THE ADVANCED MEDIUM-RANGE AIR-TO-AIR MISSILE (AMRAAM): CURRENT PLANS AND ALTERNATIVES

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NOTES

Unless otherwise stated, all years referred to in this paper are fiscal years.

Details in the text and tables of this paper may not add to the totals because of rounding.

All costs are expressed in 1987 budget authority dollars, using the Administration's February 1986 economic assumptions, unless otherwise noted.

SUMMARY

Some 2,900 fighter aircraft in the inventories of the U.S. Air Force and Navy carry radar guided missiles. These planes currently carry the Sparrow missile, which homes in on radar signals beamed out from the employing aircraft toward the target aircraft. The Sparrow is an old missile, initially deployed in 1956. Though Sparrow has been upgraded many times since then it still lacks many capabilities that the services feel are important. In the late 1970s, the Department of Defense (DoD) began a joint Air Force/Navy project to develop a new missile--the Advanced Medium-Range Air-to-Air missile, or AMRAAM. Because AMRAAM has its own radar transmitter, the employing aircraft can break away to defend itself or attack other targets once it has launched the missile.

The AMRAAM is scheduled to enter low-rate production in fiscal year 1987, some two years after its original production date. Even after adjusting for inflation, it is now projected that AMRAAM will cost about 120 percent more than estimated in 1979. This delay in schedule and cost growth led the Congress to contemplate canceling the program last year. Since then, the program has been restructured and the Secretary of Defense has certified that costs will not grow further nor will capabilities be diminished below current estimates. Nonetheless, ongoing concerns about cost increases and testing delays have prompted discussions of alternatives to the Administration's plan that would delay AMRAAM production. It appears unlikely, however, that the Congress will cancel the program this year. Thus, this paper considers only two alternatives in detail--the Administration's plan and a one-year delay in procurement to allow more time for testing. Two other alternatives--a reduction in procurement levels and program cancelation--are discussed in general terms. These might become relevant in future years if the test program goes poorly or if costs rise significantly.

ALTERNATIVE 1. THE ADMINISTRATION'S PLAN

The Department of Defense plans to buy 7,843 AMRAAMs for the Air Force and 1,250 for the Navy over the next five years, and a total of 17,123 and 7,212 for each service, respectively, by the end of the program in 1996 (see Summary Table). Procurement costs will total $4.6 billion for the two

SUMMARY TABLE TWO ALTERNATIVE AMRAAM ACQUISITION PROGRAMS (By fiscal years)

Alternative	1987	1988	1989	1990	1991	87-91	To Complete
QUANTITIES OF AMRAAM MISSILES (In numbers of missiles)							
Alternative I (Administration's Program)							
Air Force	260	833	1,950	2,600	2,200	7,843	9,280
Navy	0	0	50	400	800	1,250	5,962
Total	260	833	2,000	3,000	3,000	9,093	15,242
Alternative II (One-Year Delay)							
Air Force	0	260	833	1,950	2,600	5,643	11,480
Navy	0	0	0	50	400	450	6,762
Total	0	260	833	2,000	3,000	6,093	18,242
COSTS (In millions of 1987 dollars rounded to the nearest 10 million)							
Alternative I (Administration's Program)							
Air Force	760	990	930	780	520	3,980	1,900
Navy	0	10	150	220	270	650	1,500
Total	760	1,000	1,080	1,000	790	4,630	3,400
Alternative II (One-Year Delay)							
Air Force	190	800	940	960	820	3,710	2,540
Navy	0	0	10	150	220	380	1,770
Total	190	800	950	1,110	1,040	4,090	4,310

SOURCE: Congressional Budget Office.

services over the next five years (1987 dollars). Procurement funding over the life of the program is to total $8.4 billion, with the Air Force share to be $6.2 billion. These estimates appear consistent with funding limits imposed by the Congress. Last year the Congress required the Secretary of Defense to certify that Air Force costs would not exceed a "cap" of $5.2 billion in 1984 dollars and that a firm fixed-price contract with Hughes Aircraft Company for part of the development funding would not exceed $556.6 million, in current dollars.

The AMRAAM missile should offer the military services important advantages. It is expected to be much more capable than Sparrow. As noted above, it has an active radar seeker that will allow the launching fighter to fire and then break off to engage other targets or to leave the air battle (the so-called "launch and leave" capability). In addition, AMRAAM is smaller than Sparrow and so can more easily be used by the Air Force's F-16 fighter, which is not currently equipped to carry the Sparrow and so has no current missile with radar capability. This is important to the Air Force because about two-thirds of Air Force fighters will be F-16s by the early 1990s. The AMRAAM will also give Navy F/A-18 aircraft a launch-and-leave capability currently found only on F-14s that carry the Phoenix missile and have the extensive internal systems needed to operate it. But the Navy requirment for AMRAAM may be less urgent since all Navy fighters--including the F/A-18--can currently carry the Sparrow radar missile.

The military services, particularly the Air Force, believe they need AMRAAM quickly because of improvements in the capabilities of Soviet fighters and missiles. These include improvements in fighter radars that lead to more capability in their radar missiles, coupled with Soviet quantitative advantages on the central European front in the event of an all-out conventional war between NATO forces and those of the Warsaw Pact.

But there is still concern that AMRAAM is not mature enough to enter production. Although the AMRAAM program has already been restructured and delayed significantly, evidence exists that testing has not kept pace with the restructured schedule: only 11 of the 16 missiles that were supposed to be tested by now have been tested. Seventeen unsuccessful attempts were needed to get off the 11 shots that were made (though most of the unsuccessful attempts did not fail because of problems with the missile). Furthermore, three of the last five tests were less than fully successful, though the last two shots went well.

The missile's current cost estimates may still be too low. The General Accounting Office (GAO) recently enumerated several factors that could lead to cost growth, including DoD's assumption that procurement quantities will remain stable at high rates for a number of years and that no major design changes will be made in the missile. Concern has also been raised that the "producibility enhancement" program (PEP) planned for the missile--a series of production improvements aimed at holding down costs--is seven months behind schedule even though the number of missiles expected to benefit from PEP savings has apparently not been reduced.

ALTERNATIVE 2. DELAY PROCUREMENT BY ONE YEAR

The Congress could delay the AMRAAM program by a year to minimize the risks of unforeseen cost growth or problems in the testing program. The delay would give the Air Force time to test more missiles before committing itself to production. It should also let the service develop the producibility enhancement program further and so incorporate its features in more missiles.

The Summary Table shows the quantities and costs under this delayed schedule. According to Air Force estimates, a one-year delay would save $0.6 billion in 1987 funding; when spread over the five-year period of 1987-1991, however, net savings would only amount to $0.5 billion. Such a delay would breach the Congressionally imposed cap on procurement costs by about $0.3 billion (in 1984 dollars the breach is the same because of rounding) or 5 percent because the delay would cause the costs of initiating production and other costs to increase, although a delay would not change development funding. The delay would also mean that the military would not realize AMRAAM's benefits until a year later, thus increasing the risk that U.S. military services would face an improved Soviet force without the increased capability they believe they need.

ALTERNATIVES WITH MORE EXTENSIVE PROGRAM CHANGES

Because the Secretary of Defense recently certified AMRAAM as to cost and capability, and because of strong service support, it seems unlikely that the Congress will make drastic changes in the program again this year. Should AMRAAM go substantially above its capped costs in future years, however, or should its capabilities appear to fall far short of promises, the Congress might eventually have to consider more extensive changes to the program, perhaps including quantity reductions or even cancelation.

How might quantities be reduced? The AMRAAM's capabilities might be less important in some missions that face relatively few attackers. The Air Force mission of defending the United States against Soviet bombers during a nuclear attack might fall into this category, as might the Navy's mission of defending aircraft carriers against Soviet bombers attacking at long ranges. Should costs increase or fiscal constraints require a cost reduction, the Administration or the Congress might consider using cheaper missiles than AMRAAM to meet these needs.

If AMRAAM were to experience serious design problems and the Congress were forced to consider cancelation, other missiles could provide less expensive alternatives. For example, the Navy has completed the preliminary design of a modification to Sparrow that could yield improvements over today's capability, although not as extensive as those promised by AMRAAM. Current cost estimates, also preliminary, suggest that such a "dual seeker" version of Sparrow would be cheaper than AMRAAM, though as it went through the development process its costs might rise.

CHAPTER I. INTRODUCTION

In wartime, U.S. military aircraft would be used both to attack ground targets and to perform the "air superiority" mission--that is, to clear the air of enemy aircraft. In the air superiority role, U.S. aircraft would sometimes use infrared missiles, which home in on the heat generated by enemy aircraft and destroy them. 1/ Infrared missiles, including the Sidewinder, would be used at short ranges. At longer ranges, U.S. aircraft would use radar missiles, such as the currently deployed Sparrow and Phoenix. These are guided to their targets by radars aboard the launching aircraft or, in some cases, on board the missiles themselves.

The Advanced Medium-Range Air-to-Air Missile (AMRAAM) is a new radar missile being developed jointly by the Navy and Air Force as a replacement for the Sparrow. The Administration plans to buy 24,335 AMRAAMs, including 17,123 for the Air Force and 7,212 for the Navy. 2/ The AMRAAM has an important advantage over the Sparrow. The Sparrow missiles home in on the reflected energy from the employing fighter's radar, thus requiring a fighter to continue to illuminate the enemy target until Sparrow destroys it. The AMRAAM, in contrast, carries its own radar, which would allow the launching aircraft to turn away after the missile has acquired its target; this should enable the plane to attack several targets simultaneously or to defend itself from enemy attack. Only the Navy's Phoenix missile has this capability today, and the Phoenix missile was designed--in conjunction with the F-14's on-board systems--to defend Navy ships at very long ranges.

The AMRAAM's capabilities would be useful in a number of potential conflicts, particularly those in which NATO forces could be heavily outnumbered by the Warsaw Pact. In the early days of a major war in Europe, for

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1. Many U.S. aircraft are also equipped with guns.

2. Of the 17,123 missiles bought for the Air Force, 15 are being produced to qualify Raytheon. In addition to these production missiles, 111 development missiles are being bought; 94 of these are Air Force and the remaining 17 are Navy.

example, NATO forces could be seriously outnumbered by attacking aircraft. With AMRAAM, NATO might be able to attack these enemy aircraft before their missiles could come within range of allied forces. The AMRAAM should also allow a NATO aircraft to launch a missile at an attacker and then disengage and pursue another enemy plane. Both of these characteristics should enhance the capabilities of NATO against larger enemy forces. The ability to attack multiple targets simultaneously could also be useful in other conflicts. For example, in the case of a small conflict outside Europe that arose quickly, a limited number of locally deployed U.S. forces could find itself pitted against the larger forces of, say, a Third World country.

Radar missiles, including AMRAAM, are also useful in poor weather, which is frequently encountered in Europe. Clouds and rain mask heat signatures and so prevent effective use of infrared guidance; radar missiles, however, can still operate in these conditions.

AMRAAM's long development history started in the mid-1970s, when the Air Force and Navy needed an improved radar missile. 3/ Since then, the program has experienced problems with cost and scheduling that have delayed procurement.

DESIRED CAPABILITIES FOR AMRAAM

Earlier versions of the Sparrow missile have exhibited disappointing performance both in exercises and in actual combat. 4/ Despite their long

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3. Development of a new system by the Department of Defense is frequently a very long process. In AMRAAM's case, the need for a new missile to replace Sparrow was discussed in the mid-1970s. The requirement was defined and the "Statement of Operational Requirement" released in 1978. If AMRAAM remains on the revised schedule, it will be fielded in 1989, more than 10 years after the requirement was defined.

4. For example, a mid-1970s study of air-to-air missiles (called AIMVAL) indicated that fighters forced to continue to illuminate the target were especially vulnerable to enemy fire. Also, in the 1973 Israeli/Arab war, heat-seeking missiles were credited with destroying

range, Sparrows have been vulnerable to enemy countermeasures, such as electronic "spoofing" of their guidance systems.

Thus, in 1978, the Air Force and Navy established a Joint Service Operational Requirement (JSOR) for a new missile. Desired capabilities included missile-borne radar to eliminate the need to use the launching fighter's radar to illuminate the target, ability to engage multiple targets simultaneously, and compatibility with both Air Force and Navy fighters.

The program was broadened in 1980 to include several NATO nations through a memorandum of understanding that agreed to two development programs. With U.S. participation, the NATO countries would develop the Advanced Short-Range Air-to-Air Missile, a successor to Sidewinder. The United States would develop AMRAAM with European participation.

DEVELOPMENT PROBLEMS

The AMRAAM was originally scheduled to be deployed in 1987 and was supposed to cost less than Sparrow. 5/ Both of these projections proved

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Footnote Continued

about 200 Arab aircraft compared with about seven destroyed by Sparrow. In the 1982 Israeli-Syrian air-to-air fighting over Lebanon, Sparrow missiles destroyed only two Syrian planes in comparison with about 50 destroyed by infrared missiles. The Air Force and the Navy argue that the operational environment of these wars--in particular relatively short ranges and good weather—tend to favor infrared missile employment more than does the environment of a central European conflict. Additionally, they argue that the threat faced by the Israelis was less capable than the Soviet threat, thus allowing the Israelis to get in closer and to use short-range missiles more. For a discussion of historical missile performance, see Lon O. Nordeen, Jr., Air Warfare in the Missile Age (Washington, D.C.: Smithsonian Institution Press, 1985) and Michael J. Fitzpatrick, "A Case Study in Weapons Acquisition: The Sidewinder Air-to-Air Missile," Journal of International Affairs (Summer 1985), p. 175-190.

5. Testimony before the Senate Committee on Armed Services on March 9, 1977 by the Director of the AMRAAM Joint Systems Program Office indicated that the missile would be half as costly as Sparrow.

overoptimistic. By 1984 the program was two years behind schedule and costs per missile had grown from $182,000 to nearly $438,000 (in 1987 dollars). 6/ Hughes Aircraft Company--which developed AMRAAM--was experiencing a substantial amount of trouble in meeting the original schedule. Although development was supposed to be virtually complete by 1984, only one missile had been tested by that time. In 1985 DoD substantially changed the program, delaying the schedule by about two years and adding a series of producibility improvements aimed at holding down the program costs. The DoD also provided funds to allow Raytheon Corporation--which lost to Hughes in the competition to design AMRAAM but was designated as a second producer--to qualify for production earlier in the schedule than originally planned, thus allowing any savings from competition to be achieved more quickly. The missile now is scheduled to enter low-rate initial production in fiscal year 1987, if it receives Congressional funding.

In 1984 the Congress began to express concern about the cost of the AMRAAM program and the "concurrency" in its development schedule. (Concurrency as used by DoD means having production begin before development is completed.) By 1985 concern over cost and schedule slippage was widespread throughout committees overseeing AMRAAM. Authorizing legislation in that year required that the Secretary of Defense certify that the costs of AMRAAMs bought for the Air Force would not exceed $6.2 billion ($5.2 billion in constant 1984 dollars) for the purchase of 17,000 missiles (123 fewer missiles than are included in the actual Air Force procurement program) and that the missile would meet design requirements. The Secretary issued that certification in February 1986.

Footnote Continued

See Hearings before the Committee on Armed Services, United States Senate, 95th Congress, 1st Session, Pt. 7, pp. 4611-4638.

6. Costs referred to here are "program unit" costs that include development funding and development missile quantities. DoD also uses "procurement unit" costs that exclude development funding.

CHAPTER II. CAPABILITIES AND REQUIREMENTS

The AMRAAM is expected to provide substantial advances in capability over the currently deployed Sparrow missile. So extensive are these advances that the Air Force Chief of Staff has stated that an F-15 fighter aircraft equipped with AMRAAM would be able to destroy twice as many enemy aircraft as it could with Sparrow, while an F-16 fighter, which cannot carry Sparrow, could down six times as many enemy aircraft with AMRAAM as with Sidewinder. 1/ 2/ These improvements in capability could reduce total missile requirements for both the services, although requirements also depend on many other factors.

IMPROVEMENTS IN CAPABILITY OFFERED BY AMRAAM

The particular improvements offered by AMRAAM and their relevance to the air battle are presented below.

"Launch and Leave" Capability. Since the AMRAAM carries an "active seeker"--that is, a radar that actively sends out a signal—and so does not depend on the aircraft's radar to acquire and hold a target, an

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1. Details of these estimates are classified. The statement was made in testimony on the fiscal year 1987 budget request before the House Armed Services Committee.

2. The F-16 is unable to carry Sparrow missiles for two reasons. First, the F-16 lacks the necessary avionics to accommodate Sparrow, namely the ability to communicate target location to the missile. Second, Sparrow is heavier than Sidewinder (or than AMRAAM will be), and the Air Force argues the extra weight could impair the F-16's peformance in battle. Nor, the Air Force argues, could Sparrow be used--as AMRAAM could--to provide a self-defense capability for F-16s performing air-to-ground missions, because the weight of the Sparrow missile precludes carriage on wing tip stations; there is no room for it under the body of the airplane, when the plane carries bombs.

aircraft firing the missile could break away when the missile was within range of its target. This capability should increase aircraft survivability by allowing a plane to leave the battle area before it comes within the lethal range of enemy missiles. If desired, however, an AMRAAM-equipped aircraft could track an enemy target with its more capable radar and provide AMRAAM with periodic updates for long-range launches.

Multiple Launch Capability. This is another advantage of the AMRAAM's active seeker. Since the plane does not need to continue to illuminate the target, it could fire other missiles at other targets.

Enhanced "Electronic Counter-Countermeasures" (ECCM). AMRAAM is expected to be more resistant than the current Sparrow to enemy deception techniques, intended to deflect attacking missiles by electronic and other means. In military language, AMRAAM will have an enhanced ability to "counter" enemy "countermeasures." 3/ Though the missiles currently being tested do not yet have enhanced ECCM, later test missiles and all production missiles will have these improvements, according to Hughes.

"All Aspect" Capability. A target airplane's radar signature varies, depending on the aspect it presents to the seeking radar (head-on, side, and so forth). The AMRAAM is expected to be better than some earlier radar missile designs at seeing targets from certain aspects in certain parts of the area it can cover.

"Beyond Visual Range" (BVR) Launch Capability for F-16s. The farther away a plane is from an enemy target when it fires its missiles, the safer it is. Although the current Sparrow missile can be fired at ranges farther than the eye can see, F-16s cannot carry Sparrows. 4/ The AMRAAM would give the F-16 the capability to fire beyond visual range. To be effective, BVR requires a good ability to identify friend and foe aircraft at considerable ranges, a task that may be difficult to accomplish--though the Air Force argues that it would make BVR shots in many cases

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3. The Navy is currently planning a product improvement program (PIP) for the Sparrow that will, among other things, upgrade its counter-countermeasures.

4. Visual range is about three to four miles.

even without this ability. 5/

All-Weather, Look-Down, Shoot-Down Capability for F-16. To possess a look-down, shoot-down capability, a missile must be able to filter out ground clutter in order to track low-flying targets. All-weather capability is inherent in radar missiles because radar can see through clouds. The Sparrow has these capabilities, but deployment of the AMRAAM would provide them to the F-16.

A Low-Smoke Rocket Motor. Current missiles have highly visible exhaust trails; these not only show that they have been fired but also can reveal the location of the fighter that fired them. The AMRAAM's motor has a less visible exhaust than Sparrow's motor.

NUMERICAL REQUIREMENTS FOR AIR-TO-AIR MISSILES

AMRAAM's capabilities should improve the chances that it would be able to destroy an enemy target, thus cutting down on numerical requirements. But requirements for missiles also depend on the number of aircraft that can carry them, the number and types of targets that the planes are expected to destroy with a particular kind of missile, and a host of other operational factors. 6/ Radar missile requirements are dependent further on assump-

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5. The ability to identify friendly and unfriendly aircraft clearly enhances the utility of a BVR capability. Systems which identify friend or foe (IFF) can be divided into cooperative and noncooperative systems. With cooperative systems, the attacker interrogates the target with a signal; if it is friendly and has an operational transponder, the target responds with a signal. The current IFF system, the Mark XII, has operational problems and is subject to spoofing, and is to be replaced in the 1990s with the Mark XV. The DoD is also pursuing noncooperative methods of identification. Noncooperative systems identify some signature of the hostile target without the assistance of the target itself. The Air Force maintains that a combination of systems will enable it to establish a BVR capability, even though critics still aver that the IFF problem has not been solved.

6. Other factors include the number of missiles a plane can carry, expenditures for testing purposes, wartime aircraft attrition, and a fac-

tions about the availability of infrared missiles; the Air Force assumes that some of the targets it faces will be destroyed by them, although these missiles are not discussed in detail in this study.

Air Force Requirements

Based on the factors discussed above, the Air Force believes it needs about 17,000 AMRAAM missiles. It currently has about 2,000 aircraft capable of carrying Sparrow radar missiles, including about 730 F-15s and about 1220 F-4s (see Table 1). The F-15s would be candidates for AMRAAM, but the Air Force currently has no plans to modify F-4s to carry the missile since they will retire soon. The remainder of the Air Force planes intended for aerial combat, about 910 F-16s, are not currently capable of carrying the Sparrow. (The service has previously considered modifying at least some portion of the F-16 inventory to allow them to carry Sparrow.) The F-16 aircraft would, however, be able to carry AMRAAM, thus giving the current model F-16s a radar missile capability.

The Air Force expects to make heavy use of AMRAAM in the air superiority mission of clearing the skies of enemy fighters and bombers. The numerical superiority of the Warsaw Pact air forces is of concern to the service, as is the increasing lethality of Soviet aircraft and missile inventories. 7/ For example, with the deployment of the Flanker, the Fulcrum, and the Foxhound--three new Soviet fighters--the Soviet Union will have much improved air-to-air radars that will increase the capabilities of Soviet missiles. The Air Force believes that the combination of these qualitative improvements and long-standing Soviet quantitative advantages presents a great threat to NATO forces.

Radar missiles, including AMRAAM, would also be used for the mission of defending the United States against attack by Soviet bombers during a nuclear war (the air defense mission). The kind of aircraft that the Air

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Footnote Continued
tor for misallocation of missiles to bases.

7. In particular, the Air Force is concerned that Soviet fighters now being fielded carry medium-range air-to-air missiles that have a look-down, shoot-down capability, thus removing the sanctuary of low-level flight.

TABLE 1. RADAR MISSILE DEPLOYMENT

Service/ Country/ Aircraft Type	AIRCRAFT Missile System (Number per plane) Current	Planned	Current Aircraft Inventory
U.S. Air Force a/			
F-15	Sparrow (4)	AMRAAM (8)	730
F-16	None (Infrared Only)	AMRAAM (6)	910
F-4 b/	Sparrow (4)	None	1,220
U.S. Navy a/			
F-14	Sparrow (6) or Phoenix (6)	AMRAAM c/ (6) or Phoenix (6)	460
F/A-18	Sparrow (4)	AMRAAM d/ (6)	320
F-4 b/	Sparrow (4)	None	195
NATO Allies e/			
United Kingdom	Sky Flash f/	AMRAAM	
Tornado	(4)	(4)	g/
Sea Harrier	(0)	(2)	30 g/
Germany			
F-4F	None (Infrared Only)	AMRAAM (4)	120

(Continued)

SOURCES: All data on U.S. ships and aircraft from U.S. Air Force and Navy. UK aircraft data from British Defense Staff. German aircraft data from AMRAAM Program Office. All ship data from NATO Seasparrow Program Office.

a. Lists maximum carriage; typical tactical carriage may be lower.

b. U.S. Air Force and Navy F-4s are to be retired.

TABLE 1. (Continued)

Service/ Country/ Ship Type	SHIPS Number of Seasparrow Launchers per ship (All launchers have 8 missiles)	Number of Ships with Launchers
U.S. Navy		
CV (Aircraft Carrier)	2-3 h/	13
AOE (Fast Replenishment Ship)	1	4
AOR (Fleet Oiler)	1	5
DD 963 (Destroyer)	1	31
NATO Allies (All Frigates)		
Greece	1	2
Italy	1	4
Spain	1	4
Belgium	1	4
Netherlands	1	14
Denmark	1	5
Norway	1	5
West Germany	1	6
Canada	1	i/
Turkey	1	i/
Portugal	1	i/
Non-NATO Ally		
Japan	1	5

c. The F-14 will be able to carry 6 AMRAAMs under funding in the FY 1987 Five-Year Defense Plan. Should the Navy decide to fund further modifications to the F-14, its AMRAAM carriage could be increased to 8-10 missiles.

d. The AMRAAM is currently scheduled to be deployed only on C and D models of the F/A-18. Should the Navy decide to deploy it on A/B models, modification funding would be required.

e. Many other countries might participate in the AMRAAM program when the missile has completed development.

f. The Sky Flash is a British variant of the AIM-7E.

g. The UK plans eventually to have about 160 Tornados and 40 Harriers.

h. Six of the thirteen carriers with launchers have three missile launchers, the rest have two.

i. These countries also plan to equip several ships with Seasparrow.

Force will choose for this mission has as yet to be determined. The service is evaluating candidates for this mission including the F-16 now in the inventory and Northrop Corporation's new F-20. A decision is expected in the fall.

Missile requirements depend on the types of missions and numbers of aircraft carrying them in addition to the enemy threat and other factors discussed above. While the details of the requirement calculations are not publicly available, the Air Force estimates it will need about 17,000 AMRAAMs by the 1990s. In addition, the Air Force now has 10,824 Sparrows, which is fewer than estimated requirements. 8/ Sparrow missiles have 15- to 20-year service lives and will continue to be used on F-4 aircraft until the F-4s are replaced in the 1990s.

Navy Requirements

The Department of the Navy (which also provides missiles for the Marine Corps) states that it will need about 7,000 AMRAAMs. Current Navy fighter inventories total 975, made up of F-4s, F-14s, and F/A-18s. F-14s and F/A-18s would use AMRAAM primarily to defend themselves or Navy short-range bombers against enemy fighters on their way to attack land targets. (The Navy does not plan to equip F-4s with AMRAAM, as they are to be retired soon.) Navy needs for AMRAAM may be less urgent than those of the Air Force, since all Navy aircraft currently can carry Sparrow radar missiles, although the AMRAAM missile would provide launch and leave and multi-target attack capabilities for F/A-18 aircraft. 9/ Also, Navy F-14s carry the long-range Phoenix missile that is designed to defend ships against attacks by long-range Soviet bombers--the combat air patrol (CAP) mission.

In the CAP mission the Navy is primarily concerned about attacks by Soviet Backfire and Badger bombers carrying Kitchen and Kingfish cruise missiles. The Navy would prefer to shoot down these aircraft before they could launch their cruise missiles, which have ranges of several hundred miles. Hence, the Navy will continue to field the long-range Phoenix missile

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8. Detailed comparisons of missile requirements and inventories are classified.

9. The Navy also plans to procure a modified A-6 attack aircraft, the A-6F, that might carry AMRAAM for a self-defense capability.

as its primary armament against bombers. Sparrows are currently secondary munitions for this role, and AMRAAM would also function as a secondary weapon in the CAP mission. 10/

Although shipboard requirements do not currently influence AMRAAM requirements, they could eventually. The Navy has a requirement for radar missiles on ships that must defend themselves against enemy aircraft and missiles. This requirement is currently met by a variant of the Sparrow, the NATO Seasparrow. After completion of the program in 1992, about 110 Seasparrow launchers will be located on 63 U.S. ships of various types, including all large-deck aircraft carriers. The air-launched Sparrow and shipboard Seasparrow are similar, and AMRAAM could probably be adapted for ship use. The Navy, however, currently has no plans to replace the Seasparrow and is considering a possible modification of Seasparrow for future ships, though the service is reviewing applications of active seeker missiles in the ship self-defense mission. 11/

NATO Requirements

Several NATO countries have also expressed an intent to use AMRAAM on their aircraft. In particular, the United Kingdom plans deployment on its

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10. Considerable controversy surrounds the capability and deployment of the Soviet bombers and their air-to-surface missiles. For a discussion of the variations in data available in the public domain, see Berton Wright, Soviet Missiles: Data from 100 Unclassified Sources (Brookline, Mass.: Institute for Defense and Disarmament Studies, 1985). For two carriers, the Coral Sea and the Midway, F/A-18s equipped with Sparrow missiles (and eventually with AMRAAM) are the only aircraft available for the CAP mission, as these two small-deck carriers cannot accommodate F-14s.

11. As the Seasparrow program is a NATO program, transition to a sea AMRAAM would affect other countries as well as the U.S. Seasparrow is used on the ships of 10 countries. The rapidly diminishing Sparrow purchases under the current program could make a buyout by NATO and the U.S. Navy advisable as a means of avoiding the high unit cost increases that would come with reduced production. Such a buyout could be difficult under budget constraints.

AV-8 and Tornado aircraft, and Germany plans modification of its F-4s to carry the missile (see Table 1). Deployment of the AMRAAM on the AV-8 and the German F-4s would be particularly important as neither of these aircraft can currently carry radar missiles that can be fired beyond visual range. Several other NATO nations--particularly those with F-16s--might also use AMRAAM once it is available.

CHAPTER III. KEY PROBLEMS WITH THE AMRAAM PROGRAM

As discussed in the last chapter, AMRAAM offers the potential for substantial increases in capability, and the Navy and Air Force together believe they need about 24,000 of the missiles. But the program has had problems. Although the missile was initially supposed to be less expensive than Sparrow, it will cost about twice as much per unit according to current estimates, and those estimated costs could increase. 1/ Moreover, the test program for AMRAAM is behind its originally planned schedule.

COST GROWTH

When development of AMRAAM began in late 1979, the average program unit cost per missile--defined as the total cost to develop and buy all the missiles divided by the number bought--was expected to be $182,000 (in fiscal year 1987 dollars). The total estimated cost for 20,000 missiles--the

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1. This is based on a comparison of the total program unit cost of AMRAAM, $396,000, to the total program unit cost of Sparrow, $221,000--making AMRAAM about 80 percent more expensive than Sparrow. The Air Force prefers to compare procurement unit costs of AMRAAM to those of Sparrow, which are about $344,000 and $214,000 respectively, a 60 percent increase in cost. The service feels that these costs are more comparable as the AIM-7M--a modification of earlier Sparrow missiles--has substantially lower development costs that are not included in procurement funding. The service further argues that development funding for AMRAAM is essentially a sunk cost and has less relevance to future decisions than does procurement funding. This method of costing may, however, place the Sparrow at a disadvantage, since it includes future years of Sparrow procurement when the missile is being produced at greatly lowered production rates and raised procurement costs. Comparing AMRAAM's total procurement costs to those of Sparrow in 1987--before the transition to AMRAAM lowers the Sparrow production rate--yields a 108 percent higher cost for AMRAAM over that of Sparrow ($344,000 to $165,000). All costs discussed here are in 1987 budget authority dollars.

quantity desired by the services at that time--amounted to about $3.6 billion. In 1981, at the time of the decision to go ahead with full-scale development, the unit cost had risen to nearly $331,000; three years later cost estimates had grown further to about $438,000 per missile. At this price, the Air Force portion of the program alone would have cost $8.0 billion. 2/ The increases apparently stemmed primarily from overly optimistic estimates in the program's early years.

In early 1985, the Secretary of Defense, concerned by cost increases and schedule slippage, instructed the Air Force to study cost reduction measures for the AMRAAM program. Later that year, the Armed Services Committees limited funds for the AMRAAM development contract with Hughes Aircraft Company to $556.6 million (in current dollars) 3/ and set the amount available to procure the Air Force's roughly 17,000 missiles at no more than $5.2 billion, a unit procurement cost of about $305,000 in 1984 dollars, (the equivalent of $6.2 billion in 1987 dollars). 4/ The Secretary of Defense had to certify that these cost caps would not be breached. The Congressional language also required the Secretary to certify that the design was complete and that the missile's capability would not be degraded to meet cost goals.

In response to DoD and Congressional concerns, the Air Force initiated a number of measures, including earlier competition between manufacturers

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2. Air Force unit costs under this estimate are higher at about $466,000 per missile because Air Force funding includes early more costly procurement and contains more development costs.

3. Funding for research, development, testing, and evaluation (RDT&E) in current dollars--including inflation estimates--totals $1.1 billion, higher than the funding cap. Air Force RDT&E funding is $971.6 million and Navy funding is $176.6 million. While Congressional language does not expressly state current dollars, CBO assumes that the language is intended to refer to a current dollar development contract that the Air Force has signed with Hughes for $556.6 million.

4. The Congress did not mention Navy funding in its certification language, perhaps because of the Navy's smaller development funding and missile procurement.

and the producibility enhancement program (PEP). Specifically, the Air Force provided funds to allow the Raytheon Corporation--which lost the original competition to develop the missile but was always intended to produce it along with the missile's developer, Hughes--to be able to produce the missile one year earlier in the production program than planned. Thus, any savings from competition would be realized sooner. The Air Force also started PEP, which identified a number of changes in production techniques aimed at reducing costs. These included replacing hybrid circuitry that is costly to manufacture with large-scale integrated circuits that are cheaper to produce.

Cost Estimates

In February 1986, after reviewing the Air Force initiatives, the Secretary of Defense certified that the cost caps imposed by the Congress could be met without degradation in missile capability. The limits imply that the average AMRAAM program unit cost will be about $396,000. This is less than the estimate of $438,000 cited above, reflecting assumed savings under the PEP program. But the program unit cost of AMRAAM will still be nearly twice the program unit cost of the most recent version of Sparrow (the AIM-7M), which is about $221,000.

The estimates in the December 1985 Selected Acquisition Report (SAR) suggest that procurement funding for the Air Force will meet the Congressional cap. 5/ Also, the Air Force has signed a firm fixed-price contract with Hughes Aircraft Company that meets the Congressionally imposed development cap. The AMRAAM program manager has indicated, however, that an additional $16.5 million (in current dollars) in development funding above the cap may be needed in the near term. The funds are needed to open a third test site at Eglin Air Force Base, to pay additional Hughes personnel to interpret test results, and to buy a third AMRAAM Captive Equipment (ACE) pod that simulates missile behavior. 6/ If

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5. The Selected Acquisition Reports (SAR) are published annually by DoD. They describe the costs, procurement, development schedules, and capabilities of major weapon systems.

6. The ACE pod, containing missile guidance equipment and recorders, is carried on an aircraft that simulates the path the missile will take when it is fired. Many such simulations are carried out before an

approved, this additional funding could jeopardize the development cap. 7/

It will be difficult to ascertain whether the production cost cap will be met, however, until well into the 1990s when many AMRAAM missiles have been produced. Thus, it is worth assessing the probability that the cost caps will be met before proceeding with the program. Many observers have questioned the assumptions underlying the Secretary of Defense's certifications and have suggested that costs could be higher. In particular, the General Accounting Office (GAO) has recently published three reports on the certification. 8/

Areas of uncertainty about the current cost estimates are discussed in the following sections.

Savings from Producibility Enhancements. When the AMRAAM program was restructured in 1985, DoD sought proposals from the manufacturers to reduce missile production costs. Both Hughes and Raytheon submitted lists of potential modifications from which DoD selected 27. A competition for design of these modifications was then held, and the Air Force planned to award the contracts by December 1985. A total of $2.0 billion, or about 24 percent of the total procurement cost of

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Footnote Continued
actual test firing occurs.

7. The GAO has indicated that, prior to the enactment of the Congressional legislation, $200,000 (current dollars) above the cap had already been obligated. These funds were subsequently deobligated to meet the cap. See "Advanced Medium-Range Air-to-Air Missile (AMRAAM) Certification Issues," Briefing Report to the Chairman, Committee on Armed Services, House of Representatives, July 1986.

8. General Accounting Office, "Missile Development, Status of Advanced Medium-Range Air-to-Air Missile (AMRAAM) Certification," GAO/NSIAD (February 1986); "Missile Development, Advanced Medium-Range Air-to-Air Missile Legal Views and Program Status" (March 1986); and "Missile Development, Advanced Medium-Range Air-to-Air Missile (AMRAAM) Certification Issues," Briefing Report to the Chairman, Committee on Armed Services, House of Representatives, July 1986.

$8.4 billion, was removed from the estimated cost of the AMRAAM program, based on the assumption that the modifications would be incorporated partially in missiles bought in 1989 (Lot 3 of the initial contract) and completely by 1990 (Lot 4).

These contracts were not awarded until July 1986, however. Some analysts are concerned that more missiles than planned could be produced without the design modifications, which would push up costs. The Air Force maintains that cost-saving modifications will not be held up, despite the seven-month delay in the awarding of the contracts.

Savings from Competition. The Air Force assumed that baseline cost estimates were reduced by $0.9 billion because of savings associated with competition between Hughes and Raytheon. These savings are inevitably highly uncertain. Estimates of competitive "savings" in an Air Force independent cost analysis--associated with earlier program cost estimates--ranged from a cost increase of 9 percent to savings of 6 percent. Increases could occur if savings from lower recurring costs were insufficient to recoup the additional one-time cost of qualifying a second producer, or if competition was less aggressive than expected. Thus, competition could generate lower savings than expected.

The Office of the Secretary of Defense (OSD) raised another concern about competition. Frequently "competitive" savings are the result of increased efficiency on the part of the contractor. To the extent that efficiency improvements have already been captured under the producibility enhancement program, they should not be credited to competition.

Program Stability. The GAO expressed concern about the assumption, made by both the Navy and the Air Force, that large quantities of missiles would be produced throughout the program. In an austere budget environment, reduced purchases could occur that would increase the average cost of the missiles procured.

GAO questioned the assumption that no design changes (except the producibility changes discussed above) would occur during the production phase of the program. As evidence that this assumption might not hold, GAO mentioned several changes that some in the Air Force already intend to make in the missile. The DoD maintains, however, that the design of the missile is essentially complete, and that the Air Force envisions requiring high-level approval for any engineering change orders, similar to the controls applied to the B-1 bomber program. If the missile should prove less mature than the Air Force believes, however, or if the service should be less

restrained in approving changes than it now expects, then modifications could increase costs.

These uncertainties about future costs do not prove conclusively that AMRAAM cost estimates are too low. Indeed, DoD and the Air Force believe they are not. These concerns do suggest, however, that there is a reasonable possibility of further cost growth.

SCHEDULE DELAYS

In addition to the problems AMRAAM has experienced with cost increases, the missile has encountered scheduling delays. Originally, initial operating capability (IOC) for the missile was scheduled for 1987. (IOC is defined as the point when a 24-aircraft squadron receives a complement of missiles.) During the restructure of the program in 1985, when it was clear that the missile would be substantially delayed, DoD added about two years to the program so that IOC is now expected in 1989.

In addition to changing the schedule, DoD introduced several additional high-level program reviews. The first was to occur in June 1986. The restructured program also included 90 test firings of the missiles to be accomplished before the IOC. These are intended to determine whether the missile will perform as planned. The Office of the Secretary of Defense (OSD) directed the Air Force to test a list of performance areas and to meet specific criteria before each of the high-level reviews.

AMRAAM testing is now behind the new schedule, however. By the time of the OSD program review in June 1986, 14 of the 90 test firings were to have been made, but only eight were accomplished. (The history of AMRAAM launch attempts appears in the appendix.) Possibly for this reason, OSD delayed the review until July, during which time three more test firings took place.

This delay is, according to the Air Force, in part due to the removal of funds for a third test site at Eglin Air Force Base to meet the Congressional cap on development, rather than problems with the program. Though Hughes has produced enough missiles for testing, a lack of funds for this test site and a third ACE pod will preclude meeting the firing schedule revised in August 1985. The Air Force argues that even a reduced firing schedule will provide the information needed for the major program milestones.

The Air Force has also aborted or canceled firing attempts on 17 occasions. Ten of these involved problems unrelated to the missile (firing range, weather, target, or launching aircraft) but seven appear to have reflected problems with the missile. Of the last five firings, moreover, two were only partially successful and in another the missile's rocket motor did not ignite so that the test objectives were not accomplished. 9/ The two most recent firings were, however, fully successful.

Missiles are expected to fail sometimes in testing; otherwise there would be no need to have tests. Moreover, some types of test require kinds of information that virtually guarantee failures. The AMRAAM test program encompasses two kinds of testing that occur almost simultaneously --Development Testing and Evaluation (DT&E) and Initial Operational Testing and Evaluation (IOT&E). All shots so far have been part of DT&E. The DT&E determines whether the design of the missile meets the specifications in the contract and whether the specifications are reasonable; DT&E also tests the physical interface between the aircraft and the missile. 10/ The IOT&E evaluates missile suitability to perform in combat. Because the goals of each type of test differ, the criteria for success and the kinds of firings needed to evaluate these critieria also differ. Difficult shots that are quite relevant to IOT&E--at a rapidly manuevering target, for example--may not work, causing failures that result in fewer shots as the developers slow the program to determine what went wrong. This can delay DT&E.

A test program encompassing these various kinds of testing would be expected to experience some failures and even, depending on the severity of the testing, to be delayed. Perhaps of more concern is that only 11 of AMRAAM's 90 planned test shots have occurred. Despite that fact that 8 of

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9. The two tests that were partially successful accomplished some of the test objectives but the missile did not come within lethal radius of the target.

10. For example, the Air Force believes that a recent firing from the F/A-18 indicated that the specification for the missile's "g" forces experienced during separation from the aircraft, which is set at 15 g's, is higher than is likely to occur. (A g is a unit of measure for the force of acceleration on a body, where one equals Earth's gravitational pull.) Hence that specification has been changed.

the 11, or 70 percent, have been successful--an unprecedented number according to the Air Force--this might suggest that the time allocated to the test program should be lengthened before production is started. 11/ Yet, under the Administration's plan, low-rate production of the missile would begin in 1987.

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11. The Air Force says that the success rate of the test program is 80 percent since it has fired 13 shots--including 2 unguided "separation/control" shots intended to see whether the missile would separate cleanly from the aircraft--of which 10 have been successful. CBO has used guided test firings throughout this paper to be consistent with last year's test schedule that included 90 guided missile firings and excluded separation/control tests. The success rate for the program would be about 70 percent based on guided tests alone.

CHAPTER IV. ALTERNATIVES FOR AMRAAM PROCUREMENT

Concern over problems with the AMRAAM missiles--namely, cost growth and testing delays--has prompted some in the Congress to suggest altering the Administration's procurement plan. This chapter first describes the Administration's plan for procuring AMRAAM and other air-to-air missiles, which is consistent with a decision to place AMRAAM on U.S. aircraft as soon as possible to offset improvements in Soviet forces. Then the chapter describes the effects of delaying AMRAAM procurement by one year. This approach would be consistent with a decision to purchase AMRAAM, but only after more time had elapsed to complete testing and assess the effects of producibility changes aimed at holding down costs. It is possible, of course, that over the next few years AMRAAM could suffer further problems of cost or capability, which could necessitate considering alternative missiles to meet future air-to-air missile needs. The chapter concludes with a discussion of such alternatives.

ALTERNATIVE I--THE ADMINISTRATION'S PLAN

The current Administration program would procure over 24,000 AMRAAMs--17,123 for the Air Force and 7,212 for the Navy. 1/

Air Force Procurement

Of the 12,022 air-to-air missiles that the Administration plans to buy for the Air Force in fiscal years 1987 through 1991, 7,843 would be AMRAAMs. By 1991 the entire annual procurement--currently divided among Sparrow, Sidewinder, and AMRAAM--would be made up of AMRAAM missiles (see Table 2).

While annual procurement quantities for all types of missiles would not change appreciably during this time period, the cost of procuring them would be substantially higher in the first four years of the five-year plan than in 1986 (see Table 3). This growth would be caused, in part, by the

1. One hundred and eleven development missiles will also be bought.

TABLE 2. QUANTITIES OF AIR-TO-AIR MISSILE PROCUREMENT FOR THE AIR FORCE AND NAVY (By fiscal year, in numbers)

Missiles	1986	1987	1988	1989	1990	1991	Total 1987-1991
Air Force							
Sparrow	497	379	523	0	0	0	902
Sidewinder	1,650	1,710	956	437	174	0	3,277
AMRAAM	0	260	833	1,950	2,600	2,200	7,843
Subtotal Air Force	2,147	2,349	2,312	2,387	2,774	2,200	12,022
Navy							
Sparrow	1,948	1,716	1,594	900	400	500	5,110
Sidewinder	2,120	627	488	565	560	560	2,800
AMRAAM	0	0	0	50	400	800	1,250
Phoenix	265	205	430	560	560	560	2,315
Subtotal Navy	4,333	2,548	2,512	2,075	1,920	2,420	11,475
Total	6,480	4,897	4,824	4,462	4,694	4,620	23,497

SOURCE: Congressional Budget Office from The Budget of the U.S. Government for Fiscal Year 1987.

TABLE 3. COST OF AIR-TO-AIR MISSILE PROCUREMENT FOR THE AIR FORCE AND NAVY (By fiscal year, in millions of 1987 dollars rounded to the nearest $10 million)

Missiles	1986	1987	1988	1989	1990	1991	Total 1987-1991
Air Force							
Sparrow	80	60	100	0	0	0	160
Sidewinder	80	100	50	30	30	0	210
AMRAAM	220	760	990	930	780	520	3,980
Subtotal Air Force	380	920	1,140	960	810	520	4,350
Navy							
Sparrow	350	280	270	170	110	160	990
Sidewinder	110	70	50	60	60	50	290
AMRAAM	0	0	10	150	220	270	650
Phoenix	370	320	430	450	430	400	2,030
Subtotal Navy	830	670	760	830	820	880	3,960
Total	1,210	1,590	1,900	1,790	1,630	1,400	8,310

SOURCE: Congressional Budget Office from The Budget of the U.S. Government for Fiscal Year 1987.

higher expense of AMRAAM relative to Sparrow, but even more by the completion of the Sidewinder procurement and its replacement with AMRAAM in the Air Force missile procurement account. Because AMRAAM costs about five times as much as Sidewinder, the shift in mix from Sidewinder to AMRAAM would greatly alter total costs. 2/ While this sharp growth in missile costs could be a problem in an era of tight budgets, air-to-air missile procurement in the 1987 budget request is only 10 percent of the total Air Force missile account, which is itself only 9 percent of the entire Air Force budget. Thus, the growth might well be accommodated.

While the Air Force would buy 7,843 AMRAAMs over the next five years, it would procure nearly 10,000 more in the years beyond. The total estimated cost for the roughly 17,000 missiles the service intends to buy would amount to about $6.2 billion (the equivalent of $5.2 billion in 1984 dollars).

Navy Procurement

As Table 2 shows, the Navy plans to procure 11,475 air-to-air missiles over the five years--almost as many as the Air Force--including both Sparrow and Sidewinder, as well as long-range Phoenix missiles.

The Navy's costs would total $4.0 billion for its slightly smaller missile purchase. Continued procurement of the Phoenix missile, which at $1.6 million each (in fiscal year 1987 procurement unit costs) are substantially more expensive than either the AMRAAM or the Sparrow, coupled with sizable increases in Sparrow's unit costs because of reduced procurement quantities, would cause the Navy's program costs to approach those of the Air Force. Navy air-to-air missile funding would be lower in the first two years than in 1986, although costs would rise by the end of the five-year period. Navy air-to-air missile funding was substantially higher in 1986 than it had been for at least the preceding decade.

As with the Air Force, Navy procurement of the AMRAAM would continue beyond the next five years. In all, the Navy would purchase about 7,212 of the missiles at a total procurement cost of about $2.2 billion.

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2. Based on a comparison of average procurement unit cost for the total AMRAAM program with Sidewinder fiscal year 1987 procurement funding (both in 1987 dollars).

Advantages and Disadvantages of the Administration's Plan

The Administration's approach to buying AMRAAM has important advantages. Although the procurement schedule has been delayed, this plan would still deliver a substantial number of AMRAAM missiles by the early 1990s. If AMRAAM performs as expected, its delivery would provide the Air Force's F-15—the premier fighter in the counterair mission—with the ability to launch a missile at a target and leave and to engage multiple targets simultaneously. In the Air Force's view, these capabilities are critical because of the Soviet Union's larger number of aircraft and because of Soviet improvements in fighter and air-to-air missile capabilities. In addition, deliveries of AMRAAM would give the Air Force's F-16 fighter a radar missile capability and, thus, the ability to attack enemy aircraft at greater ranges than is possible with the infrared Sidewinder. This could be very important since, by the early 1990s, the F-16 will make up more than two-thirds of all Air Force fighters. In addition, AMRAAM would improve Navy capabilities by providing its F/A-18 fighters with a multitarget capability, thus improving their performance in the combat air patrol mission. This is particularly important for the two small-deck carriers that operate without F-14s and their Phoenix missiles.

On the other hand, the Administration's program presents substantial risk of increased costs. As the latest chapter suggested, costs could grow beyond levels now estimated, which are already much higher than originally planned. Also, because of delays in testing, there is the possibility that production might proceed before all design problems had been uncovered.

ALTERNATIVE II—DELAY PROCUREMENT FOR ONE YEAR

In light of the risks in the Administration's plan, the Congress could choose to defer AMRAAM production for one year. 3/ This would yield the

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3. Alternatively, the Congress could elect a lesser delay. The General Accounting Office (GAO) has prepared a briefing that examines the possibility of reducing procurement in the first year of the program. GAO considered alternatives that include reducing procurement in 1987 from 260 to 240, 180, or 135 missiles. "AMRAAM Budget Alternatives," GAO/NSIAD, April 1986, is an unpublished briefing prepared by GAO's National Security and International Affairs Division.

procurement profile shown in Table 4. Under such a profile 3,000 fewer missiles would be bought during the five-year period than under the Administration's plan, and deliveries by the early 1990s would be similarly reduced.

Advantages of a Procurement Delay

If production was delayed a year, more missiles could be tested before a production decision would need to be made, thus supplying more data for a production review. As Chapter III indicated, fewer AMRAAM test shots have been completed than were expected under the schedule issued in August 1985 (see Table 5). Under that schedule, 14 shots should have been fired by June 1986, but only 8 were completed. Moreover, in addition to the 8 that had been completed, 16 had been either aborted or canceled because of some problem (see Appendix). The shortfall in testing may indicate difficulties that will require time to resolve, though much of the delay may have arisen from problems unrelated to the missile. For example, some of the cancelations were apparently due to difficulty scheduling time on the firing range.

Delaying production for a year would enable extra tests that might provide important information about program risks. Problems are not unusual in a missile test program, but the history of AMRAAM's predecessor suggests some reason for concern. The AIM-7M version of Sparrow also experienced extensive problems with its guidance software when it reached the next stage of evaluation—operational testing—and three changes in its software proved necessary. These changes, and perhaps other problems, delayed production by two years.

According to Air Force estimates, a delay of one year would reduce fiscal year 1987 funding by about $0.6 billion. While higher costs in the later years would lower the five-year savings, they would still amount to about $0.5 billion. These and other costs noted below are based on Air Force estimates.

The costs provided by the Air Force for this option assume that the producibility enhancement program (PEP) would also be delayed for one year. The service has indicated that production of 10 missiles in 1987 would be necessary to keep that program on schedule. While procuring the 10 missiles would increase 1987 funding, it could decrease subsequent funding as more missiles would be produced under the program and so would benefit from the lower costs that PEP is designed to produce.

TABLE 4. TWO ALTERNATIVE AMRAAM ACQUISITION PROGRAMS
(By fiscal years)

Alternative	1987	1988	1989	1990	1991	87-91	To Complete
QUANTITIES OF AMRAAM MISSILES (In numbers of missiles)							
Alternative I (Administration's Program)							
Air Force	260	833	1,950	2,600	2,200	7,843	9,280
Navy	0	0	50	400	800	1,250	5,962
Total	260	833	2,000	3,000	3,000	9,093	15,242
Alternative II (One-Year Delay)							
Air Force	0	260	833	1,950	2,600	5,643	11,480
Navy	0	0	0	50	400	450	6,762
Total	0	260	833	2,000	3,000	6,093	18,242
COSTS (In millions of 1987 dollars rounded to the nearest 10 milllion)							
Alternative I (Administration's Program)							
Air Force	760	990	930	780	520	3,980	1,900
Navy	0	10	150	220	270	650	1,500
Total	760	1,000	1,080	1,000	790	4,630	3,400
Alternative II (One-Year Delay)							
Air Force	190	800	940	960	820	3,710	2,540
Navy	0	0	10	150	220	380	1,770
Total	190	800	950	1,110	1,040	4,090	4,310

SOURCE: Congressional Budget Office.

TABLE 5. AMRAAM TEST SCHEDULE

Event	1986		1987	1988	1989
Major Milestone					
Original Schedule Released 1979			Initial Operating Capability (IOC)		
Major Milestones and Test Launches					
	June	July	April		
Revised Schedule Released August 1985	Program Review by Office of the Secretary of Defense (OSD)		Defense Systems Acquisition Review Committee (DSARC) IIIA		DSARC IIIB IOC
Cumulative Number of Guided Missile Firings	14 Test Shots	16 Test Shots	48 Test Shots	90 Test Shots	
Current Schedule Released June 1986		OSD Program Review	DSARC IIIA		DSARC IIIB IOC
Cumulative Number of Guided Missile Firings	8 Test Shots a/ b/	11 Test Shots b/	47 Test Shots	89 Test Shots	

SOURCE: Congressional Budget Office from U.S. Air Force.

a. The Air Force has also completed two unguided firings that were not included as part of the original 90-missile-shot program and hence are not counted here.

b. These numbers are actual firings; the June 1986 schedule indicated that 11 and 13 shots would have occurred by June and July respectively.

Disadvantages of Delay

On the other hand, the one-year delay would increase costs over the life of the AMRAAM program by about $0.3 billion. (This number is the same in both constant 1984 dollars--the dollars of the Congressional cap--and in 1987 dollars--the dollars used throughout this paper--because differences caused by inflation are balanced out by rounding.) Thus, if the Congress were to delay AMRAAM procurement by one year, the cap would have to be increased modestly. The Congressional limit on the costs of full-scale development would not have to be increased, however, since development funding would not be altered under this alternative.

This modest increase in the production cost cap appears consistent with recent testimony by the AMRAAM program manager. That testimony suggested that procurement in 1987 could be reduced from the planned level of 260 to 180--a substantial cut though less than a one-year delay--without any need to increase the cost cap.

In addition to breaching the production cap, this alternative would delay fielding of the missile for a year--meaning one more year before the F-15 would have the improved capabilities that AMRAAM is intended to bring, and one more year before the F-16 would have any of the capabilities provided by a radar missile. This delay would occur at a time when the Air Force feels that the Soviets are rapidly increasing their capability.

This delay could also conceivably increase requirements for Sparrow missiles. Since the AMRAAM is expected to provide a higher probability of kill (Pk)--the probability of destroying a target--fewer missiles would be needed to destroy a given threat. If AMRAAM was not availale until later, more Sparrow missiles might be needed. Considering the great uncertainty in Pk estimates, however, a delay of only one year might well not alter significantly the actual procurement rate of Sparrow missiles.

Finally, the Air Force maintains that slippage in the test schedule is no reason to delay the AMRAAM program. The service says that the tests already completed, though few, provided the information required by the Office of the Secretary of Defense by the time of the July review. And indeed, AMRAAM passed that review. The service also argues that an unprecedented number of test firings (8 of 11) have been successful, and that this bodes well for the success of the program.

Clearly, the Air Force and Navy believe that the AMRAAM missile would add substantially to the capability of their fighter aircraft. While

both services want a thorough testing of the missile, they also want to procure and field it as quickly as possible. The Congress must weigh the desirability of getting AMRAAM's potential added capability into the field quickly and the increased start-up costs of a one-year delay against the extra testing information and greater opportunities for cost control through producibility enhancement that the delay in procurement would afford.

OTHER APPROACHES

Considering how recent was the Secretary of Defense's certification of AMRAAM's costs and capability, and how strong is the service support for the program, it seems unlikely that the Congress will consider far-reaching alternatives to the program this year. Over the longer term, however, the Congress may want to consider such alternatives if current projections of the missile's cost or capability prove overoptimistic. In general terms, the Congress could choose either to reduce program quantities or to cancel the program and substitute a different missile.

Reduce Program Quantities

If AMRAAM's unit costs should rise substantially, reductions in program quantities might have to be imposed to stay within the Congressional cost cap. Whether unit costs rose or not, reductions might also be needed to meet fiscal constraints. One approach would be to remove AMRAAM from the air defense mission of defending the United States against Soviet bombers in a nuclear war.

Some have suggested that AMRAAM's multiple-launch capability might be of less utility in its air defense mission than in its air superiority mission. This is because the number of Soviet bombers attacking the United States in a nuclear war would be far smaller than the threat that the Air Force might encounter in European skies during a conventional war--though the Air Force has argued that the AMRAAM's enhanced electronic counter-countermeasures (ECCM) ability would be needed to attack larger planes that can carry more capable countermeasures. If air defense missile requirements were removed from the program, about 1,000 fewer AMRAAMs might be needed. At unit costs now planned for AMRAAM, this could save about $0.3 billion.

The alternative might not save this amount, however, if, in the

absence of AMRAAM, the Air Force still decided to equip all air defense aircraft with the Sparrow radar missile in order to provide them with the ability to attack enemy bombers at long ranges. Currently, the Air Force is evaluating several alternative candidates, among them the F-20 and a modified version of the F-16, to determine what plane should be used for air defense. Neither of these planes can currently carry the Sparrow. If the winner is to carry Sparrow, modifications to the basic aircraft would have to be included in the price. The Air Force estimates that needed modifications would cost about $0.3 million to $0.6 million (in current dollars) each for as many as 198 F-16s. 4/ Savings from fewer AMRAAM missiles would also be offset by the cost of extra Sparrows to meet requirements that AMRAAM would have met. Finally, the Air Force plans to field AMRAAMs with most air defense squadrons late in the procurement cycle, so any savings under this approach would probably not be realized until the mid-1990s.

If AMRAAM costs were to increase, another perhaps more promising way to reduce quantities would be to buy some variant of Sparrow rather than AMRAAM for the Navy. As earlier indicated, all Navy fighters can carry Sparrow. Also, Navy fighters with the most demanding mission already have a long-range, multishot capability with the Phoenix missile. Thus, the Navy requirement for AMRAAM might not be as urgent as that of the Air Force. Furthermore, the Navy plans to retain a version of Sparrow, the Seasparrow, on its ships. Putting AMRAAM on Navy aircraft could burden the Navy's supply systems which would have to carry parts and people to maintain both Sparrow and AMRAAM. Finally, keeping Sparrow in production for Navy aircraft would hold down the costs of Sparrows needed on ships, because the increased numbers would lower unit costs. Indeed, deletion of the air-launched portion of the Sparrow procurement would cause the unit costs of Sparrows for ships to nearly double by the end of the next five years. 5/

This approach could also save money on total missile procurement. If,

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4. The precise costs would depend upon which model of the F-16 was modified. Also the costs of this modification might be lower in General Dynamics's competitive proposal. Modification costs for the F-20 have not been made public.

5. Navy Sparrow procurement unit costs are scheduled to grow from $163,400 in 1987 to $325,000 in 1991 (in 1987 dollars).

instead of buying 7,212 AMRAAM missiles as currently planned, the Navy were to buy an equivalent total quantity of Sparrow missiles, it could save about $1.0 billion. 6/

Deleting Navy purchases of AMRAAM would, however, affect Air Force costs. Because the total purchase would be smaller, the Air Force estimates that costs to procure its AMRAAM missiles would increase by nearly 10 percent or $0.6 billion, even if its annual procurement rates were increased to make up for the Navy's lost procurement. (This increase would be about $0.5 billion in the 1984 constant dollars of the Congressional cap.) If procurement rates were decreased by the amount of lost Navy purchases, costs would rise even more. The added costs would occur because the smaller the total buy of missiles, or the lower the annual rate of procurement, the greater the unit cost (reflecting the effects of learning on costs and the effects of fixed overhead). Thus, if the Navy buys were dropped, the caps on procurement costs of the Air Force AMRAAM missiles would be breached.

The Navy might also want to improve the capabilities of the Sparrow that it buys in place of AMRAAM. This could further erode cost savings, though probably not by much. The Navy has examined the possibility of a tail-control Sparrow that would decrease the space and weight taken up by the missile's guidance package. 7/ The missile could then carry a larger warhead or, if it were left lighter, it could fly faster or farther. Preliminary Navy cost estimates total about $100 million for development of the tail-control Sparrow--though these costs could increase if the Navy were to develop the missile. The Navy believes that the production cost of the enhanced version might be the same as for the current Sparrow, since the new technologies might make the missile easier to produce.

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6. This calculation is based on using funds available for Sparrow and AMRAAM during the five-year period to buy Sparrows only. Because the current Navy plan for Sparrow missile procurement includes low production rates, CBO assumed that more Sparrows than AMRAAMs could be bought in the years 1988 to 1991.

7. This would be done by moving the control fins from the center of the missile to its tail section, and by incorporating new computer technology. The combination of these changes would reduce drag and weight.

Program Cancelation

If AMRAAM's cost increased substantially, or if it appeared that the missile's expected capability would not be achieved, the Congress might have to consider canceling the program. The blue-ribbon panel set up to look at the AMRAAM program last year considered several alternatives to replace AMRAAM if it were canceled, though it found them all unacceptable for one reason or another.

One alternative that might be considered if AMRAAM were canceled is a modification of the tail-control Sparrow that would incorporate an infrared seeker along with Sparrow's current radar receiver. At long ranges, this missile would still depend on the fighter to illuminate the target, but at shorter ranges it would rely on its infrared seeker and let the aircraft turn away or engage other targets. The Navy has not done more than to make a preliminary design of such a missile, and there is no certainty that the design will prove operationally sound. If it does, it would provide the Sparrow with AMRAAM's launch-and-leave capability for at least part of its flight coverage, in addition to the advantages discussed above for the tail-control Sparrow. Program cost estimates--very preliminary in nature--amount to abut $300 million for development, with additional production costs per missile totaling less than $100 thousand above those for the current version of Sparrow--though these costs could rise in development. This new missile would thus cost a little less than AMRAAM is now expected to cost, and so would provide a hedge should AMRAAM's costs grow significantly.

The tail-control Sparrow with dual seeker (radar receiver and infrared) would not, however, have launch-and-leave capability at as great a range as AMRAAM, because AMRAAM's radar seeker would have more range than the infrared seeker envisioned for Sparrow. But this lack of range might not result in a great loss of capability. When the Air Force conducted a simulation of operational conditions using two groups of fighter pilots, multiple shots and long-range shots were seldom taken. 8/ The Air Force argues, though, that these results were dictated more by the way the simulation was structured than by actual missile capability.

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8. For more detail on this evaluation, see "Advanced Medium-Range Air-to-Air Missile Operational Utility Evaluation (OUE)" IDA Study, SECRET (December 1982).

Despite its promise, the tail-control Sparrow with dual seeker would involve new risks because of its new, and untested, technology and would not save substantial amounts of money unless the costs of AMRAAM were to grow well above their present estimated level. And the Sparrow costs might also increase. Moreover, the tail-control Sparrow was not judged desirable by the Air Force's blue-ribbon panel, which felt that an active radar seeker would be necessary to meet the Air Force's needs, including the desire to have a launch-and-leave capability at the greatest possible range.

APPENDIX HISTORY OF AMRAAM LAUNCH ATTEMPTS

Table A-1 provides a list of the AMRAAM test firings to date, as well as a list of the times the Air Force or the Navy has attempted to fire the missile but failed to do so. Thirty attempts or launches have been made through July 1986. The missile was actually fired from the plane 13 of these times. Two of the 13 firings were "Separation and Control" tests that were not fired at a target but were intended to determine if missile controls would work and whether the missile would separate cleanly from the aircraft.

Of the 11 guided missile firings that were actually directed at a target drone, 8 were described by the Air Force as successful. Two of the three that were not fully successful were partially successful from a development perspective in that they fulfilled some of the test objectives—though the missiles did not come within lethal radius of the target. The third launch fulfilled no test objectives since the missile's rocket motor did not ignite.

On 17 other occasions the missile was not fired from the aircraft. Four times the AMRAAM—which has the capability to "self test" or to check to see if it is working--did not separate when launch was attempted. Thirteen other scheduled tests were canceled before launches were attempted, though the aircraft carrying the missile was aloft on some occasions. Of these cancelations, three were related to problems with the missile and the remainder are variously explained as problems with the range, with the aircraft, or with the drone that is the missile's target.

The missile numbering sequence on the chart is based on the order in which the test missiles were produced by Hughes. Missiles used for the separation tests are different from those used in guided shots and are hence numbered separately.

TABLE A-1. HISTORY OF AMRAAM LAUNCH ATTEMPTS

Launch Number	Date	Missile Number	Result
1	7 Dec 84	Separation/ Control Test Vehicle (S/CTV-1)	Launch successful.
	17 Jan 85	AMRAAM Air Vehicle Instrumented (AAVI)-1	Mission canceled because of aircraft telemetry problem. No missile launch was attempted.
	25 Jan 85	AAVI-1	Missile aborted launch attempt. Terminal seeker on the battery squib on the missile was miswired.
	22 Feb 85	AAVI-1	Missile aborted launch attempt. Launch sequence timing problem.
	3 Apr 85	AAVI-1	Missile aborted launch attempt. Missile battery did not function. Wire from terminal was broken.
2	14 May 85	AAVI-1	Launch successful.
3	7 Aug 85	AAVI-2	Launch successful.
4	17 Sep 85	AAVI-3	Launch successful.
	12 Dec 85	AAVI-5	Arrived at Holloman Air Force Base December 1, 1985. The December 12 launch was canceled because an overcurrent was discovered during missile checkout. No launch attempt was made. Missile was sent back to factory for repair on December 9, 1985.

(Continued)

TABLE A-1. (Continued)

Launch Number	Date	Missile Number	Result
	25 Jan 86	AAVI-6	Mission canceled. Higher priority tests on range. No launch was attempted.
	27 Jan 86	AAVI-6	Mission canceled. Higher priority test on range. No launch was attempted.
	29 Jan 86	AAVI-6	Missile aborted launch attempt. Cause was transmitter arc.
	5 Mar 86	AAVI-6	Missile lost pressure before launch. Mission canceled. No launch was attempted.
5	7 Mar 86	S/CTV-2	Launch successful.
6	25 Mar 86	AAVI-6	Launch successful.
7	18 Apr 86	AAVI-5	Launch successful.
8	8 May 86	AAVI-4	Launch successful.
	16 May 86	AAVI-7	Mission canceled. Missile did not fit on Modular Rail Launcher on aircraft during loading. Installation of forward "button" hook did not allow adequate clearance.
	22 May 86	AAVI-7	Mission canceled. Range telemetry problem. Aircraft carrying missile was aloft.
	23 May 86	AAVI-7	Mission canceled. Drone control problems. Aircraft carrying missile was aloft.

(Continued)

TABLE A-1. (Continued)

Launch Number	Date	Missile Number	Result
	27 May 86	AAVI-7	Mission canceled. Range telemetry problem. Aircraft carrying missile was aloft.
	29 May 86	AAVI-8	Mission canceled. Range radar could not track missile tracking beacon in telemetry section.
	31 May 86	AAVI-8	Mission canceled because of weather. No launch was attempted.
	2 Jun 86	AAVI-7	Mission canceled because of weather. No launch was attempted.
9	2 Jun 86	AAVI-8	Missile ejected from F/A-18 but did not fire the rocket motor since a proper ejection stroke was not sensed. No test. Test office believes that the specification for the separation force is too high.
10	4 Jun 86	AAVI-7	Missile launched. Test was a partial success, though the missile missed the target.
	2 Jul 86	AAVI-10	Mission canceled because of an aircraft Inertial Navigation System (INS) problem.
11	3 Jul 86	AAVI-10	Missile launched. Test was a partial success, though the missile missed the target.
12	15 Jul 86	AAVI-12	Launch successful.
13	29 Jul 86	AAVI-11	Launch successful.

SOURCE: U.S. Air Force.