 discussed two options for integrating software test and evaluation into the TEMP: embedding the software test and evaluation details into the body of the TEMP or attaching the software test and evaluation details as an appendix, while not repeating items addressed in the main document. Given the TEMP's 30-page restriction in DoD Manual 5000.2-M (excluding appendixes), the documentation of planned software test and evaluation in an appendix to the TEMP appears to be the most practical approach. We also recognize that software may not be a critical area on every MDAP. Therefore, the recommended revision to DoD Manual 5000.2-M should be limited to those programs where software was rated as moderate to high risk in Annex D, Risk Assessment, of the Integrated Program Summary. We, therefore, ask that management provide comments on our revised recommendation in response to the final report.

d. Designate an office of primary responsibility for determining whether new Data Item Descriptions must be developed to allow for submission of contractor prototyping plans and contractor reports documenting the results of prototyping risk reduction efforts.

Audit Response. We added Recommendation 1.d. in response to Director, Defense Procurement and Director, Acquisition Program Integration, comments received on Recommendation 3. in the draft report. We, therefore, request the Under Secretary of Defense for Acquisition and Technology to provide comments on Recommendation 1.d. in response to the final report.

Overall Director, API, Comments on Recommendation 1. The Director agreed with our overall finding that prototyping could be used more effectively to reduce risk and assess how design approaches will operate before proceeding with EMD. However, he did not support most of our recommendations because he believed the recommendations would radically reduce the flexibility provided to the milestone decision authorities under DoD Instruction 5000.2, that is, to choose an acquisition strategy appropriate to the specific situation. The Director

further stated that he believed that our recommendations would add unnecessary oversight and appear to conflict with Secretary of Defense guidance concerning waiver authority, streamlining, and reduction of bureaucratic regulations. Also, he stated that prototyping requires additional up-front money and that our recommendations could hinder the Armed Forces by diverting funds from production to mandatory prototypes. Finally, he believed that our findings (specific problems cited on individual MDAPs) were weak, that we did not provide enough information on the Army Comanche and Air Force F-22 programs, and that our report had too much background information that he already was aware of.

Audit Response. We disagree with the contention that our recommendations would radically reduce the flexibility provided to the milestone decision authorities under DoD Instruction 5000.2 and result in unnecessary oversight in conflict with Secretary of Defense guidance on waiver authority. Rather than reducing flexibility and adding oversight, our recommendations are designed to provide information that will improve the quality of decisionmaking at Milestones I, II, and IV. We advocate an amended policy framework that not only would still allow program managers to choose the acquisition strategy they believe is most appropriate but also requires them to document the trade-off analysis made to support their decisions. If carefully planned and supported decisions are made at the scheduled milestones, the need for unscheduled oversight between the milestones will be reduced. In our responses to the management comments on individual recommendations, we explained the need for the changes to DoD Instruction 5000.2 and the benefits of increased roles in developing prototyping acquisition strategies by the Director, ARPA, and the Director, Program Analysis and Review.

o In our responses to management's comments, we have provided further rationale for changing policies related to prototyping. Additionally, Appendix G. documents that prototyping was too limited to adequately reduce risk in four of the six programs we reviewed. The four programs had significant limitations in the planning or execution of hardware prototyping strategies. Two of the four programs also had limitations in software prototyping strategies and two programs had limitations in prototyping manufacturing processes. Also, Early Operational Assessments used to determine whether acceptable performance is achievable based on the recommended design approach were not adequately supported by the test and evaluation of prototypes for three of the six programs. Additionally, the results of our review reaffirmed the following conclusions of earlier studies on prototyping performed by RAND and the IDA:

o Confusion regarding terms, including prototyping, has historically led to inconsistencies in acquisition policy and strategies.

o Lack of a clear definition of prototyping has contributed to a lack of consensus on prototyping policy.

o Criteria provided by DoD Instruction 5000.2 for determining whether to use competitive prototyping could be applied to other forms of prototyping activity as well.

o Important and challenging programs should be prototyped.

o We recognize that prototyping may divert additional funds to system development; however, if properly planned and executed, most prototyping will also reduce overall program cost. Prior research by the IDA documented the positive relationship between prototyping and reduced program cost growth. Prototyping, when properly executed, also provides information that makes costs more predictable and thus facilitates more accurate budgeting of resources. Our recommendations are intended to foster informed choices concerning the amount of prototyping that is done and to ensure that the optimal amount of risk and cost reduction benefits accrue.

o Management's contention that our draft report discussed extensively acquisition policies and prior studies with which the Director, Acquisition Program Integration, was already familiar may be valid, but is irrelevant. A thorough discussion of the relevant acquisition policies and studies is necessary to provide all readers with the necessary background to understand the problems relating to prototyping and the need for implementing our recommendations. The final report will be distributed to a variety of users.

o We disagree with management's claim that our draft report had many inaccuracies relating to the UTTMDS, JSOW, and FDS programs and that our report was unbalanced because it largely ignored the F-22 and Comanche programs. In Appendix I, we clarified factual information on UTTMDS, JSOW, and FDS. In the draft report, we cited the F-22 program as a positive example of how effective interface between the program manager and the Military Department's operational test organization can support successful progression to Milestone II, Development Approval. The Comanche Program was in Appendix F of the draft report, which shows that prototyping on the program was too limited to adequately reduce hardware risk. Although we did not cite the Comanche program as a specific example in Part II of the draft report, we determined that the Comanche Program, like the BAT Program, was progressing to EMD with inadequate hardware risk reduction. Appendix I provides additional information related to the limitations of prototyping on the Comanche. For brevity, we only discussed the BAT example in Part II of the draft report.

The complete text of the Director, Acquisition Program Integration, comments is in Part IV. The audit responses to the Director's comments on the text of our finding are provided in Appendix I.

2. We recommend that the Director, Program Analysis and Evaluation, report on the sufficiency of the proposed prototyping plan at Milestone I in support of preparation of adequate cost and operational efficiency analyses and life-cycle cost estimates.

Director, Program Analysis and Evaluation, Comments. The Director nonconcurred, stating that the report contained no clearly identifiable statement of findings and, to the extent that a finding can be inferred, lacked compelling supporting rationale. He further stated that it seems premature to change DoD Instruction 5000.2 to mandate a highly structured, prescriptive prototyping plan given the lack of compelling rationale. The complete text of management comments is in Part IV.

Audit Response. We have difficulty understanding management's comments that the report did not clearly identify the finding condition and did not provide compelling supporting rationale. The finding condition is clearly stated in the first sentence: "Prototyping could be used more effectively in the acquisition strategies for major Defense acquisition programs to identify and reduce risk and to assess whether the most promising design approaches will operate in the intended operating environment before preceding with EMD." The finding is supported by our documentation of deficiencies in the planning and execution of the prototyping strategies in six major Defense acquisition programs and the results of the numerous earlier studies of prototyping presented in Part II of the report and in Appendix D.

o Our recommendations would result in a structured but flexible methodology for determining the level and scope of prototyping warranted on each program. As explained in our report, a prototyping plan would involve the iterative application of an analytical process to arrive at a tailored course of action suited to the needs of a given program. The prototyping plan for each program would be based primarily on the judgment of experienced engineers and managers. We endorse authorizing program managers to update and revise the prototyping plan as the program moves toward Milestone I. The first version of the plan would be prepared before issuance of the Request for Proposals for the Demonstration and Validation contract. Later, the program managers should be allowed to update the plan based on contractor input provided in response to the Request for Proposals and ARPA recommendations made at Milestone I. Accordingly, we request that the Director, Program Analysis and Evaluation, reconsider his position in response to the final report.

Appendix I contains audit responses to Director, Program Analysis and Evaluation, comments on the text of our finding.

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Part III - Additional Information

Appendix A. Use of Prototyping in the Acquisition Process

History of Prototyping. Prototyping has long been part of the acquisition process for weapon systems. However, the use of prototyping has been cyclical according to RAND National Defense Institute Report No. R-4161-ACQ, "The Nature and Role of Prototyping in Weapon System Development," 1992. RAND prepared this report for the Under Secretary of Defense for Acquisition and Technology (USD[A&T]).

Early Usage. The RAND Report states that prototyping of aircraft engine and airframe combinations was the pattern of aircraft development before 1940 and was common into the 1950s. With the advent of the "total system concept" in the early 1950s, the use of prototyping declined. The pattern reversed in the late 1960s when (then) Deputy Secretary of Defense Dr. David Packard instituted a "fly before you buy policy." While the use of prototyping was included in DoD acquisition regulations in the 1970s, the RAND Report states that the Military Departments resisted the policy and it was not fully accepted or applied.

Renewed Interest. In the mid-1980s, DoD interest in prototyping again increased. In June 1986, "A Quest for Excellence, Final Report to the President by the President's Blue Ribbon Commission on Defense Management," referred to as the Packard Commission Report after the chairman of the Commission, recommended that a high priority be given to building and testing prototype systems to:

- Demonstrate that new technology can substantially improve military capability and
- Provide a basis for realistic cost estimates before a full-scale development decision.

The Packard Commission emphasized that prototyping before commitment to full-scale development (currently Phase II, Engineering and Manufacturing Development) would enhance source selection, provide early demonstrations of the feasibility and operational utility of new technologies, and improve initial cost estimates of new systems. Subsequent studies by RAND, the Institute for Defense Analysis, and the Defense Science Board also advocated greater use of prototyping.

When the Packard Commission Report was issued, both Congress and DoD began to encourage use of prototyping. In 1986, Congress added title 10, United States Code, section 2365, "Competitive prototype strategy requirement: major Defense acquisition programs," which expired on September 30, 1991. The statute required that before development under an MDAP begins, contracts must be entered into with two or more contractors for competitive design and manufacture of a prototype system or subsystem. Only Congress could waive

the requirement. The 1991 expiration date was designed to permit DoD time to develop appropriate regulatory guidance for use of competitive prototyping strategies. On October 23, 1992, the competitive prototyping requirement was reinstated in title 10, United States Code, section 2438, "Major Programs: Competitive Prototyping." Reinstatement was prompted by congressional observation of the success of a program that used competitive prototyping and problems in programs that had not.

DoD acquisition regulations became more specific on the requirements for using prototyping with the issuance of DoD Instruction 5000.2, "Defense Acquisition Program Procedures," September 1, 1987. This version of the Instruction required establishment of a competitive prototyping strategy at Milestone I, Concept Demonstration/Validation Decision (now Concept Demonstration Approval), and use of results from prototyping to support the Milestone II, Full-Scale Development Decision (now Development Approval). Prototyping has remained a part of the Instruction through all subsequent updates.

Recent Initiatives. In January 1993, the report of the Acquisition Law Advisory Panel to the United States Congress, "Streamlining Defense Acquisition Laws," recommended that title 10, United States Code, section 2438 be repealed. While the Panel believed that competitive prototyping makes "eminently good sense," the panel did not believe it should be statutorily prescribed. Rather, the Panel believed that the better approach is to allow the Secretary of Defense to address the issue by internal regulation and ensure that competitive prototyping is considered as part of the overall acquisition strategy. The Panel concluded that DoD has regulations that encourage competitive prototyping in certain circumstances and that repeal of the statute would provide DoD greater management flexibility in developing its acquisition strategies. On October 26, 1993, Senate Bill S.1587 was introduced that, if passed, will repeal Section 2438.

Increased Use of Prototyping. Continued encouragement of the use of prototyping by Congress and DoD has increased its use in the acquisition of MDAPs. Appendix B shows that prototyping was used in 53 percent of the MDAPs we surveyed that started since 1987 as compared with 40 percent for MDAPs started before 1987. However, those statistics are based on the traditional hardware-oriented definition of prototyping that does not include electronic design simulation and analysis, now widely used in DoD programs. As discussed in this report, the use of such "electronic prototyping" should be more fully considered in prototyping acquisition strategies. Also, we used the same methodology as the RAND National Defense Institute in its study that credited programs as having used prototyping if it was used to any extent regardless of whether additional prototyping benefits were available but not pursued for the programs.

Appendix B. Most Major Defense Acquisition Programs Used Some Prototyping

Program	System Level	Subsystem[1] Level	Software Level	Manufacturing Process
AWACS RSIP	N	Y	Y	N
Comanche	Y	Y	Y	Y
CSSCS	N	Y	Y	N
FA-18 E/F	N	N	N	N
FMTV	N	N	N	N
JDAMS	N	Y	Y	Y
JPATS[2]	Y	N	N	N
JSIPS	N	N	N	N
JSOW[2]	Y	Y	N	N
Kiowa Warrior	N	N	N	N
PLS	N	N	N	N
SCAMP	Y	Y	N	N
SMART-T	N	N	N	N
SRUAV	N	N	N	N
UTTMDS	Y	Y	Y	Y

Y - prototyping used
N - prototyping not used

[1]We assumed that some partial or subsystem level prototypes were built if a program used system-level prototyping. We also credited a program as prototyping at the subsystem level if any aspect of the program was prototyped. In some cases, however, further prototyping opportunities existed on other subsystems.

[2]Competing contractors did some degree of prototyping before contract award or outside the scope of the contract.

Appendix B. Most Major Defense Acquisition Programs Used Some Prototyping

Summary

Of the 126 Major Defense Acquisition Programs identified in the most recent USD(A&T) listing dated July 19, 1993, 15 ongoing programs had a Milestone I review since 1987. Our analysis excluded ship and satellite programs. We found that 8 of 15 (53 percent) programs used or plan to use prototyping strategies before EMD. We compared our audit results to those of the IDA November 1992 study for USD(A&T). We omitted ship and satellite programs from the results the IDA reported to be comparable with our data base. After we omitted ship and satellite programs, we found that 37 of 93 (40 percent) programs started before 1987, which were identified over 32 years, used prototyping strategies.

Legend

AWACS RSIP	Airborne Early Warning and Control System Radar System Improvement Program
CSSCS	Combat Service Support Control System
FMTV	Family of Medium Tactical Vehicles
JDAMS	Joint Direct Attack Munitions System
JPATS	Joint Primary Aircraft Training System
JSIPS	Joint Service Imagery Processor
PLS	Palletized Load System
SCAMP	Single Channel Anti-Jam Manportable Terminal
SMART-T	Secure Mobile Anti-Jam Reliable Tactical Terminal
SRUAV	Short Range Unmanned Aerial Vehicle

Appendix C. Summary of Contractor Survey Concerning the Use of Prototyping

Most (four, five, or six) of the six contractors surveyed agreed to each of the following statements:

- Prototyping's effectiveness as a risk-reduction tool suffers when it occurs outside the contract, i.e., on corporate funds (Independent Research and Development or Bid and Cost Proposal).

- Government funding and planning must remain consistent if prototyping is to be successful.

- Full-system prototypes are good marketing tools for Congress, but are not as cost-effective as subsystem prototyping in high-risk areas.

- Critical software algorithms should be prototyped.

- Properly done, prototyping is beneficial to a program.

- A written Defense Acquisition Board-approved prototyping plan will help outline contractor and program office responsibilities. This strategy will help preliminary (Pre-milestone I) prototype planning.

- Operational Test and Evaluation should use prototypes to the maximum extent practicable.

- Critical manufacturing technologies, especially important materials, should be prototyped as early as possible in Demonstration and Validation.

- Models and simulations should be used extensively, but their effectiveness is limited unless prototyping verifies the results.

- Prototyping should be used in direct proportion to the level of expected technological risk.

- Prototyping Demonstration and Validation should be done using a cost-plus contract.

- ARPA could play a limited advisory role.

Appendix D. Prior Audits and Other Reviews

General Accounting Office

Report No. GAO/NSIAD-90-107 (OSD Case No. 8341), "Weapons Testing: DoD Needs to Plan and Conduct More Timely Operational Tests and Evaluation," May 17, 1990, found that although some prototypes have been used for Development and Test and Evaluation, the Military Departments generally are not planning to use them for Operational Test and Evaluation before production start-up. The General Accounting Office believes, however, that with adequate planning, prototypes can be designated for Operational Test and Evaluation.

Report No. GAO/NSIAD-89-98 (OSD Case No. 7800), "Navy Weapons Testing: Defense Policy on Early Operational Testing," May 8, 1989, found that the Navy often proceeded to full-scale development or low-rate initial production before Operational Test and Evaluation was complete. The General Accounting Office recommended that the Secretary of Defense reemphasize the desirability of performing Operational Test and Evaluation of representative hardware as early as possible in the acquisition cycle. The OSD Director of Operational Test and Evaluation partially concurred and stated that a redefinition of the testing process had already been proposed to the House and Senate Armed Services Committees. The OSD proposal would enhance the valuations of new systems by providing for operationally oriented evaluations of a system's expected capability as early as possible in the acquisition process.

Report No. GAO/NSIAD-89-72 (OSD Case No. 7844), "Light Helicopter Program: Risks Facing the Program Raise Doubts About the Army's Acquisition Strategy," December 23, 1988, found that the current Light Helicopter Program Acquisition Strategy of eliminating test and evaluation of prototypes runs counter to DoD acquisition guidance.

Office of the Inspector General, Department of Defense

Report No. 94-014, "Low-Rate Initial Production in Major Defense Acquisition Programs," November 9, 1993, recommended establishing a required milestone review before entry into Low-Rate Initial Production (LRIP). We believe the expanded use of prototypes will be consistent with improving the quality of both EMD and low-rate initial production milestone decisions. Report recommendations were made to the Under Secretary of Defense for Acquisition and as follows:

1. Revise DoD Instruction 5000.2 concerning major Defense acquisition programs to:

a. Establish a required milestone review for entry into low-rate initial production, including confirmation of required initial production quantities, attainment of all required exit criteria, and designation of approval authority for subsequent low-rate initial production contracts. Program documentation listed in Appendix F (of Low-Rate Initial Production report) should be required for the milestone review.

b. Provide guidance on the specific minimum required program accomplishments for initially committing long-lead procurement funding for low-rate initial production, entering low-rate initial production, and awarding subsequent low-rate initial production lots. As a minimum, operational assessment, design and production readiness review, and operational testing prerequisites should be established.

c. Require that program-specific exit criteria be established for initial long-lead procurement funding, entry into low-rate initial production, and subsequent initial production lots at the Milestone II decision point and incorporated as events in development contracts.

d. Direct that engineering and manufacturing development contracts include requirements for production-representative engineering development models for purposes of performing operational assessments before initially committing long-lead procurement funding, unless specifically waived by the milestone decision authority at Milestone II, Development Approval.

2. Require Military Standard 499A to include a direct link between systems engineering requirements and low-rate initial and full-rate production decisions.

3. Require that the minimum low-rate initial production quantities necessary for initial operational test and evaluation, establishment of a production base, and orderly increase to a full-rate production be separately identified, documented, and approved by the milestone decision authority at the Milestone II, Developmental Approval, decision point and reaffirmed before entry into low-rate initial production.

4. Review low-rate initial production quantities in the guidelines for production readiness reviews and require certification as a result of the review of the minimum low-rate initial production quantity.

5. Require that the cost and benefits of a break in production versus annual low-rate initial production buys be assessed by the milestone decision authority before entry into low-rate initial production to limit low-rate initial production quantities to the minimum necessary while providing production units for operational test and evaluation.

6. Require Service Acquisition and Technology Executives to request a program-specific waiver from the Under Secretary of Defense for Acquisition before award of low-rate initial production contracts whenever testing and review prerequisites in DoD regulations and the approved acquisition strategy are deleted, modified, or not met.

As of March 11, 1994, the Under Secretary of Defense for Acquisition and Technology had tentatively planned corrective actions that meet the intent of all recommendations. On May 11, 1994, the Assistant Inspector General for Auditing agreed with a proposal from the Under Secretary of Defense for Acquisition and Technology to implement the recommendations together with recommendations to be presented by the Defense Acquisition Board Process Action Team.

Report No. 93-017, "The Critical Design Review Process for Major Defense Acquisition Programs," November 5, 1992, recommended that the Critical Design Review be an element of the acquisition program baseline and that completion of the Review be an exit criteria for entering production. We believe that a significant level of design review can be supported through the use of prototypes. The Under Secretary of Defense for Acquisition and Technology agreed to modify DoD Instruction 5000.2 to require that the completion date for the Critical Design Review be included in the Acquisition Program Baseline and to require that the Critical Design Review be included as one of the minimum requirements for approval of entry into low-rate initial production.

Report No. 91-INS-05, "Defense Advanced Research Projects Agency," March 15, 1991, determined that no formal process provides structure to the Defense Advance Research Projects Agency's (now ARPA) involvement in prototyping. No official policy addresses prioritization, approval, funding, oversight, and other issues relating to the ARPA's expanded prototype role. The Report recommended that the Under Secretary of Defense for Acquisition (now USD[A&T]) clarify the ARPA prototype mission and establish a process governing ARPA involvement in prototyping. The Under Secretary of Defense for Acquisition partially concurred with the recommendations stating that the Agency's mission has been clarified by the Executive Director of the Packard Commission in response to a request by the Director, Advanced Research Projects Agency, to do so (the "clarification" refers to the April 1989 letter from Dr. David Packard and Dr. William J. Perry discussed under "ARPA Involvement in Formulating Prototyping Strategies"). The Under Secretary of Defense for Acquisition further stated that the Secretary of Defense can task the ARPA to perform such technology projects as deemed necessary and that no additional processes for governing the Agency's involvement in prototyping were needed.

Other Reviews

"Report of the Defense Science Board Task Force on Aircraft Assessment," February 25, 1993, stated that both ground and flight prototype testing during Phase I, Demonstration and Validation, reduced the technical risk of aircraft programs, thereby reducing the schedule and cost risks in proceeding to EMD and production.

RAND Report R-4161-ACQ, "The Nature and Role of Prototyping in Weapon Systems Development," 1992, concluded that some form of prototyping is almost always appropriate. RAND indicated that prototyping will generate information to improve the quality of decisionmaking in an environment of risk and uncertainty. The Report recommended that a rational decisionmaking process for considering the full range of prototyping considerations be defined and applied to the development of acquisition strategies for weapon systems.

IDA Paper P-2722, "The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs," November 1992, states that prototyping, when done before full-scale development, greatly reduced development cost growth in tactical munition programs, where the programs with the greatest technical risk were prototyped. In addition, prototyping helps developers and users understand technical risks and uncertainty of the requirements. The Paper recommended that acquisition managers consider using more prototyping.

The Institute for Defense Analyses Document D-1097, "Prototyping Defense Systems," December 1991, concluded that prototyping makes development costs more predictable and production cost growth lower. The Report recommended prototyping systems involving: new performance or manufacturing technologies for the contractor(s), high cost per unit and large production quantities, or long lead time or high cost to correct potential unforeseen problems.

The "Defense Management Report to the President," June 12, 1989, recommended a more vigorous policy direction in the early phases of system development, especially those that involve funds and schedules for prototyping and testing. The report advocated building and testing system and critical subsystem prototypes as well as the early test and evaluation of prototype hardware.

"Packard Commission Report," June 1986, recommended that the role of Defense Advance Research Projects Agency (now ARPA) should be expanded to include the additional mission of stimulating greater emphasis on prototyping Defense systems. ARPA should actually conduct prototype projects that embody technology that might be incorporated in joint or selected Military Department programs. ARPA should also, upon request, assist the Military Departments in their own prototyping programs. The Packard Commission also strongly encouraged prototyping to resolve program risk.

Appendix E. Prototyping Guidance

DoD Instruction 5000.2, "Defense Acquisition Policies and Procedures": The Instruction, issued February 23, 1991, provides policies and procedures for program managers, milestone decision authorities, and the respective supporting staffs to acquire products that emphasize acquisition planning, communications with users, and risk management in all phases of the acquisition process. The Instruction identifies prototyping as a major element of Phase I, Demonstration and Validation, to assess and reduce risks from integrating available and emerging technologies to satisfy a valid mission. In addition, the Instruction provides the following guidance:

o Programs will establish requirements for prototyping at Milestone I, Concept Demonstration Approval. Those requirements will be based on an assessment of technological, manufacturing, and cost risk associated with the proposed concept and the results of technology demonstrations.

o Prototyping is a critical element in meeting the objectives for Phase I, Demonstration and Validation, to reduce risk and provide the operational test organization an opportunity for early operational assessment of effectiveness and suitability. Prototyping will also provide the opportunity for early assessment to identify the need for new or modified test capabilities to support system development.

o Programs should use the results of the test and evaluation of prototypes to confirm the feasibility of a specific design approach relative to its ability to satisfy the mission need and to achieve acceptable operational performance requirements within affordable constraints.

o Programs should establish a competitive prototyping strategy at Milestone I, Concept Demonstration Approval, and use the results to support the Milestone II, Development Approval. Programs are to use competitive prototyping of systems or critical subsystems unless the milestone decision authority issues a specific waiver.

o Programs may not enter Phase II, EMD, unless the milestone decision authority confirms, before the Milestone II, Development Approval, that prototyping results provide reasonable assurance that the technologies and processes critical to success are attainable.

DoD 4245.7-M, "Transition from Development to Production": The Manual, issued in September 1985, helps structure technically sound programs, assess their risk, and identify areas needing corrective action. The assistance is in a series of templates; each template discusses an area of risk and then provides methods for reducing that risk. The templates are based on lessons learned from analyses of programs.

The Manual states that program risk is introduced when a particular element is started late or continues beyond the time line. Knowledge gained through

prototyping experiences during Demonstration and Validation can minimize risk for 30 of 31 elements (97 percent) identified under "Design," "Testing," and "Production" categories listed in the Manual.

Military Standard 2167A, "Defense System Software Development": The Military Standard, issued February 29, 1988, establishes uniform software requirements that are applicable throughout the system's life cycle. The requirements of the standard allow the Government to oversee a contractor's software development, testing, and evaluation efforts. The requirements in the standard apply to the development of computer software configuration items.

The standard must be appropriately tailored to require only what is needed for each acquisition. The program manager should tailor this standard to ensure that only cost-effective requirements are cited in Defense solicitations and new contracts. Specific tailoring guidance is in DoD Handbook 248, "Guide for Application and Tailoring of Requirements for Defense Material Acquisitions."

Draft Military Standard 498, "Software Development and Documentation," December 22, 1992, will merge DoD Standard 2167A, "Defense System Software Development"; DoD Standard 7935A, "DoD Automated Information Systems Documentation Standards"; and the Data Item Descriptions associated with those standards. Thus, a single DoD software development standard will be usable for any software. The standard will establish uniform requirements for software development that are applicable throughout the system's life cycle. As required for application of Military Standard 2176A, this standard also provides for appropriate tailoring to require only what is needed for each item or type of software developed.

Military Standard 1521-B, "Technical Reviews and Audits for Systems, Equipments, and Computer Software": This military standard, issued June 4, 1985, identifies requirements for technical reviews and audits, which occur throughout the acquisition process. The specific reviews that occur during Phase I, Demonstration and Validation include:

o System Design Review: This review is conducted to evaluate the optimization, correlation, completeness, and risks associated with the allocated technical requirements. This review also includes a summary review of the system engineering process and engineering plans for the next phase of the effort. This review is conducted when the system definition effort has proceeded to the point where system characteristics are defined and the configuration items are identified.

o Preliminary Design Review: This review is a formal technical review of the basic design approach for a configuration item or aggregate of configuration items. The overall technical program risks associated with each configuration item shall be reviewed on a technical, cost, and schedule basis. For computer software configuration items, this review will focus on:

o the evaluation of the progress, consistency, and technical adequacy of the selected top-level design and test approach;

o compatibility between software requirements and preliminary design; and

o the preliminary version of the operation and support documents.

Draft Military Standard 499B, "Systems Engineering": The draft military standard, dated May 6, 1992, is being prepared by OSD, the Military Departments, and an Industry Steering Committee. The draft standard requires establishing and implementing a structured, disciplined, and documented systems engineering effort incorporating the systems engineering process; multi-disciplinary teamwork; and the simultaneous development of products and processes needed to satisfy operational needs. The draft standard defines a total system approach for developing Defense systems, defines requirements for technical reviews, and provides a method for evaluating progress in achieving system objectives. In regard to prototyping, section 5.4.3, "Prototyping," requires that organizations evaluate whether prototyping should be used to identify and reduce risk of integrating available and emerging technologies into an item's design for satisfying requirements. Prototyping should provide timely assessment of item testability to identify the need for new or modified test capabilities. In addition, prototyping should address all aspects of the emerging technology that bear upon its successful application (i.e., software, hardware, and manufacturing processes).

Appendix F. Impact of Prototyping and Low-Rate Initial Production Reports

Italic sections show proposed changes to DoD Instruction 5000.2.

MILESTONE I	MILESTONE II	*MILESTONE [1,2] IIIA*	MILESTONE III
• Approval to enter Phase I • Approve the acquisition strategy ***(with prototyping plan)*** and concept baseline ***(with prototyping milestone dates)*** • Establish exit criteria for Phase I ***(to include quantifiable exit criteria for the use of prototypes)*** • ***Require independent test organizations report on acquisition strategy reports (to include prototyping plans relative to performance of operational assessments)*** • ***Require ARPA and OSD to report on prototyping plans***	• Approval to enter Phase II ***based on meeting Phase I exit criteria including producibility analysis based on prototyping and completing an initial design review*** • Approve the acquisition strategy and development baseline • ***Establish Milestone IIIA review for programs planning LRIP[2]*** • Establish specific exit criteria for ***award of long-lead procurement for LRIP[2]*** and for Phase II • Identify LRIP quantities ***(Separate LRIP quantities approved for operational testing, production base, and increase to full-rate production)*** • ***Require EMD contracts to provide for production-representative models before committing long-lead procurement funding***	• ***Approval to enter Phase IIIA (based on, at a minimum, operational assessment, design and production readiness reviews, demonstration of operational requirements, and meeting program-specific exit criteria)[2]*** • ***Reaffirm LRIP quantities[2]*** • ***Update the acquisition strategy report and development baseline[2]*** • ***Establish program-specific exit criteria for award of subsequent LRIP lots[2]***	• Approval to enter Phase III • Approve the acquisition strategy and production baseline • Establish specific exit criteria for Phase III

[1]Milestone IIIA will be an additional review for programs that the Milestone II review determined Low-Rate Initial Production to be necessary before full production.

[2]Tentative agreement already reached with USD(A&T) to implement these changes.

Appendix G. Summary of Deficiencies in the Use of Prototyping

	Comanche	BAT	JSOW	FDS	F-22	UTTMDS
Planning and Building						
- Prototyping too limited to adequately reduce risk						
-- hardware	X	X	X	X		
-- software			X	X		
-- manufacturing process		X		X		
- Competition						
-- Waivers required but not submitted for relief from competitive prototyping requirements			X			
-- Inadequate control over competitive prototyping						X
- Acquisition program baseline for Demonstration and Validation inadequate to measure progress in prototyping		X[1]	2	2	2	X
Testing						
- Limited Operational Assessment						
-- Over-reliance on modeling and simulation			X			
-- Inadequate assessment of operational suitability		X	X	X		
- Planning for test and evaluation of software insufficiently documented at transition to EMD		X	X		X	

[1]Pertains to baseline information on the pre-planned product improvement portion of the program, which is still in Demonstration and Validation.

[2]We did not examine Demonstration and Validation baselines for these programs since they had already progressed to EMD.

Appendix H. All Systems Evaluated Used Some Prototyping

Program	Hardware System Level	Hardware Subsystem Level	Software Level	Manufacturing Process
BAT	N	Y	N	N
Comanche	Y	Y	Y	Y
F-22	Y	Y	Y	Y
FDS	N	Y	N	N
JSOW*	Y	Y	N	N
UTTMDS	Y	Y	Y	Y

Y - prototyping used
N - prototyping not used

*Competing contractors did prototyping outside the scope of the contract.

Appendix I. Audit Response to Specific Management Comments

The Director, Acquisition Program Integration; the Director, Program Analysis and Evaluation; and the Director, Defense Procurement, provided specific comments on the body of the audit finding in the draft report. Below we discuss each management comment and provide our audit response.

Director, Acquisition Program Integration, Comments

Comments. The Director questioned why we did not discuss the Navy's FDS in the body of the draft report. The FDS is one of the four programs identified as having limitations in planning or execution of hardware prototyping strategies.

Audit Response. We used specific program examples to show the types of limitations identified with program hardware prototyping strategies rather than discuss in detail all four programs we identified with limitations. Although the FDS system was not used as an example in our discussion of hardware prototyping strategies, we subsequently did discuss limitations in the FDS hardware prototyping strategy as part of our discussion of "Early Operational Assessments of Prototyping Efforts."

Comments. The Director stated that the draft report was incorrect in stating that the JSOW program did not plan to use prototyping in Demonstration and Validation. Specifically, the JSOW program office planned an appropriate amount of component prototyping using the Recoverable Test Vehicle Program. When the Recoverable Test Vehicle Program ran into difficulties, the JSOW program office coordinated with the three Demonstration and Validation contractors to modify their plans to include prototyping. These contractors used their own funds to develop and demonstrate the maturity of their systems. If the JSOW program office had contracted for three independent prototyping efforts, the cost and schedule impact on the program would have been an additional $64 million and a delay of 2 years.

Audit Response. We agree that the JSOW Program did plan to use prototyping in Demonstration and Validation as discussed in the draft report. However, what we pointed out in the draft report was that the planning and execution of prototyping had significant limitations for the JSOW Program, not that the Program did not plan to use prototyping in Demonstration and Validation. Our estimate of $34 million to modify the three Demonstration and Validation contracts to require competitive prototyping was based on information provided by the JSOW Program Office.

Comments. The Director stated that the report recognized that prototyping is primarily a risk-reduction activity but fails to recognized that the whole premise

of the JSOW program is low-risk integration of existing technology. The Director further stated that experienced program managers and engineers assessed program risks and developed the prototyping strategy accordingly. It was determined at Milestone I that conducting subsystem testing, analysis, simulations, and demonstrations in Demonstration and Validation would be adequate to support a decision to move into the EMD Phase.

Audit Response. Development of JSOW was considered low risk and involves the integration of existing technology. However, the point we were conveying was that performing the vast majority of prototyping activity outside the scope of the contracts seriously impacted the JSOW Program Office's ability to further reduce JSOW development risk in Demonstration and Validation before proceeding into EMD. The JSOW Program Office's ability was impaired because the Program office:

o could not directly interface with the contractors concerning how prototyping could be used most effectively and efficiently;

o did not have approval authority over contractor testing of prototype hardware; and

o could not establish exit criteria involving events or achievements using prototypes to support Milestone II, Development Approval, and award of the EMD contract.

Comments. The Director stated that our reference to "Shore Signal Information Processing System" should read "Shore Signal Information Processing Segment."

Audit Response. We revised the final report as suggested.

Comments. The Director stated that prototyping of software was not performed for the underwater segment of FDS because only 2,500 lines of code were in the underwater segment of FDS. Therefore, the level of risk did not warrant the added cost of prototyping software.

Audit Response. We revised the first sentence of our FDS example in the Software section of the final report to read, "Prototype software was not developed and tested during Phase I, Demonstration and Validation for the shore segment of the FDS." This change makes it clear that we are talking about the estimated 1.6 million lines of code for the shore segment of FDS that were needed to test the hardware for the underwater segment of FDS and not the specific lines of code for the underwater segment of FDS. The shore segment software was not available to support testing of the underwater segment hardware because of the 29-month disconnect between the development of the underwater segment and the development of the shore segment. The underwater segment was approved to enter EMD in September 1989 while the shore segment did not enter EMD until February 1992.

Comments. The Director stated that the report does not recognize that formal prototyping was not accomplished because insufficient funds were available.

Further, the FDS program office believes that manufacturing technology during Demonstration and Validation of FDS was in accordance with DoD Directive 4245.6.

Audit Response. We do not understand management's response that "formal prototyping was not accomplished because insufficient funds were available." The IDA Report D-1097, "Prototyping Defense Systems," December 1991, stated that prototype cost should probably be less than 25 percent of the EMD cost estimate. During Demonstration and Validation, the FDS Program Office received approval for accelerated funding in December 1982 (FY 1983), and did, in fact, expend 20 percent ($249 million of $1.2 billion) of its Research, Development, Test and Evaluation funds from FYs 1984 through 1989 during the Demonstration and Validation Phase. Although the percentage of the funds to be spent on prototyping has not been established, 20 percent is a significant amount of money to be spent during Demonstration and Validation without formal prototyping of manufacturing processes.

Also, the FDS program office did not meet the requirements of manufacturing technologies in DoD Directive 4245.6, "Defense Production Management," January 19, 1984 (cancelled by DOD Instruction 5000.2 in 1991). The Directive required that manufacturing voids and deficiencies be addressed during Demonstration and Validation through the use of manufacturing technology projects. These projects are to involve the development or improvement of manufacturing processes and equipment to help bridge the gap between system feasibility and production. The FDS Program Office did not use manufacturing technology prototyping during Demonstration and Validation because it was:

o concentrating on verifying the feasibility of a new pattern for distributing listening devices by using existing hardware from the Sound Surveillance System (the predecessor to FDS) during Demonstration and Validation and

o planning for the development of hardware to be accomplished during EMD.

Comments. The Director disagreed with the report statement that the JSOW program failed to comply with title 10, United States Code, section 2365, which required a waiver if prototyping was not used. The Director stated that the JSOW program office maintained that it was conducting an appropriate amount of prototyping. In addition, the Under Secretary of Defense for Acquisition and Technology stated that the JSOW prototyping strategy complied with DoD policy at Milestone I, Concept Demonstration Approval.

Audit Response. We stand by our position that the Navy did not satisfy the requirements of title 10, United States Code, section 2365 because a prototyping waiver request was not forwarded through the Secretary of Defense to Congress as required in 1988. As stated in the draft report, the JSOW acquisition plan submitted at Milestone I did not require the contractors to use prototypes during Demonstration and Validation. The acquisition plan clearly stated that statements of work for the Demonstration and Validation contracts would stop

short of requiring prototype design, fabrication, and test. Therefore, Congress should have been informed that the JSOW Program Office did not intend to use a competitive prototype acquisition strategy during Demonstration and Validation as required by title 10, United States Code, section 2365.

Comments. The Director disagreed with the audit conclusion that the Government should control the subcontract competition or subject the prime contractor's selection of a subcontractor to Government approval. He stated that this procedure is inconsistent with holding the prime contractor responsible for the performance of the total integrated system.

Audit Response. We agree with the management comments. We, therefore, deleted the audit conclusion from the final report.

Comments. The Director stated that Footnote 2 in Appendix B (Appendix A in the Draft Report) was incorrect in stating that the Joint Primary Aircraft Training System's contract had been awarded.

Audit Response. We agree. We revised Footnote 2 in Appendix B accordingly.

Comments. The Director stated that the draft report incorrectly stated that the UTTMDS Acquisition Program Baseline did not include delivery dates for the prototype missiles. Also, he stated that the Theater High Altitude Area Defense provisional performance criteria (the equivalent of an Acquisition Program Baseline) has test start dates and missile delivery dates.

Audit Response. We agree. We eliminated the references to UTTMDS missile delivery dates in the final report.

Comments. The Director took exception to our characterization of existing guidance in DoD Instruction 5000.2 by stating that:

o The Instruction shows a clear preference for prototyping and a requirement to discuss prototyping in addressing the recommended acquisition approach.

o The Instruction's guidance is not limited to competitive prototyping.

o Section 4-D of DoD Manual 5000.2-M requires discussing the requirement to prototype in the Acquisition Strategy Report, approval of the Acquisition Strategy Report by the milestone decision authority, and justifying a decision not to prototype in the Acquisition Strategy Report.

Audit Response. We agree with the Director's characterization of prototyping requirements in the DoD 5000 series of directives. However, we still believe that the prototyping guidance in DoD Instruction 5000.2 can be improved in the areas of planning and execution of prototyping acquisition strategies to assess and reduce program risk. The draft report included specific improvements.

Comments. The Director stated that he found essentially no discussion of the Comanche program in the finding text. Also, he was concerned about the Comanche's so-called "streamlined" program of two EMD prototypes and three Low-Rate Initial Production helicopters rather than three Demonstration and Validation prototypes and three EMD prototypes. He felt that a great deal of risk is being placed on the Low-Rate Initial Production decision because the Army is not performing final development testing until the Low-Rate Initial Production helicopters are available for testing.

Audit Response. We agree with management comments. In Appendix F of the draft report, we indicated that prototyping was too limited to adequately reduce hardware risk for the Comanche Program based on the deferral of a number of Demonstration and Validation tasks to EMD. Although we did not cite the Comanche Program as a specific example in the Hardware section of the draft report, we believe that the Comanche Program, like the BAT Program, was progressing to EMD when the risk reduction strategy for Demonstration and Validation was incomplete.

Director, Program Analysis and Evaluation, Comments

Comments. The Director cited selected quotations from the RAND Report R-4161-ACQ, "The Nature and Role of Prototyping in Weapon Systems Development," 1992, that he believed argue against, rather than for, a highly structured prototyping plan. The RAND Report stated:

o On deciding via policy whether or not to prototype: "This analysis suggests that attempts to define such a policy at any but the broadest levels should be avoided . . . . Thus, it is not possible or even desirable to develop a set of firm decision rules."

o On performing the cost versus benefits analysis of prototyping:

> In summary, there are tremendous difficulties involved in operationalizing the simple concept depicted in Figure 6.1 (cost versus benefit). We cannot be confident that we can identify all possible benefits and costs . . . . Even if we could measure all costs and benefits, we do not know how to consistently weigh them in a decision process.

o On trying to analyze costs versus benefits of prototyping: "In the end, there is no substitute for informed judgment made by experienced managers and engineers."

o Regarding DoD regulations: "This conceptual framework for policy and decisionmaking is quite similar to what is contained in existing regulations."

o On prototyping versus non-prototyping: "However, there are few significant differences between prototyping and non-prototyping programs with respect to cost growth, total actual program duration, or schedule slip."

Audit Response. Management has interpreted the above quotations out of context. The conclusions and recommendations in our draft report are consistent with the conclusions and recommendations made in the RAND Report.

o Our draft report was fully consistent with RAND's position that policy regarding prototyping should be defined only at the broadest level. We stated that no single prototyping strategy fits all programs, but that basic guidelines are needed to determine when prototyping is appropriate and what types of prototypes would be effective and efficient in reducing risk in a particular program. We stated that, at a minimum, policy should provide:

o general definitions of system level, partial system level, and subsystem level prototyping and

o considerations (not strict rules) for determining the appropriate level of prototyping for hardware, software, and manufacturing processes.

While RAND advocates defining prototyping policy at broad levels only, the need for a prototyping plan is supported by RAND's conclusion: "We believe that the policy should be to use some form of prototyping in almost every case and the burden of proof should be on those that argue that a prototyping activity is unnecessary or impractical." The formulation process that would be necessary to develop a prototyping plan, as we conceive it, would help satisfy the "burden of proof" that RAND discussed by documenting the cost-benefit analysis performed to support decisions to use a particular level of prototyping or to support not using prototyping. We realize that the prototyping plan should incorporate the best judgment of experienced engineers and managers. However, we also believe that program managers should be required to document and justify the extent of prototyping planned for Phase I, Demonstration and Validation.

o We recognize the difficulty to identify and weigh cost versus benefits of prototyping and that much judgment is involved in this process. However, the RAND report listed some factors that need to be evaluated when considering prototyping. None of our recommendations advocates a firm set of decision rules or assigning specific weights to a given factor for every program. Our finding and recommendations instead discuss the need for better defining and documenting the decisionmaking process related to formulation of a prototyping strategy for a given program.

o The RAND report stated that its conceptual framework for prototyping policy and decisionmaking is consistent with the portion of the DoD Instruction 5000.2 that discusses establishment of competitive prototyping strategies based on program-specific risk assessments. RAND further stated that the current regulation applied only to competitive prototyping and not other

forms of prototyping activity. RAND believed that the criteria provided for competitive prototyping could be expanded in the regulation to cover other forms of prototyping activity.

o While the RAND report did say that RAND could identify few significant differences between cost and schedule results of prototyped versus nonprototyped systems, the report also concluded that the effect of prototyping on program outcomes is ambiguous due to the effect of confounding variables. According to RAND, these variables included such factors as budget stability, technical difficulty (comparisons are biased if only the most technically challenging programs are selected for prototyping), and the ability and willingness of decisionmakers and program managers to use the improved information generated through use of prototypes. RAND concluded that some form of prototyping is almost always appropriate. RAND's conclusion was based on the existence of powerful institutional pressures that lead to systematic underestimation of program risks.

Comments. The Director questioned our presentation of data taken from the IDA Report D-1097, "Prototyping Defense Systems," December 1991, that showed that development and production cost growth was significantly less for programs using prototypes. He contended that:

o The report did not assert unequivocally that cost growth was less for prototyped programs since the report stated that prototyping was significantly beneficial for munitions programs with the benefits for aircraft being less apparent.

o The report did not count programs that were modifications to existing systems as having prototypes. The Director believed that the previously existing systems could be considered as prototypes.

Audit Response. While the IDA report did state that the effect of prototyping was smaller for aircraft programs than for munitions, the report also offered some explanations for the less dramatic (and not statistically significant) effects in aircraft:

o Historically, aircraft systems that were pushing the state of the art the least (such as the F-5E and the F-16) were prototyped, while others that were more technically difficult (such as the F-14) were not. In munitions, the study states the opposite and more logical approach was used.

o Prototyped aircraft showed significantly lower development costs than nonprototyped aircraft when helicopters were removed from the statistics because helicopters generally had higher cost growth regardless of prototyping strategy.

Finally, the Director's argument that the IDA report should have counted existing systems as prototypes for subsequent modifications is not logical unless the acquisition strategy for the modification efforts specified some level of prototyping for the technology improvements being added to the existing systems.

Comments. The Director stated that the sample of programs we selected for review was too small to be statistically significant and too narrowly focused. He believed that our sample selection precluded identifying the effects of not prototyping since all programs we discussed used prototyping and no program sampled had completed EMD, which precluded identifying the effects of prototyping on total EMD cost and schedule.

Audit Response. We did not select the programs reviewed with the intention of performing a statistical sample or making statistical projections. The scope and methodology section of the draft report stated that programs were judgmentally selected and were intended to provide examples of the types of deficiencies that can occur relating to planning and execution of prototyping strategies.

Regarding identifying the effects of prototyping versus not prototyping on cost and schedule, these relationships had already been explored in the two broadly based reports issued by RAND and the IDA. The RAND report was supported by information gathered on 287 programs from 1960 through 1988. The IDA report included data on 52 major acquisition programs, including aircraft, tactical munitions, and satellites over 32 years ending December 1987. After close examination of the scope and methodology of these reports and discussions with their authors, we found no need to duplicate the extensive efforts that had already been made to document the effect of prototyping on cost and schedule.

Director, Defense Procurement, Comments

Comments. The Director nonconcurred with revising the Defense Federal Acquisition Regulation Supplement to provide solicitation language to use in requesting contractor input, through Requests for Proposals, concerning proposed prototyping plans and to allow development of data item descriptions for contractor prototyping plans and contractor reports documentating the results of prototyping risk reduction efforts. She stated that it would be more appropriate to revise DoD Instruction 5000.2 language on prototyping to require that the solicitations proposal preparation instructions include a complete description of the prototyping plan required to be submitted with the proposal. She stated that this type of solicitation requirement will have to be tailored for each program and is not susceptible to standardization. She stated that any "standard" Defense Federal Acquisition Regulation Supplement provision would become redundant "boiler plate" and that the real information about what was required would have to appear in the proposal preparation instructions anyway. Further, the Director stated that the portion of our recommendation regarding the development of data item descriptions for contractor prototyping plans and contractor reports should be redirected to the Director, Continuous Acquisition and Life-Cycle Plans and Policy Division, who reports to the Office of the USD(A&T).

The complete text of management comments is in Part IV.

Audit Response. The Director, Defense Procurement, comments were responsive to the intent of our recommendations. As a result, we redirected Recommendation 3. (renumbered 1.a.[11]) to the Under Secretary of Defense for Acquisition and Technology and added Recommendation 1.d. in the final report.

Comments. The Director stated that she agreed that Government approval of the source-selection plan and source-selection criteria should be used when the Government has a critical interest in the selection of a subcontractor or component. However, she also believed that subjecting the prime contractor's selection of a subcontractor to Government approval or veto would be inconsistent with holding the prime contractor responsible for the performance of the total integrated system.

Audit Response. We agree as stated in our response to Director, Acquisition Program Integration, comments.

Comments. The Director stated that Footnote 2 in Appendix B was incorrect in stating that the Joint Primary Aircraft Training System's contract had been awarded.

Audit Response. We agree. The footnote was revised in the final report.

Auditor Note: Although not requested to respond to the draft report, we received comments from the Army Program Executive Office, Tactical Missiles, and the Program Manager, Comanche Helicopter Program. Where deemed appropriate, we revised the final report in response to the management comments.

Appendix J. Summary of Potential Benefits Resulting From Audit

Recommendation Reference	Description of Benefit	Amount and/or Type of Benefit
1.a.(1)	Internal Control. Will provide consistent application of prototyping in the acquisition process.	Nonmonetary.
1.a.(2)	Internal Control. Will ensure that program managers consider prototyping strategies to reduce technical, cost, and schedule risk of transitioning from Demonstration and Validation to EMD.	Nonmonetary.
1.a.(3)	Internal Control. Will ensure that input from ARPA on prototyping plans will be available to the acquisition decision authorities before the Milestone I, Concept Demonstration Approval, decision.	Nonmonetary.
1.a.(4)	Internal Control. Will ensure that input from ARPA concerning prototyping as a risk reduction method will be available to the acquisition decision authorities before the Milestone IV, Major Modification Approval, decision.	Nonmonetary.
1.a.(5)	Internal Control. Will ensure that Military Department-independent test organizations report on early operational effectiveness and suitability.	Nonmonetary.

Recommendation Reference	Description of Benefit	Amount and/or Type of Benefit
1.a.(6)	Internal Control. Will ensure that managers have an adequate reference point for measuring and reporting the status of program implementation and that baseline information includes prototyping milestone dates.	Nonmonetary.
1.a.(7)	Internal Control. Will ensure that development decisions are based on specific program accomplishments.	Nonmonetary.
1.a.(8)	Internal Control. Will ensure that initial design reviews are completed before a Milestone II, Development Approval.	Nonmonetary.
1.a.(9)	Internal Control. Will reduce risks related to manufacturing processes critical to successful production of weapon systems.	Undeterminable. Amount will vary with each program and benefits will continue as programs define producibility quantities.
1.a.(10)	Internal Control. Will ensure that contracts cite cost-effective requirements from DoD Standard 2167 or applicable commercial standards.	Undeterminable. Amount will vary with each program.
1.a.(11)	Internal Control. Will ensure that contractor inputs are considered in preparing prototyping plans.	Nonmonetary.
1.b.	Internal Control. Will provide guidance for program managers to formulate prototyping plans before concept demonstration approval.	Nonmonetary.

Appendix J. Summary of Potential Benefits resulting from Audit

Recommendation Reference	Description of Benefit	Amount and/or Type of Benefit
1.c.(1)	Internal Control. Removal of a faulty reference in DoD Instruction 5000.2 will ensure better implementation of the provisions of the instruction.	Nonmonetary.
1.c.(2)	Compliance with DoD Guidance. Will require program managers to include software test and evaluation plans as part of the TEMP.	Nonmonetary.
1.d.	Internal Control. Will ensure new Data Item descriptions are developed as needed to support submission of contractor prototyping plans and reports.	Nonmonetary.
2.	Internal Control. Will require OSD to ensure that prototyping plans are included in the cost and operational efficiency analysis and life-cycle cost estimates.	Nonmonetary.

Appendix K. Organizations Visited or Contacted

Office of the Secretary of Defense

Under Secretary of Defense for Acquisition and Technology, Washington, DC
Comptroller of the Department of Defense, Washington, DC
Assistant Secretary of Defense (Command, Control, Communications and Intelligence), Washington, DC
Director, Defense Procurement
Director, Program Analysis and Evaluation, Washington, DC
Ballistic Missile Defense Organization, Washington, DC

Department of the Army

Assistant Secretary of the Army (Research, Development and Acquisition), Washington, DC
U.S. Army Operational Test and Evaluation Command, Alexandria, VA
U.S. Army Program Executive Office Tactical Systems, Redstone Arsenal, AL
U.S. Army Program Office, Brilliant Anti-Armor Submunition, Redstone Arsenal, AL
U.S. Army Program Office, Comanche Helicopter, Saint Louis, MO
U.S. Army Program Office, Combat Service Support Control System, Fort Belvoir, VA
U.S. Army Program Office, Kiowa Warrior, Saint Louis, MO
U.S. Army Program Office, Palletized Loading System, Warren, MI
U.S. Army Program Office, Secure Mobile Anti-Jam Reliable Tactical Terminal, Fort Monmoth, NJ
U. S. Army Program Office, Short Range Unmanned Aerial Vehicle, Huntsville, AL
U.S. Army Program Office, Single Channel Anti-Jam Manportable Terminal, Fort Monmoth, NJ

Department of the Navy

Assistant Secretary of the Navy (Research, Development and Acquisition), Washington, DC
Naval Operational Test and Evaluation Force, Norfolk, VA
F/A-18 E/F Program Office, Naval Air Systems Command, Washington, DC
Fixed Distributed System Program Office, Space and Naval Warfare Systems Command, Washington, DC
Joint Stand-Off Weapon Program Office, Naval Air Systems Command, Washington, DC

Department of the Air Force

Assistant Secretary of the Air Force (Acquisition), Washington, DC
Assistant Secretary of the Air Force (Financial Management and Controller), Washington, DC
Air Force Operational Test and Evaluation Center, Albuquerque, NM
System Program Office, E-3 Airborne Warning and Control System - Radar System Improvement Program, Hanscom Air Force Base, MA
System Program Office, F-22 Advanced Tactical Fighter, Wright-Patterson Air Force Base, OH
System Program Office, Joint Direct Attack Munitions System, Eglin Air Force Base, FL
System Program Office, Joint Primary Aircraft Training System, Wright-Patterson Air Force Base, OH
System Program Office, Joint Service Imagery Processing System, Hanscom Air Force Base, MA

Other Defense Organizations

Defense Advanced Research Projects Agency, Arlington, VA
Defense Logistics Agency, Cameron Station, Alexandria, VA
Defense Plant Representative Office - The Boeing Company, Seattle, WA
Defense Plant Representative Office - Lockheed Aeronautical Systems Company, Marietta, GA
Defense Plant Representative Office - McDonnell Douglas Aerospace East, Saint Louis, MO
Defense Plant Representative Office - McDonnell Douglas Helicopter Systems, Mesa, AZ
Defense Plant Representative Office - Northrop Corporation, Pico Rivera, CA
Defense Plant Representative Office - Sikorsky Aircraft, Trumbull, CT
Defense Plant Representative Office - Texas Instruments, Dallas, TX

Non-Defense Organizations

The Boeing Company, Seattle, WA
Institute for Defense Analysis, Alexandria, VA
Lockheed Corporation, Lockheed Aeronautical Systems Company, Marietta, GA
McDonnell Douglas Aerospace East, Saint Louis, MO
McDonnell Douglas Helicopter Systems, Mesa, AZ
Northrop Corporation, Northrop Aircraft Division, Pico Rivera, CA
RAND Corporation, Santa Monica, CA
Texas Instruments Incorporated, Dallas, TX
United Technologies Corporation, Sikorsky Aircraft Division, Trumbull, CT

Appendix L. Report Distribution

Office of the Secretary of Defense

Under Secretary of Defense for Acquisition and Technology
  Deputy Under Secretary of Defense for Acquisition Reform
  Director, Defense Procurement
Comptroller of the Department of Defense
Assistant Secretary of Defense (Command, Control, Communications and Intelligence), Washington, DC
Assistant to the Secretary of Defense for Public Affairs
Director, Ballistic Missile Defense Organization

Department of the Army

Secretary of the Army
Assistant Secretary of the Army (Research, Development and Acquisition)
Director, U.S. Army Operational Test and Evaluation Command
Auditor General, Department of the Army
U.S. Army Program Executive Officer, Tactical Systems
  U.S. Army Project Manager, Brilliant Anti-Armor Submunition
U.S. Army Project Manager, Comanche Helicopter

Department of the Navy

Secretary of the Navy
Assistant Secretary of the Navy (Financial Management)
Assistant Secretary of the Navy (Research, Development and Acquisition)
Comptroller of the Navy
Commander, Naval Operational Test and Evaluation Force
Auditor General, Department of the Navy
Program Manager, F/A-18 E/F, Naval Air Systems Command
Program Manager, Joint Stand-Off Weapon System, Naval Air Systems Command
Program Manager, Fixed Distributed System, Space and Naval Warfare Systems Command

Department of the Air Force

Secretary of the Air Force
Assistant Secretary of the Air Force (Acquisition)
Director, Audit Liaison and Follow-Up
Assistant Secretary of the Air Force (Financial Management and Comptroller)
Auditor General, Department of the Air Force
Commander, Air Force Operational Test and Evaluation Center
Program Manager, F-22 Advanced Tactical Fighter

Other Defense Organizations

Director, Defense Contract Audit Agency
Director, Advanced Research Projects Agency
Director, Defense Logistics Agency
Commander, Defense Plant Representative Office - The Boeing Company
Commander, Defense Plant Representative Office - Lockheed Aeronautical Systems Company
Commander, Defense Plant Representative Office - McDonnell Douglas Aerospace East
Commander, Defense Plant Representative Office - McDonnell Douglas Helicopter Systems
Commander, Defense Plant Representative Office - Northrop Corporation
Commander, Defense Plant Representative Office - Sikorsky Aircraft
Commander, Defense Plant Representative Office - Texas Instruments
Director, National Security Agency
Inspector General, Central Imagery Office
Inspector General, Defense Intelligence Agency
Inspector General, National Security Agency
Director, Defense Logistics Studies Information Exchange

Non-Defense Federal Organizations

Office of Management and Budget
U.S. General Accounting Office, National Security and International Affairs Division, Technical Information Center

Chairman and Ranking Minority Member of Each of the Following Congressional Committees and Subcommittees:

Senate Committee on Appropriations
Senate Subcommittee on Defense, Committee on Appropriations
Senate Committee on Armed Services
Senate Committee on Governmental Affairs
House Committee on Appropriations
House Subcommittee on Defense, Committee on Appropriations
House Committee on Armed Services

Non-Defense Federal Organizations (Continued)

House Committee on Government Operations
House Subcommittee on Legislation and National Security, Committee on Government Operations

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Part IV - Management Comments

Under Secretary of Defense for Acquistion and Technology Comments

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

ACQUISITION AND TECHNOLOGY

13 JUN 1994

API/ASM

MEMORANDUM FOR DIRECTOR, ACQUISITION MANAGEMENT DIRECTORATE,
DoD INSPECTOR GENERAL

SUBJECT: The Effectiveness of Prototyping Acquisition Strategies for Major Defense Acquisition Program (Project No. 2AE-0051)

I have reviewed your draft summary report dated March 30, 1994, and offer the following overall response to your findings and recommendations. The findings are extremely weak and I non-concur with all 13 recommendations except for two that I partially concur in and only one other that I concur with. In general, I am disappointed in the lack of constructive recommendations from this extensive effort.

I agree that prototyping could be used more effectively reduce risk and assess how the design approach will operate before proceeding with EMD. However, I strongly disagree with your proposal to radically reduce the flexibility currently provided to the Milestone Decision Authority (MDA) to choose an acquisition strategy appropriate to the specific situation. You recommend very significant 5000.2 changes (Milestone I/II/ IV, early operational test, acquisition baseline, exit criteria, TEMP software plan, prototyping plan, DoDS 2167A, producibility analysis, and the creation of a new handbook). You also recommend revision to the FAR, and a greatly increased role for ARPA and PA&E in the DAB process based on weak and unconvincing rationale. These recommendations would add significantly and unnecessarily to bureaucratic oversight, and appear to conflict with Secretary Perry's recent memo regarding waiver authority, streamlining, and reduction of bureaucratic regulations. Because additional prototyping requires additional up-front money and acquisition strategies must be carefully constructed, your proposals could ultimately reduce the capability of the Armed Forces by diverting funds, for example, from production to low-payoff mandatory prototypes.

I would like to call your attention to how little new data you have in your report. There are only approximately 10 pages out of your 63 page report that purports to give any new insight into prototyping. An inordinate amount of the report simply states what is written in 5000.2, what RAND and IDA concluded, DMR recommendations, and Packard Report recommendations. We are quite familiar with these.

I am disappointed by the evaluations that you conducted on the 6 MDAPs (UTTMDS, Comanche, BAT, JSOW, FDS, and F-22). There are many inaccuracies in your findings on UTTMDS, JSOW, and FDS, as well as essentially no data on F-22 and Comanche. In particular your report is unbalanced to the extent that it only illuminates problems with the aforementioned MDAP prototypes, and largely ignores the very large (and expensive) and very successful F-22 Dem/Val competitive prototyping effort that included an actual "fly-off" between the prototypes. I also note there is a dearth of information on Comanche. Given the status of Comanche as one of the few remaining Army major acquisition programs, I feel that you should have devoted substantial attention to its prototyping approach.

In summary, I have considerable concerns about your misunderstanding of the need for the flexibility inherent in the current 5000 series directives and the DoD acquisition process in general as noted in the attached detailed comments. I suggest you consider withdrawing this draft report.

Gene H. Porter
Director, Acquisition
Program Integration

Attachment

Final Report
Reference

Attachment

Findings

10

- On page 12, the section on Hardware indicates that four of the six programs reviewed, including the Army BAT and Comanche programs, and the Navy FDS and JSOW programs, had limitations in planning or execution of hardware prototyping strategies. However, there is no discussion in this section on what, if any, limitations FDS had in planning or execution of hardware prototyping strategies.

12

- On page 14, the report indicates inaccurately that the JSOW program did not plan to use prototyping in Dem/Val. The JSOW program planned on an appropriate amount of component prototyping using the Recoverable Test Vehicle Program. When that program ran into difficulties, the JSOW program adapted, and coordinated with all three Dem/Val contractors to modify their plan to include missile prototypes. These contractors, using their own funds, invested in their own development programs to demonstrate the maturity of their systems, recognizing the competitive environment and considering the potential for future contracts. Investing IR&D funds and other corporate resources is a normal commercial activity. This occurred at a time when DoD was encouraging contractors to participate in the risks of development. As a result, the cost to the government of the three, fixed price Dem/Val contracts was $1.5 million. Had the JSOW program contracted for three independent prototyping efforts as proposed by the DoDIG report, the impact would have been an additional $64 million and a delay of 2 years.

12-13

Although the report recognizes prototyping is primarily a risk reduction activity, the report fails to recognize, primarily on pages 14 and 15, that the whole premise of the JSOW program is low risk integration of existing technology. Experienced program managers and engineers did assess program risks and developed the prototyping strategy accordingly. This strategy was scrutinized by ASN and OSD, determined to be sound, and hindsight only demonstrates the validity of those actions. The JSOW program is now in EMD, and the use of prototypes is continuing, with Structural Test Vehicles, Advanced Development Models, Engineering Development Models, and Production Representative Models all being produced to support the necessary testing at the appropriate time.

- All-up-round prototyping was not part of the JSOW Dem/Val effort because the Baseline JSOW vehicle was considered low risk as other similar vehicles were being tested in the Navy and Air Force. Based on the estimated cost of further prototype testing for three Dem/Val competitors, it was not considered cost effective to do this prototyping for the additional information which would be gained .

- It was determined at Milestone I that conducting subsystem testing, analysis, simulations, and demonstrations in Dem/Val would be adequate to support the risk assessment and a decision to

Final Report Reference

move into Engineering and Manufacturing Development. These included:

-- Wind tunnel tests to validate kinematics range

-- Launch separation analysis and wind tunnel tests to validate separation effects

-- 3-DOF/6-DOF simulations for guidance, control, and range information

-- Hardware-in-the-loop testing

-- Ground testing of radar cross section

-- Analysis and ground testing of payload dispenser mechanization

-- Targeting, accuracy and lethality analysis

-- Producibility analysis/studies, structures, materials, loads and handling tests, and airframe/wing deployment tests

- The three competing contractors were given the option to conduct captive and free flight tests for demonstration if they desired. Each did conduct a free flight demonstration of their vehicle design.

- On page 16, "Shore Signal Information Processing System" should read, "Shore Signal Information Processing Segment." 14

- On page 16, the report states, "Prototyping software was not developed and tested during Phase I, Dem/Val for the underwater segment of the FDS." Prototyping of software was not performed because there are only 2500 lines of code in the underwater segment of FDS. The level of risk did not warrant the added cost of prototyping software. 14

- On page 18, the report does not recognize that while some manufacturing technologies were developed for the FDS program, formal "prototyping" was not accomplished because insufficient funds were available. Furthermore, the FDS program office believes that manufacturing technology was in accordance with DoD Directive 4245.6 during demonstration validation of FDS. 16

- On page 19, the report states that the JSOW program failed to comply with Title 10, United States Code, Section 2365, which requires a waiver request if prototyping is not to be used. The JSOW program office maintains it was conducting an appropriate amount of prototyping. Furthermore, the issue was raised at the Milestone I DAB on June 5, 1989, and specifically addressed in the Executive Summary of the decision memorandum. USD(A) stated that the prototyping strategy complied with DoD policy and approved the Milestone I. 16

Final Report Reference

17-18

- Your finding on competitive prototyping by subcontractors, addressed on pages 19 through 21, deals with competitive prototyping, focused on key subsystems, restricted to the subcontractor level. You contend that "the winning subcontractor must be selected based on the best interest of the government," and commend the Army BAT program's approach to "control[ling] the selection of the winning subcontractors." Specifically, "[t]o maintain control over subcontractor competition, the BAT Program Office . . . inserted provisions into the Request for Proposals . . . that allow the government to establish the selection criteria to be used for choosing the subcontractors . . . [and] provide that no authorization can be given to proceed with a subcontract until the government has approved." You view this as a necessary element of "effective management of subcontractors" and state that "similar contractual provisions should be used in all acquisition programs where competitive prototyping is limited to the subcontractor level." This discussion is not translated into an IG Recommendation.

  There are numerous situations in which the government has awarded a prime contract, and has a critical interest in the prime's post-award selection of a subcontractor for a particular subsystem or component. In these cases, we agree that the prime contract should require government approval of the prime's source selection plan, including selection criteria, before the prime issues its solicitation. Through normal contract administration, the government can ensure the prime complies with the approved plan. We disagree that the government should "control" the subcontract competition, or subject the prime's selection to government approval or veto. This is inconsistent with holding the prime responsible for performance of the total, integrated system. If this degree of control is required, the subsystem or component should be provided as government furnished equipment after a government-conducted source selection.

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- On page 37, Recommendation 1.a.(3) should be rewritten to limit ARPA review to the prototyping plans rather than to the entire Acquisition Strategy Reports.

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- On page 42, footnote 2, regarding JPATS, is incorrect. There is no JPATS contract. The Air Force has recently issued the Request for Proposals intended to lead to the first JPATS contract.

20, 29, 61

- The statements on pages 22, 23, 32, and 54 that the UTTMDS APB did not include dates of delivery of prototype missiles are incorrect. The 40 User Operational Evaluation System (UOES) missile delivery dates are in the UTTMDS APB, and the THAAD Provisional Performance Criteria (PPC) has UOES test start dates as well as delivery dates. The PPC is equivalent to an APB.

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- I disagree with your conclusion on page 24 that a definition of prototyping is needed in 5000.2, with your only rationale being that it is in a RAND report. Which of the six MDAPs you evaluated suffered from lack of a definition? I feel prototyping is a well known concept. 22

- What new IG data supports your statement on page 29 that deficiencies observed in MDAP strategies were due to lack of ARPA involvement? Your discussion only references the 1986 Packard Report and offers no other substantiation of your finding. ARPA does not have the knowledge or expertise in MDAPs that is resident in the Services' and BMDO organizations. While ARPA's role in the technology base area is important, the Services and BMDO correctly argue that ARPA is not resourced or staffed to be the single DoD focal point for all prototyping. 26

- I take issue with your characterization of existing guidance on page 26. 23

  - DoDI 5000.2 shows a clear preference for prototyping and a requirement to discuss prototyping in addressing the recommended acquisition approach.

  - Paragraph 3.f.(1) of Section 5-C states, "Prototyping will be a major element of Phase 1, Demonstration and Validation." Note that this sentence is not limited to competitive prototyping. Paragraph 3.f continues with a discussion of how to do prototyping and the focus of prototyping.

  - The Acquisition Strategy Report in Section 4-D of DoD 5000.2-M contains a requirement for discussing the acquisition strategy including the requirement to prototype. That strategy must be approved by the milestone decision authority. A decision not to use prototyping must be justified in the ASR.

  - Part 12 of DoD 5000.2-M was removed from the manual because it contained a format for submitting waivers of competitive prototyping to Congress. Congress removed the requirement for waiver notification when it reinstated the CPS requirement.

- I find essentially no discussion of Comanche in the findings, even though you say on page 5 that you evaluated it. What did you find? Comanche plans 5 "development aircraft": 2 EMD prototypes; and 3 LRIP aircraft. This is the so-called "streamlined" program; the original program called for 3 Dem/Val prototypes and 3 EMD prototypes. Army claims it can cut out the number of prototypes because of increased reliance on modeling and simulation. 3

  Several OSD officials are skeptical about this approach. The 2 EMD prototypes are scheduled as follows: AV-01 has first flight in early FY96; and AV-02 has first flight in a little over two years. But that's it until the first LRIP test aircraft which doesn't have first flight until 2002. Also, this strategy pushes a great deal of risk off on the LRIP decision because Army isn't doing final development testing until the LRIP helicopters.

Recommendation 1.a.1

I non-concur with the recommendation to add definition of prototyping to 5000.2. Prototyping is a well known concept.

Recommendation 1.a.2

I non-concur with the recommendation to revise 5000.2 to require the PM to submit a prototyping plan for Milestone I. The plan is an inherent part of the ASR and TEMP already. Additional oversight is not justified by your findings, and runs counter to the streamlining required by Executive Order 12861. Adding to the PM workload is also contrary to NPR efforts.

No quarrel can be made for the need for prototyping (though traditionally satellite programs and Navy shipbuilding programs do not use prototyping). However, there remains the question of how prototyping should be done.

At present, there is a significant effort by the Acquisition Task Force on Modeling and Simulation (ATFMS) to use computer-generated models in lieu of actual soft-tooled prototypes. This approach could greatly shorten the acquisition cycle and could provide a much less costly approach than building actual prototypes. Before accepting your far-reaching recommendations, we should wait until the ATFMS has had an opportunity to present its findings to the OSD leadership. That effort should be completed within the next 90 days.

Recommendation 1.a.3

I non-concur with the recommendation to revise 5000.2 to have ARPA report to MDA on all ACAT Is and IIs before Milestone I. I see no strong rationale supporting this for MDAPs or ACAT IIs, as noted in our comments on your page 29 finding. The ARPA role is technology based.

Recommendation 1.a.4

I non-concur with the recommendation to revise 5000.2 to have ARPA report to MDA on all ACAT Is and IIs before Milestone IV for the reason given in 1.a.3 above. Producibility will be very important at Milestone IV, and I question whether ARPA is the correct organization to review this.

Recommendation 1.a.5

I partially concur with the recommendation to revise 5000.2 to require Directors of Military Departments' OT&E organizations to

report to MDA on prototyping requirements. D,OT&E sees benefit in this, but Army and Navy have some questions as to how this would be accomplished.

Recommendation 1.a.6

I concur with your recommendation to revise 5000.2 to add prototype schedule dates to the DAES baseline.

Recommendation 1.a.7

I non-concur with your recommendation to revise 5000.2 to require exit criteria for prototyping during phase I. Requiring specific exit criteria, design reviews, and producibility analysis gives no leeway to the program manager or the Milestone Decision Authority (MDA). One of the basic tenets of the revised DoD 5000 series was to provide sufficient guidance and then allow leeway to the program manager and the MDA to run the program in a manner that reflects good business practice. Requiring certain steps regardless of the program particulars appears to be a radical change from this basic tenet. Requirements should be couched in a manner that reflects that these actions are necessary to support the use of prototypes, rather than having a blind requirement for each program.

This recommendation presupposes that all programs are prototyped, which is not likely.

Recommendation 1.a.8

I non-concur with your recommendation to revise 5000.2 to require that an initial review based on prototyping be completed before Milestone II. My non-concurrence is similar to 1.a.7 above . . . not all programs are prototyped.

The existing decision criteria specified in DoDI 5000.2 for Milestone II make this requirement unnecessary. The decision authority must confirm that "Prototyping and Demonstration results to date provide reasonable assurance that the technologies and processes critical to success are attainable."

Recommendation 1.a.9

I non-concur in your recommendation to revise 5000.2 to require a producibility analysis be prepared based on prototypes. Again, not all programs will be prototyped.

A producibility analysis is normally prepared during Engineering and Manufacturing Development to support the Production Readiness Reviews. Such analysis is normally based on the

engineering development model, but the prototype can also be used for input into the analysis.

Recommendation 1.a.10

I non-concur in your recommendation to revise 5000.2 to require a software T&E plan to be part of the TEMP for all milestone decisions.

Software test and evaluation is currently required to be an integral part of the Test and Evaluation Master Plan. What do you propose to revise?

Recommendation 1.a.11

I partially concur in your recommendation to revise 5000.2 to require RFPs for Dem/Val contracts include tailoring of DoD Standard 2167A. It is inappropriate to require the use of a DoD Standard when commercial standards are preferable according to Dep Sec Def guidance.

Recommendation 1.b

I non-concur in your recommendation to revise 5000.2 to issue a guidance handbook on prototyping. While it is not clear that a handbook is necessary , it is certainly not necessary to revise 5000.2 to accomplish this.

Recommendation 1.c

I non-concur in your recommendation to reinstate guidance deleted in the February 1993 Change 1 to 5000.2-M.

Change 1 to DoD 5000.2-M incorporated the requirement to include the rationale in the Acquisition Strategy Report, when it is not practicable to use a competitive prototyping strategy. See our comments on your page 26 findings.

Recommendation 2

We non-concur in your recommendation that PA&E report on sufficiency of the proposed prototyping plan at Milestone I. I non-concurred in the requirement for a formal, stand-alone prototyping plan, so there is no need for this. I understand that PA&E is also non-concurring under separate cover to you.

Recommendation 3

I partially concur in your recommendation to revise the DFARS to provide solicitation language and DIDs development to document results of prototyping.

Regarding the first point, the Director, Defense Procurement suggests that your purpose would be better served by indicating in the suggested DoDI 5000.2 language on prototyping that the solicitation's proposal preparation instructions include a complete description of the prototyping plan required to be submitted with the proposal. This type of solicitation requirement will have to be tailored for each program, and is not susceptible to standardization. Any "standard" DFARS provision would become a redundant "boilerplate," while the real information about what is required would appear in proposal preparation instructions anyway. Consequently, we also recommend that the following sentence be deleted from "Contractor Input to Prototyping Plans" on page 29: "To accomplish those objectives the [DFARS] should be amended to provide the solicitation language to use in the Request for Proposals."

DDP also reports that they do not have a role in the authorization or preparation of data item descriptions (DIDs). In an effort to identify an appropriate office to which this recommendation could be addressed, they learned that there is no obvious addressee. A DID is originated by the organization needing data delivered under a contract that cannot be obtained through use of an existing DID listed in the "Acquisition Management Systems and Data Requirements Control List," DoD 5010.12-L. If USD(A&T) agrees that DIDs should be used as the IG recommends, then he should designate an Office of Primary Responsibility in one of the Components and direct it to verify no existing DIDs would suffice before developing new ones.

Director, Program Analysis and Evaluation Comments

PROGRAM ANALYSIS AND EVALUATION

OFFICE OF THE SECRETARY OF DEFENSE
1800 DEFENSE PENTAGON
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03 JUN 1994

MEMORANDUM FOR THE INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE

SUBJECT: Draft Inspector General (IG) Audit Report on The Effectiveness of Prototyping Acquisition Strategies for Major Defense Acquisition Programs (MDAP), (Project No 2AE-0051)

Thank you for the opportunity to comment on the finding and recommendations in the draft report on prototyping. I cannot concur with the current version of the report: it contains no clearly identifiable statement of findings; and, to the extent that a finding can be inferred, the report lacks compelling supporting rationale. The remainder of this memorandum discusses issues that should be clarified in a revised draft.

Inferred Finding and the RAND Prototyping Study. The "Conclusions" section of the draft states: "Effective prototyping to reduce program risk in transitioning from Dem/Val to EMD can only occur through the development and implementation of a structured decisionmaking process that will result in a documented and executable prototyping plan." Assuming that this is a valid statement of the draft report's finding, it appears to be supported primarily by reference to the RAND report (R-4161-ACQ) The Nature and Role of Prototyping in Weapon System Development. The following citations taken from the RAND study seem to argue against, rather than for, highly structured prototype planning, however:

On deciding via policy whether or not to prototype, the RAND report says, "This analysis suggests that attempts to define such a policy at any but the broadest levels should be avoided. ... Thus, it is not possible or even desirable to develop a set of firm decision rules."

On performing the cost versus benefits analysis of prototyping that the draft report recommends be mandated in DODI 5000.2, the RAND report says, "In summary, there are tremendous difficulties involved in operationalizing the simple concept depicted in Figure 6.1 *(cost versus benefit).* We cannot be confident that we can identify all possible benefits and costs ... Even if we could measure all relevant costs and benefits, we do not know how to consistently weigh them in a decision process."

On trying to analyze costs versus benefits of prototyping, the RAND report says, "In the end, there is no substitute for informed judgment made by experienced managers and engineers."

Regarding current (1992) DoD regulations, the RAND report says, "This conceptual framework for policy and decision making is quite similar to what is contained in existing regulations..."; and, "From the perspective of this research, the expressed policy of DoD is consistent with the conceptual framework developed both in this section and in Section 2.

The basic implication, then, is that acquisition policy should reflect only broad guidelines on prototyping, ... "

On prototyping versus non-prototyping, the RAND report says, "However, there are few significant differences between prototyping and non-prototyping programs with respect to cost growth, total actual program duration, or schedule slip."

A revised report should reconcile these statements with the references to the Rand study appearing in the current draft asserting that the present acquisition regulations regarding prototyping are inadequate, and that a highly structured process, incorporating a cost-benefit analysis, should be adopted.

The IDA Prototyping Study. The draft report also presents data taken from an IDA study (actually, a scripted briefing) indicating that development and production cost growth is significantly less for programs using prototypes than for programs excluding prototypes. The IDA report does not assert this conclusion unequivocally, however. It notes that prototyping is significantly beneficial for munitions programs, with the benefits for aircraft programs being less apparent. Moreover, many of the programs counted by IDA as excluding prototypes were modifications to existing systems; but, the existing systems could arguably be considered prototypes of the subsequent modifications. Given these caveats and the conclusions of the RAND study, the evidence supporting the draft report's finding and recommendations appears ambivalent.

The Draft Report's Review. The draft report lists six programs as subjects of a review by the IG staff, but discusses only five; three of the five programs are discussed in detail. Two of the five--Upper Tier Theater Missile Defense (UTTMDS) and the Fixed Distributed System (FDS)--are anomalies in the acquisition process: deployment of UTTMDS dem/val operational prototypes was assessed by the Defense Acquisition Board to increase program risk; and, FDS will be terminated after EMD with "deployment" of one test unit. In addition to being too small to be statistically significant, the sample selected is too narrowly focused: all the programs considered include prototyping--which precludes understanding the effects of not prototyping--and none have completed engineering and manufacturing development (EMD)--which precludes identifying the effects of dem/val prototyping on total EMD cost and schedule. In a revised report, the IG staff should consider a more broadly based, statistically significant sample of programs.

Conclusion. Given the lack of compelling rationale supporting the current draft report's inferred finding, it seems premature to change DoDI 5000.2 to mandate a highly structured, prescriptive prototyping plan. I will be happy to review the findings and recommendations of a revised report addressing the issues raised in this memorandum.

For William J. Lynn
Director
Program Analysis and Evaluation

Director, Defense Procurement Comments

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

MAY 31 1994

ACQUISITION AND TECHNOLOGY

DP(DAR)

MEMORANDUM FOR DIRECTOR, ACQUISITION MANAGEMENT DIRECTORATE,
OFFICE OF THE INSPECTOR GENERAL FOR AUDITING, DOD

THROUGH: CHIEF, CONGRESSIONAL ACTIONS AND INTERNAL REPORTS 2 Jun 94

SUBJECT: Draft Audit Report, Project No. 2AE-0051, Effectiveness of Prototyping Acquisition Strategies for Major Defense Acquisition Programs

This responds to your March 30, 1994, memorandum requesting comments on recommendation 3 in the subject draft report.

Recommendation 3 recommends revising the Defense Federal Acquisition Regulation Supplement (DFARS) to provide solicitation language to use in requesting contractor input, through Request for Proposals, concerning proposed prototyping plans and to allow development of data item descriptions for contractor prototyping plans and contractor reports documenting the results of prototyping risk-reduction efforts.

We do not agree with the recommendation. Standard solicitation language would not be useful because this type of solicitation requirement should be tailored for individual programs. We recommend instead revising the suggested DoDI 5000.2 language on prototyping to state that the solicitation's proposal preparation instructions should include a complete description of the prototyping plan required to be submitted with the proposal. Detailed comments are attached.

The recommendation regarding development of data item descriptions should be directed to the Director of the CALS Plans and Policy Division, as that office has cognizance over data item descriptions.

Eleanor Spector

Eleanor R. Spector
Director, Defense Procurement

Attachment

Final Report
Reference

Attachment

Director of Defense Procurement Comments
Recommendation 3
Draft Audit Report
"Use of Prototyping in Acquisition Strategies"
(Project No. 2AR-0051)

DoDIG Recommendation 3: Revise the Defense Federal Acquisition Regulation Supplement (DFARS) to provide solicitation language to use in requesting contractor input, through Request for Proposals, concerning proposed prototyping plans and to allow development of data item descriptions for contractor prototyping plans and contractor reports documenting the results of prototyping risk-reduction efforts.

DDP Comment: Regarding the recommendation to revise the DFARS to provide the solicitation language to use in requesting contractor input concerning proposed prototyping plans, we recommend instead revising the suggested DoDI 5000.2 language on prototyping to state that the solicitation's proposal preparation instructions should include a complete description of the prototyping plan required to be submitted with the proposal. This type of solicitation requirement will have to be tailored for each program, and is not susceptible to standardization. Any "standard" DFARS language would become redundant "boilerplate," while the real information about what is required would appear in proposal preparation instructions anyway. Consequently, we also recommend that the following sentence be deleted from "Contractor Input to Prototyping Plans" on page 29: "To accomplish those objectives the [DFARS] should be amended to provide the solicitation language to use in the Request for Proposals."

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Regarding the recommendation to revise the DFARS to allow development of data item descriptions for contractor prototyping plans and contractor reports, my organization does not have a role in the authorization of data item descriptions (DIDs). A DID is originated by the organization needing data delivered under a contract, when that data cannot be obtained through use of an existing DID listed in the "Acquisition Management Systems and Data Requirements Control List," DoD 5010.12-L. This recommendation should be directed to the CALS Plans and Policy Division, as that office has cognizance over DIDs.

DoDIG Comments on Competitive Prototyping by Subcontractors (pages 19 through 21): These comments deal with competitive prototyping restricted to the subcontractor level. The authors contend that "the winning subcontractor must be selected based on the best interest of the Government" and commend the Army BAT program's approach to "control[ling] the selection of the winning subcontractors." Specifically, "[t]o maintain control over subcontractor competition, the BAT Program Office...inserted provisions into the Request for Proposals...that allow the Government to establish the selection criteria to be used for

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Attachment

choosing the subcontractors...[and] provide that no authorization can be given to proceed with a subcontract until the Government has approved." The authors view this as a necessary element of "effective management of subcontractors" and state their belief that "similar contractual provisions should be used in all acquisition programs where competitive prototyping is limited to the subcontractor level." This discussion is not translated into an IG recommendation.

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Miscellaneous: On page 37, recommendation 1 a (3) should be rewritten to limit ARPA review to the prototyping plans rather than to entire Acquisition Strategy Reports 35

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