Critical Examination of a

Complex and Critical Major Acquisition for the Department of Defense:

The Advanced Medium Range Air-to-Air Missile (AMRAAM)

By

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B.S., Physics
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Submitted to the Sloan School of Management
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Management

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Abstract

In 1976, a group of United States Air Force and United States Navy fighter aircraft pilots told the acquisition professionals of the Armament Development and Test Center at Eglin Air Force Base in Florida the operational requirements for a new, lightweight air-to-air missile. They dreamed that the engineers and scientists of the US aerospace community could put an entire radar system more powerful than most aircraft radar into a 7 inch diameter, and that the resulting missile would let them launch multiple missiles at multiple enemy aircraft from beyond visual range. As of March of 1994, the operational forces have received over 3,000 missiles that surpass all expectations in performance and reliability.

This thesis is a case study of the acquisition strategy and Government organization that the Department of Defense used to acquire the AMRAAM system. The AMRAAM program is explained and analyzed from a managerial perspective from the genesis of the operational requirements until March of 1994. Positive and negative lessons-learned, as well as critical programmatic issues, are described for research and development, introduction of production competition through a leader/follower technique, pre-planned product improvements to sustain system performance well beyond the year 2010, management in the joint-service environment, and multi-national participation.

The thesis concludes with alternative acquisition strategies that the Air Force has for the AMRAAM program. The road to AMRAAM's success as a program was long and difficult. Current and future Department of Defense programs will be benchmarked against the AMRAAM accomplishments.

Thesis Supervisor: Dr. Janice Klein
Title: Visiting Professor of Management

Acknowledgments

I wish to thank several special people that motivated me to attempt to capture the significance of the Advanced Medium Range Air-to-Air Missile (AMRAAM) program as a worthwhile case study of Department of Defense (DOD) major weapon system acquisition. There are atleast 4 "heroes" in the history of the AMRAAM JSPO without whom the outcome of the program likely would have been much different:

Lt. General Thomas Ferguson (USAF retired) who showed me and the rest of the Joint System Program Office (JSPO) the power of teamwork and the tremendous potential for creativity and effectiveness within the DOD acquisition process. He instilled confidence in AMRAAM not only within the program team, but also throughout the Pentagon and onto Capitol Hill.

Lt. General Edward Franklin (USAF) who taught me and the rest of the Government and industry team a new meaning of quality and pursuit of excellence. He led the team by working with more dedication and perseverance than anyone knew possible. He also established the highest level of cooperation possible between two intensely competitive missile producers, saving the program from unexpected show-stopping reliability challenges that arose during initial production. He inspired us all.

Mr. Richard Calano, my good friend and co-worker for many years, who dedicated almost 16 years to make AMRAAM the premiere joint-service success story within the US Department of Defense. Rich has been the Navy corporate knowledge and stabilizing influence on the program since the Conceptual Phase, and provided me with invaluable insight into the Navy's perspective on program issues and lessons learned.

Last, I want to give special thanks to my long-time friend and supporter, Ms. Bobbi VanDyke, who was the executive secretary to 7 AMRAAM program directors over the 16 years from AMRAAM's inception to beyond its first operational success. I could not have survived as the Director of AMRAAM Acquisition, let alone have documented AMRAAM's history, without Bobbi's generous help.

Too numerous to individually mention, but most important, are the members of the AMRAAM JSPO and industry team who shared their thoughts and notes so openly, and who took time out of their busy schedules to support me. I hope I have captured their challenges and their accomplishments.

Thank you all very much.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SLOAN SCHOOL OF MANAGEMENT

SLOAN FELLOWS PROGRAM

Thesis Title: Critical Examination of a Complex and Critical Major Acquisition for the Department of Defense- The Advanced Medium Range Air-to-Air Missile (AMRAAM)

1.0 Introduction and Background

The US Department of Defense (DOD) has attempted to employ multi-faceted acquisition strategies to obtain advanced systems necessary to meet the requirements of the operational forces world-wide. DOD acquires many such critical systems each year that amount to billions of dollars of procurement. The strategies to acquire these systems are built on lessons-learned from previous acquisitions, on the laws and regulations governing the Federal sector, and on executive policies that are used to shape implementation of these laws and regulations by acquisition organizations. These strategies are relatively complex, are long-term in nature, undergo an excruciating review process before and audit process during/after execution, and are typically impacted during their execution by external events beyond the control of the acquisition organization. Even with this complex and sometimes overbearing process, many of these acquisition strategies have proven to be very effective over time. One such acquisition strategy was developed for the Advanced Medium Range Air-to-Air Missile system, also known as AMRAAM. The AMRAAM program is a progressive example for best practices and success during the late 1970's until today. As with any complex acquisition over a 15 year period, we can also look back at the challenges that the program faced, the success (or non-success) with which they were handled, and how the challenges and disruptions to the

program might have been avoided. This thesis will be a critical case analysis of the AMRAAM system acquisition strategy and execution.

The AMRAAM program contains many of the most complex acquisition challenges that DOD and US industry face today. The program has the following complexities:

- Multi-service use: AMRAAM is being used by the US Air Force and the US Navy.
- Multi-national use: AMRAAM is being acquired for many US allies.
- State-of-the-art design: The AMRAAM is the most versatile and operationally effective missile ever to be introduced to the US operational forces. Due to its unique capabilities (including its own active on-board radar system), AMRAAM has produced a multiplier effect to US fighter aircraft effectiveness.
- Highly competitive acquisitions: Throughout the program, the USAF has stressed competition. Unique to the AMRAAM program as a major weapon system, two competitive sources for the missile were developed successfully through a leader/follower program. Other elements of the system were also competitively acquired, some successfully and some not as successfully.
- Value engineering: AMRAAM has successfully executed DOD's largest value engineering program.
- Pre-planned product improvement (P^3I) program: AMRAAM has a very large and active P^3I program that will sustain its operational effectiveness well beyond 2000.

This thesis will explore the AMRAAM program historically and will examine current planning. The thesis will investigate the management methods employed over the program evolution, with particular emphasis on:

- Program planning, execution and oversight
- Organizational structures within the Government and US aerospace industry
- AMRAAM's Producibility Enhancement Program

- Second source development at the prime and subcontractor levels
- Cooperative (multi-contractor) pre-planned product improvement
- Technology transfer of design and manufacturing processes

The thesis will then review the alternative acquisition strategies available to the Government for each major element of the program remaining, with special emphasis on missile production.

Data has been obtained through interviews with Government and contractor program personnel, review of program documentation and review of periodicals. It is the intent of this thesis to provide key acquisition personnel from DOD and industry a relevant weapon system case study that compares the management methods used in a current complex US acquisition with new international methods used in commercial product development and acquisition. It is further intended that this thesis will complement the Lean Aircraft Initiative ongoing at MIT.

1.1 AMRAAM Program Goal and System Description:

To understand the decision process that has occurred on the AMRAAM program and the issues the program continues to face today, it is essential that the program goal and requirements of the system be understood. Out of context, many elements of the strategy and the decision process cannot be fully understood.

The goal of the AMRAAM program has been to develop, acquire and support the world's most effective air-to-air missile system for the United States tactical air forces and important allies well beyond the year 2000. "Air-to-air" missiles are shot by fighter aircraft to destroy or disable enemy aircraft in flight. The AMRAAM system is required to operate in all environments faced by US and Allied operational forces throughout the world. The AMRAAM system operational performance is required to provide US pilots the stand-off range to attack enemy aircraft beyond the US pilot's (and his enemy's) visual capability. Compared to potential enemy weapon systems as well as other US missiles, AMRAAM has many other superior performance characteristics that are critical to its operational users such as:

a. A radar system internal to the missile that allows the pilot to launch the missile beyond visual range and then maneuver to safety. This feature is called "launch and leave" and is a significant improvement over previous missiles, such as the AIM-7 Sparrow, which require the pilot to continue to fly toward the enemy aircraft until missile impact.

b. A system that permits one fighter aircraft to simultaneously attack many enemy aircraft at one time in a "multi-shot" mode that fires multiple missiles at specific targets. This feature is known for its "multiplier effect" that allows one aircraft to be effective against many enemy aircraft at one time.

c. An extremely versatile computer which is sophisticated in defeating enemy electronic counter measures (ECM). In addition, the software used within the computer may be updated to include new ECM defeat mechanisms developed by the enemy.

d. Factory delivered as an "all-up-round", meaning that it is shipped fully assembled (less control fins) and is immediately ready to be loaded onto the aircraft for combat out of its shipping container. Previous missiles required assembly and testing before being combat ready. This all-up-round feature frees ground personnel to perform other critical tasks and lowers the required level of technical expertise in the field to successfully employ the system.

e. Much improved system reliability, which translates not only to operational effectiveness in combat, but also to improved maintainability, availability and logistics supportability.

The AMRAAM system consists of the basic missile (military nomenclature AIM-120), the missile rail launcher, and associated training and support equipment. The AIM-120 is a follow-on to the AIM-7 missile. The AIM-120 is faster, smaller, lighter and has the many increased performance features described above.

The missile rail launcher (MRL) is the complex electromechanical device that physically attaches the missile to the aircraft before launch. The MRL has the requirement to be compatible with two basic types of missiles: both the AMRAAM (AIM-120) missile and the Sidewinder (AIM-9) missile. The MRL is also required to be compatible with many aircraft types such as the Air Force F-15's and F-16's, as well as the Navy F-14's and F/A-18's. To accommodate these aircraft varieties, three versions (configurations) of the missile rail launcher are required.

There is other important equipment related to the AMRAAM system. For example, the support equipment includes the missile "built-in test" set which allows for the majority of the missile's functions to be safely checked out in the field with ease and with minimal technical expertise. Load/training missiles simulate the missile in physical characteristics and interfaces to allow load crews the opportunity to train and remain proficient without exposing the actual missiles to accidents. Examples of other handling and loading equipment include the missile containers which house up to 4 missiles each,

and the one-step loading equipment used by the Air Force to remove the missile from the container and load it on the aircraft in one operation.

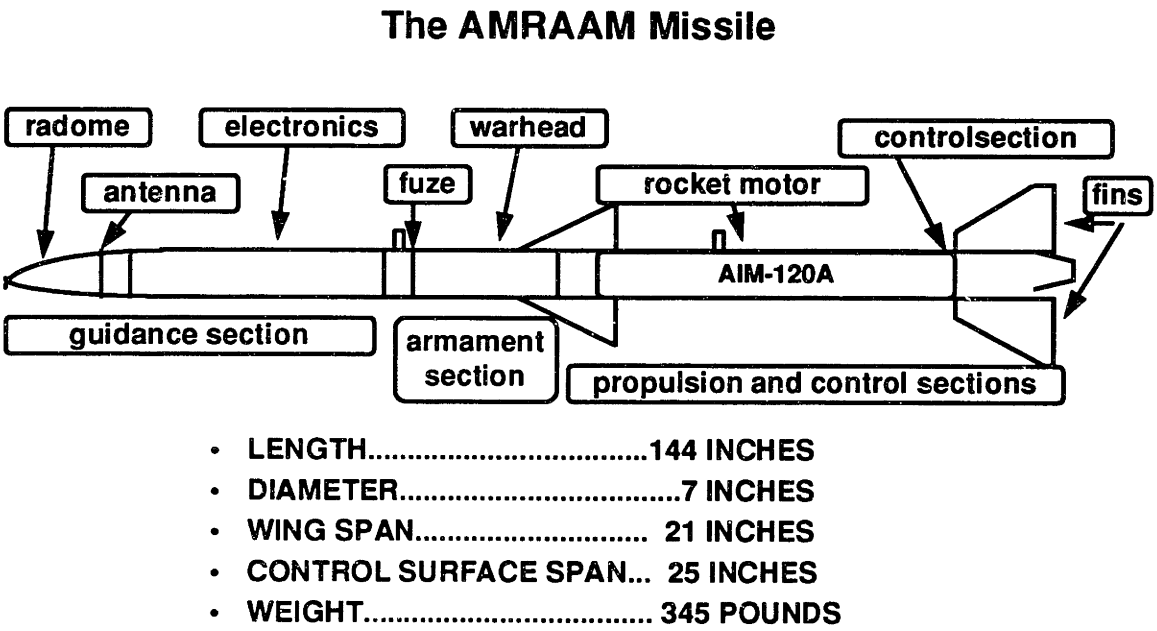

Figure 1.1

1.2 Overall AMRAAM Program Approach

The AMRAAM development strategy was the first Air Force program structured in compliance with Office of Management and Budget (OMB) Circular A-109. This strategy consisted of three development phases, with the number of competing contractors being reduced for each successive phase. Phase I, the Concept Definition Phase, consisted of preliminary development efforts by five competing contractors. These contractors were Hughes Aircraft Company, Ford Aerospace company, Northrop Corporation, General Dynamics Corporation, and Raytheon Company.

AMRAAM Competitive Acquisition Strategy Followed OMB Circular A-109

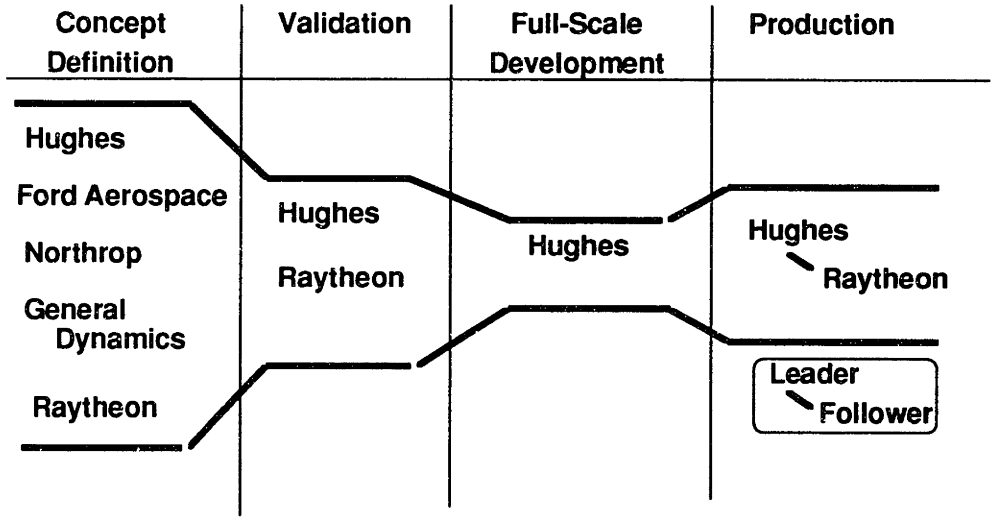

Figure 1.2

Two of the five contractors, Hughes and Raytheon, were selected to conduct the 33-month Validation Phase, Phase II, which included the fabrication and test of prototype missile and launchers[1]. On December 11, 1981, Hughes Aircraft Company was selected to accomplish Phase III, Full Scale Development (FSD). Raytheon was later selected (as

[1]Validation Phase contracts were awarded to Hughes in the amount of $45,432,503 (Contract F08635-79-C-0044) and to Raytheon Company in the amount of $39,094,140 (Contract F08635-79-C-0043) on 2 February 1979.

will be described later within this thesis) to become the second source competitive producer of AMRAAM.

In accordance with OMB Circular A-109, there were specific objectives of each phase of development. These objectives were tailored to each program's distinct needs. In AMRAAM's case, the Concept Definition Phase allowed each of the five AMRAAM competitive contractors to:

- Develop critical technologies peculiar to its concept
- Assess technological risks
- Explore the performance and cost sensitivity to requirements
- Conduct design performance specification iterations on conceptual designs
- Assess the commonality potential of its design with other anti-air requirements
- Solidify the design to be proposed for Validation Phase prototype flight demonstrations
- Conduct Electronic Countermeasure (ECM), clutter, and multiple target/multiple engagement analyses.

Each of the five Conceptual Phase contractors pursued these objectives with rigor. The Validation Phase source selection reviewed the results of the Conceptual Phase studies, tests and analysis, and down-selected to two competitors.

The Validation Phase program consisted of the preliminary development and test of missiles, launchers, aircraft interfaces, carrier aircraft equipment, and support equipment. The primary objectives of this phase were to:

- "Fly Before Buy" philosophy which meant that the Government would not make large, protracted investments in systems during Full-Scale Development (FSD) and production without reducing risk through prototype flight testing
- Prototype fabrication and testing of other critical system elements such as the missile rail and eject launchers that attached the missiles to the various aircraft

- Documentation of requirements to be used during FSD in system specifications, test aircraft modifications, interface control drawings, and interface specifications.

Hughes and Raytheon competed head-to-head during the Validation Phase to propose and demonstrate prototypes of the optimal design to carry forth into the next phase (FSD). Hughes Aircraft Company's Missile Systems Group out of Canoga Park, California was the winner of the FSD competition.

The Full Scale Development program had many objectives that were needed to make AMRAAM a reality to the users in the field. The program objectives were to:

- Fully develop a producible, supportable and affordable tactical missile that met all Air Force, Navy and allied requirements
- Perform very extensive environmental and flight test qualification
- Conduct a comprehensive, combined Developmental and Operational Test and Evaluation (DT&E/IOT&E) that would assure the operational community they were receiving an effective and reliable design solution
- Total development of all system elements except for Class V modifications[2] to aircraft and modifications to related aircraft armament system test equipment.
- Generation of a procurement data package with sufficient design disclosure to allow competitive reprocurement of the missile, missile rail launcher and other system elements through open competition
- Technology transfer of the missile design and unique manufacturing processes to an eventual second source producer through a leader/follower program (to be described Section 4.3.4)

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[2]Class V modifications are changes such as wiring, avionics and software which are made to operational aircraft to accommodate new systems such as AMRAAM. Since each aircraft represents a complex weapon system, the actual Class V aircraft modifications to allow integration of AMRAAM were and are the responsibility of the appropriate Air Force and Navy aircraft program offices. These modifications were to be consistent with the interface specifications developed during the AMRAAM Validation Phase, and updated during the FSD Program. The AMRAAM-generated carrier aircraft equipment specifications were also used by the aircraft program office.

The Production Phase of AMRAAM has consisted of an initial production phase that began concurrently with the completion of development followed by the full-rate production that came after competition was solidly in place. The degree of concurrency between development and initial production, and between initial production and full-rate production, was a major acquisition strategy issue that was debated throughout the program and was driven by several factors. The first factor was that the production contracting of weapon systems within DOD is normally done on an yearly basis. The second factor that drove concurrency was that the production lead-time[3] for AMRAAM and other missiles was approximately 21 months during early production. A third factor considered was that a break in the manufacturing line routine typically causes a program to suffer production shut-down and start-up costs, as well as loss of reliability growth. Thus, to prevent a break in the manufacturing line, the Government is required to order a future lot of missiles before initiation of acceptance of the current lot. The AMRAAM transition-to-production strategy was to provide a minimum break between FSD missile deliveries and initiation of production deliveries through FSD/production concurrency. Therefore, the Government planned for ordering long-lead components for Lot I missiles (warheads, rocket motors, radomes and many more items) in November/December 1986, concurrent with the completion of selected FSD tasks. The phrase most often used in the program's documentation was "The AMRAAM production strategy includes a manageable degree of concurrency".[4]

The AMRAAM program employed a "leader/follower" strategy to develop a competitive second source. Hughes was required to function as a "leader" to transfer technology through documentation and technical assistance to Raytheon as the "follower" during FSD, a Qualification Lot, Lot 1 and Lot 2. The leader/follower initiative was

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[3]The "lead-time" for production is defined as the length of time between a contract being awarded and the first production unit of the lot being delivered.

[4]AMRAAM Milestone I Defense System Acquisition Review Council (DSARC) Decision Coordinating Paper and Integrated Program Summary

intended to provide full competition between Hughes and Raytheon for the missile production program by the Lot 3/4 time frame.

A pre-planned "block" approach to missile hardware and software configuration releases for production was structured to provide a means to continuously upgrade performance capability. As an example, these updates provided Tape 3A software configuration missiles for Lot 1 and Tape 4 missiles for Lot 2 and beyond. In addition, implementation of producibility enhancement changes in FY86 were planned to allow cost savings to be realized beginning with the Lot 2 missiles.

Missile production **Lots 1 and 2 were directed splits** between Hughes (as the leader) and Raytheon (as the follower). These directed splits were designed to allow the follower sufficient opportunity to qualify and be established as a true competitor prior to attempting competition.

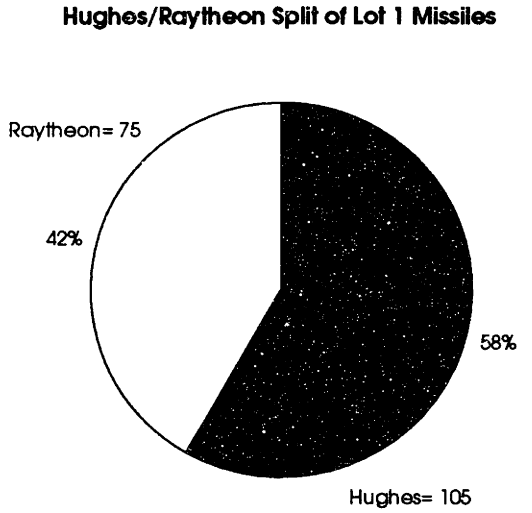

Figure 1.3

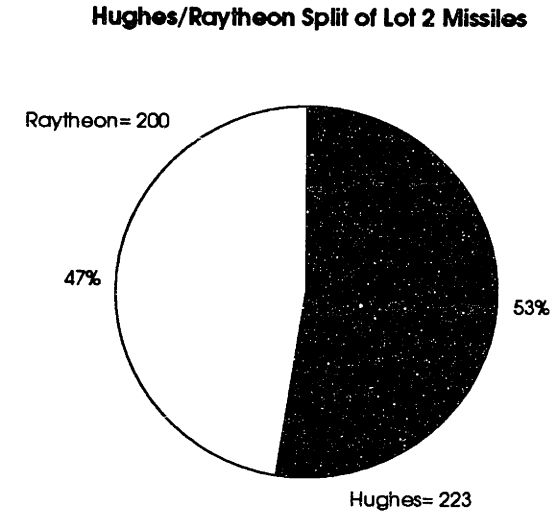

Figure 1.4
Lot 3 was acquired under competition but with limited success.

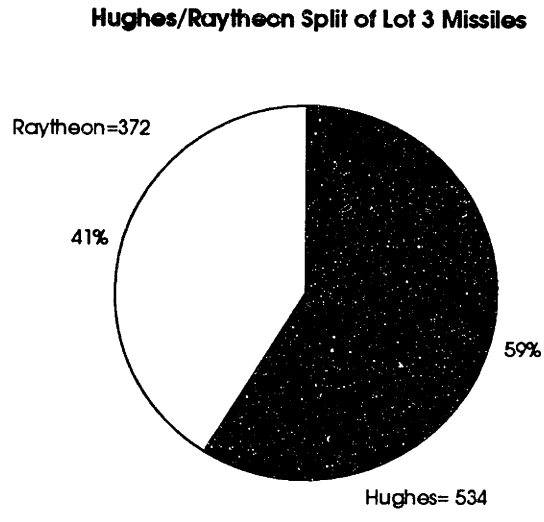

Figure 1.5

The JSPO determined that adequate price competition did not yet exist between the two prime contractors based on the proposals received for Lot 3, which significantly exceeded Government price projections. As a result, the Government requested certified cost and pricing data, which was audited and negotiated to allow the Government to obtain a fair and reasonable price.

Subsequent to this Lot 3 source selection, technical problems on the program arose concerning the reliability of the missile when being captively carried on the F-15. Because relatively few missiles were to be acquired during Lot 4, effective competition was not anticipated. As a result, the Secretary of the Air's Acquisition Executive approved a determination that Lot 4 would be a directed split between Hughes and Raytheon. The equally important reason for a directed split was to assure that the two contractors would as cooperative as possible in joint efforts to identify, qualify and incorporate necessary changes into each contractor's production line without interruption or delay.

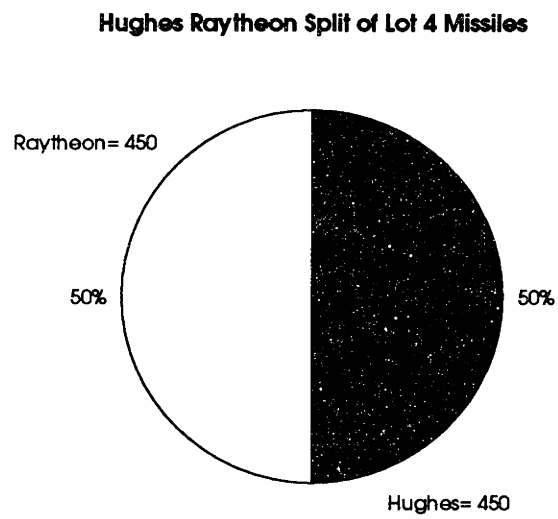

Figure 1.6

Full competition occurred in Lot 5. The Acquisition Strategy Panel (ASP) on May 9th, 1990, approved a Lot 5 competitive acquisition strategy with an option for Lot 6. The FY91 Appropriations Conference Markup approved the requested 900 missiles, but appropriated only $815 million, which was $50 million less than the President's Budget Request. This first competition resulted in Hughes being awarded 540 missiles and Raytheon being awarded 270 missiles for a total of 810 out of the 900 authorized by the US Congress.

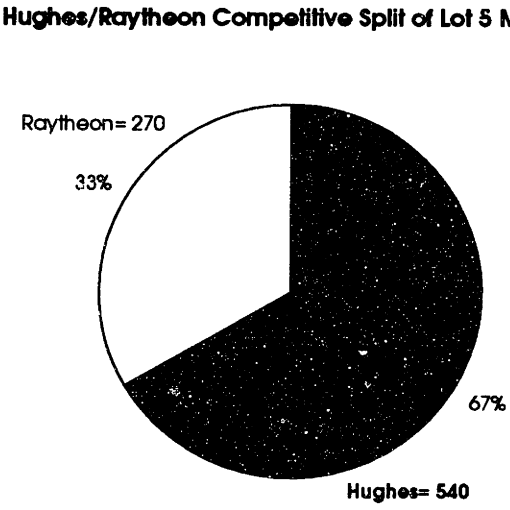

Figure 1.7

The Lot 6 options were exercised on March 23rd, 1992, in which Raytheon was awarded 490 missiles and Hughes 401 missiles for a total of 891. In addition, to take advantage of the excellent prices that were available, another 90 missiles from the FY91 appropriation were added to Lot 6 in the same percentage as the basic option (50 to Raytheon and 40 to Hughes). The final total awarded for Lot 6 was 981 missiles.

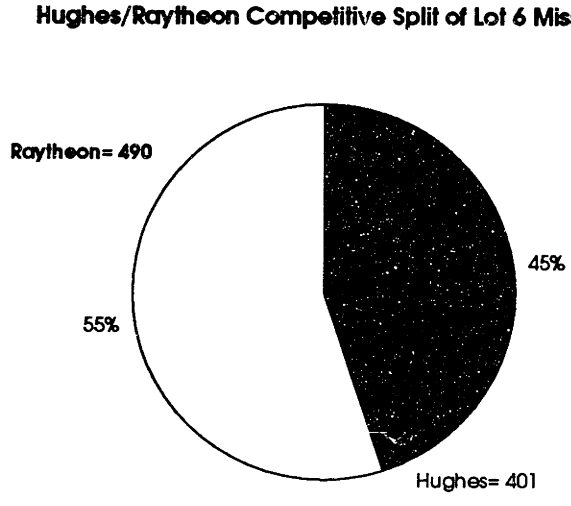

Figure 1.8

In Lot 7, a strategy similar to the Lot 5/6 competitive strategy was used to obtain an option for Lot 8. A configuration change will occur in the deliveries of Lot 7 missiles to an APREP Block II design, which will include extensive producibility changes. The new configuration is known as the AIM-120B (versus the original AIM-120A) and will be introduced in the later part of Lot 6. The FY93 Appropriations Act anticipated that Lot 7 quantities would be 1040 missiles (900 Air Force and 140 Navy). However, the language of the act allowed the JSPO to acquire additional missiles if funding allowed. **Due to the success of the competition combined with producibility changes, a 25% cost reduction occurred between Lot 6 and 7 and allowed the JSPO to purchase an additional 100 Air Force and 25 Navy missiles.** These added to 298 Foreign Military Sales (FMS) missiles for a total of 1463 missiles in Lot 7.

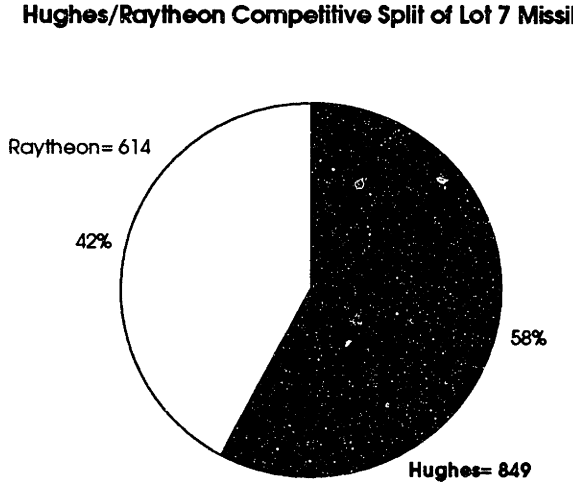

Figure 1.9

The Lot 7/8 solicitation requested the procurement of the AIM-120B version, however the JSPO planned to modify the Lot 8 Call For Improvements (CFI) to implement the AIM-120C Pre-planned Product Improvement (P^3I) into production to

facilitate the acquisition of the AIM-120C (P^3I) version into Lot 9. The CFI provision allowed the JSPO to sustain competitive pressures by allowing the contractors to make a downward only adjustment to the Lot 8 option prices that were included in the Lot 7 contracts. Further, the contractors were given the opportunity to propose the number of AIM-120C configuration missiles they would be willing to produce as part of Lot 8, and to present a production implementation plan that would demonstrate their ability to achieve the AIM-120C deliveries. (FMS would continue to be the AIM-120B configuration.) The final mix of the US deliveries in Lot 8 was determined by an evaluation of the risk associated with their ability to meet delivery schedule of the AIM-120C's proposed, coupled with other more traditional selection factors such as cost, performance and management. The Government anticipated that competing both recurring and non-recurring costs would provide significant monetary and man-hour savings compared to costs that would have been received through individual negotiations with each contractor. The Call For Improvement (CFI) solicitation was issued on September 1st, 1993, and was answered by contractor proposals on October 15th.

Lot 8 quantities were planned to be approximately 793 missiles (725 Air Force operational missiles, 24 Air Force Seek Eagle program for aircraft integration testing, and 44 Navy) in the FY94 President's Budget. In addition, signed FMS cases for the UK, Norway, and Turkey brought the Lot 8 anticipated quantity to 1023.

The Lot 8 competition was even more effective than anticipated. Lot 8's missile price reduction was an average of 23%, which was again very impressive after the Lot 7 25% reduction the preceding year. The average unit price declined $87,000 per missile, down to 299,000 in the Lot 8 1994 buy from the $386,000 unit price in Lot 7's 1993 buy. Much of this success was due to Raytheon being awarded 769 missiles (60% of the total buy) at a unit price of $254,546 for operationally configured US missiles. Of these 769 Raytheon missiles, 120 are for Foreign Military Sales: 12 are destined for Turkey, 66 for the United Kingdom, and 42 are for Norway. For the US, 604 missiles are

for Air Force consumption, and 45 missiles are for the Navy. Hughes was awarded 40% of the buy which amounted to 513 missiles at an average air vehicle recurring cost of $367,153. Both contractors also provided a 10 year warranty, virtually unheard of in weapon system procurement until recent successes on the AMRAAM program.

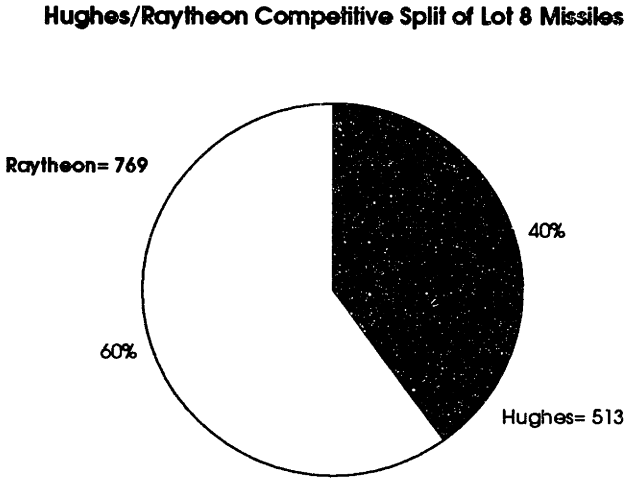

Figure 1.10

The outstanding results of AMRAAM's recent competition were summarized by Lieutenant General Richard E. Hawley who is the Principal Deputy Assistant Secretary of the Air Force for Acquisition, "The AMRAAM program is a shining example of an intelligently managed competition. Any time you can increase the quality, reduce price, and provide additional world class weapons for our war fighters, you are doing something right." The results were also praised by Mr. Harry E. Schulte who is the Air Force Program Executive Officer for Conventional Strike at the Pentagon who pointed out the benefits to be gained by the Lot 8 competition. Mr. Schulte stated "Not only will our war fighters get extra missiles, but they get an improved version and higher reliability." His remarks were praise for two important facts. First, Hughes and Raytheon had both proposed to bring on the more capable AIM-120C version on earlier than planned. Second, each of the contractors had also raised the level of reliability performance to be

required of the missiles during the rigorous, Government -conducted, production reliability acceptance testing.

Colonel Richard L. Dickson, Director of the AMRAAM JSPO, stated "I was pleasantly surprised with this year's results. With the savings from our AMRAAM Producibilty Enhancement Program already taken in last year's unprecedented reduction for Lot 7 and a reduced missile quantity for Lot 8, we expected competition only to maintain existing (last year's) prices." He noted that others had thought that competition had already played itself out, perhaps underestimating the impact defense cutbacks have had on industry's desire to maintain their business base. Colonel Dickson believes that as long as quantities can be maintained high enough to sustain two sources, "further benefits can still be gained" from the competitive dual source strategy.

Another important part of the Lot 8 contract awards was the influence of the foreign military sales, also known as the security assistance program. In Lot 8, 1007 missiles were bought for the Air Force, 75 for the Navy, and 200 for our allies through the security assistance program. The security assistance sales allowed the US Government to reduce the price of US missiles by $20,000 per copy due to economies of scale based on analysis by the joint-service source selection team. With the dramatic reduction in quantities of AMRAAM's expected to be submitted to Congress for the FY95 budget, allied purchases are expected to be even more important in the future to maintain effective competition.[5]

To briefly summarize the results of the AMRAAM production awards to date, the Figure 1.11 is provided. (The lot by lot delivery performance and other production summary data will be given in Section 3 of this thesis.)

[5]US Air Force Press Release, 1994 AMRAAM Production Contracts Awarded, January 4, 1994

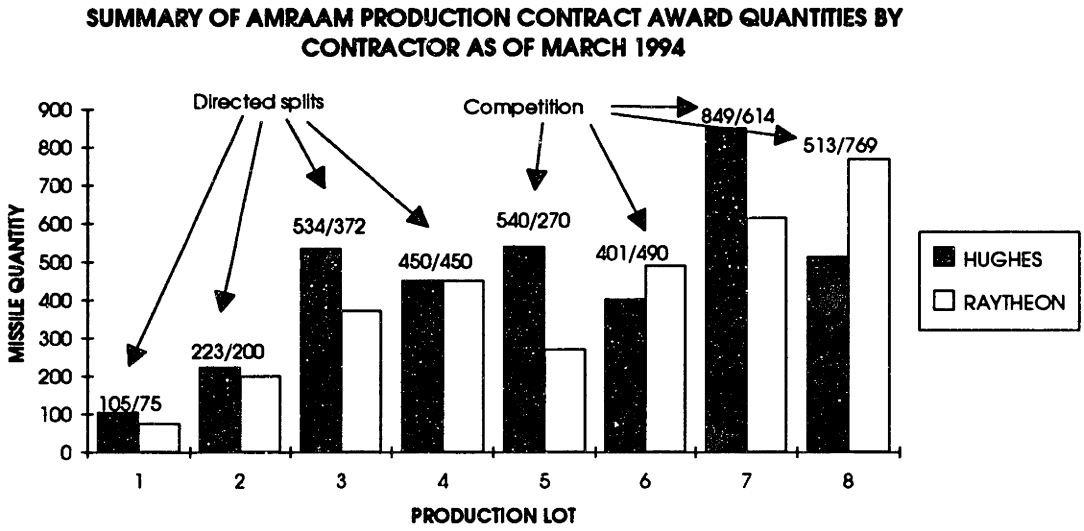

Figure 1.11

This brings the program to the acquisition strategy issues of today. The first issue revolves around the question of how many lots beyond Lot 8 does the Government need to continue to acquire AMRAAM. AMRAAM will continue to need pre-planned product improvements to continue to sustain its performance advantage over enemy systems and to be compatible with advanced aircraft such as the F-22. Issues, constraints and major considerations are as follows:

1. Program Stretch-out: The Air Force Chief of Staff has directed the program to analyze stretching the production schedule beyond the current 16 lots of planned production. The purpose of this stretch-out is to sustain the production and technology base of the missile.
2. Yearly Production Rate and Sustaining Two Competitive Producers: The overall quantity of required missiles for the US is relatively fixed. Therefore, program stretch-out would further reduce the yearly quantity to be acquired. As such, a question enters whether or not the quantity to be produced each year will sustain two production sources at the prime contractor level.

3. Future Improvements to AMRAAM: There will continue to be a requirement to upgrade the missile's performance to counter evolving electronic countermeasures, to integrate on new aircraft, and to improve producibility for further cost reductions. At present, Hughes and Raytheon both participate in these activities through direct or indirect (sub-) contracts with the Government. If there are not sufficient quantities to economically justify two production sources, there would also be acquisition strategy ramifications for future improvements to the missile system.
4. Government Program Office Personnel Constraints: A fact-of-life circumstance with the overall reduction of our military forces is that the acquisition corps is also being drawn down. Even with its program priority, the AMRAAM Joint System Program Office (JSPO) has not been immune to reductions. The number of people required to effectively manage the acquisition of a system is clearly dependent, to some degree on the complexity of the acquisition strategy. Therefore, organizations that control staffing resources that are used within the JSPO have the motivation to influence the acquisition strategy to free personnel resources for reassignment, independent of the macro-level economics that would justify sustaining two competitive contractor sources for production and/or improvements.

1.3 AMRAAM Program Background and History

In October of 1975, the Undersecretary of Defense for Research and Engineering formed a working group to examine operational requirements for Air Force and Navy air-to-air missiles for 1985 and beyond. The charter of this group, which consisted of actual combat experienced aircrews from the Air Force, Navy and Marine Corps, was to develop a single document that contained the consolidated requirements of all three services. This group successfully identified and prioritized the major requirements into a draft Joint Service Operational Requirements (JSOR) document that reasonably predicted the needs for an advanced tactical air-to-air missile through at least the next 20 years. AMRAAM was designed to meet these requirements.

The Headquarters of the Air Force (HQUSAF) directed the initiation of a Joint Air Force and Navy development effort for AMRAAM in October 1976.[6] The draft JSOR provided the primary technical guidance in the form of prioritized requirements rather than specifying a design solution. In November of 1976, Headquarters of Air Force Systems Command (HQAFSC) issued direction[7] that the Armament Development and Test Center (ADTC) at Eglin Air Force Base in Florida would lead the effort and an AMRAAM Joint System Program Office (JSPO) was established. The "joint" term in the office title referred to the fact that both Air Force and Navy personnel would make up the program office.

The early acquisition strategy in 1977 was to provide the operational requirements to industry and solicit their concepts. This phase, called the Concept Definition Phase, awarded contracts to 5 competing teams to define the optimal design solution to the draft JSOR. In March of 1978 a new program direction[8] was issued by HQUSAF to continue the Concept Definition Phase and to initiate a Validation Phase in the early part of Fiscal Year 1979. (Government fiscal year 1979 is equivalent to calendar year dates of October

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[6]Headquarters US Air Force Program Management Directive (PMD) No. RQ7002(1)/63316F
[7]HQAFSC Form 56 dated 12 November 1976
[8]HQUSAF PMD No. RQ 7002(2)/63316F/63370F&N

1, 1978 through September 30, 1979.) The direction required an expanded Validation Phase (to include flight testing) that would permit a shorter Full-Scale Development (FSD) Phase. The first production delivery goal was directed to be mid-1985. This direction was provided to the JSPO by HQAFSC direction in April of 1978[9]. The program office then developed an overall acquisition strategy to openly compete the Validation Phase contract activity and down-select to two competitive contractors. Within the Validation Phase solicitation, the Government reserved the right to limit competition for subsequent Full-Scale Development contracts to the competitors of the Validation Phase.

The program was provided much oversight during this period, and throughout the remainder of the program to date. The Government has a management oversight process that uses a set of acquisition review councils to approve any major system proceeding into subsequent phases of development and production. In AMRAAM's case, the structure included formal reviews at the major command level (HQAFSC), at the Headquarters of the Air Force and Air Force Secretariat level, equivalent reviews in the Navy chain of command, numerous Office of the Secretary of Defense (OSD) staff reviews, and finally a Defense Systems Acquisition Review Council (DSARC).

The first Air Force Secretariat level management review for readiness to proceed into the Validation Phase occurred on October 2, 1978, and was known as an Air Force Systems Acquisition Review Council (AFSARC). The review was preceded by briefings to the lead comptroller and financial managers of the Air Force by an independent cost analysis group during September 1978. In November, the program was briefed to the DSARC, which resulted in an AMRAAM Decision Coordinating Paper[10] being issued in January, 1979, that approved the program strategy and released the JSPO to award Validation Phase contracts. Two contractors were selected for the Validation Phase on

[9]HQAFSC Form 56 dated 5 April 1978
[10]AMRAAM Decision Coordinating Paper Number 174, dated 12 January 1979

February 2, 1979- Hughes Aircraft Company of Canoga Park, California, and Raytheon Company of Bedford, Massachusetts. Validation Phase required design, fabrication and flight testing of prototype missiles in a 33-month period by each of the two contractors.

In this same time frame, the AMRAAM program became an international effort. The Federal Republic of Germany and the United Kingdom signed a significant Memorandum of Understanding (MOU)[11] with the United States regarding the development and production of air-to-air missiles. The government of France was also a signatory to the MOU with the option to participate at a later date.

The AMRAAM program was on the forefront of acquisition improvement initiatives during the late 1970's and on into the 1980's. It was the first Air Force program to implement the improvements in the acquisition process directed by Deputy Secretary of Defense Carlucci. The strategy emphasized an acquisition approach that would reduce AMRAAM's schedule risk to achieve the initial operational capability (IOC) for the missile. The approach included managing the degree of concurrency between development phases and initial production, pre-planning product improvements, reducing life cycle costs, improving the operational force's defensive posture, and increasing missile availability, and overall reduction in risk to efficiently meet operational requirements.

Following the Validation Phase, in the Fall of 1981, an extended series of program briefings went forward to Air Force and Navy acquisition officials with program results and more detailed planning for Full Scale Development (FSD) and production. As a result, the JSPO was released to award the FSD contract and proceed through the preliminary design review phase.

In December of 1981, Hughes Aircraft Company was awarded the contract for AMRAAM FSD in an intensive competition with Raytheon Company. This contract was

[11]The MOU was an agreement that the US would have the prerogative to develop any new medium range air-to-air missile, and that the European group would develop any new short range missile. The intent was to minimize or eliminate any redundant development costs. The MOU also facilitated the exchange and access to data between signatories.

aggressively paced to provide an early operational capability to the F-16. Without AMRAAM, the F-16 had a significant operational weakness: no medium range missile capability due to limitations of the aircraft's radar system and weight/size of existing medium range missiles. The planned FSD schedule was 50 months long. The program was to culminate with the delivery of 122 test missile assets and completion of a comprehensive combined development and operational test program on the F-16 equipped with AMRAAM. The program included the concurrency between the FSD Phase and the Initial Production Phase that had been established at the DSARC in November of 1978 (Milestone I). The FSD contract included pre-priced production options which had been obtained in the competitive environment for the first two initial production lots. The plan was to equip the F-16 with operational Lot 1 missiles as soon as possible and to use the remaining Lot 1 missiles for testing the F-14, F-15 and F/A-18.

To preclude "gaming" on the part of Hughes and Raytheon during the Validation Phase, the second sourcing decision for the program was separated from the Full-Scale Development decision process.[12] The FSD contract contained an option for a leader/follower program in which the FSD contractor (as the leader) would be required to provide technical data, training and hardware for coassembly to a follower contractor. Although the Government had reserved the right to award the follower contract to the unsuccessful offeror from the Validation Phase (Raytheon), this decision process was not finalized until after the FSD contract was awarded to Hughes. The second sourcing strategy development and management review cycle occurred during the Winter of 1982 and was extensively reviewed up through the Secretariats of both the Air Force and Navy. In July of 1982, Raytheon was, in fact, selected as the follower contractor to be eventually

[12]A concern existed that if the Government were totally committed to select the unsuccessful offeror from the Validation Phase as the second source producer of AMRAAM, the competitors might actually game the competition to become the second, rather than the prime source. Rationale that went behind this point was that FSD contractor would take on all of the program risk and would be required to provide complete design disclosure to the second source. The second source would then be free to compete without the same degree of commitment and openness. Therefore, the decision process was structured to minimize the possibility of gaming to become the second versus prime source on the program.

a competitive producer of AMRAAM. The planned production competition was seen as the primary means to control program costs. It was very clear that Raytheon was well qualified to eventually apply competitive pressure on Hughes during production. It was also important to Air Force management that Raytheon be capable of providing technical assistance to Hughes and /or the Air Force if required.[13]

With the FSD contract and Follower contract both in place, the program once again successfully went through the numerous briefings required in the DSARC cycle in September 1982. The program presented at DSARC II estimated $6.7 billion in Air Force procurement of AMRAAM production missiles. The DSARC approved the program to move forward to complete FSD and delegated the production decision to the Air Force if established program thresholds in cost, schedule and performance were not breached.

The "honeymoon" of FSD between the Government and Hughes was soon over in December of 1983 when Hughes Aircraft acknowledged that they could not meet schedule for initial deliveries of FSD missiles as required by the contract. Hughes proposed extension of the 50 month schedule to 53 months to complete contract requirements. Hughes also came forth with a software development schedule that only provided the tactical version of software to be available on late missiles to be delivered on the FSD program. In May of 1984 the Air Force recognized that further, more significant FSD schedule slips were going to occur. In addition, congressional funding cuts had occurred that precluded the ability of the Air Force to award the production options. The Air Force elected to hold commitment of any production funding until Hughes had demonstrated sufficient progress to warrant the further contract awards. Because of these schedule

[13]In the second source decision briefings that went up through Air Force and Navy management, a point was added by Headquarters Air Force acquisition officials that if Hughes were to withdraw from the defense business or fail to complete the AMRAAM effort for any reason, Raytheon's participation on the program was essential to carry out the task. Raytheon had actually been more successful during the Validation flight test effort than Hughes, though the Hughes design was judged to be a more optimal tactical solution for FSD and production.

problems and the Congressional funding issue, the Air Force did not exercise the competitively obtained, pre-priced production options before their expiration date.[14]

A major restructure then occurred to the FSD contract that resulted in a 60 month FSD program. Following the restructure, an independent cost estimate was performed in December 1984 that projected the program procurement costs to be $8.4 billion for the Air Force planned requirement of 17,123 missiles along with $3.3 billion for 7,212 Navy missiles. This cost projection moved the Office of the Secretary of Defense (OSD) on the 28th of January, 1985, to direct the FSD program be retained in its full scope and that a "Blue Ribbon Committee" be formed to investigate alternatives that would reduce the projected cost for the AMRAAM program. OSD also required the Air Force and Navy to form a high level military requirements group to assess military impact of various cost reduction alternatives.

To this point, the entire program had been constructed to provide the earliest possible Initial Operational Capability to the F-16. In February of 1985, the F-15 was established to be the primary aircraft for FSD flight testing and the first aircraft to be equipped with AMRAAM for an IOC.

In the three months from February to March of 1985, the Blue Ribbon Committee (BRC) carefully reviewed the alternatives to reduce the cost of AMRAAM. The BRC was comprised of premiere, independent technical and acquisition experts from throughout the Department of Defense. In addition, Hughes and Raytheon were awarded study contracts to support the BRC cost reduction initiative. Many projects were identified that in total were estimated would save the Government between $1.1 and $1.4 billion. The JSPO also worked with Hughes to develop a revised FSD schedule that

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[14]A major lesson was learned by the Air Force when the pre-priced, competitively obtained production options could not be exercised. The options had been tied to calendar dates rather than program milestones such as FSD testing or qualification completion. Discussions occurred within the Government debating whether or not Hughes had intentionally delayed FSD progress to abrogate the production option prices. Since then it has become a Department of Defense policy that options on major programs be tied to milestones rather than only to calendar dates.

complied with the OSD direction to complete all elements of the original FSD contract. The newly baselined FSD contract called for the last FSD missile to be delivered by the 75th month after FSD contract award and to support FSD flight testing up until the 79th month (4 months after the last FSD missile was delivered). A new HQUSAF Program Management Directive (PMD)[15] was issued in March, 1985.

The AMRAAM rebaseline was completed in June of 1985 when the Secretary of Defense approved a program that would include a comprehensive set of cost reduction initiatives. The cost reductions were projected to allow the Air Force to buy 17,000 missiles for $7.5 billion (which was equivalent to $5.2 billion in Fiscal Year 1984 dollars). Because the pre-priced options for FSD had been lost, the Secretary of Defense also required the program office to obtain firm and not-to-exceed prices from the prime contractors for Fiscal Year 1986 and 1987, respectively. He went on to state that a cost cap would be placed on the entire Air Force and Navy missile procurement once a final, approved cost baseline was obtained. The effect of the cost cap would be that the program would come under very close scrutiny (including serious termination consideration) if the projected cost were to ever exceed the threshold established.

Congressional committees during the 1986 mark-up of the President's budget were very harsh on the AMRAAM program. The Senate Armed Services Committee (SASC) wanted to delete $166.5 million from the Air Force procurement and $17.1 from the Navy's Research, Development, Test and Evaluation (RDT&E) funding. The House Armed Services Committee (HASC) wanted to delete all program funding and to cancel the program. The SASC and HASC came to an agreement in conference to continue the development of AMRAAM, but only provided $5 million RDT&E to the Navy and $101.4 million procurement funding to the Air Force. The conference results went on to restrict the obligation of the Air Force $54.4 million RDT&E until the Secretary of Defense certified numerous items:

[15]HQUSAF Program Management Directive No. 17, dated 22 March 1985

- AMRAAM design completion
- AMRAAM's system performance had not been degraded
- Maximum cost reduction changes would be included in the flight test program
- The restructured FSD contract was negotiated and signed at a fixed price not to exceed $556.58 million
- The total production price of 17,000 Air Force missiles would not exceed $5.2 billion (FY84$)

In addition to the certification, Congress required the Secretary of Defense to report back the results of a formal production readiness review before any of the $59.4 million advance procurement funds could be used to buy long-lead parts for initial production.

A new series of reviews were successfully completed up through OSD and, on August 16, 1985, the DSARC principal members endorsed the Air Force's plan to complete the FSD program and to reach a favorable 1987 low-rate initial production decision. The Air Force plan also formally rebaselined the FSD program, began the qualification of Raytheon as a competitive second source producer, and initiated the AMRAAM Producibility Enhancement Program (APREP), which would implement the recommended cost reductions supported by the Blue Ribbon Committee.

In October of 1985, a Secretary of Defense Decision Memorandum (SDDM) was issued that documented the results of the 16 August 1985 review.[16] The SDDM required the Air Force to accomplish the following by the end of December 1985:

- Recommend decision criteria to be used by the DSARC for upcoming major reviews for allowing the program to proceed through initial production and on in to full-rate production
- Document the APREP initiative in detail in the Decision Coordinating Paper that would support the mid-1986 DSARC for proceeding into initial production

[16]Secretary of Defense Decision Memorandum dated 25 October 1985, Subject: AMRAAM

- Add definitive test goals and thresholds to the Test and Evaluation Master Plan (TEMP)
- Report on the feasibility of soliciting from the contractors price limits on several lots of missiles that included APREP cost reductions

The Secretary of Defense certified to Congress on February 28, 1986, that the AMRAAM program met all the criteria required by the 1986 Department of Defense Appropriations Act.[17]

In mid-July 1986, the Air Force awarded 24 competitive producibility enhancement projects to Hughes and Raytheon (8 and 16 projects, respectively) as part of the APREP initiative. In December 1986, a 9th project was awarded to Hughes, bringing the total number of projects to 25. By September 1987, two additional projects had been awarded to Hughes, while two Raytheon projects were discontinued due to technical and schedule difficulties. Three more projects were added (two to Hughes in August, 1988, and one to Raytheon in January, 1988) raising the total number of on-going projects to 28. A final down-selection of the competitive projects and restructure of the APREP contract relationship between the Government, Hughes and Raytheon was made. The project count then stood at 25 (10 Raytheon and 15 Hughes with Raytheon as subcontractor to Hughes on two projects). These projects were scheduled to be implemented into production in Lots II, III, IV and V, and were projected to save approximately $1.96B in FY 84$.

The AMRAAM program successfully completed a Joint Requirements Management Board (JRMB) Review on 25 July 1986. The results of that review[18] provided/required the following:

- Release of FY86 advance procurement funds and FY87/long lead funds for production start up for Lot I
- Retention of the 90-missile FSD flight firing program

[17] Public Law 99-145, Section 210

[18] Undersecretary of Defense for Acquisition Decision Memorandum (USDADM) dated 5 November 1986

- Direction to establish a third test site and procure a third AMRAAM captive-carry equipment (ACE) pod
- Requirement to submit a revised test schedule and test and evaluation master plan by 20 December 1986
- Direction to accomplish test verification of design changes to correct reliability deficiencies and the guidance section seal before Milestone IIIA
- Plan for an FY88 JRMB Program Review between Milestones IIIA and IIIB to approve funding release for the Lot II full go-ahead and Lot III advance buy
- Direction to submit recommended decision criteria for the FY88 JRMB Review and the JRMB IIIA Review.

FY87 congressional language for research and development (R&D) provided relief to the $556M cap on the Hughes FSD contract with the caveat that requirements and funding could be added to the existing contract provided they are accomplished at no overall increase to the total development program of $972.4M. For procurement, the congressional language supported the start of missile low rate initial production with FY87 funding. However, Congress reduced the Lot I and Lot II missile quantities by 30 percent (from 260 to 180) and 24 percent (from 833 to 630), respectively. The total planned procurement quantity remained at 24,320 missiles. The FY87 congressional language also recognized that the production cost cap ($7.0B, FY84$, 24,000 missiles) may be adjusted to reflect the effects of congressional funding actions.

On November 6, 1986, the Secretary of the Navy approved incorporation of AMRAAM on the F-14D aircraft, under development by Grumman Aerospace Corporation. AMRAAM was planned to be incorporated as part of the first engineering change proposal for the F-14D. The German Air Force entered full scale development of the F-4F Improved Combat Efficiency program in December 1986. The program incorporates the integration of AMRAAM, the implementation of APG-65 radar, Laser Inertial Navigation System, and a new Central Air Data Computer. Logistic Operational

Capability (LOC) was scheduled for October 1992, while the Initial Operational Capability (IOC) was scheduled for mid 1993.

In December 1986, the AMRAAM flight test program began expanding operations to a third simultaneous test site at White Sands Missile Range. The first live missile launch was conducted at Eglin Air Force Base on the 19th of December. Full three range test capability was achieved in March 1987. This action was taken to decrease the schedule risk for completing flight testing in the Developmental Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) phase of the program. In addition, a third ACE-2 pod (form-factored AMRAAM captive equipment) was procured. The pod was not available for FSD testing, but was needed for post-FSD testing and planned to be available in the fall of 1989.

On 4 June 1987, the Defense Acquisition Board (DAB) conducted a Milestone IIIA review of the AMRAAM program.[19] Based on that review, approval was provided for low rate initial production (release of funds for Lot I and long lead for Lot II) along with an extension of the top defense acquisition priority rating to 30 June 1988. In addition, definitive criteria for the Spring 1988 OSD Review were approved with the stipulation that if the criteria could be satisfactorily accomplished prior to the review, OSD would consider canceling or abbreviating the review.

In 1988, Congress[20] reduced Lot 2 funding from $837M to $673.1M (including Initial Spares) and quantities from 630 to 400. This caused a curtailment of the production ramp-up rate and forced and an additional year of missile production to be planned to acquire the quantity of operationally required missiles. Another impact of this Lot II quantity reduction was to drive down the planned quantity for Lot 3 from 1,800 to 1,270 missiles (thus extending the ramp-up of both producers from Lots 4 and 5 to Lots 5

[19]The DOD acquisition process changed from the DSARC management approval process to the DAB approval process during the mid-1980's. The level of review was essentially the same up through and including the senior acquisition executives within OSD.
[20]The 1988 Appropriations Act for Procurement

and 6). The congressional language directed that the reduced funding level be allocated to ensure competitive incentives remain maximized and total acquisition costs be minimized. Because of the congressional action that stretched the schedule a year, the cost cap was increased from $7.172B to $7.585B in FY84$.

On 19 May 1988, the Defense Acquisition Board (DAB) met to review the AMRAAM program. Based on the DAB's recommendation, the Air Force was authorized to proceed with full go-ahead for Lot 2 production, and funds would be released accordingly. In addition, the DAB would consider release of long lead funds for Lot 3 after a review of additional flight test data by OSD's Conventional System Committee (CSC).

On 15 September 1988, the CSC met to consider the release of long lead funds for Lot 3 production of the AMRAAM. As a result, the AMRAAM program was continued in low rate production with a maximum of 900 missiles to be procured in FY89. Also, six (6) additional missiles would be procured for foreign military sale (FMS).

On 29 September 1988, the Congressional Appropriation Conference agreed to provide $798.7M for the procurement of AMRAAM missiles. However, it required that the Air Force provide an updated Acquisition Plan for the FY89 AMRAAM program. No production funds appropriated for the AMRAAM missile could be obligated until the Committees on Appropriations had received the revised FY89 Acquisition Plan for AMRAAM. Upon submission of the report to Congress, the Air Force would be authorized to proceed with long lead procurement for production of Lot 3, and funds would be released accordingly. Furthermore, the conference directed the Air Force to take necessary steps to lower the unit cost of AMRAAM missiles in FY89, and the outyears.

In early December 1988, the Defense Acquisition Executive submitted the revised AMRAAM Acquisition Plan to Congress. On 13 December, not-to-exceed (NTE) long

lead contracts[21] were awarded for the production of 906 AMRAAM missiles, 534 missiles to Hughes, and 372 to Raytheon. The exercise of options for Lot 3 Full Go-Ahead (FGA) was anticipated for July 15th, 1989.

The comprehensive FSD live-fire test program was completed on January 30th, 1989. Ninety-five missiles were launched in FSD (76 guided without warheads, 4 guided with warheads, 6 separation/control test vehicles (S/CTV's), and 9 IRAN (Inspect/Repair as Necessary) missiles. All IRANs and 3 of the S/CTV's were launched in the F-15 Seek Eagle program. The other 3 S/CTV's were launched to evaluate missile kinematics. Of the guided launches, 58 were successful (included 19 direct hits), 2 were no tests, 3 were not for score (2 for F/A-18C aircraft integration), and 17 were unsuccessful. Additionally, all of the required FSD captive flight testing was completed.

In early December of 1988, the Defense Acquisition Board (DAB) reviewed the AMRAAM program and approved Full Go-Ahead (FGA) for Lot III and Long Lead Procurement for Lot IV. The DAB also reviewed the cost and schedule breaches and directed use of low risk estimating assumptions. The FGA Lot III contracts were awarded 29 December 1989 (Hughes) and 22 December 1989 (Raytheon).

Congress[22] reduced the Lot 4 funding request from $1.032 billion for 1600 missiles to $794 million for 900 missiles. The reduction forced curtailment of the planned ramp-up for another year and extended the program and additional year contributing to a breach of the Acquisition Program Baseline (APB) cost threshold.

On February 8, 1990, the JSPO suspended acceptance of missiles pending identification and resolution of reliability problems that were being seen when missiles were being captively carried on the F-15 aircraft.[23]

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[21]The NTE contracts allowed the contractors to proceed with financial cap on the amount of funding the Government would commit to the procurement. This is often used, though not preferred, while the Government and contractors go through the extended process (solicitation, proposals, audits and negotiations) for a definitive contract.

[22]The FY90 Appropriations Bill

[23]The F-15 reliability problem was the most major technical issue ever to occur on the AMRAAM program. Even after extensive captive carriage of instrumented missiles during the Validation Phase and

In March of 1990, the DAB was briefed on the status of the program, recent Captive Carry Reliability Program (CCRP) failures, and the "4 missile vs. 4 target" testing requirement. The DAB directed a formal review be conducted to address the program breaches, CCRP status, Red Team[24] results, and plans to correct identified problems. The DAB concurred in the necessity for the program, endorsed corrective actions, and recommended certification to Congress. The Under Secretary of Defense for acquisition certified the program to Congress on April 13th, 1990. In response to the direction contained in the resultant Acquisition Decision Memorandum[25], the JSPO developed the AMRAAM Corrective Action and Reliability Improvement Plan, which was completed on April 30th, 1990. This plan described the comprehensive set of activities that were underway and others that would be initiated to assure the reliability of missiles to be delivered to operational inventory from Lot IV and beyond. The plan addressed the incorporation of already identified CCRP fixes into missiles as early as Lot II, which was very aggressive due to manufacturing lead-times. Other items in the plan were the update of the technical data package (drawings and specifications) to incorporate design and process changes, manufacturing and vendor process control reviews, and the incorporation of the F-15 environmental changes to performance specifications that would appear in production contracts. All actions within the plan were completed, and the delivery suspension of missiles was lifted on August 13th, 1990.

In August of 1990, the DAB reconvened to review the program to decide on the release of additional long-lead funding for Lot 4. CCRP Stage III results, status of Corrective Action Plans of both Hughes and Raytheon, a new CCRP demonstration plan,

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early FSD, a very harsh vibration environment on the fuselage stations of the F-15 went undiscovered until this late in the program. The vibration levels were many times that to which the missile had undergone qualification testing. Much missile level and component level requalification, as well as much closer manufacturing process control, was required to overcome this hurdle.

[24]A "Red Team" is group of experts typically from outside an organization (such as the JSPO) that is pulled together to assist the normally responsible organization with a critical issue or issues. It is very common in DOD acquisition to use this technique to solve important problems as rapidly and as thoroughly as possible.

[25]Under Secretary of Defense Acquisition Decision Memorandum dated 13 April 1990

and the funding required were briefed. The DAB concurred in the planned actions and approved additional Lot 4 long-lead and program operating funds through April, 1991. The DAB directed 50%/50% split production contract awards be given to Hughes and Raytheon for Lot 4.

Congress[26] reduced the Lot 5 funding request from $1.3 billion for 1800 missiles to $815 million for 900 missiles. The final award was for 810 missiles- 540 to Hughes and 270 to Raytheon.

The FY92-97 Air Force and Navy POMs[27] substantially reduced projected annual quantities from 3000 missiles per year to 1300-1700 missiles per year. The Headquarters of the Air Force[28] told the JSPO to plan for a total quantity of 15,500 (12,000 Air Force and 3,500 Navy). The headquarters[29]further reduced the total quantity of missiles to 13,038 (9623 Air Force and 3,415 Navy). On April 24th of 1992 the DAB IIIB approved AMRAAM for full-rate production.

The Lot 6 contract was awarded in 1992, and for the first time Raytheon won the larger share- 490 missiles as compared to 410 for Hughes. Ninety additional missiles from the Lot 5 appropriation were also awarded- 50 to Raytheon and 40 to Hughes. In March 1992, the JSPO issued a modification to the Hughes Lot 6 contract for the nonrecurring and recurring costs to deliver 201 of its Lot 6 total in a configuration that incorporated APREP Block II changes. This configuration reduced the overall production cost for the lot and introduced EEPROM (Electronically Erasable Programmable Read-Only Memory) technology into AMRAAM. Due to this significant configuration change, the APREP Block II missile was officially designated the AIM-120B. A similar modification for non-recurring costs to build 150 APREP Block II missiles was issued to Raytheon in April 1992. A proposal for recurring costs for production implementation and ramp up of the

[26]The FY91 Appropriations Bill
[27]Program Object Memorandum (POM) documents are budget requests by each service that are sent up through OSD and eventually to Congress.
[28]February 1990 Program Management Directive (PMD)
[29]April 3, 1992, PMD

AIM-120B in Lot 6 was received in August 1992 and finalized in June 1993 after many months of negotiations.

Lot 7 has been the largest AMRAAM acquisition to date. The JSPO awarded 1463 missiles- 849 to Hughes and 614 to Raytheon. The US total was 125 more than the FY93 President's Budget Submission, facilitated by the $123,000 drop in missile unit price, which went below $400,000 for the first time. The contractors also offered enhancements to missile warranty and reliability. Lot 7 also marked the first sale of AMRAAM to allied forces. Four FMS cases were awarded: Korea-96 operational missiles; Turkey- 96 operational missiles; United Kingdom- 100 instrumented missiles; The NATO European Fighter Management Authority (NEFMA)- 6 instrumented missiles. All Lot 7 missiles will be of the AIM-120B configuration (APREP Block II).

In March of 1991, the JSPO issued a development contract for the first phase of the three phase Pre-planned Product Improvement (P^3I) program. The first phase will provide a compressed carriage AMRAAM configuration for internal carriage in the F-22 (Advanced Tactical Fighter) and an enhanced electronic counter-counter measure (ECCM) capability. Development of these Phase I enhanced performance capabilities will conclude in November of 1994 and production incorporation is scheduled to coincide with the beginning of Lot 8 deliveries.

Quantities decreased to 1282 during Lot 8 as a result of DOD-wide budget cuts. Even so, the Lot 8 competition was the most effective competition yet conducted on AMRAAM. It reduced the average missile cost from slightly below $400,000 in Lot 7 down to less than $300,000 in Lot 8 (approximately $255,000 for Raytheon and $346,000 for Hughes) for a reduction of 23%.

Production testing is ongoing. As of the first of June of 1993, AMRAAM had experienced an overall success rate of 82.4% against targets, which is far better than any other air-to-air missile has ever achieved despite the much more challenging test scenarios with which AMRAAM has been challenged. A total of 116 Air Force and Navy

development and operational test and evaluation launches had been accomplished. Of these, 61of the 74 scored launches were successful, 57 were aircraft separation tests, and 21 were either invalid tests, software demonstrations, or hardware/software verifications. **The results of nine Navy test shots are pending final review and release by the Navy.** Included in these results are the outcome of the May 4th, 1990, 4-versus-4 launch which successfully showed that a single F-15 could launch 4 missiles near-simultaneously against 4 separate targets which were supported by electronic countermeasures. Three of the 4 missiles scored direct hits and the 4th passed within lethal range of its target.[30] Additionally, in November, 1990, a new F-15 radar software was verified that could provide a dual AMRAAM/Sparrow (AIM-120/AIM-7) against two separate targets.

In December of 1992, AMRAAM was first used in combat. As part of the US effort to maintain the UN imposed "no-fly" zone over southern Iraq, the first two AMRAAMs fired under hostile conditions scored direct hits and destroyed two Iraqi aircraft. The success of the third AMRAAM which was shot was undetermined. In February of 1994, the US Air Force was imposing a similar "no Fly" zone for the United Nations over Bosnia, the second conflict in which AMRAAM has been employed. An Air Force F-16 fighter shot down a fighter/bomber that had violated the zone and bombed a village. AMRAAM's operational utility is being felt world-wide.

[30]For safety and to conserve targets, a live warhead was not used, which would likely have blown up and destroyed the 4th target also.

Table 1.1- Timelines for

AMRAAM Major Program Events

PROGRAM PERIOD	EVENT	DATE
Pre-conceptual	OSD directed working group examines operational requirements.	1975-1976
	Armament Division Study (Eglin AFB) proposes program.	1976
Conceptual	5 Conceptual Phase contracts conducted	November 1977-November 1978
Validation	Hughes and Raytheon Competitive contracts to "Prove the Concept"	February 1979-November 1981
Full-Scale Development	FSD contract awarded to Hughes	December 1981
	Follower contract awarded to Raytheon	July 1982
	Hughes first discloses FSD program schedule problems	December 1983
	FSD flight test program complete	January 1989
Producibilty Enhancement	OSD directs cost reduction effort for AMRAAM	January 1985
	Contractor producibility studies	February 1985-July 1985
	First AMRAAM Producibility Enhancement Program contracts awarded	January 1986
Initial Production	Defense Acquisition Board approves low-rate initial production release	June 1987
	Defense Acquisition Board approves Full Go-ahead for Lot 2	May 1988
	Defense Acquisition Board approves long-lead release for Lot 3	September 1988

	Defense Acquisition Board approves Full Go-ahead for Lot 3 and long lead for Lot 4.	**December 1988**
	Government suspends acceptance of missiles due to reliability problems	**February 1990**
	Suspension on delivery of missiles lifted	**August 1990**
Competitive Production	**Lot 5 Contracts Awarded**	**May 1991**
	Lot 6 Contracts Awarded	**March 1992**
	Lot 7 Contracts Awarded	**February 1993**
	Lot 8 Contracts Awarded	**January 1994**
Operational	**Initial Operational Equippage[31]**	**September 1991**
	Initial Operational Capability- 33rd Tactical Fighter Wing[32]	**March 1991**
	Two aircraft shot down over Iraq	**December 1992**
	One aircraft shot down over Bosnia	**March 1994**

[31]Initial Operational Equipage is defined as when the first operational wing organization within the Air Force is provided sufficient quantities of missiles to operate.

[32]Initial Operational Capability is defined as when the first operational wing is given not only sufficient missiles to go to combat, but also all other system elements such as test equipment, technical orders, training, etc. that are required to sustain operations.

2.0 AMRAAM's Development Phases

2.1 Pre-Conceptual Phase/Development of the Requirement

AMRAAM began as an outcome of the emergence of the advanced combat fighter type of aircraft that had demonstrated that high performance aircraft could be produced at an affordable cost through the use of modern technology. The Armament Division located at Eglin Air Force Base in Florida conducted advanced planning that indicated that the same design philosophy could be used in many missile subsystems to provide a reliable, lightweight radar guided missile that would be compatible with these advanced aircraft. As a result of the Armament Division Medium Range Missile Study, a proposed prototype program was briefed to the Headquarters of the Air Force and was subsequently approved to begin in Fiscal Year 1977.[33] The Government formed a joint-service operational requirement committee to define the operational needs of the system. The committee consisted of actual combat experienced air crews from the Air Force, Navy and Marine Corps who were able to effectively define and prioritize the needs of the Department of Defense operational community. With this was begun the developmental process of the most advanced medium range missile the world has ever known to the present time. The development of the system was broken into distinct phases that followed the Office of Management and Budget (OMB) Circular A-109 which outlined the program structure to be used in the acquisition of major weapon systems. A-109 called for four specific phases and advocated the use of competition. The following figure shows A-109 program phasing on the AMRAAM program originally planned in 1977:

[33]A "Fiscal Year" in the Government is the financially based calendar that begins on October 1 of any year and runs through the following September 30.

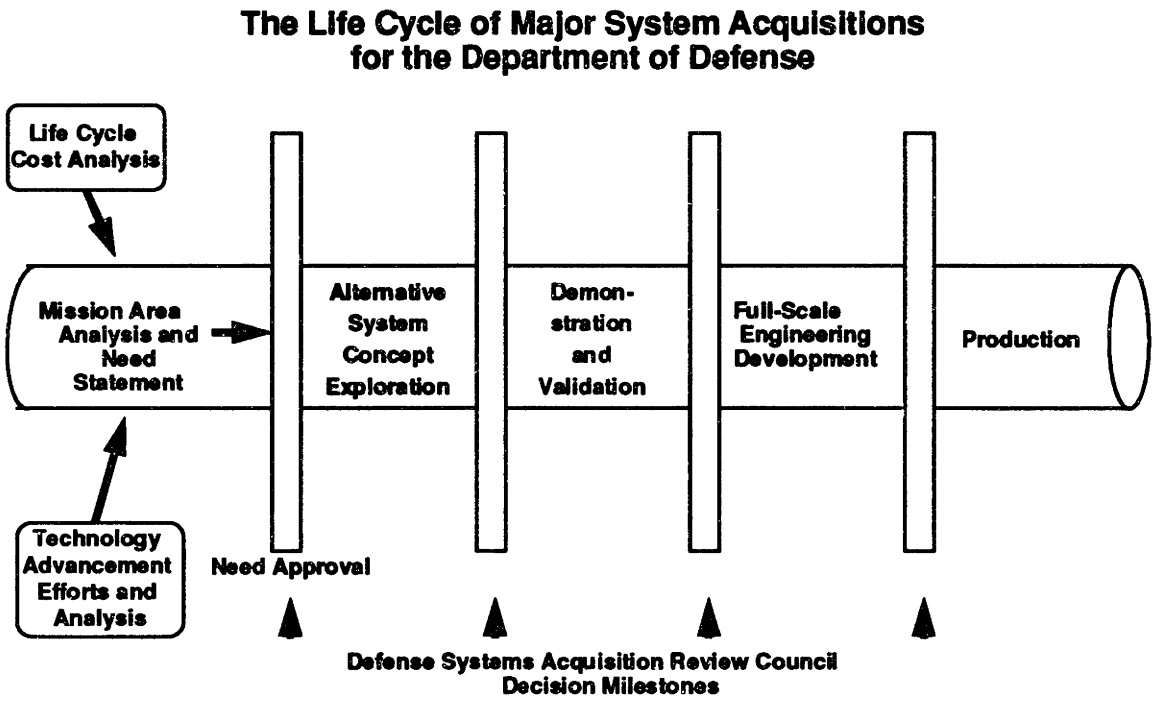

Figure 2.1

AMRAAM had now entered the acquisition pipeline when the operational community completed a mission area analysis, the long range technology planners had concluded that emerging technology was ready to support the concept, and Air Force management had inserted a funding request for the budget to initiate the program.

2.2 Conceptual Phase

In the Conceptual Phase, a Joint System Program Office (JSPO) manned by Air Force and Navy military and civilian employees was established at Eglin Air Force Base to manage the AMRAAM acquisition. The JSPO initiated a design definition effort in the Conceptual Phase to stimulate US aerospace industry to compete for the design rights to AMRAAM. Six potential sources were evaluated and all but one participated in the initial design definition effort. Funded contracts (approximately $800,000 each) were awarded to Hughes Aircraft Company, Canoga Park, Ca., General Dynamics, Pomona, Ca, and Northrop Corporation, Los Angeles, Ca. In addition, Raytheon Company of Bedford, Ma. and Aeronutronic Ford of Newport Beach, Ca. requested and were awarded no cost

contracts to pursue the next phase of design definition efforts. In November of 1977, all 5 contractors were funded to initiate Phase I of the design definition. The major areas of effort required in Phase I were:

- Design and analysis of missile guidance systems.
- Preliminary design of missile system concepts.
- Evaluation of operational capabilities of weapon system designs. Definition of weapon system designs for prototyping.
- Development of unit procurement and life cycle cost estimates for candidate designs.
- Definition of alternative logistics concepts for supporting the missile system.
- Fabrication and test of critical subsystem components.

In July of 1978, a contract modification for the continuation of these design definition efforts was awarded to each of the 5 contractors for approximately $2.3 Million each.

From June of 1976 to May of 1978, laboratory testing of guidance section components and limited integration testing occurred at each of the contractors facilities. Parallel warhead and rocket motor testing was also conducted. After numerous technical meetings with the Government to demonstrate the potential designs that were available, the five contractors were requested in August, 1978, to submit competitive proposals to the Government for the Validation Phase.

Another critical event occurred in 1978. The Air Force had deployed F-16's throughout Europe without any Beyond Visual Range air-to-air protection. It was determined by Air Force management that the AMRAAM development schedule must be shortened from 7.5 years to 6 years and 1 month. This was done by eliminating plans for a sequential pilot production phase and reducing plans for FSD from 54 months to 40 months. To minimize the risk of such a shortened acquisition cycle, increased emphasis was supposed to be placed on various Validation Phase contract activities such as:

- Preparation of comprehensive system and development specifications
- Expanded integrated logistics support activities

- Reliability and maintainability efforts
- Producibility, including manufacturing technology investment strategies
- Aircraft integration to include actual flight test with the F14, F-15 and F-16
- As well as the ten guided missile launches from each contractor.

Conceptually, in fact, these steps would have allowed the program to exit the Validation Phase with tactically representative hardware and software that would have been relatively straight forward to finish full development. However, as the next section describes, these plans proved to be overly optimistic.

2.3 Validation Phase

Excellent proposals were submitted from all five contractors, and on February 2, 1979, two contracts were awarded for the Validation Phase, one to Hughes and one to Raytheon, in the amount of $45,432,504 and $39,094,140, respectively.[34] This phase was scheduled for 33 months and was intended to "prove the concept" for AMRAAM, including guided weapon launches by each contractor.

The contractors approached the Validation phase with rigor, but it was obvious early on that certain enabling technologies (such as the solid state transmitter components) would require significant improvements to support the operational requirements. The two contractors independently strove to shrink the missile subsystems into the size and weight envelope that would be compatible with the F-16, the smallest of US fighters.

For a 33 month effort, the Validation Phase was very aggressive in expectations. The principal objectives of the Validation Phase testing were:

- to assist and reduce risk in the continued development of AMRAAM,
- to provide a sound basis for source selection of the final design to be brought forward into the Full-Scale Development Phase,
- to identify and minimize high risk areas of concern in the contractor's designs,

[34]Contract FO8635-79-C-0044 to Hughes and Contract FO8635-79-C-0043 to Raytheon.

- to verify critical performance parameters of components, systems, and integrated missiles were achievable.

In other words, prove the concept to the Air Force, Navy, Office of the Secretary of Defense, and the Congress by "Flying before buying."

The program set out to determine the design adequacy with engineering models in the laboratory and simulation facilities, as well as with instrumented captively-carried pods on test aircraft. Limited qualification testing was done in environmental labs around the US, and wind tunnel testing was completed at an Air Force facility. Missile mock-ups were "fitted" to actual aircraft and to develop loading and checkout procedures.

All these activities made progress toward having prototype missiles for flight test, but certain guidance section electronics components were not being so cooperative. The AMRAAM design was dependent on an internal high-powered transmitter. To insert this transmitter into the size allowable for a light weight missile, a new technology using "impat diodes" was necessary. Hughes and Raytheon independently attempted to produce these diodes with sufficient efficiencies to generate the transmitter amplifier power needed for AMRAAM's range. Progress was steady at each contractor, but the solid state amplifier using the diodes did not reach the required level of performance in time to support the program schedule.

The Validation Phase originally planned that 20 missiles would be fabricated (10 from each contractor). The contractors were not able to design and fabricate this many missiles within the window of time available for Validation Phase flight testing. Raytheon was close to meeting the minimum power levels with sufficient diodes to support the program, and fabricated the majority of their required missiles. Hughes was not quite so far along with their diode development, and decided on a strategic change. In the last 6 months of the Validation Phase, Hughes announced to the Government that they were making a fundamental change in their transmitter design to use a proven technology called traveling wave tube (TWT) amplification. Although Hughes did not have time to build

TWT transmitters and insert them into the Validation Phase prototype missile design, they assured the Government that as consideration they would build and thoroughly ground test a TWT guidance section in this last 6 months of the Validation Phase. They did build a laboratory model, but were only able to superficially test the model prior to the Full-Scale Development source selection and contract award. Analytically, the new Hughes design looked to be a low risk approach to AMRAAM's requirements.

The program schedule in January of 1981 looked as follows:[35]

AMRAAM Schedule as of January, 1981

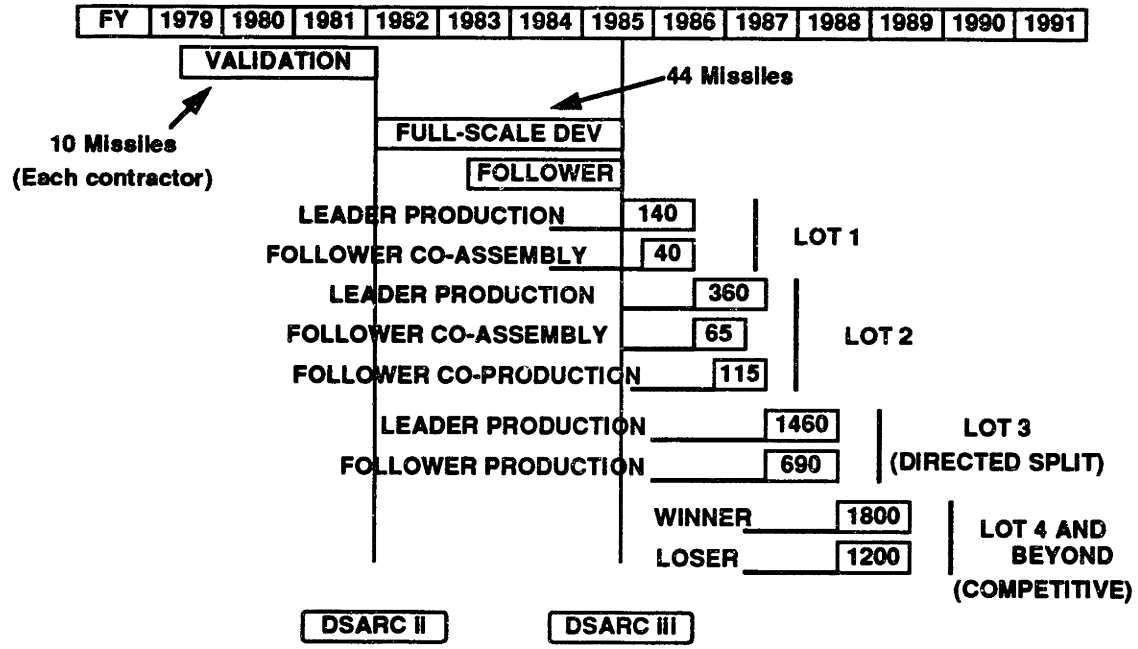

Figure 2.2

Hardware and software had to be designed and fabricated. Guidance section development testing was necessary in both airborne and laboratory conditions. Notice the period over which 10 missiles were to be delivered by each contractor and flight tested during the Validation Phase. In actuality, only three Raytheon and two Hughes missiles were fired.

[35]AMRAAM Acquisition Plan dated January 8, 1981

During the first part of 1981, the test community from both services joined to prepare much more detailed plans for what needed to be tested for qualification and operational evaluation. These plans called for increased FSD requirements from the 44 missiles shown on this January 1981 schedule to over 120 missiles in August 1981 schedules[36].

In summary, the backdrop for the FSD contract was this:

- The AMRAAM schedule was compressed to meet a critical F-16 operational need.
- The aggressive Validation Phase schedule allowed for only a portion of the missiles to be delivered and tested.
- Hughes made a strategic last minute change to their missile design during the Validation Phase which brought them in front of Raytheon for the source selection.
- Much of the planned risk reduction efforts intended for the Validation Phase had to be bow-waved forward into FSD.

2.4 Full-Scale Development Phase

In December, 1981, a contract was awarded to Hughes for approximately 122 AMRAAM's to be delivered over a 50 month program[37] which would conclude with completion of Initial Operational Test and Evaluation (IOT&E) on the F-16. During the period following the contract award, Hughes program manager[38] told the Government that the highest priority and most critical task was: "to get the missile within the missile". This meant that Hughes was challenged to compress the new traveling wave tube design with its high voltages into the guidance section space available.[39] As schedule milestones began to sl[illegible]e Government requested Hughes to provide schedule estimates for recovery. [illegible]ghes was intent on first missile delivery and was not willing or able to

[36]AMRAAM Acquisition Plan dated August 5, 1981

[37]The higher headquarters previously-directed 40 month schedule for FSD was not placed on contract due to contractor inputs and Government assessments of excessive schedule risk.

[38]Mr. Walter McGuire at the FSD Preliminary Design Review in September, 1982.

[39]High voltages in a confined area tend to arc. The solid state transmitter had used lower voltages and was not as vulnerable to this type of problem.

provide an updated prediction, despite strong Government pressure. In December of 1983, Hughes acknowledged that they could not meet the 50 month schedule and asked for an extension to 53 months to meet their contractual obligations.

Further, more significant, schedule slips were evident by May of 1984. The AMRAAM Government program office attempted to renegotiate a more realistic schedule that Hughes could comply with in December of 1984, as opposed to the current contract schedule that had become meaningless from a program execution perspective. This renegotiatied schedule of 60 months also removed certain activities from the contract scope. This renegotiation was disapproved by the Office of the Secretary of Defense and the JSPO was directed to retain the full scope of the FSD contract. At all subsequent reviews with OSD, the 90 missile firing program was used as one of the key criteria to measure successfully completion of FSD.[40]

The comprehensive FSD live-flight test was finally completed on January 30, 1989, seven years after the FSD program had begun.[41] A total of 95 missiles were flight tested during FSD, including:

- 76 Guided missiles without warheads
- 4 Guided missiles with warheads
- 6 Separation/control test vehicles to verify aircraft safe separation, and
- 9 Other reliability test missiles.

Of the 80 guided launches, 58 were successful (including 19 direct hits), 2 were "no tests" due to other than missile problems, 3 were not scored, and 17 were unsuccessful.

2.5 AMRAAM Developmental Lessons Learned

With a developmental program history as full of successes and hurdles as AMRAAM, there are many lessons learned that will be etched in the minds of both the

[40]Undersecretary of Defense for Acquisition Decision Memorandum dated November 5, 1986

[41]Recall that the original schedule was for 50 months, compared to the actual FSD duration of approximately 84 months.

Government and industry for a long time. Looking back over the program, it is much easier to find things that might have been better had another path been taken. Other things worked out better than would have been expected. The following are lessons-learned[42]:

- **The Original 40-Month AMRAAM Full-Scale Development Schedule:**
  - Forty-month development was unrealistic.
  - It was driven by the F-16 operational need date rather than by an in-depth examination of missile design requirements and design/technology availability.
  - The many late changes the contractor (Hughes) made between the Validation Phase design and the FSD design greatly impacted the ability to meet the schedule.
  - Validation Phase tasks were not fully completed, transferring risk to the FSD program.
- **System Integration and Aircraft Integration:**
  - Neither area received enough emphasis in the developmental program. The AMRAAM Government and industry teams were too focused on the "missile" rather than the "missile as an element of a larger system".
  - Overly optimistic technical assessments early in the program that were based on individual subsystem/component design accomplishments.
  - Real technical issues surfaced during the integration of subsystems.
  - The Government and contractor teams were not systems oriented.
  - The contractor (Hughes) did not have total system performance responsibility (TSPR). The Government was responsible for aircraft interface data including currency/accuracy of that information. Total aircraft/weapon system was not optimized to the extent it could have been. Also, much of the reliability problems that disrupted the production program could have been avoided if Hughes had been given TSPR.

[42]These lessons-learned were generated through the help of Mr. Richard C. Calano, AMRAAM Navy Assistant Deputy, who has carefully studied the AMRAAM acquisition history.

- Direct subcontracting from the prime weapon contractor to the aircraft contractors for technical support should have been a requirement. Also, a comprehensive interface document should have been deliverable and placed under Government configuration control.

- **Fixed-Price Contract not Suitable for a Highly Complex Technology Effort:**
  - Hughes likely underbid the FSD program.
  - Hughes was at contract ceiling half way through the FSD program.[43]
  - Engineering thoroughness declined. Hughes stopped surfacing technical problems in an effort to minimize engineering expense. Also, Hughes did not examine technical issues to the level of detail that would have been appropriate due to Hughes management pressures to keep cost down.
- **Test Program Schedule Pressures:**
  - Undue schedule pressures were exerted on the flight test team.
    - -- Lessons learned not incorporated/validated until late in the FSD program.
    - -- Test objectives were not efficiently combined.
  - "Failure" not permitted.
    - -- Political influence force a less aggressive test scenario for risk of interference.
    - -- Missile performance growth was paced by test program.
  - Joint developmental/operational test involvement worked extremely well, but was criticized by OSD's test community. Probably was a "rice bowl" issue.

- **Quality/Reliability:**
  - Large percentage of missile components/subassemblies are contracted out from the primes. Subcontractor management by the primes was a priority concern of the Government during early program stages.

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[43]In a fixed price type contract, the contractor receives no additional funding once he reaches the ceiling price.

- Quality emphasis not flowed down to the subcontractors.

- Inadequate monitoring of subcontractor qualification and acceptance testing early in the program.

3.0 AMRAAM's Production Phase

3.1 Production Options to the Full-Scale Development Contract

The AMRAAM JSPO had included competitively obtained production options in the FSD contract at the direction of the secretariat of the Air Force to help prevent "buy-in" by either Hughes or Raytheon into the FSD program. The FSD contract that was awarded to Hughes had two pre-priced options for the first two lots of production and an unpriced option for the third lot. The deliverables for these options are summarized below. Note that the options contained variable quantities that could be unilaterally exercised by the Government.

3.1.1 FSD Option for Lot 1

This option had an initial target price[44] of $231,489,721 and a ceiling price of $295,071,641. The original deliverables were as follows:

1. Missiles (variable quantity - 174 to 354)
2. Associated containers and support equipment
3. Rail launchers
    - F-16 (variable quantity 130 to 350)
    - F-14 (variable quantity 8 to 32)
    - F-18 (variable quantity 7 to 28)
4. Leader support to follower co-assembly (40 missiles of the 174 to 354 were to be co-assembled by the follower)
5. Test and evaluation support
6. Data and special studies
7. Production engineering

[44]The term "initial target price" is used because the contract type was "fixed price with successive targets", normally referred to as an FPI(S) contract. In this contractual arrangement, the target price can be renegotiated during the course of the contract. On a scale of contract types that would have cost-type contracts as the least risky to the contractor to the firm-fixed-price contracts in which the contractor bears the bulk of the risk, the FPI(S) is considered to be in the middle, but does have a larger share of financial risk on the contractor's side due to the fixed ceiling that is not readjusted.

8. Allied support
9. Logistics support
10. Special tooling and test equipment
11. Training and qualification hardware

3.1.2 FSD Option for Lot 2

This option had an initial target price of $394,260,120 and a ceiling price of $493,546,596. The original deliverables were as follows:

1. Missiles (variable quantity - 250 to 1420)
2. Associated containers and support equipment
3. Rail launchers
    - F-16 (variable quantity 270 to 750)
    - F-14 (variable quantity 35 to 180)
    - F-18 (variable quantity 50 to 130)
    - F-15 (variable quantity 270 to 740)
4. Leader support to follower co-assembly (64 missiles of the 250 to 1420 were to be co-assembled by the follower)
5. Test and evaluation support
6. Data and special studies
7. Production engineering
8. Allied support
9. Logistics support
10. Special tooling and test equipment
11. Training and qualification hardware
12. Storage Reliability Verification Guarantee Program

3.1.3 FSD Option for Lot 3

This option was unpriced.[45] The original deliverables were as follows:

1. Missiles (variable quantity - 794 to 3064)
2. Associated containers and support equipment
3. Rail launchers
    - F-16 (variable quantity 350 to 1700)
    - F-14 (variable quantity 125 to 600)
    - F-18 (variable quantity 175 to 900)
    - F-15 (variable quantity 150 to 800)
4. Leader/follower assistance and configuration management
5. Data and special studies
6. Training hardware
7. Production engineering and technical services
8. Logistics support
9. Allied support

3.1.4 Discussion of the FSD Options

The FSD contract options were lost on the program when insufficient progress was made on the FSD effort to justify expenditure of production funding prior to the option expiration dates. Even so, several important issues become clear when examining the FSD options:

- **Optimistic Projection of Hughes Ability to Ramp-up to Production Option Rates:** The quantities the Air Force and the Navy were intending to buy on the options reflect the underestimation of the program challenge to bring the missile up to production rate that was later observed. Note that the sum of the first three lots of production from Hughes only ranged from a minimum of 1218 to a maximum of

[45]The reason for not asking the contractor to price the third option was that it was thought to be too far in the future for the contractor to price at the time of FSD proposals and source-selection.

4838 missiles. The ramp-up to achieve this quantity of missiles is now looked back on as very unrealistic, based on the experience that was gained on the Hughes design during FSD and later production.

- **Leader/Follower Strategy Revision:** The leader/follower strategy underwent major revision after the FSD contract options were lost. Notice that Lot 1's option included the leader supplying 40 missile kits (at the missile section-level) for follower co-assembly and Lot 2 envisioned the leader providing 64 missile kits (at the chassis level) for follower co-assembly. After the FSD contract options expired, Hughes would not agree to provide Raytheon these kits for co-assembly. The leader/follower plan was then changed to remove the co-assembly element from the program and to go to a follower stand-alone qualification lot of only 15 missiles. The Hughes technical assistance for this effort was funded through two contract vehicles, neither of which were very cost-effective. The first contract vehicle was limited to the support that the Government obtained on the negotiated Hughes Lot 1 and Lot 2 contracts; the second was through the Qualification Lot and Lot 1 contracts with Raytheon through a cost-reimbursable line item for Hughes subcontract support.
- **Missile Rail Launchers:** An equivalent issue to the loss of missile production options occurred with the missile rail launcher (MRL). Based on having FSD contract MRL production options, the Air Force anticipated that the cost risk for obtaining launchers on the Hughes contract was very low. The MRL was developed as an element of the AMRAAM program, but was actually a new rail launcher to be used for the numerous AIM-9 Sidewinder aircraft stations also. (The existing launchers would not have been adequate for launching AMRAAM.) Therefore, the Air Force closed down the AIM-9 compatible launcher production line to go to the new AMRAAM/AIM-9 Missile Rail Launchers that were to be provided on the Hughes FSD contract options. The Hughes MRL program developed significant technical and manufacturing problems. The Government's assessment of the MRL effort is that

Hughes management was so occupied with the missile, that they ignored the MRL. Discussions of the MRL program with either the Government or the Hughes team revealed that key people were fired (and others moved to other programs) due to the problems that occurred on the MRL. Although the AMRAAM missile has been effectively produced now by two contractors (Hughes and Raytheon), the MRL, with its relative simplicity, continues to have problems with the sufficiency of its data package for competitive reprocurement. In comparison with the missile, the MRL has been termed an "anvil", but its acquisition has proved to be a disaster.

- **Fundamental Flaw: Tying Options to Calendar Dates versus Contract Milestones:** It is viewed by some within industry and Government that Hughes was very much incentivized to break the FSD production options. The prices for production options were obtained in a competitive environment for FSD and were known to be one of the determinants for source selection. These options provided a window of opportunity over which the Hughes proposal had claimed very low risk for the FSD program. In actuality, it is possible that Hughes never had any intention to meet the FSD schedule that would have permitted the Government to exercise the FSD options. Since the options were tied to calendar dates, rather than FSD milestones such as design review completion or flight test completion, slipping the FSD schedule effectively abrogated the contract options with the Government. Hughes then was on a sole-source negotiation basis with the Government and was able to greatly increase the missile and launcher prices for Lots 1 and 2, along with the supporting elements that are listed above (including the leader/follower effort). This loss of contract options because of being tied to calendar dates precipitated a policy action out of OSD and the headquarters of the services that similar options in the future must be tied to contract milestones on all major programs.

With the production options out the window, the JSPO and the Contractors went on to negotiate each contract lot until competitive procurement, as has been described in

Sections 1.2 and 1.3 of this thesis. The following sections will show the originally scheduled, modified and actual delivery dates for both Hughes and Raytheon.

3.2 Lot 1 Missile Production

3.2.1 Hughes Lot 1 Missile Deliveries

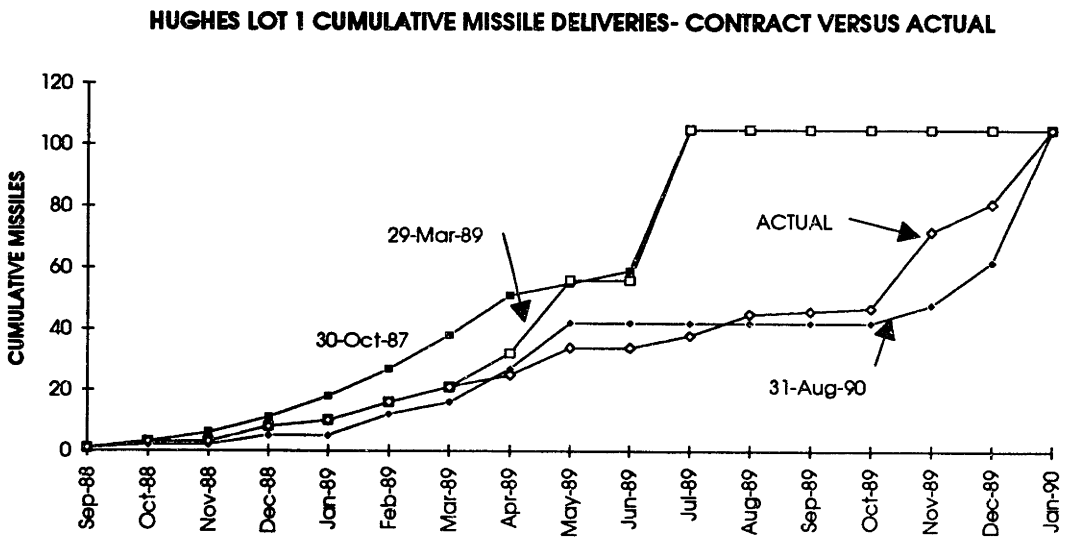

Figure 3.1

Examination of the Figure 3.1 shows three different modifications to the Hughes Lot 1 contract schedule versus the actual delivery schedule. Note that the October 1987 and the March 1989 schedules show that all 105 missiles were to be delivered by the end of June, 1989. Compare this with the flat period from March of 1989 until August of 1990. During this period the Government stopped accepting missiles due to a captive carry reliability problem that appeared on the F-15. The final modification to the contract after these problems were rectified shows that the Lot 1 missiles deliveries were actually completed in January of 1990, approximately 6 months behind the original schedule.

3.2.2 Raytheon Lot 1 Missile Deliveries

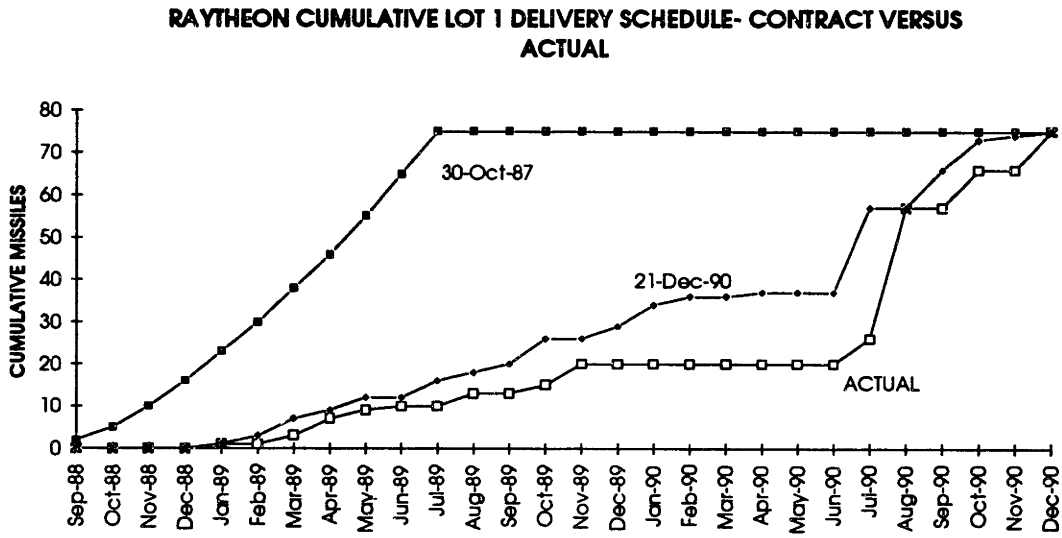

Figure 3.2

Three major factors effected the Raytheon schedule for Lot 1. The first was the completion of their Qualification Lot contract which had fallen behind. The next was the establishment of factory test equipment which also was lagging behind plans. Last, the same reliability problems that had the Government put a hold on accepting missiles from Hughes also stopped deliveries from Raytheon.

Although for clarity of presentation only two contract modification schedules are shown on Figure 3.2, in actuality there were a total of 7 contract modifications that adjusted Raytheon's contract schedule during the course of the lot. In any event, what had set out to be an 11 month schedule beginning in September of 1988 and ending in July of 1989 finally had first deliveries in January of 1989 and completed deliveries in January of 1991.

3.2.3 Captive Carry Reliability Problems and Teamwork for Solutions

With all the negatives that come with facing crisis, the AMRAAM program turned disaster into achievement during Lot 1. When early Lot 1 missiles became available for captive carriage testing on the F-15 to verify reliability, a critical problem was found. The

missile had been designed and qualified to environmental vibration levels that had been measured in FSD with instrumented test vehicles. In Lot 1, it was found that these levels dramatically understated an extreme environment that was to be encountered on the F-15 fuselage. The captive carriage reliability plummeted compared with previous observations on the F-16 during FSD.[46] The AMRAAM Program Director made the decision to halt deliveries on all production missiles until the cause of the reliability failures could be found and fixes put into the missile.

In a forced marriage, Hughes, Raytheon, and the Government took off parochial hats and merged technical talent to identify the causes and the solutions to the problems. This fundamental environment drove a design and process review to a depth not likely duplicated in conventional armament development. In the end, the team successfully quantified the environment, re-qualified critical components, sections and all-up missiles, and resumed production. As a result, in later lots of production the missile reliability has exceeded even the most optimistic levels. Contractor confidence has grown tremendously in the reliability of the missile and unprecedented warranties have been provided by both Hughes and Raytheon.

[46]Recall that the original aircraft that was to receive AMRAAM was the F-16. Therefore, captive carriage reliability program (CCRP) during the FSD program was primarily on the F-16. In retrospect, had the CCRP been on the F-15, these problems would have been found much earlier. The F-15 vibration environment is many times more harsh than the F-16.

3.3 Lot 2 Missile Production

3.3.1 Hughes Lot 2 Missile Deliveries

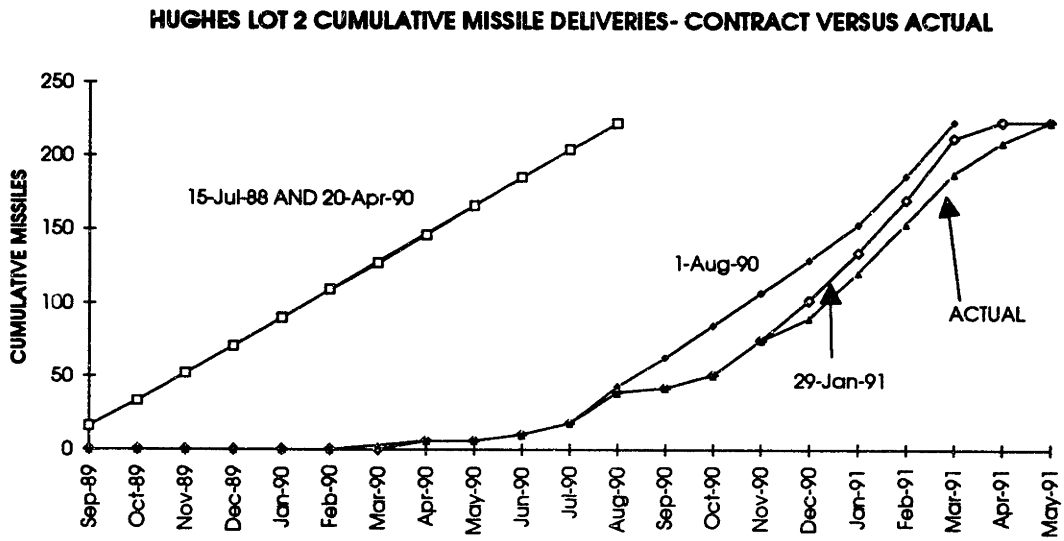

Figure 3.3

In addition to the problems that the program had regarding with captive carry reliability that bow-waved over into Lot 2, Hughes also had difficulties producing selected advanced guidance system electronics that were required beginning in Lot 2. These same technologies were to be passed to Raytheon and also caused delays in their production line. These producibilty problems were finally resolved through changes introduced from the AMRAAM Producibility Enhancement Program (APREP).

3.3.2 Raytheon Lot 2 Missile Deliveries

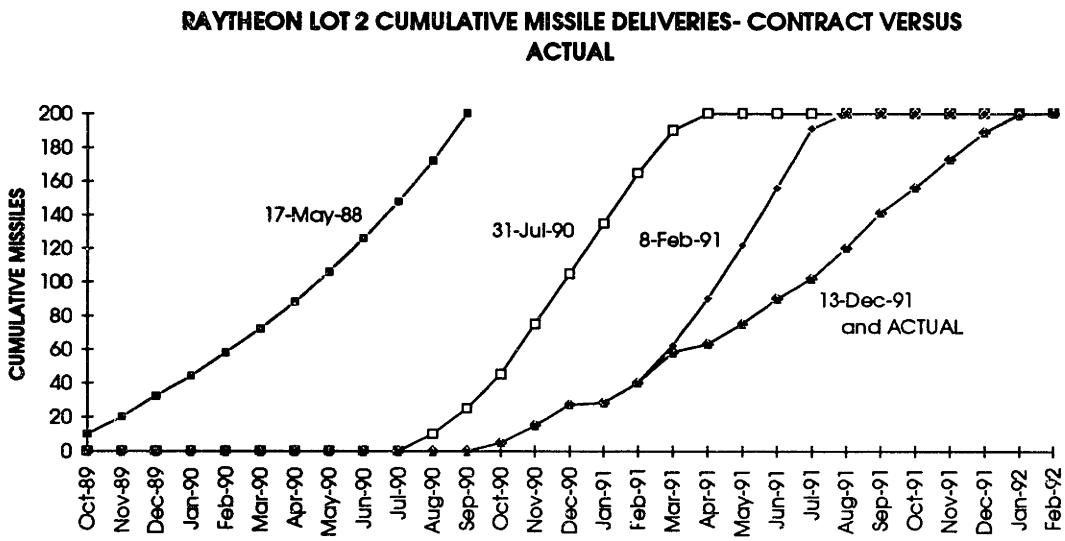

Figure 3.4

This Lot 2 schedule in Figure 3.4 shows the effect of the Lot 1 schedule slip due to reliability as well as other delays. Note that the schedules that were renegotiated in July of 1990 and February of 1991 have unrealistic ramp-up rates. (Which is, of course, much easier to see now than looking forward back then.) You can also observe that the contract modifications to synchronize contract requirements and actual deliveries continued to occur with regularity.

3.4 Lot 3 Missile Production

3.4.1 Hughes Lot 3 Missile Deliveries

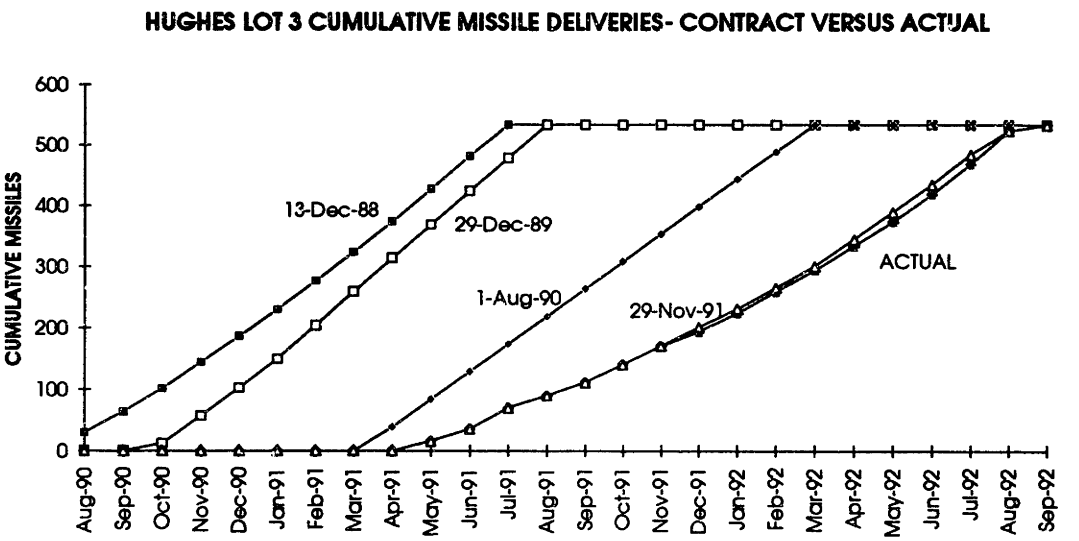

Figure 3.5

Lot 3 at both Hughes and Raytheon felt the same impacts as the Lot 2 deliveries. Notice, however that Hughes was able to sustain between 45 and 50 missiles per month over a 4 to 5 month period, reflecting that the producibility was improving.

3.4.2 Raytheon Lot 3 Missile Deliveries

Raytheon also was able to sustain a much higher rate during Lot 3 than on previous lots. After a delayed start due to coming up to production rate on the previous lots, Raytheon averaged over 30 missiles a month for the last 10 months of Lot 3 deliveries. They, like Hughes, were beginning to have the advantages of enhanced producibility from the APREP initiative (described in Section 5.0).

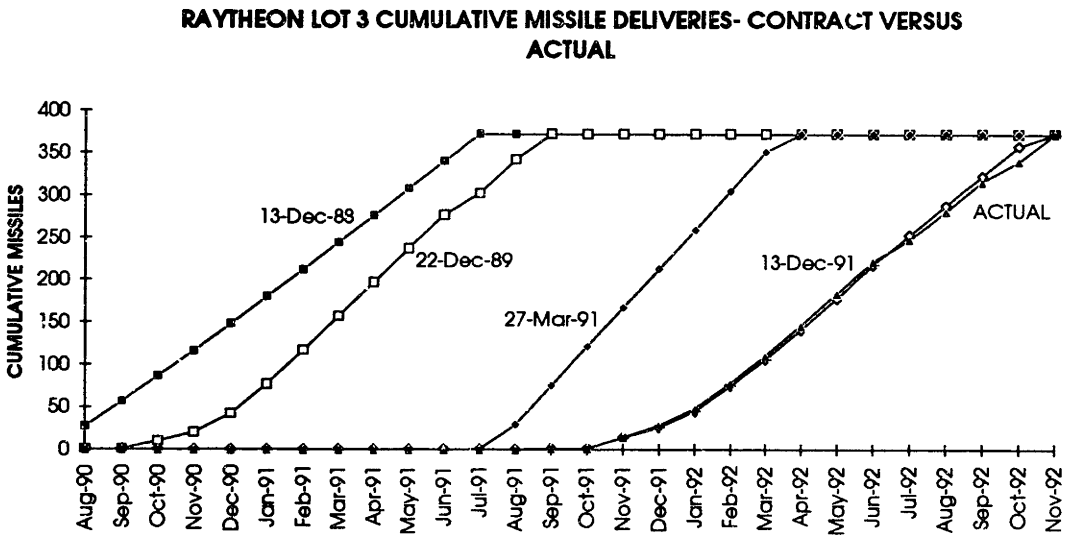

Figure 3.6

3.5 Lot 4 Missile Production

3.5.1 Hughes Lot 4 Missile Deliveries

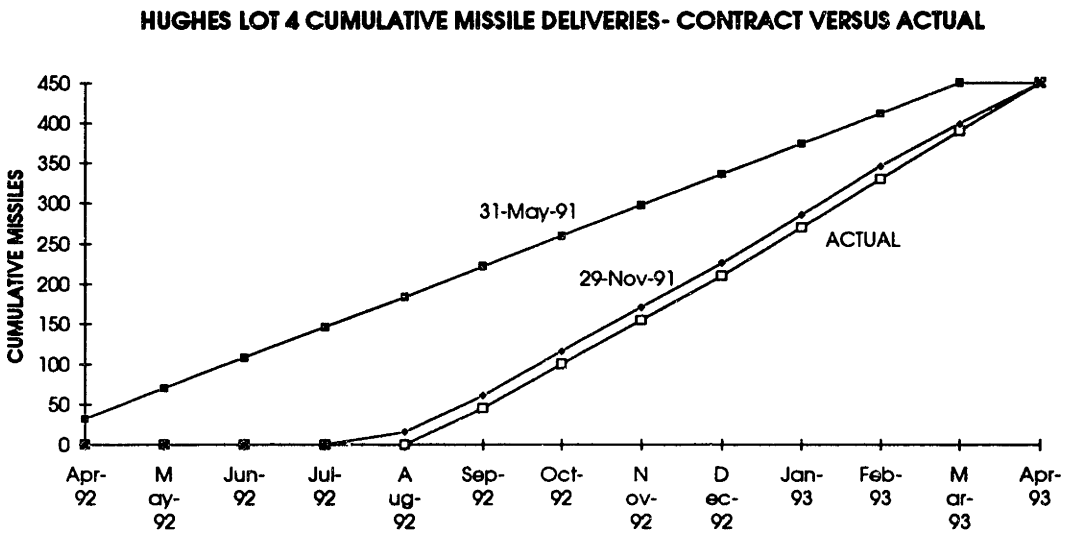

Figure 3.7

In Lot 4 a wonderful thing occurred! Hughes was able to meet the negotiated delivery schedule and delivered 450 missiles in less than 9 months. They were able to readily demonstrate 60 missiles per month.

3.5.2 Raytheon Lot 4 Missile Deliveries

Raytheon was equally impressive with actually delivering consistently ahead of the negotiated schedule.

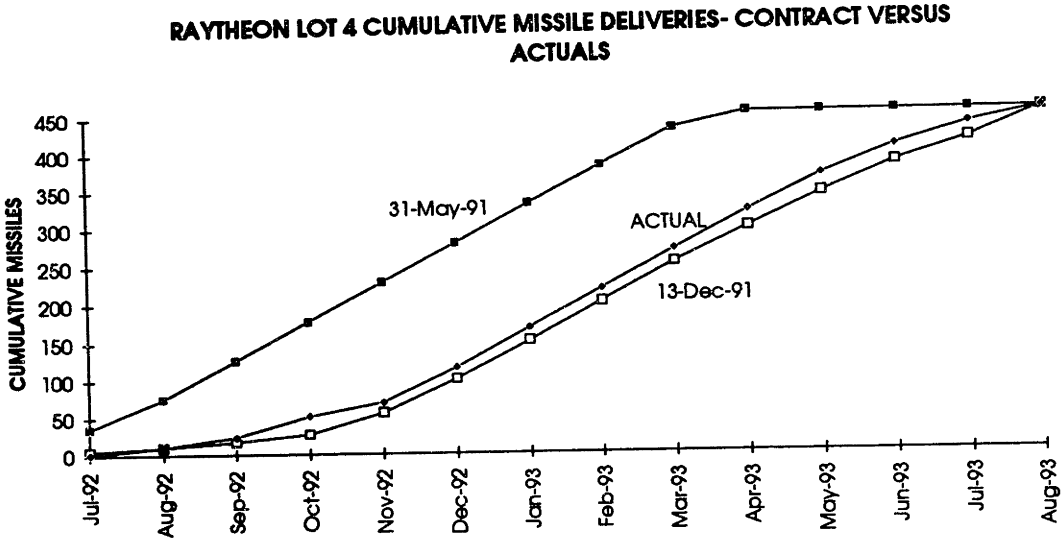

Figure 3.8

3.6 Lot 5 Missile Production

3.6.1 Hughes Lot 5 Missile Production

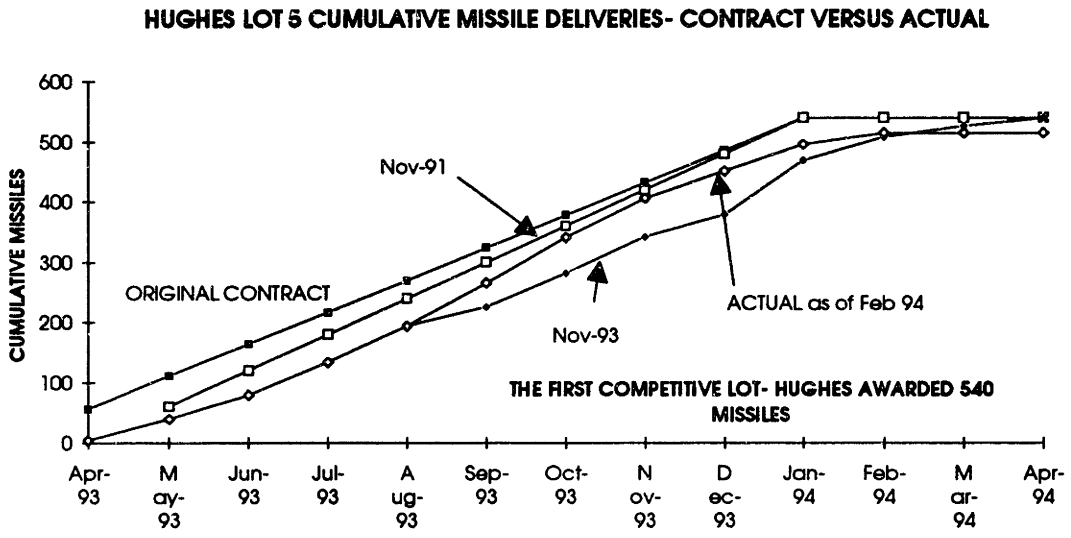

Figure 3.9

Hughes won the Lot 5 competition and received an award of 540 missiles. They have delivered on or before the negotiated schedule for the entire production run.

3.6.2 Raytheon Lot 5 Missile Deliveries

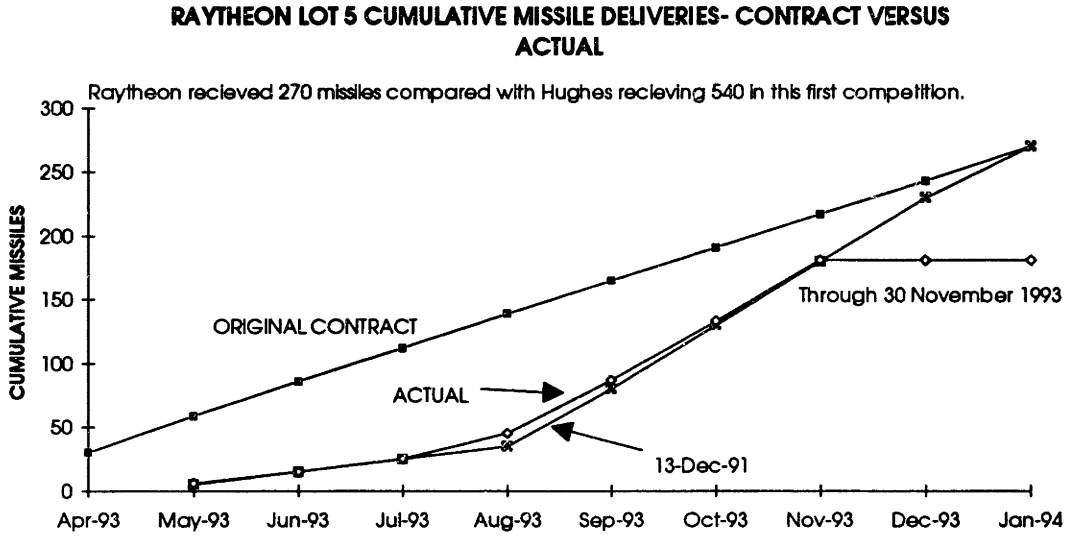

Figure 3.10

In the first competition since Full-Scale Development, Raytheon received 33% of the missiles for Lot 5- 270 versus the Hughes quantity of 540 missiles. As of March of 1994, it is evident that both contractors are able to achieve required delivery schedules. Some adjustments to contract delivery schedules should be caused by production rate smoothing when a follow-on lot is received. For example, for Lot 6 production option to Lot 5, Raytheon came back on March 23, 1992 to win the majority of the missiles (490 versus the Hughes award of 401). At that time, it was prudent to examine the Lot 5 and Lot 6 schedules in combination, and make refinements as necessary. Most production managers state that there is inefficiency in step-function changes in production rates when they can be avoided by better planning. Therefore, in Lot 5/6/7 transition, Hughes going from producing 540 in Lot 5 to 401 in Lot 6 to 849 in Lot 7 would be less expensive if adjustments were made to each lot's delivery schedule. The same would be true for Raytheon to a lesser degree because their Lot 5/6/7 rates are 270 to 490 to 614 missiles per year, which is a sustained production delivery growth rate. See the Figure 3.11 on the next page to graphically observe the variations in production quantities by lot for each contractor.

3.7 Summary of Awards to Date Including Lots 6, 7 and 8 Competition Results

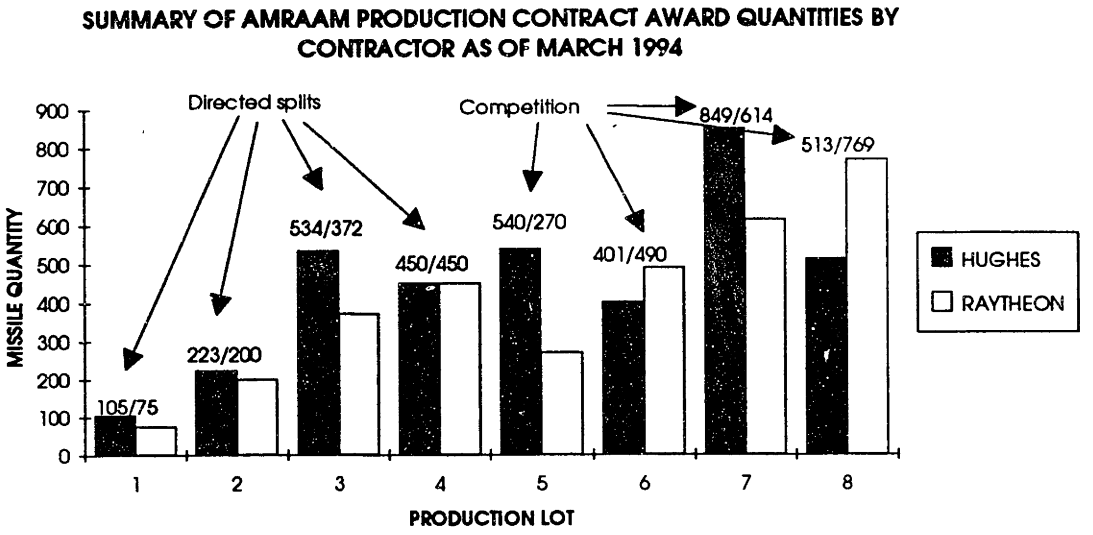

Figure 3.11

This shows that the competition is not one-sided. Notice that since Lot 5, which was the first competitive production lot, there has been an exchange of the larger quantity of missiles with each lot. As stated earlier, the competition is intense, and the average unit price of the missiles dropped 25% between Lot 6 and 7, and 23% between Lots 7 and 8.

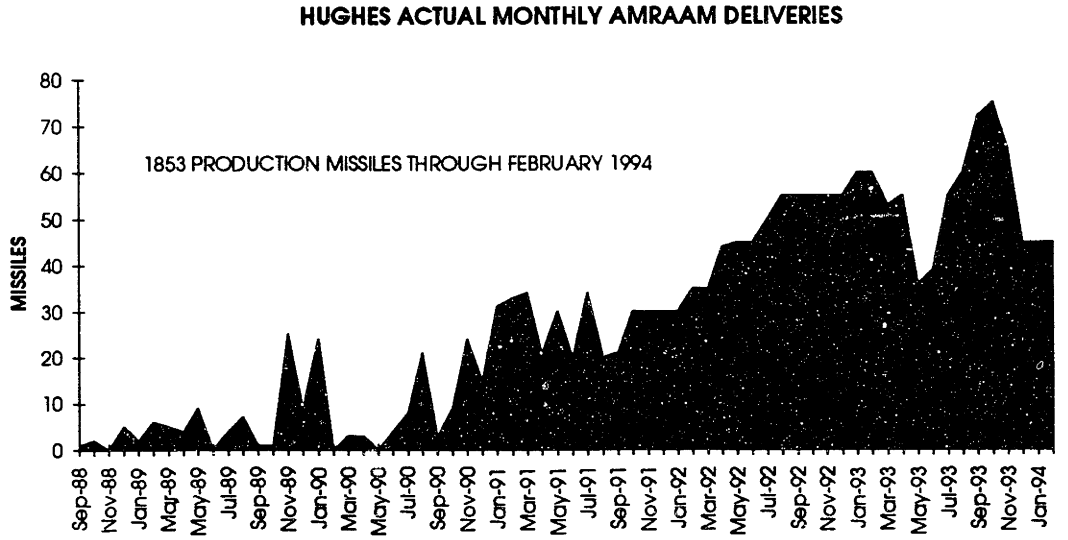

Figure 3.12

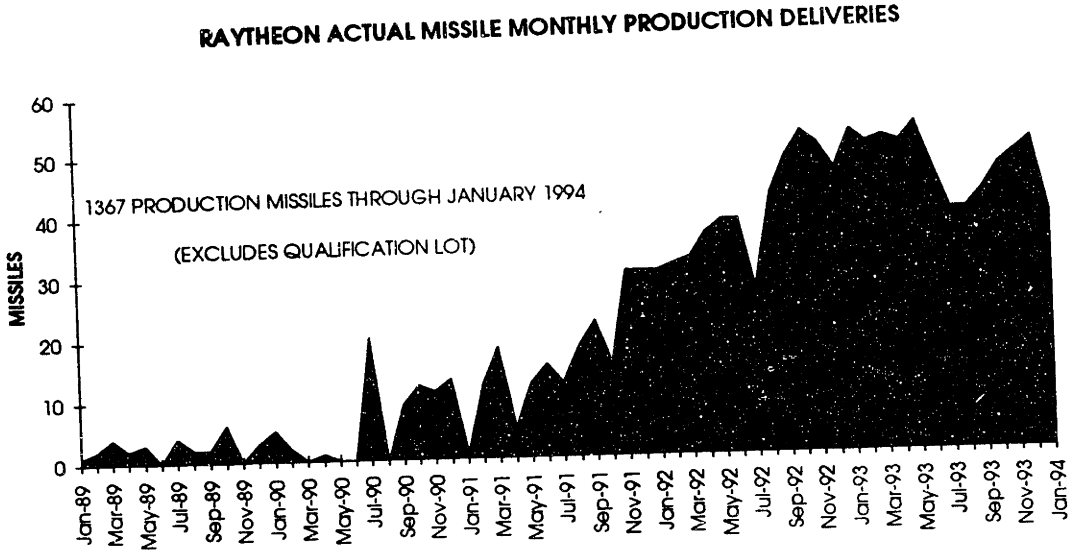

Figure 3.13

To summarize the production section of this thesis, it is appropriate that the reader look back at the progress that each contractor has made in producing missiles for the operational inventory. As shown in Figures 3.12 and 3.13, the production deliveries of each contractor have now reached a level that the Government can have confidence that the operational capability will be provided to world-wide forces on or before schedule. In fact, the last two competitions have resulted in the Government being able to buy more missiles than planned due to the price improvements demonstrated through competition and APREP.

Today's challenge in AMRAAM production is to introduce APREP and Pre-Planned Product Improvement (P^3I) without disrupting the production line momentum and sustained quality. Until now, at least, excellent planning for configuration changes has allowed block change to the missile to occur very smoothly.

4.0 AMRAAM Second Source Development and Technology Transfer

The most successful element of the AMRAAM program is, of course, the technical achievement to give the US and allied operational users the most effective air-to-air missile that the world has ever seen. One of the other most successful elements of the program is the development of a competitive second source and the resultant benefits that have been achieved by AMRAAM's use of competition to date. This section discusses the development, implementation and results of the strategy for a second source on AMRAAM. It provides insight into:

- Why second sources are developed,
- The processes used to formulate the second-sourcing strategy and to obtain approval for the strategy within the Department of Defense,
- Alternative strategies considered,
- The significant experiences encountered by the Government, the original source, and the second source,
- The cost and non-cost results,
- A summary of lessons learned on the second-sourcing effort and,
- Today's alternatives regarding sustaining a second source on AMRAAM.

4.1 The Purposes of Developing a Second Source

Whether or not a second production source would be appropriate and affordable on the AMRAAM program was examined closely beginning in June of 1978. The Joint Systems Program Office (JSPO) faced with this fundamental question as it went forth to advocate the long-term acquisition strategy to upper levels of management in the Air Force, the Navy and the Office of the Secretary of Defense (OSD). There were various reasons to consider a second source:

4.1.1 Potential Benefits in Having a Second Source Producer on AMRAAM

- **Cost Savings and Control:** The first and principal reason was to use competition to drive down the cost of the missile system and contain cost growth on the program.

Experience on many other programs within all the US services had shown that high priority programs in a non-competitive environment typically grew in cost over what was expected in earlier program cost estimates.

- **Expanded Production Base:** The second reason to consider multiple sources was to ensure that a sufficient "production base" was available to supply the large quantity of missiles needed to meet operational projections. With plans to have AMRAAM be the single medium-range missile for all US services , the quantity of AMRAAM weapons was anticipated to be over 20,000 for the operational inventory of the Air Force, Navy and Marine Corps. There was a significant concern about the ability of any single missile producer in the US (or the world) to sustain the required rate of production necessary to deliver the required inventory.
- **Avoiding Sole-Source "Lock-In":** Related to the issue of whether a single producer could deliver the entire quantities needed by the services was an issue about DOD investing so heavily[47] in one missile producer that no other aerospace company would ever be able to penetrate the air-to-air missile market with new technologies. In other words, the Government would be "locked-in" to a single source, even though other sources might have ideas that would make the system more effective, affordable and/or supportable.
- **Single Production Line Vulnerability:** A similar reason was the vulnerability in having one source for such a critical system. With one source, any interruption- whether it be from technical difficulties, acts of war, a natural disaster, or a labor issue- could stop the flow of missiles to the field. The risk seemed small, but the impact too drastic to ignore. Also, in the summer of 1978, the AMRAAM program office witnessed production lines of two of the five competing Conceptual Phase contractors effectively at a standstill due to labor strikes.

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[47]In special facilities, tooling and test equipment

- **Expanded Technology and Engineering Talent Base:** Another important consideration was that the program was pushing the state of the art in several technologies such as: high-power radar confined in a very small space; the use of digital computers for guidance functions and electronic countermeasures; and the simultaneous integration of the missile on several aircraft that would require two modes of launcher operation. These technical issues were very challenging. Two contractors would address these issues in the Validation Phase program and would derive potential solutions. Therefore it was determined that the another competent weapon system producer could provide a broader technical base upon which the program might draw if issues developed on the program. In other words, the Air Force expected a second source could bring more to the program than only being a "build -to-print" contractor. Without a second source, "all eggs would be in one basket" to attack the hurdles the program would likely face.
- **Improvements in System Performance, Quality, and Reliability:** A very positive motivation to have a second source was that on selected programs it had been observed that improvements in product performance (including quality and reliability) had been realized through competition.

4.1.2 Concerns with Introducing a Competitive Second Source Producer

On the negative side, there were also reasons the AMRAAM program office considered <u>not</u> introducing another source on the program:

- **Dilution of Focus on the Basic AMRAAM System Development:** The technical challenge of the AMRAAM undertaking was tremendous. A genuine concern existed as to whether or not dilution of focus on the primary development would occur by attempting to manage a second source development effort.
- **Affordability Issues:** A large issue developed over the affordability of having two sources. It was recognized that front-end costs to establish a second source would be very significant. The Government knew that the second source would require an

"education" to be able to effectively produce. It would also require a substantial amount of special tooling and test equipment, as well as facilities, to make an "equivalent" missile to the original source. A more comprehensive data package without proprietary restrictions would be required from the original developer to support open competition. Any second source producer would require a formal qualification effort and testing by the operational community. These would be redundant efforts to those required for a single source. Configuration management of two sources would be more complex and expensive. These are examples of the additional burdens the Air Force recognized it would face. All of these burdens increased upfront program costs.[48]

- **Fear of Diverging Designs:** The AMRAAM support concept required that all missiles have the same configuration to the lowest depot repairable level. This requirement was driven by previous experiences on the AIM-9 missile program in which the operational forces obtained missiles from two competing contractors with obvious differences in performance and reliability. The Navy also found that parts were not interchangeable on the two contractors' missiles. In other words, the missile designs had diverged in the pursuit of competitive production. Missile systems previous to AMRAAM required a significant amount of assembly and test within the field prior to being ready for load onto an aircraft. Most of the AMRAAM requirement for field-level assembly and test was driven by problems with designs and reliability of earlier missile systems. AMRAAM was required to be easily supportable and require virtually no field level (flight line or shop) maintenance. AMRAAM was further required to be an all-up-round ready for operational use directly out of the

[48]Numerous cost studies by the program office and independent sources did determine over the course of the program that it would be very cost effective for AMRAAM to introduce two sources, especially considering the large projected quantity required by the operational forces. The results of these analyses are included in a later section.

shipping container. However at weapon servicing depots[49], it was anticipated that AMRAAM would be disassembled, and upgraded/repaired as necessary. A fundamental requirement was placed on the program that missiles acquired from either a prime or a second source must be identical to the lowest depot-repairable level. Although this was seen to increase initial acquisition costs, it was also seen likely to significantly reduce life cycle costs driven by depot upgrades and repairs. It also gave the logistics community a secondary benefit of strong competition for spares to be used as depot replacement sections.

4.1.3 Strong Policy Emphasis for Competition

On top of all the programmatic reasons for carefully planning for competition on the AMRAAM program in 1978 was the strong and growing advocacy for competition throughout the Government. The President, Office of Management and Budget, Congress and service executives were in strong agreement. In the 1960's and 70's there had been many experiences of cost over-runs that were attributed to a single (sole) source environment. Much emphasis was being placed on sustaining competition throughout the production phase of a program, because after a contractor competed and won a full-scale development contract, there was ineffective cost control available to the Government. Many developmental competitions had been early "buy-ins" by contractors.[50] Contractors who successfully bought-in and established a position of sole-source would attempt and usually be successful in recouping early losses either later in development or in production.

In 1984, the Defense Systems Management College (DSMC) produced a manual for program managers to use when establishing a second source which stated:

> "The program manager should note the emphasis that DOD and the Congress place on the effective use of competition. Competition is not advocated

[49]Depots are large maintenance facilities typically at Air Force Air Logistics Centers or a Naval Weapons Stations around the US.

[50]A "Buy-in" is an intentional under-pricing of a proposal to develop a system to become the sole producer.

merely for the sake of competition but rather as a means to enhance the overall value of weapon systems procurement to the Government, considering the economic, technical, schedule, and logistics effects. Thus, when considering the use of competition, the program manager must assess all relevant factors to ensure that competition is effectively employed."[51]

To overcome perceptions that might exist regarding the degree of discretion a program manager or service acquisition executives have regarding supporting competition, it should be understood that competition in weapon systems acquisition (and most defense goods and services) is legally mandated. DOD and Congress have been in almost total agreement in concept in the need for competition to control cost and ensure that procurements are fair. There has been emphasis in legislation, Federal Acquisition Regulations, and DOD and Service regulations that clearly advocate the use of competition.

A premiere example of legal preference for competition was enacted in 1947.[52] A congressional act mandated that the acquisition of weapon systems, as well as all contracts for goods and services, be formally advertised. Only by specific exception can negotiations with only one contractor be used to establish a contract. Negotiations are required to be competitive whenever practicable. This act has been amended and refined periodically since 1947 to apply additional emphasis to competition.

In 1984, for example, the Congress specifically emphasized competition in the production phase of programs. Public Law 98-212 stated:

"None of the funds made available by this Act shall be used to initiate full-scale engineering development of any major defense acquisition program until the Secretary of Defense has provided to the Committees on Appropriations of the House and Senate:

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[51]Establishing Competitive Production Sources, A Handbook for Program Managers, August 1984, Defense Systems Management College

[52]The Armed Services Procurement Act of 1947

(a) a certification that the system or subsystem being developed will be procured in quantities that are not sufficient to warrant development of two or more production sources, or

(b) a plan for the development of two or more sources for the production of the system or subsystem being developed."[53]

Note that this law now requires that a cost analysis be performed on a program to make a determination whether or not a second source is cost effective. Cost analyses were done on the AMRAAM program at each major OSD decision point in which the acquisition strategy was reviewed.

Requirements for program offices to respond to legislation generally comes to Government system program offices through Department of Defense regulations/instructions and the Federal Acquisition Regulations that provide expanded guidance. For example, the Office of Management and Budget (OMB) directed that competition be incorporated throughout the entire acquisition process- meaning development, production, and sustainment.[54]

The "Bible" for contracting within the DOD is the Federal Acquisition Regulation (FAR). The FAR mandates the use of competition. The FAR states:

"Contracts shall be awarded in accordance with formal advertising procedures whenever feasible and practicable. Except where negotiation is specifically required by this regulation (e.g., foreign purchases by overseas activities), this rule shall be followed even though existing conditions would satisfy one or more of the circumstances permitting negotiation."[55]

Later in the FAR it is required that negotiations be conducted competitively whenever practicable:

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[53]Section 797 of the Department of Defense Appropriations Act of 1984
[54]OMB Circular A-109
[55]FAR Subpart 14.103-1(a)

"Negotiated contracts shall be awarded on a competitive basis to the maximum practical extent. To this end:

(a) Offers shall be solicited from the maximum number of qualified sources consistent with the nature of and the need for the supplies or services being acquired. Acquisition information shall be publicized in accordance with 5.101.

(b) Before negotiating a contract on a noncompetitive basis, the contracting officer is responsible not only for ensuring that competition is not feasible and practicable under the existing conditions and circumstances but also for acting whenever possible to avoid the need for subsequent contracts. This process shall include --

(1) Examination of the reasons precluding competition for the current requirements; and

(2) Taking steps to foster competition in the future, particularly with respect to the availability of complete and accurate data, reasonableness of the delivery requirements, and possible breakout of components for competitive contracting."[56]

The emphasis also has come from other agencies and offices such as the Office of Federal Procurement Policy (OFPP). In 1984 this office set very strict limits on the use of sole source contracts and required that competitive awards be used except in the case of seven specific circumstances.[57]

The Department of Defense publishes additional guidance to acquisition personnel in directives and instructions. A hallmark is DOD Directive 5000.1 which highlights the use of competition:

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[56]FAR Subparts 15.105(a) and (b)

[57]OFPP Policy Letter 84-2. This policy letter was later implemented into the FAR on 29 June 1984.

"Effective design and price competition for defense systems shall be obtained to the maximum extent practicable to ensure that defense systems are cost effective and are responsive to mission needs."[58]

There were other influences on AMRAAM's acquisition strategy regarding competition. For example, in 1981, the Defense Acquisition Improvement Program (DAIP) included an initiative to increase the competition. The DAIP team interviewed many key AMRAAM personnel at length and were provided details of AMRAAM's acquisition strategy. The DAIP team later used AMRAAM as an example to be followed for creating competition throughout the acquisition life cycle of major programs.

The Under Secretary of Defense for Research and Engineering also formed a group to investigate methods to promote the effective use of competition. Once again AMRAAM was selected as a model program. One example of an idea that AMRAAM had used to emphasize competition was the designation of a senior program manager within the program office to serve as an advocate for competition in 1981. This was long before it was suggested or required within all DOD acquisition organizations. In 1984, all services were required to appoint Competition Advocates to encourage use of competition and to challenge the use of non-competitive procurements at all levels of contracting actions.

In the mid-1980's, Congress became even more active in promoting the use of competition. The AMRAAM program was on center stage within the acquisition community to demonstrate feasibility of the Government constructing and implementing a long-term strategy that would supply two competitive sources throughout the developmental phases and through the majority of the production phases of the program. By this time Hughes was significantly through the Full-Scale Development Phase, and Raytheon had been "following" FSD activities closely.

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[58]Department of Defense Directive 5000.1, "Major System Acquisitions," USDR&E, 29 March 1982

4.1.4 Summary of the Political Environment

The AMRAAM JSPO was attuned to the mood of the Congress as well as acquisition executives within the Office of the Secretary of Defense and the Air Force and Navy Secretariats. Whereas competition had been strongly recommended by most acquisition officials and had been integrated into the AMRAAM acquisition strategy from the beginning, other people thought the establishment of a second source was too expensive, and that the costs would never be recovered. These people had to be convinced by sound analysis. In addition, although Hughes had proposed bringing on a second source during the FSD phase as part of their competitive FSD proposal, Hughes exerted considerable influence (ineffectively) to advocate the termination or delay of the second-source developmental activities, once they had won the FSD competition.

4.1.5 Strong Endorsement/Direction by Senior DOD Executives

In 1981, The Undersecretary of Defense for Research and Engineering told the Senate Appropriations Committee:

> "My recommendation is that we select both competitors (Raytheon and Hughes) and fund both in production and let them compete for the life of the program. A dollar worth of investment in developing a second source will return over $20 in a program's life. The F-18 is a problem now because we're down to one competitor." [59]

The atmosphere in Congress continued to be very pro-competition during this period and three pieces of legislation passed that further cemented that the AMRAAM acquisition strategy reflected the will of the Congress:

- The Competition in Contracting Act of 1984[60]
- The Small Business and Federal Procurement Competition Act of 1984[61]
- The Defense Procurement Reform Act of 1985[62]

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[59]Aviation Week and Space Technology, 27 July 1981, "Pentagon Urges Competition on Missile"
[60]Public Law 98-369
[61]Public Law 98-577

In 1981, after considering all the positive and negative programmatic points, and examining the political environment, the JSPO Program Director elected to stay the course with the second sourcing strategy that had been planned in 1978. Higher acquisition authorities in DOD approved continuing the concept of having more than one source on the AMRAAM program.

In the late 1970's and early 1980's, there were many subordinate issues that had to be addressed in detail to implement the AMRAAM second-sourcing acquisition strategy such as:

- How to bring on the second source
- The timing of bringing on the second source, and
- The selection of the second source.

Each of these issues is discussed later in some detail.

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[62]Public Law 98-525

4.2 Formation of the Strategy and the Strategy Review Cycle

The process that the AMRAAM JSPO used to formulate the acquisition strategy was interactive with all levels within the services and OSD, and included continuous input from industry. First, a small team of JSPO personnel "brainstormed " the many alternatives that were available. (These alternatives will be discussed in the next section.) The team consisted of a program manager/team leader, a procurement contracting officer, an engineer, a logistics specialist, and a program cost estimator/budgetary specialist. This team served as the right hand of the Program Director and the basic JSPO unit to generate alternatives, to develop pro's and con's, to obtain consensus, to document plans and analyses, to staff formal coordination, to react to acquisition panel inputs, and to translate the plans into solicitations to industry.

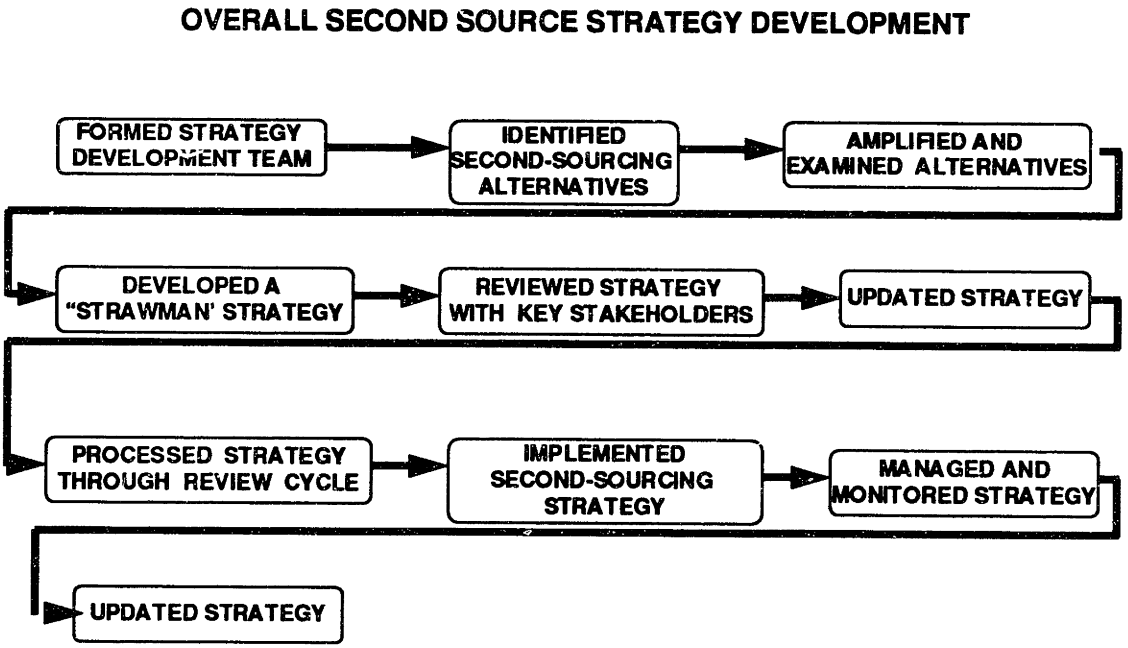

Figure 4.1

The team environment was very much akin to the current Integrated Product Team (IPT) movement now in 1994 ongoing within Air Force Material Command. Although team members came from different functional backgrounds, there were no barriers to prevent any person from actively providing input on any subject. Engineers were deeply

engaged side by side with cost estimators and program managers to evaluate program alternatives. This team relationship is discussed in the organizational section of this thesis (Section 10).

The first task of the team was to research the various methods that were available to develop second sources. They employed a multiple-pronged approach which included simultaneously discussions with, and review of program office documentation from, other DOD personnel within program offices and within the acquisition policy community, with the leaders of aerospace industry, and with the academic community such as the Defense Systems Management College.

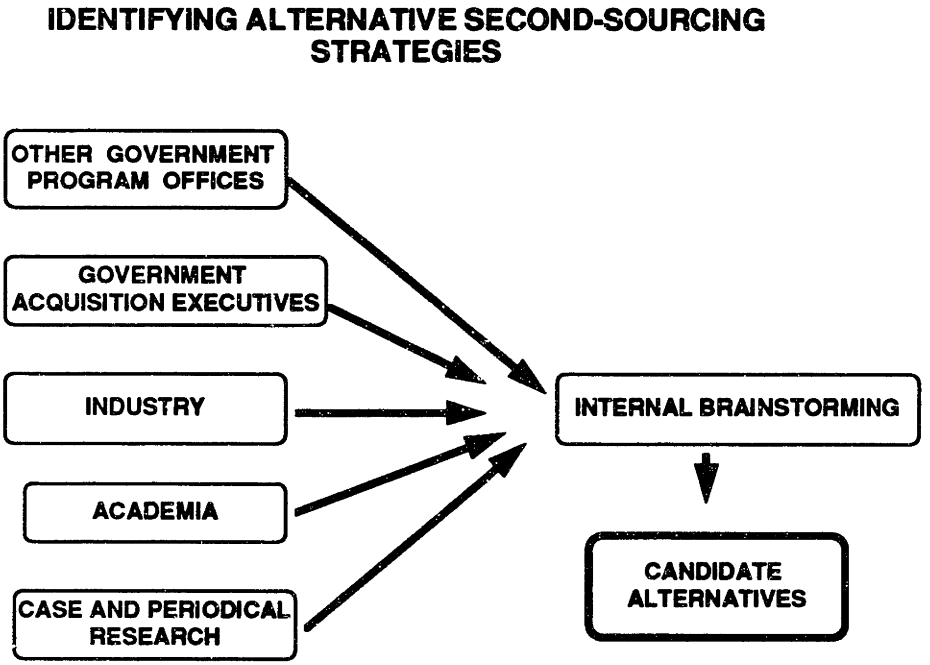

Figure 4.2

The team provided the second-sourcing alternatives and recommendations to the AMRAAM Program Director, along with his JSPO division chiefs from each of the functional areas[63], and a legal representative. This group acted as a sounding board to probe issues and expand alternatives. The group made suggestions such as that the JSPO

[63]The JSPO had divisions for Program Management, Engineering, Test, Contracting , Logistics, Configuration Management, and Program Control (for primarily budget issues).

have an independent group examine the cost-effectiveness of competition in previous DOD programs.

From this interaction, a preliminary acquisition strategy was developed that would go forward external to the program office and the process would be repeated at the next level. The entire JSPO management structure then went forth to present the second sourcing strategy to relevant counterparts on other programs and to the next level of functional management to get reactions and suggestions informally. The strategy worked its way through the staff at the Air Force Development and Test Center (AFDTC) at Eglin Air Force Base in Florida, on through the Headquarters of the Air Force Systems Command, through the Headquarters and Secretariat of the Air Force and Navy and to the Office of the Secretary of Defense. The results were that in every instance in which the second sourcing strategy needed to be approved, issues[64] were explored and resolved with appropriate staffs informally prior to final reviews and requests for approval. This same strategy development and coordination approach was taken on every important element of the AMRAAM acquisition strategy.

Several documents were prepared that described the strategy. The AMRAAM program was designated as a "Major System Acquisition" under the criteria of DODI 5000.1 and therefore was subject to the Defense System Acquisition Review Council (DSARC) process that was discussed earlier. This process required that the program prepare certain specific documents that discussed the program alternatives and acquisition strategy such as the Decision Coordinating Paper and the Integrated Program Summary. In addition, the program office was required to be responsive to the Federal Acquisition Regulation[65] requirements to prepare an acquisition plan that included areas such as:

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[64]Typical issues were:

- At what level to bring on another source- system versus subsystem,
- When to bring on the source(s),
- What method to use to bring on the second source (Technical Data Package, Leader/follower, etc.)
- and Who the second source should be.

[65]Federal Acquisition Regulation (FAR) Part 7, Acquisition Planning

- Program Requirements
- Acquisition Background and Program Direction
- Type of Contract(s) Envisioned
- Funding Requirements and Availability
- Program Schedules
- Procurement Method
- **Maximization of Competition**
- Contract Incentives
- Lead-times for Deliveries
- The Method for Source Selection and Criteria to be Used
- The Performance of Contract Administrative Duties

The significance of preparing this comprehensive procurement planning was that it focused the attention of the entire program office into integrating consideration of second-sourcing into virtually every major program trade-off.

4.3 Alternative Second-Sourcing Strategies

Perhaps the most constructive part of AMRAAM's acquisition strategy development, especially in the area of second-sourcing, came from the lengths to which alternative strategies were evaluated. One advantage the AMRAAM program had in developing alternative strategies was the breadth of experience and networking that the members of the Joint-Service Program Office had acquired prior to being assigned to the program. Not only were the personnel experienced on a broad spectrum of weapon system acquisitions (many of which had been competitive), they also represented the experience base of both the Air Force and The Navy, and had strong contacts within the Army. The alternative strategies considered were as follows:

- No Second Source
- Form, Fit and Function Competition
- Technical Data Package Competition
- Leader/Follower Second Source Development
- Licensing
- Contractor Teaming
- Subsystem (Sub-Tier) Second Source Competition

Each of these strategies and their advantages and disadvantages will be discussed below.

4.3.1 No Second Source Requirement

The intent of the Federal Acquisition Regulation and the Congress has not been to insert competition into a program if it were not appropriate. For example, if quantities were too small, it would not have been appropriate due to the up front expenses that are necessary to establish a second source. But in AMRAAM's case quantities that were projected for operational use were originally over 20,000. Break-even analyses varied, but all indicated that if 10,000 to 13,000 missiles were to be acquired that the savings from competition would more than account for the costs to establish a second source. Therefore it was determined that it would be cost effective.

Many other reasons than cost reduction existed for establishing a second source, as previously mentioned. The Navy Competition Handbook[66] which was published in 1989 cites AMRAAM as an example several times and lists some of the reasons a second source might be needed:

- Improving quality and reliability
- Encouraging industry to invest in innovative techniques to improve their competitive position
- Improving program manager control and leverage over contractor activity
- Enhancing the industrial base for mobilization and surge capacity
- Improving delivery schedules to the operational forces
- Motivating contractors to suggest design changes which result in price reductions, rather than cost growths

These reasons were all briefed in 1981 to the Secretariats of the Air force and Navy. The decision was made that a second source was appropriate for AMRAAM and the alternative not pursue a competitive second source was eliminated.

4.3.2 Form, Fit and Function (F^3) Competition

The next form of competition that was considered for use on AMRAAM was to have two contractors deliver missile systems that had the same external characteristics (form), would interface (fit) identically on the various required aircraft, and were functionally identical (or at least interchangeable) in all aspects of performance. The advantage of the F^3 approach was that through allowing designs and manufacturing processes to be flexible, contractors could be more creative in reducing costs. An additional advantage would have been that the developer would not have been required to develop a full open-competition type technical data package. Another important consideration was that the Government would not have been liable for the quality of the technical data package.

[66]Navy Competition Handbook, Second Edition, Dated April, 1989

However, this F^3 alternative in essence would have required a totally redundant Full-Scale Development (FSD) Phase for the second source, which was cost prohibitive. Of greater issue were the supportability considerations of having two configurations to maintain and provide spares throughout the program life cycle. The logistics community had a strong voice in establishing that this was not a viable alternative for AMRAAM. One last nail in the coffin of the F^3 approach was that there had been experiences on a previous Navy program in which the operational forces had found one contractor's product had been significantly inferior from a quality and reliability perspective from a second contractor's product. Therefore, the recommendation was that identical acceptance test equipment must be used for all sources of the missile, which virtually eliminated a purely F^3 approach.

Although the F^3 technique had been proven to be acceptable on more simple systems[67], it was determined not to be appropriate on AMRAAM.

4.3.3 Technical Data Package Competition

The Technical Data Package (TDP) method of establishing a second source is by far the most common. In this technique, a TDP is developed during the Full-Scale Development Phase of a program, usually, or even after a program has entered into production, and is provided to potential second sources as the basis for contracting. The TDP is a stand-alone document (actually, collection of documents such as specifications and drawings) to which all sources will be required to produce. The Government is generally the owner of and responsible for the maintenance of the TDP.[68]

The TDP process has several steps that are shown in the following figure:

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[67]Darrell R. Hoppe , "Dual Awards and Competition--You Can Have Both," Seventh Annual Acquisition Conference, Hershey, Pa, 1978. Mr. Hoppe uses the successful example of the GAU-8/A 30-millimeter ammunition which was developed at Eglin Air Force Base in Florida in support of the A-10 aircraft program. In this case the prime gun contractor (General Electric) was required to develop a second source for ammunition to lower acquisition cost and to ensure an adequate supplier base for ammunition.

[68]The Government is responsible for the maintenance of the TDP, but may contract out this responsibility to one of the suppliers or an independent third party.

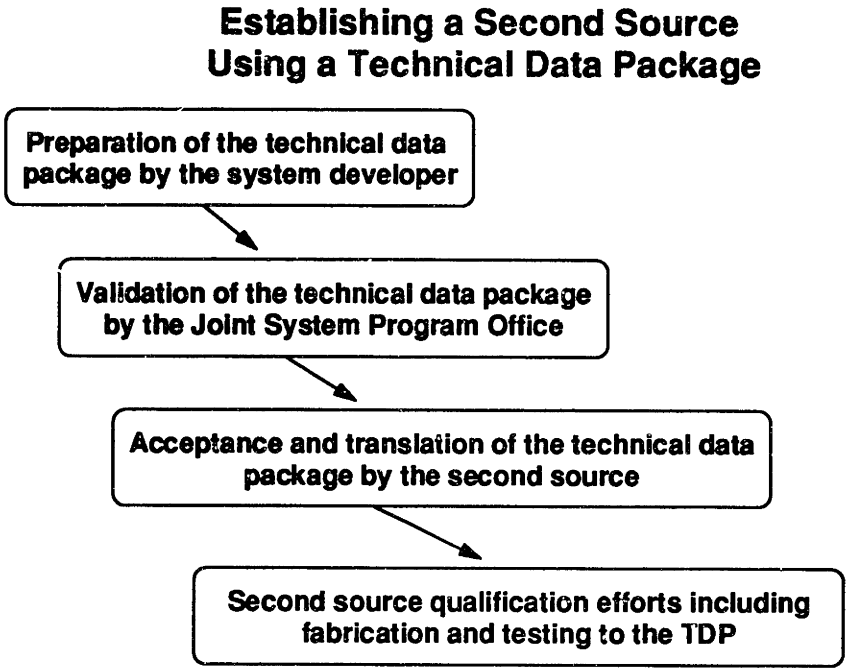

Figure 4.3

Obviously, the quality of the TDP is crucial to the success of the TDP approach to establishing competition. Specific characteristics[69] that are necessary are:

- Specific requirements of the missile and all subsystems/components in terms of detailed physical and performance characteristics within the operational environment in which the system is required to operate.
- Quality assurance provisions which include sampling plans and acceptance criteria, acceptance test equipment, and acceptance test plans and procedures.
- Packaging requirements that ensure adequate and supportable preparation for delivery, storage and use from production to use in the field. This would include repackaging instructions also.
- Unique manufacturing process plans and instructions that are needed to ensure that all sources are producing equivalent missiles.

[69]"Technical Data Package Development and Management," Army Management Course, US Army Management Engineering Training Activity, October 1982

The establishment of a second source on AMRAAM by the TDP method would have had several strong points. First, if the TDP were allowed to mature (to be completely proven out and baselined) prior to introduction of a second source, several other aerospace contractors could have been competed to determine the second source. Second, if the quality of the TDP was very good, technology transfer could occur without the need for technical assistance from the original developer, and that expense could have been avoided. An additional strong point would have been that the TDP method is "cleaner" from a contracting perspective. Competing contractors simply bid to supply missiles to the technical data package and special provisions of the contract, and the basis of award is straightforward.

On the negative side, TDP competition is only as good as the TDP. A large risk existed that the Government would not be able to "prove-out" the data package without a second source actually attempting to build to it. This was especially true with a system as complex as AMRAAM[70]. This was confirmed in meetings between the program office and industry prior to the FSD Phase of the program. Contractors unanimously stated that the AMRAAM system was too complex for a second source to be brought on board to build an identical missile to the lowest depot repairable level without technical discussions between the two sources.

Another issue stymied the TDP approach. It was highly desirable to introduce a second source as early as possible in the program. The TDP approach allows the original developer to produce to the data package and complete a physical configuration audit

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[70] There had been reasonable success at the TDP method on at least one previous missile program (the AIM-7F) in which the Navy established an in-house team supplemented by a support contractor to review Raytheon (the developer's) drawings. In doing so, the Navy assumed the responsibility for the adequacy of the data package. Significant delays occurred in establishing the second source that were attributed to testing problems and funding shortfalls. However in the end, the fruits of competition have shown to be reduced cost and improved quality on the AIM-7F program. The AIM-7F technology was approximately 10 to 15 years older than AMRAAM's.

(PCA) prior to baselining[71] the technical data package. PCA therefore does not occur until approximately 18 to 20 months after the first production contract award. Usually corrections are required to the TDP as a result of the PCA process. If these were to take 4 to 8 months, it would be well over 2 years after the first production contract were awarded before a solicitation for the second source could be released. When the length of time to bring up a second source from contract award to being ready to compete is added to this TDP development period, true competition on the program would be at least 5 years into production. The Air Force was hopeful that competition would be introduced earlier.

For these reasons, especially the fact that technology was thought to be most effectively transferred through a combination of both a technical data package and technical assistance, the TDP method was not selected by the program office.

4.3.4 Leader/Follower Second Source Development

The leader/follower (L/F) method of developing a second source differs from the TDP method in one significant way. In the L/F method, the original developer is contractually responsible to bring on the second source through a combination of methods of technology transfer such as technical data package and technical assistance. In addition, the L/F contract requirements might call for training, as well as learning "kits" of missile hardware and software, and special tooling and test equipment.

The Federal Acquisition Regulation[72] provides conditions under which the leader/follower concept can appropriately be used. It is considered an extraordinary procurement technique and restricts its use to the following circumstances:

- The leader has the necessary know-how and is able to furnish required assistance to the follower.

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[71]"Baselining" occurs when the Government takes control of the drawings and specifications to which a contractor builds. Beyond this point, a contractor has to submit engineering change proposals to make changes to the TDP.

[72]Federal Acquisition Regulation (FAR) Subpart 17.4

- No other source of supply can meet the Government's requirements without the assistance of the leader company.
- The assistance required of the leader company is limited to that which is essential to enable the follower company to produce the items.
- Its use is authorized in accordance with agency procedures.

There are several contractual arrangements in which the leader may be contractually obligated to provide the necessary technology to the follower. These are also identified in the FAR:

- Alternative 1- A prime contract can be awarded directly to the leader that requires the contractor to subcontract a portion of the production contract to a follower, and to assist the follower in the production of the end item deliverables.
- Alternative 2- A prime contract can be awarded directly to the leader that requires the contractor to provide technical assistance to a follower who also has a prime contract with the Government.
- Alternative 3- A prime contract can be awarded directly to the follower that requires the contractor to provide a subcontract to a leader to obtain necessary technical transfer.

These alternatives were all reviewed with the 5 contractors who were competing for the Validation Phase on AMRAAM in acquisition strategy discussions with the Government. Without exception, the contractors stated that if they were the leader, they would prefer to use Alternative 1 and select the follower themselves. If they were allowed to select the follower, it was very likely that they would be able to select a marginal eventual competitor, and would be able to control the pace of learning. As such, each of the contractors agreed that it was in the Government's best interest for the Government to select the follower. All 5 contractors further agreed that it would be much more effective to have prime contracts between the Government and both the leader and the follower- Alternative 2. This was especially true because the Government had the leverage to

include the leader task as an element of the Full-Scale Development Phase competitive solicitation. Alternative 3 was deemed to be the weakest of the three because the Government would have no leverage in ensuring that the leader would provide an effective technology transfer to the follower. Therefore, Alternative 2 was selected by the program office and approved by the higher headquarters.

The advantages of the leader/follower technique to the Government were as follows:

- The Government was able to define a precise method and contractual obligation on the original developer's (Hughes) part to provide a comprehensive technology transfer program to bring on a second source. The Government strategy was very open. The Government asked both of the FSD competitors (Hughes and Raytheon) to provide a technology transfer plan as part of their FSD proposal that would be considered in the source selection. This technology transfer plan would be placed on the contract as an optional line item that could be exercised by the Government during the FSD program to begin the technology transfer process. This strategy was effective in acquiring leader support for the L/F program in the competitive environment, and allowed the Government to obtain all necessary data rights and technical assistance at a very reasonable price.
- The second advantage of the alternative selected was that it limited the Government's responsibility for the quality of the technical data package. The prime contractor for development was required to deliver and provide technical assistance on a complete data package to the follower sufficient to ensure missiles were identical to the lowest depot repairable level. The follower was obligated to review the data package in the process of its formulation and to provide comments to both the leader and the Government. The follower also was to receive hardware kits and special tooling and test equipment that could be used to verify the data package.

- The next advantage was that the leader follower program was designed to surface/resolve problems early, and to bring on the second source through a series of increasing responsibilities beginning in FSD and continuing into initial production. The net result was intended to accelerate when the developer would be required to price and perform under the pressures of competition.

The single disadvantage to the leader/follower technique was how to motivate the leader to complete his contractual obligations for technology transfer once the FSD contract were awarded. However, this disadvantage was actually inherent with all alternatives, and was thus not a significant discriminator. The selected alternative, in fact, was considered the strongest contractual method for assuring that the leader lived up to his competitively proposed promises for technology transfer, because the Government had direct access to monitor the follower's progress, and because the Government had the leverage of the mainstream FSD contract with which to control the leader.

4.3.5 Licensing as a Technique to Bring on Competitive Second Source

In early acquisition strategy discussions a technique known as licensing[73] was briefly considered. In this technique, the Government would have paid royalties and fees to the developer who would be required to assist a licensee to manufacture missiles. Two significant issues eliminated this alternative. First, the Government had obtained complete rights to data on AMRAAM. Therefore there was no basis to pay such royalties. Second, it was assessed as unlikely that the developer would ever be motivated through this method to bring a second source up to the level of manufacturing proficiency and effectiveness that they would provide sufficient competitive pressure.

4.3.6 Contractor Teaming to Introduce Competition

Contractor teaming was strongly considered within the program office during the Validation Phase. The strategy basically would have had the two Validation Phase

[73]Gregory Carter, "Directed Licensing: An Evaluation of a Proposed Technique for Reducing the Procurement Cost of Aircraft," Rand Corporation, December 1974

contractors (Hughes and Raytheon) form a team to develop the missile during FSD. It was quite apparent that each of the two competitors had strengths that would have benefited the other in deriving the optimal design form the Government's perspective. In discussions with the contractors, it was apparent that there was no desire on their part to work together as a team. Each considered themselves as having the clear advantage to win the FSD contract on their own. Also, had the program office pursued the teaming concept, there were other prime contractors who indicated that they wanted to be back in the running, and the strategy become overly complex. In addition, the baseline strategy had been to sustain competition throughout the program, if possible. The program office viewed teaming as making the FSD program a sole-source negotiating effort with both Validation Phase contractors, and likely to be unaffordable[74]. In retrospect, some members of the program office stated within interviews that if this approach had been affordable, and had Hughes and Raytheon management provided sufficient support, there would have been technological advantages to such teaming. Also, each contractor would have been dependent on the other for program progress and the technology transfusion effort both ways might have been preferable to the "one way street" in leader/follower. In any case, in the heat of the Validation Phase flight testing and competition for FSD, the atmosphere between the two contractors was not conducive to a teaming option.

On October 8, 1985, the Assistant Secretary of the Navy (Research, Engineering and Systems)[75] stated a policy that he thought would improve and strengthen the Navy's acquisition process. He wanted greater use of competition, increased contractor

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[74]The affordability issue of a teaming arrangement is certainly debatable, looking back over the program. The affordability logic at the time was that the Government would not be able to award an affordable contract that was negotiated in a sole-source environment, whereas a contract that was awarded competitively was much more likely to be affordable. The Air Force, Navy and OSD had all been "burned" by sole-source negotiations on other programs, and the baseline strategy was to maintain the pressures of competition through all phases of the program. In the end, Raytheon came up to speed as a design agent on the AMRAAM Producibility Enhancement Program (APREP) for some of the most sophisticated subsystems being produced at both contractors. However, once again, APREP was awarded competitively.

[75]Melvin R. Paisley was then the Assistant Secretary.

investment, and earlier use of fixed price contracts in the research and development cycle. He established that it would be Navy policy that there would be competition with a minimum of two contractors up until FSD, and that in FSD there would be a teaming arrangement throughout FSD. At the end of FSD, the two contractors would have the validated technical data package necessary to enter into a yearly competitive buy. Whereas this is directly the opposite direction from the Air Force policy on contract type[76], the teaming arrangement is very similar to the concept considered (and dismissed) for AMRAAM several years earlier.

4.3.7 Subsystem (Sub-tier) Competition

There were advocates for an option that would have looked to force competition at the sub-tier level as opposed to the prime contractor level. In the early 1980's, it was recognized that a large portion of the cost for a complex system came from the lower tier suppliers. Many people were concerned that, to have effective competition, you would have to force prime contractors to increase competition of the major subcontractors. In the early 1960's, the proportion of subcontracted effort that was reported to exist was approximately 50%[77], whereas by the early 1980's this proportion had grown to 60 to 75%[78]. The Office of the Secretary of Defense reacted to this trend by issuing a memorandum[79] in 1984 that outlined circumstances when competition at the subcontract level should be used. However, this guidance came after the implementation of the AMRAAM acquisition strategy, and was not a major influence on the program.

The memorandum listed circumstances when subcontract competition could be effectively employed:

- When a system contained high-price components. AMRAAM did.

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[76]The Air Force policy now strictly prohibits the use of fixed-price contracts in development.
[77]"Analysis of Extent of Competitive Procurement by DOD Prime Contractors," Logistics Management Institute, January 1964.
[78]"The Economics of Second Sourcing in the Aerospace Industry," Trainor Associates, Inc., April 1983.
[79]Deputy Secretary Defense Memorandum, "Increasing Subcontract Competition," 5 April 1984

- When quantities to be obtained would be sizable. AMRAAM was projected to require over 20,000.
- When the requirements for the item are expected to continue for a considerable period of time. AMRAAM's acquisition was anticipated to extend beyond 10 lots of production at the time. Now, a minimum of 16 lots are projected, and it is likely that the production will actually be continued for at least 20 lots.
- When it has been assured that the existing subcontractor possesses standard manufacturing techniques required for production of the item and no proprietary rights for the component being considered. The Government had acquired complete design disclosure and rights to data on the Hughes FSD contract. (However, Hughes had some difficulty in providing this contractual obligation. They contracted to provide these data with unlimited rights without soliciting prices from their subcontractors, or obtaining subcontractor agreement to sell the rights. This later became a significant issue in FSD.)
- When to do so would enhance the industrial base or mobilization capabilities, or when future requirements are expected to exceed planned subcontractor capability. There were obvious signs during the FSD program that selected subsystems were a bottleneck to the production rate on AMRAAM.
- When there is a problem, or a potential problem, in the performance of the major end item that can be attributed to the subcontracted end item. (Use of another subcontractor with better manufacturing capability or technical expertise could resolve the problem.) The AMRAAM development effort identified multiple subsystems that had marginal performance in the intense environment in which AMRAAM was required to operate. Also, certain subsystem contractors were found to be excellent developers, but had limited capabilities as producers on AMRAAM's required scale.

From this brief analysis, it should be clear that the characteristics of a program underwhich the 1984 OSD guidance advocated sub-tier competition existed on

AMRAAM. By this time the AMRAAM program was well into FSD and had the leader/follower strategy well underway. As such, the guidance was not viewed as an alternative to leader/follower, but as a complementary strategy that could be selectively employed. The AMRAAM Producibilty Enhancement Program, which is discussed in Section 8 of this thesis, fully exploited the expansion of vendor base competition as a means to reduce program costs and satisfy other objectives within the OSD guidance.

There also became extremists in advocating the sub-tier second sourcing strategy. Such groups as the DOD Inspector General organization thought that AMRAAM should breakout components of AMRAAM and provide them to the prime contractors as Government Furnished Equipment (GFE). AMRAAM formed a component breakout committee that looked seriously into this option in several areas. However, it was apparent that the value added from the system contractor management of these subcontractors far outweighed the cost advantages (which were very questionable, especially considering GFE risks and liabilities) that might have occurred with a component breakout strategy.

There are other programs that have been criticized by the Department of Defense Inspector General (DODIG) much more strongly for not using component breakout procedures. It happens that one program, the Phoenix missile system, is also being produced by Hughes, and Raytheon has been developed as the competitive second source. The DODIG released a report[80] that strongly criticized the Navy's plans to award a $483 million contract for 560 Phoenix missiles before Raytheon's missiles completed testing. Hughes had produced Phoenix on a sole-source basis since 1971. The Navy had wanted to introduce competition for some time, but yearly quantities had never warranted it. In any case, it appears that the DODIG is much more in favor of component breakout than all-up-round competition.

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[80]Defense News, "Audit Agency Blasts Navy Plans for 2nd Phoenix Contractor", dated 29 August 1988.

4.4 The Full-Scale Development (FSD) Solicitation and Source Selection

To preserve its options to allow for the leader/follower strategy, the Government informed industry that it reserved the right to award the second-source effort on the AMRAAM program to the unsuccessful Validation Phase contractor. The Government rationale was that a large investment would have been made by both the Government and the Validation Phase contractors to prove the concept and that this investment would have significant residual value during FSD and production. The Government did not commit to the Validation Phase contractors, however, that they were locked into be either the prime or second source by being selected as the Validation Phase contractors.[81] There was a concern that one or both of the contractors might "compete to be the follower" if the Government had made such a commitment[82].

4.4.1 Requirement for a Technology Transfer Plan

The FSD solicitation contained a section that required the contractors to propose how they would perform as a leader in the event they were selected as the FSD contractor. The solicitation was very specific in its requirement for a technology transfer plan (TTP) to be included in the contractor's proposal that would be made part of the contract and exercized at the Government's option. (This TTP requirement will be described later in this section.)

4.4.2 Requirement for an Associate Contractor Agreement

The AMRAAM leader/follower effort required that Hughes and Raytheon establish an associate contractor agreement that would establish the necessary

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[81]When issuing the Validation Phase solicitation, the Government reserved certain rights regarding the development of a second source producer of AMRAAM:
A. To compete the second source, "follower" role, or
B. To retain the unsuccessful offeror for FSD as the follower, or
C. To abandon the leader/follower concept.

[82]By "competing to be the follower", conservatives thought that either of the contractors might pursue a strategy that being in the follower role would provide direct insight into their major competitor's design and manufacturing process, and that the developer would bear all the risk of the program, while the follower would have limited to no risk.

understandings to transfer technical data and technologies between themselves and subcontractors to allow dual-source production of an identical end item to the lowest depot repairable level. Contractor-to-contractor relationships, activities, and communication were essential for leader/follower to be effective. This agreement was formalized on August 9, 1982, when both contractors signed the document. The agreement specified terms, conditions, period of applicability, and other critical understandings which were agreed to by Hughes, Raytheon, subcontractors, vendors and other necessary parties.

4.4.3 Rationale for Separation of the FSD Contractor and the Follower Selection Decisions

As previously discussed very briefly, the AMRAAM Joint System Program Office (JSPO) and the higher acquisition authorities had some degree of concern that the Validation Phase contractors, Hughes Aircraft Company and Raytheon Corporation, might find it to be an appropriate strategy to be the follower rather than the leader during the Full-Scale Development Phase. Although both companies had been very aggressive in both the Conceptual Phase and the Validation Phase, the argument that they might be less aggressive for the FSD phase took the following shape:

- The FSD solicitation required the contractor to fully develop and document the tactical design for AMRAAM on a very optimistic schedule that had been directed to the JSPO by higher headquarters. The technical risk for either contractor to develop the required missile system, without these schedule constraints, was assessed as low-to-moderate based on the Validation Phase results. However, the technical risk that either contractor could complete the required task within the dictated schedule was moderate-to-high. Therefore, there existed a cost risk to the FSD contractor that was driven primarily by this schedule risk. On the other hand, the follower had virtually no risk during the FSD phase because the follower's responsibility was limited to reviewing the leader's design and planning for production. Also, the follower contract

would be negotiated in a noncompetitive environment. In contrast, the competition for the FSD contract was likely to be very tough because the winner was assured the inside track for at least a piece of future Air Force and Navy air-to-air missile contracts.

- The FSD solicitation required the Validation contractors to pre-price two lots of initial production, which further extended the risk of the FSD contractor. From the Government's perspective, this was to help preclude a "buy-in" on the FSD contract by either offeror, and to ensure that realistic production cost estimates were provided in the FSD proposals. Although price escalation clauses were available that could remove some uncertainty of inflation rates, the pre-priced production options extended the contractor's liabilities 5 to 6 years from the date of contract award. This was further exacerbated by the use of a fixed-price type contract[83] for FSD.
- There were also Government discussions regarding the desire that either contractor might have to obtain insight into the design and manufacturing technologies that the other contractor would use on AMRAAM. The Government included the requirement for a complete reprocurement data package for an identical item to be delivered during the FSD contract and would be provided to the follower. Also, the follower would be allowed to participate in the design review process during FSD. These technologies

[83]A dilemma existed in determining the appropriate contract type. Contract type is usually driven by Government and contractor risk to perform contract requirements. Low risk efforts are generally "fixed price" contracts which bound the Government's liability; moderate to high risk efforts are generally "cost reimbursable" contracts which limit the contractor's exposure and unbound the Government's risk. Both Validation Contractors indicated to the Government that there was very little technical, cost or schedule risk to take their Validation Phase missile designs and complete Full-Scale Development. This might have been due to over-confidence, or simply aggressive marketing to ensure the Government would have confidence in their designs during source selection for FSD. At the higher levels of DOD acquisition authority, there had been experience that many aerospace contractors proposed lower than realistic costs during development, and had recovered costs through contract change orders later in the program. In any case, although the Government thought the risk was moderate, a fixed price contract vehicle was selected during the Government's acquisition strategy panel, consistent with the general mood within DOD during the late 1970's and early to mid-1980's. The DOD-wide practice of using fixed price-type contracts during development has since been halted by policy.

would be valuable not only on AMRAAM to the follower, but also on other programs that used similar technologies.

Because of this concern about the motivation either contractor might have to be the follower, the Government separated the decision process for selecting the second source from the FSD decision. Hughes was selected to be the FSD contractor based on a superior proposal for the AMRAAM system, as well as a strong commitment to bring on a second source as a follower. The Government placed the requirement for the FSD contractor to perform the role as leader as an option to the FSD contract.[84] This option allowed the FSD contract to be awarded in December 1981 prior to any commitment on the Government's part as to who would be the follower. This follower selection/decision process[85] occurred during April through June of 1982, allowing the follower to be brought on board in July 1982 prior to the Preliminary Design Review in the September/October 1982 timeframe.

The decision to select Raytheon as the follower after Hughes was selected as the FSD contractor was a carefully thought-through effort. This unilateral Government option had been established prior to the Validation Phase contracts, and thus was at the Government's discretion in a sole-source action without an open, industry-wide re-competition. The major reasons that Raytheon was selected to become the follower were as follows:

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[84]A fundamental issue with the leader/follower strategy was how to incentivize the leader. Obviously, the small fee that the leader would receive for transferring technology to the follower would never be equivalent to the loss in profits that a competitive second source would cause to the developer. The only incentives that were put into place were: 1) that the FSD contract proposals that were to be competitively evaluated were to include the contractor's plan for educating the second source; and 2) a recurring award fee criteria that was to be evaluated and communicated back to Hughes management directly. However, neither of these incentives were actually sufficient to modify the Hughes behavior toward performing as a more effective leader.

[85]On 27 March 1982, the Commander of the Air Force Systems Command endorsed the program office recommendation that Raytheon be selected as the follower. The Undersecretary of the Air Force for Acquisition and Logistics (SAF/AL) directed that the program office select Raytheon to be the follower in April 1982, concurrent with awarding the Leader option to the Hughes FSD contract.

- Raytheon had outstanding results during the Validation Phase. They had delivered more missiles and had provided significantly more flight test results to prove the AMRAAM concept than had Hughes during the Validation Phase. Their proposed FSD design was basically less risky than the Hughes design, but was deemed, in the aggregate, to have less longer term potential than the Hughes design. Raytheon also committed to the Government that if selected as the follower, they would give the Government complete rights to their Validation Phase design. In the Government's opinion, these Raytheon designs and technologies were very valuable in reducing the overall risk to the AMRAAM program[86].
- There was a desire on the Government's part to apply continuous pressure on Hughes to make the missile as producible as possible. The Navy brought up concerns over experiences they had previous encountered in which Hughes was unable to effectively transfer designs from the engineering team to the production floor.[87] Senior acquisition advisors suggested that a strong "production house" be selected as the second-source/follower to provide Hughes with motivation to become more effective as a producer. Raytheon had such a reputation as a strong producer.
- Raytheon work on other missile systems such as the Sidewinder and Sparrow was thought to be very related to the AMRAAM program. Hughes was not involved with either of these efforts.

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[86]Although the Government program office was very optimistic that the Raytheon technologies might reduce some of the technical risks contained within the Hughes-proposed FSD design, Hughes management told the Government that they were not interested in the Raytheon-generated designs. After many months and at the insistence of the Government, Hughes did receive a cursory overview briefing of the Raytheon designs, but stated that it was too late and too complicated to include any of these design features in their FSD efforts. As one Government program office person described, "If it was not invented at Hughes, it wasn't good enough."

[87]This concern was described as the "Cactus Curtain" between Hughes design operation in Conoga Park, California, and their production operation in Tucson, Arizona. The Navy's reference was probably related to the Phoenix missile program.

4.4.4 Follower FSD Tasks

The Government developed a clear set of expectations for Raytheon as the follower during FSD. They were as follows:

- To participate in the leader's design process as an observer, and to provide constructive input. This was to have the follower to become as familiar as possible with the design as well as the manufacturing processes related to the program. The follower was to monitor the qualification activities of the leader as well.[88] Raytheon had been selected as follower because of the excellent technical foundation they had established during the Validation Phase. It was thought that they could contribute this experience to the Government and Hughes during FSD and provide a broader engineering base to the technical challenges.[89]
- Warranty preparation: It was felt that the second source and the original source should compete on an equivalent, or nearly equivalent as possible, basis. The Government informed Raytheon that it would be required to sign up to the same level of warranty requirements as Hughes during competition. In fairness, the Government thought that Raytheon should be a close observer in the FSD program to enable the second source to accept performance responsibility and warranty requirements to be forthcoming in production.

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[88]Raytheon was expected to attend Hughes design reviews, selected production readiness reviews, interface control/configuration management meetings, test planning and test debriefing meetings, etc. Raytheon also received selected data items that the Government had identified as required in the Hughes FSD contract. Expectedly, despite clear intentions on the Government's part and Hughes promises within the FSD proposal, Raytheon's access to information was constrained to a great degree by Hughes. On occasion, Raytheon personnel would arrive at a Hughes hosted meeting and find that their security clearances had not been processed at Hughes, and were denied or delayed access. In other areas, Hughes would either not send Raytheon contractually required documents, or would mark documentation with restrictions that would not allow Raytheon to use the documents as intended. These efforts were deliberate actions on Hughes' part to impede the Government's plans to bring on the Follower.

[89] There was another motive on the Government's part. There were thoughts in the Secretariats of the Air Force and Navy that Hughes might attempt to walk away from the FSD program if they were not able to technically or financially complete the program that they had competitively proposed, and the Government were to enforce the fixed-price contract provisions. In this unlikely but possible scenario, the Government desired a second contractor that could "pick up the pieces" at whatever stage this were to occur and carry the program further with minimized delay.

- Raytheon was to be used to validate the technical data package during its incremental delivery during FSD.
- Raytheon was to prepare for production by extensive planning, and would submit this planning to the Government for approval.
- Raytheon was required to become as familiar with AMRAAM hardware, software, and factory test equipment as possible. Hughes provided two guided test vehicles to Raytheon for disassembly, analysis, reassembly and test. Hughes also provided Final Assembly and Checkout test equipment for Raytheon to learn how to operate.
- Raytheon was also to attend training sessions on missile manufacture provided by Hughes.

In summary, Raytheon was to learn the AMRAAM design and to prepare to produce the missile almost simultaneously with Hughes during initial production.

4.4.5 Leader Full-Scale Development (FSD) tasks

Leader FSD tasks were generally outlined in the solicitation for FSD and included providing the technical data, technical assistance/training, hardware, software, and access to program reviews and planning that was necessary for the second source to come up to speed quickly. Hughes and Raytheon were each requested to describe in their competitive proposal how they would transfer the necessary technology to allow a follower to manufacture a missile that was identical to the lowest depot repairable level. The competitors for FSD were also informed in the FSD solicitation that the Preliminary Technology Transfer Plan[90] they submitted as part of their proposal would be placed on contract as an optional line item that the Government could exercize after a follower were selected. The technology transfer plan (TTP) was termed "preliminary" until it could be jointly updated by Hughes and the follower contractor. This was to occur after the leader option was exercized and the follower contract were awarded. Both the leader and the

[90]Perhaps one of the most comprehensive descriptors of the necessary activities to execute an effective leader/follower program is the unique Data Item Description UP-374-YM that was attached to the FSD solicitation and later the Hughes FSD contract FO8635-81-C-0001.

follower contractors were required to sign the TTP. The major elements of the TTP were as follows:

- Purpose: An introduction into the purpose of the technology transfer. It was thought to be very important that all parties agree to the reasons for which the technologies were being transferred from one prime contractor to another.
- Overview: An overview of all the related contractual relationships that were effected by the TTP.
- Missile System Description: A system description of the missile and its subsystems being second-sourced.
- Leader Make or Buy Plan: A detailed, time-phased Leader Make or Buy Plan for development, initial production and full production.
- Follower Make or Buy Plan: A detailed, time-phased Follower Make or Buy Plan for development, initial production, and full production. (This section was added after the second source was selected and contract awarded.)
- Schedules: Detailed schedule information on the leader's FSD program including contract award dates, design reviews, functional and physical configuration audits, production readiness reviews, long lead releases, test schedules, data item delivery dates, etc. After the follower was selected, the equivalent schedule information was required on the follower activities.
- Leader/Follower Organization: Leader organization including required areas of expertise and relationship to the basic design team necessary to support the leader/follower activities. Also, the corresponding follower organization necessary to perform required tasks to prepare for production and to provide the leader constructive feedback on the design and producibility of the missile.
- Leader Tasks: A listing and description of all leader tasks necessary to teach the follower manufacturing, test, failure analysis, support, and other required expertise. This section also described a leader conducted training program for the follower,

where and when facilities, hardware and test equipment would be provided to the follower, etc. This section described, for example, that the leader would give the follower 2 guided test vehicles for the follower to study, a final assembly and check-out station for test completed missiles, and other hardware and technical data.

- Follower Tasks: Description of all the tasks the follower would need to perform to become qualified to compete on and contribute to the missile production effort: Learning activities, verification of data, producibility, production planning, and cost reduction planning.
- Configuration Management responsibilities of the leader and the follower.
- Logistics Planning: Logistics impact of two sources, levels of interchangeability, depot repair requirements, identification, etc.
- Data List: All data to be delivered to the Government and /or the follower to efficiently develop and assess the readiness of the follower. Also a list of any data not releasable to the follower.
- Associate Contractor Agreement: Terms, conditions, periods of applicability, etc. between the leader and the follower.

4.5 Planned Follower Qualification Schedule

The following schedule shows how the Government in 1985 envisioned the follower to be qualified. Notice that the effort was concurrent with the completion of Hughes FSD program to allow Raytheon to participate in initial production on a schedule roughly equivalent to Hughes. Also, you can observe the fact that the special test equipment efforts were contracted for separately from the qualification lot.

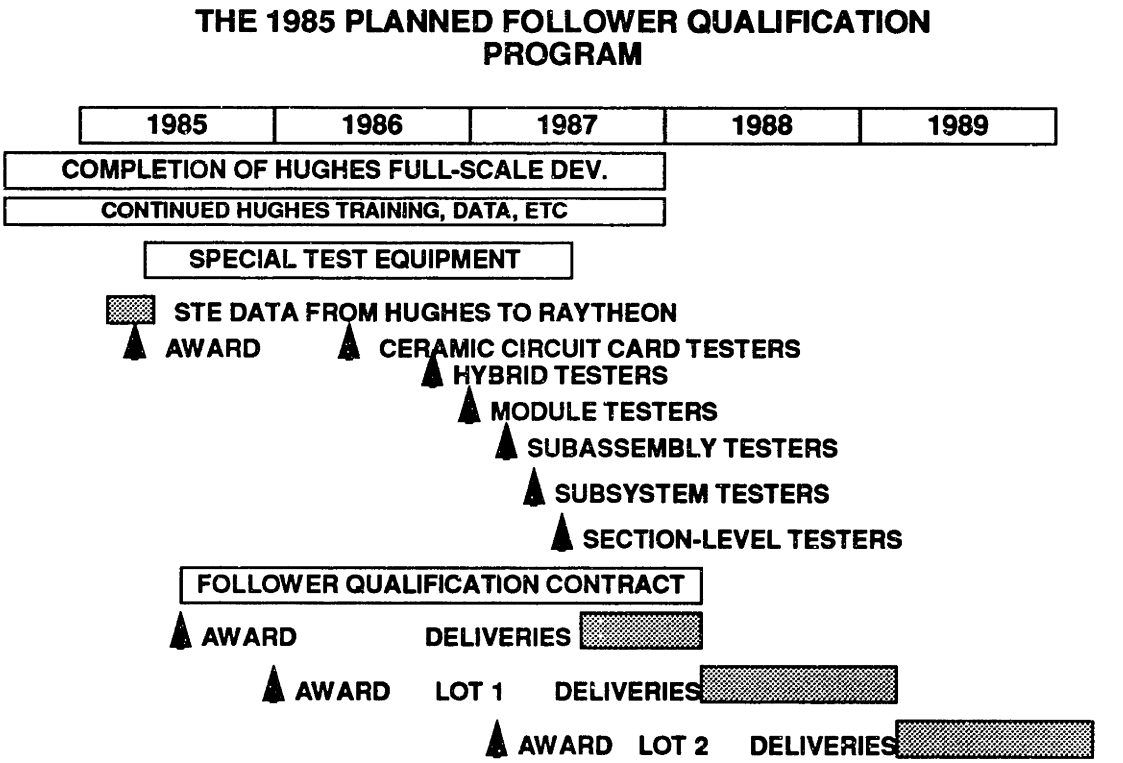

Figure 4.4

The actual execution of the special test equipment and qualification lot contracts are discussed in Sections 4.6 and 4.7, respectively. The efforts were completed, but behind this schedule. (Remember that Hughes did not finish flight testing the last FSD missile until January 1989. Therefore, the entire program schedule was translated to the right.) Raytheon's qualification effort completion was likewise delayed until the end of 1989.

4.6 Special Tooling and Special Test Equipment (ST and STE)

Acquisition of the ST and STE[91] required by Raytheon as the follower and eventual competitive second source was broken into four segments:

- Final assembly and check-out (FACO) test equipment
- Chassis-level and above ST/STE,
- Below-chassis level ST/STE, and
- Data/verification hardware to ensure appropriate commonality of Hughes and Raytheon test capabilities.

The first two categories, FACO test stations as well as the chassis-level and above ST/STE, were required to be identical at both the Leader and Follower production facilities to provide confidence that the performance standards of each contractor's missile subsystems were equivalent. In contrast, the below-chassis level STE was designed and manufactured by Raytheon from Hughes developed Acceptance Requirements Documents. This allowed Raytheon to tailor the below-chassis level testing to Hughes-provided verification hardware that was used to verify the proper operation of Raytheon manufactured STE.

The chassis level and above STE was originally to have been provided to the Follower through a prepriced option on Hughes FSD contract for approximately $19M. When the Government failed to exercise the option within the time provided for in the contract[92], Hughes submitted a new estimate ($42M) that more than doubled their prepriced option. The Government requested and Raytheon provided an informal estimate to the Government for $20M for the chassis level and above test equipment, which was closely in line with previous Hughes prepriced option. The Government secured

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[91]For definitions of what constitutes special tooling and special test equipment, refer to the Federal Acquisition Regulation (FAR) Sections 52.245-17 and 52.245-18.

[92]The Government did not exercize the STE option on the contract because Hughes was significantly behind schedule and had not performed many critical verifications of the ST/STE designs when the calendar date of the option expired.

accelerated delivery of STE drawings[93] from Hughes to provide to Raytheon to determine the feasibility of competing the identical chassis level and above STE between the Leader and Follower. Raytheon responded positively as to their ability to build the STE and willingness to compete. The decision was made to compete the identical chassis level and above STE. This competition took place and resulted in an award to Raytheon of approximately $11.5 million, compared with the Hughes sole-source estimate of $42 million[94]. This was the first verification on the AMRAAM program that competition would be worthwhile.

Contractor-unique below chassis level STE for the follower was a sole source acquisition to Raytheon for $45.6 million. By requiring Raytheon to design and manufacture their own below chassis level STE, the Government was able to obtain optimum use of the existing Raytheon facilities, test equipment, and unique manufacturing processes.

The hardware to be used for the verification of STE operation was provided by Hughes under the FSD contract [95]. This FSD contract also required Hughes, per their technology transfer plan, to respond to Raytheon interface memoranda, to transfer STE drawings, to provide FACO test stations (and upgrade kits as appropriate) to support the competitive (chassis level and above) and sole-source (Raytheon unique below chassis) STE acquisitions.

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[93]This "acceleration" of data was relative to Hughes existing plans at the time. Per the basic FSD contract, the drawings were already deliverable.
[94]The Hughes competitive bid was significantly lower than the $42 million sole-source estimate, but was continued to be much higher than the Raytheon bid.
[95]F08635-82-C-0001

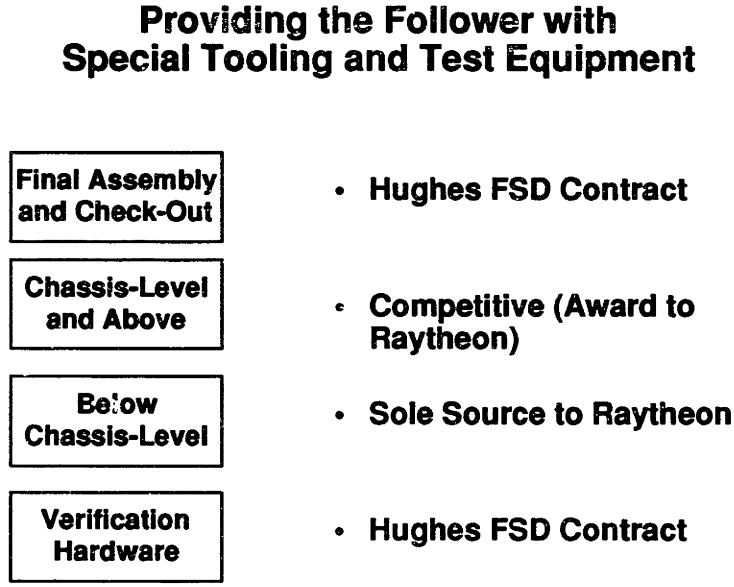

Figure 4.5

A typical issue that the program faced when trying to establish a second source on AMRAAM is exemplified by inconsistencies/discontinuities of funding policies with other acquisition initiatives. Whereas there existed clear guidance and direction to establish competitive sources when effective, funding of the development of second sources was not as straight-forward. As part of the FSD and subsequent production contracts, the Air Force had funded all special tooling and test equipment that Hughes had needed through the third lot of production. Raytheon's factory was continuing to be equipped. In February, 1988, the AMRAAM JSPO received a letter from the Assistant Secretary of the Air Force for Acquisition regarding funding policies for peculiar special tooling and test equipment. The Fiscal Year 1988 law on PST/PSTE was modified from the FY87 law[96]. A complex funding arrangement was required because Hughes, as the leader, had acquired their PS/PSTE under the prior law (FY87) which permitted (actually called for) full Government funding for such tooling and test equipment. Raytheon's PST/PSTE was being acquired a year or so behind Hughes and fell under the new law (FY88) and could be funded only to the 50% level. Obviously the playing field was not going to be level for

[96]Referring to FY87 and FY88 Appropriations Acts. For solicitations being released after April 2, 1988, the FY88 law applied.

the two competitors, and the Assistant Secretary interceded to authorize equivalent funding arrangements for both contractors. This issue is described to show a couple of points:

- High level management with the Air Force had to become involved (and did) to resolve potential conflicts in policy conflicts.
- Much attention on the Government's part was directed to pushing through "unplowed policy territory" in the development of second sources.

The funding required for follower ST/STE is shown in Table 4.1:

Table 4.1
Funding for Follower
Special Tooling and Special Test Equipment

Type of ST/STE	Source and Cost
Final Assembly and Check-Out Station	Within Hughes FSD Contract Price
Chassis-Level and Above ST/STE	$11.5 Million (FPIF)[97]
Below Chassis Level ST/STE	$45.6 Million (FPIF)
Verification Hardware and Data	Within Hughes FSD Contract Price

4.7 Raytheon Qualification Lot

To provide Raytheon the opportunity to build actual missiles and to allow the Government the opportunity to verify Raytheon's capability to build AMRAAM, a qualification lot was awarded to Raytheon in November, 1985. In this effort, Raytheon went on to produce and test fifteen qualification missiles that were delivered between July 1988 and January 1989. The major goal of this effort was to qualify Raytheon as a second-source producer prior to Lot 3. During the Qualification Lot, Raytheon was directed to use the vendor base established by Hughes for critical items. The

[97]Fixed Price Incentive Firm (FPIF) is a fixed price contract with a target and a ceiling price. Target prices are shown. For any amount the contract exceeds the target price, the contractors fee is reduced by a share ratio with the Government. When the contract value reaches ceiling, the Government has fully funded its responsibility and the contractor is required to pay for further overruns.

Qualification Lot allowed the Government to accomplish several key steps toward establishing a second source:

- It qualified Raytheon as a producer of AMRAAM. Missiles manufactured by Raytheon were subjected to both ground environmental and flight testing.
- It provided an atmosphere of pending competition to Hughes, and a second basis of actual factory assembly experience with which the Government could develop appropriate cost estimates for negotiations and budgetary purposes.
- It identified and corrected many areas of the technical data package that needed improvement.
- It provided confidence to the program office and the higher headquarters that the missile was producible by other than a Hughes engineering-strong organization. (This became a significant item of interest to the Defense Systems Acquisition Review Council in approving the program for further phases of production.)
- It provided another vantage point to suggest producibility improvements to the missile design.
- It established an effective 3-party (Government/Hughes/Raytheon) configuration management and control system on the missile.

The Raytheon Qualification Lot was not without significant hurdles. First, it became very clear that Hughes was not providing the same technical data to Raytheon from which they were manufacturing missiles. There were probably multiple reasons. First, Hughes was having continuing problems delivering missiles to the Government that could have been considered of the required tactical fidelity. Selected subsystems took much longer to develop than Hughes had planned. Second, it was obvious that Hughes was protecting its competitive advantage as long as possible. Hughes established a Leader/Follower management organization to carefully control and delay as long as possible the release of information to Raytheon.

This tactic was successful to a large extent. The Government understood the need for Hughes to concentrate on the FSD problems, and therefore kept the leader/follower task as a second-level issue. Many elements of the Hughes FSD proposal went by the way side that would have facilitated bringing on a follower. For example, Hughes committed to investigate the use of electronic media to transfer drawings. Hughes performed a cursory study that said it was not feasible, and paced transfer of paper copies to Raytheon over many years[98]. Hughes also refused to provide selected data that was generated under the FSD contract that would have made bringing on the second source much less expensive. This effort had to be reaccomplished by Raytheon at the Government's expense. In any case, Raytheon probably became a stronger competitor by Hughes forcing the Government to underwrite reaccomplishment of many of these tasks.

[98]Finally, Hughes now (in 1994) has a contract obligation to transfer engineering data electronically. It is ironic to note that Raytheon is now being obstinate in providing equivalent data to Hughes.

4.8 The Theoretical Basis for Production Competition

Many studies have been accomplished to analyze the cost effectiveness and theoretical basis for using competitive strategies in the acquisition of weapon systems. As part of the Joint System Program Office's (JSPO's) attempt to select the optimal strategy, they examined programs from all 3 major services and previous efforts to model what might be expected in the competitive versus the sole-source environment. This section provides insight into the theory and special considerations the AMRAAM JSPO used to select and obtain approval of their leader/follower concept. The following discussion will start with the very basics of competition and will discuss predictions and results of AMRAAM and other programs.

4.8.1 Basic Cost Improvement Curve Theory

The most effective and rigorous studies of competition have been based on the theories of cost improvement curves, or learning curves.[99] The concept is quite simple. A cost improvement curve describes the relationship between the unit cost of any production product and the cumulative quantity that has been produced. The curves are usually described by the percentage an item will cost when the cumulative quantities have doubled. For example, an "80% learning curve" would describe a product whose price would be reduced by 20% every time the quantities of the item were doubled. Mathematically, the cost of the 2^{Nth} unit is 20% less than the cost of the Nth unit.

There is a standard method for displaying a cost improvement curve. A graph typically plots unit cost on the vertical axis and quantity on the horizontal as follows:

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[99]Throughout this discussion, the terms "cost improvement curve" and "learning curve" will be used interchangeably as is the most common practice in cost analysis. However, a few sources differentiate between the two curves. Most simply stated, the phrase "learning curve" came from an original theory that the amount of recurring labor hours that were needed to produce an item on a manufacturing line would decrease over time as assemblers became more adept in the operations. Learning curve theory originally held constant, or did not address, other elements of the factory environment such as production tooling and the degree of automation. The "cost improvement curve" theory is a more current expansion of the original "learning curve" theory and takes these and other factors as inputs to cost improvement in addition to labor.

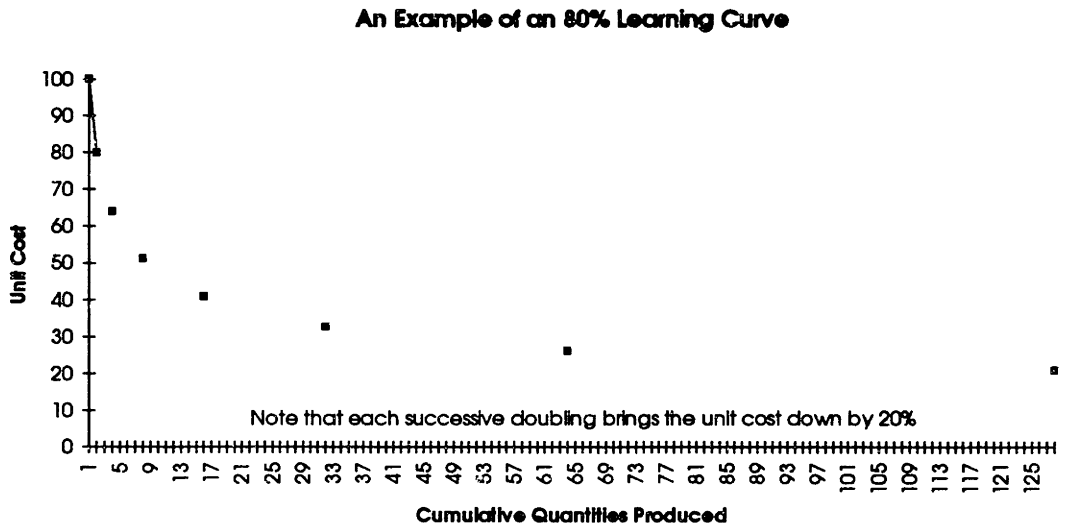

Figure 4.6

This curve shows the recurring cost of each unit of production as a function of the cumulative quantity produced up to that unit. The area underneath the curve traced by the dots is the total recurring production cost of the production. Typically, you see this curve displayed on logarithmic scales because the curve will then become a straight line.

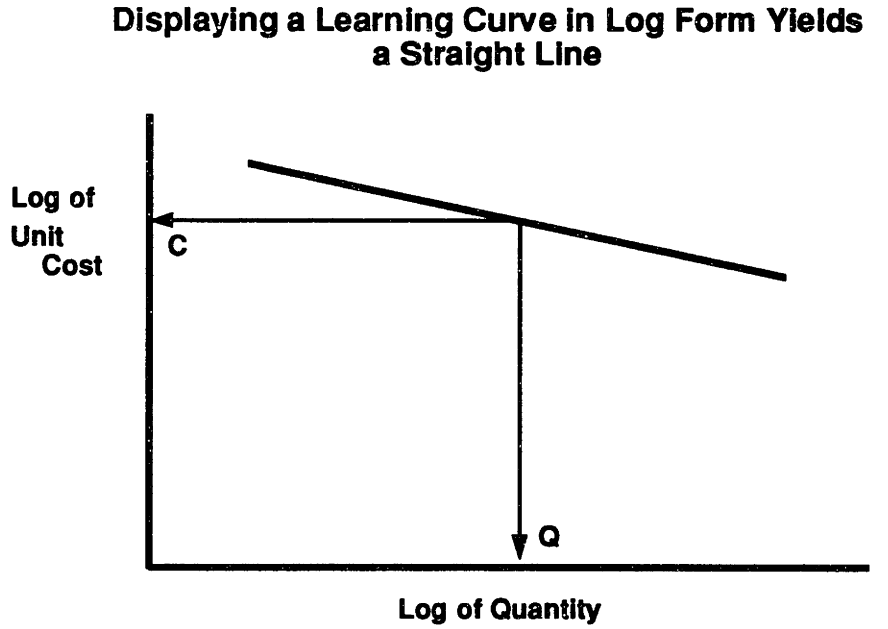

Figure 4.7

The theory leads us to a dilemma. It can be seen in Figure 4.6 that if we give one manufacturer 64 units to produce, we will have a last unit cost of $26.21. If we were to divide the quantity and give two sources 32 units each to produce, we would have a unit price from each contractor of $32.77. Thus the dilemma: How can going to two sources ever be as economical as giving twice the quantities to one source? It appears from basic learning curve theory that the recurring sole-source price would be 20% less than the dual-source price.

All that has been discussed to this point has been the recurring missile production costs. We must also consider the non-recurring costs associated with establishing a second source such as factory tooling and test equipment, training, etc. These non-recurring costs would also tend to dissuade us from wanting to have two rather than one production source.

4.8.2 Effects of Competition on the Learning Curve

What must be done to learning curve theory is to adjust the model to account for the effects of competition. That is precisely what the AMRAAM program office attempted to do. The Analytical Sciences Corporation (TASC) of Arlington, Virginia, was hired to support the JSPO's efforts to model the phenomena surrounding competition.[100] The JSPO and TASC were able to isolate two distinct effects that the introduction of competition had on the learning curve. The first of these was a downward "shift" in the learning curve caused by the contractor being forced by competition to reduce his cost and profit rate. The other effect was that an increase in the learning rate (slope of the learning curve) increased with competition. TASC was able to isolate these two effects on multiple competitive production programs. The average shift was 12.5% and the average rotation was 11.0%. Looking at this graphically:

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[100]Contract Number FO8635-80-C-0137, Completed October 20, 1980.

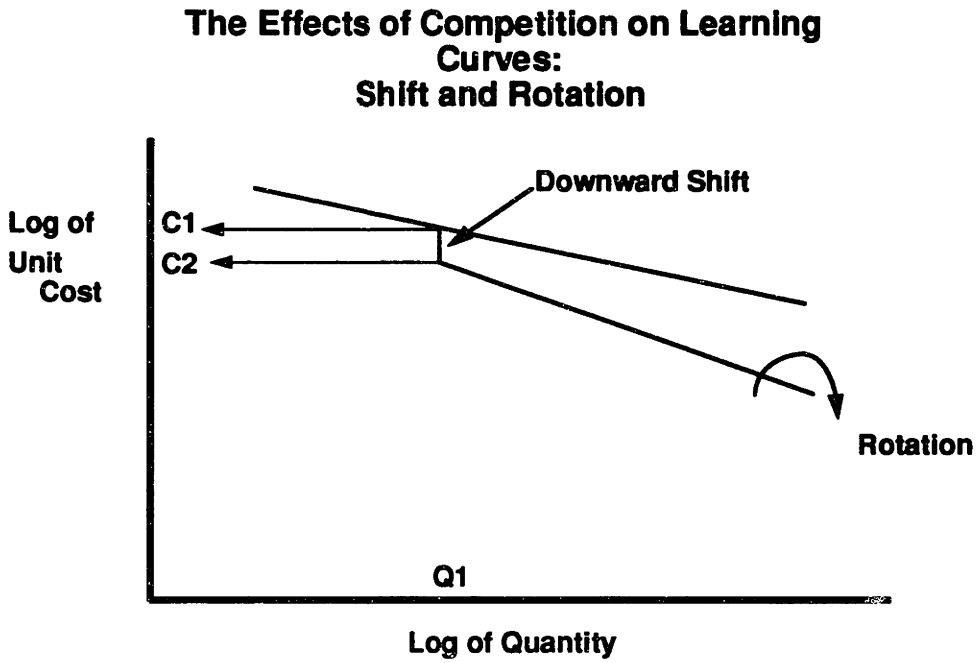

Figure 4.8

Notice that the shift drops the instantaneous price from C1 to C2 as a one-time reduction in the contractor's cost and profit. The longer term effect, however, is the rotation of the learning curve that will continue to reduce costs relative to the sole source curve as long as competition applies pressure.

Based on the six weapon system cases that were studied by TASC for the AMRAAM JSPO, this theory was used to explain and model what the JSPO should expect on AMRAAM with various second-sourcing strategies.

4.8.3 Original Learning Curve Data- Circa World War II

Frederick Scherer looked at 12 bomber programs in World War II and was able to see a defined rotation of learning curves after the introduction of competition.[101] His data showed 4.4% on the average, which is less than what has been observed with modern system acquisitions. More than likely, the competitive environment faced by contractors during World War II was not as intense as today's competitive environment. Mr. Scherer's results were as follows:

Table 4.2

Improved Learning Curves for World War II Bombers

Aircraft	Company	Learning Curve %
B-17	Boeing (Seattle)	73.7
B-17	Douglas	73.9
B-17	Lockheed	70.1
B-24	Convair	78.0
B-24	North American	73.2
B-24	Ford	69.8
B-24 E&H	Convair	77.5
B-24 E&H	Douglas	72.1
B-29	Boeing (Wichita)	66.7
B-29	Boeing (Renton)	78.9
B-29	Martin	77.3
B-29	Bell	74.6
	Average for all sources:	**77%**
	Average for competitive sources:	**73.8%**

[101]Frederick Scherer, The Weapons Acquisition Process: Economic Incentives

4.8.4 AMRAAM Program Office Directed Studies

TASC was directed by the AMRAAM program office to review the single source data from 35 programs to obtain realistic expectations of the learning curve slopes in a non-competitive environment.

Table 4.3

Single Source Learning Rate for Various Programs

TOW LAUNCHER	93.0%	RADAR INDICATOR	72.7%
FAAR RADAR	88.0	USM-181 TELEPHONE TEST SET	82.1
FAAR TADDS	88.0	FGC-20 TELETYPE	97.0
AN/ARC-131 RADIO	99.0	MD-522 MODULATOR	85.9
UPM-98 TEST SET	85.0	MK-117 750 POUND BOMB	90.0
PP4763/GRC POWER SUPPLY	95.0	CV-1548 SIGNAL CONVERTER	82.7
HAWK MOTOR METAL PARTS	87.4	SIDEWINDER AIM-9D/G MISSILE*	92.0
TD-204 CABLE COMBINER	86.6	SIDEWINDER AIM-9B MISSILE*	83.0
TD-202 RADIO COMBINER	82.8	SPARROW AIM-7F MISSILE*	87.0
TD-352 MULTIPEXER	95.8	HARPOON MISSILE*	92.0
TD-660 MULTIPEXER	70.8	SHILLELAGH MISSILE*	89.5
60-6402 ELECTRIC CONTROL	95.7	TALOS MISSILE*	93.3
MK-48 TORPEDO WARHEAD	88.8	BULLPUP 12B MISSILE*	81.0
MK-48 TORPEDO ELECTRICAL ASSEMBLY	80.6	**AVERAGE FOR 35 PROGRAMS:**	**88%**
SPA-66 RADAR INDICATOR	95.4	**AVERAGE FOR 7 MISSILE PROGRAMS:**	**88%**
ROCKEYE BOMB	82.0		
APX-72 AIRBORNE TRANSPONDER	80.5		
AN-ARC-54	92.4		
AN-PRC-77 RADIO	85.6		
AN/GRC-106	84.0		
AN/GRC-103	90.4		
AN/APM-123	96.9		

The average for these 35 programs was 88%, with individual curves ranging from 70.8 to 99 percent. When these programs were necked down to missile systems, the average was shown to be 88% as shown in Table 4.3. The data in this table provided excellent insight for the JSPO into the general behavior and level of learning that might be expected in a sole source environment. The JSPO also obtained data on programs that had gone into competition, some after many years of sole-source, and asked TASC to model the cost improvement rate for these programs. Table 4.2 shows the results:

Table 4.4

Multiple Source Cost Improvement after Competition

MISSILE PROGRAM	CONTRACTOR	COST IMPROVEMENT RATE
TOW	HUGHES (DEVELOPER)	87%
SHILLELAGH	PHILCO-FORD (LEADER)	85%
DRAGON	McDONNELL DOUGLAS (LEADER)	86%
SPARROW AIM-7F	RAYTHEON (DEVELOPER)	78%
	GENERAL DYNAMICS (2ND SOURCE)	72%
BULLPUP	MARTIN MARIETTA (DEVELOPER)	74%
SIDEWINDER AIM-9B	GENERAL ELECTRIC (CO-DEVELOPER)	69%
	AVERAGE:	**79%**

One other important piece of data that was derived from the program set studied was the savings that were probably accrued by each program based on the required levels of investment to establish a competitive second source and the observed changes to the cost improvement curves after competition:

Table 4.5

Calculated Savings from

Competing Previously Single Source Contracts

TOW LAUNCHER	30.2%	SPA-25 RADAR INDICATOR	10.7%
FAAR RADAR	16.6	USM-181 TELEPHONE TEST SET	36.3
FAAR TADDS	18.2	FGC-20 TELETYPE	39.9
AN/ARC-131 RADIO	-16.1	MD-522 MODULATOR	51.9
UPM-98 TEST SET	11.5	DRAGON TRACKER	12.3
PP4763/GRC POWER SUPPLY	0.5	CV-1548 SIGNAL CONVERTER	45.4
HAWK MOTOR METAL PARTS	49.9	SIDEWINDER AIM-9D/G MISSILE*	.7
TD-204 CABLE COMBINER	42.0	SIDEWINDER AIM-9B MISSILE*	-5.6
TD-202 RADIO COMBINER	40.2	DRAGON MISSILE*	2.8
TD-352 MULTIPEXER	55.6	TOW MISSILE*	12.3
TD-660 MULTIPEXER	28.4	SHILLELAGH MISSILE*	9.4
60-6402 ELECTRIC CONTROL	52.7	TALOS MISSILE*	39.8
MK-48 TORPEDO WARHEAD	48.6	BULLPUP 12B MISSILE*	81.0
MK-48 TORPEDO ELECTRICAL ASSEMBLY	47.0	STANDARD MISSILE MR RIM 66A	59.2
SPA-66 RADAR INDICATOR	-3.4	STANDARD MISSILE ER RIM 67A	34.0
ROCKEYE BOMB	-4.5	**AVERAGE FOR ALL PROGRAMS:**	**33%**
APX-72 AIRBORNE TRANSPONDER	23.3	**AVERAGE FOR MISSILE PROGRAMS*:**	**20%**
AN-ARC-54	63.1		
AN-PRC-77 RADIO	41.9		
AN/GRC-106	41.8		
AN/GRC-103	60.1		
AN/APM-123	0.0		

4.8.4 Decision Tree Analysis of Second Sourcing Alternatives

The preceding data allowed the JSPO and TASC to input different expected values of cost improvement rates for various alternatives. The alternatives that were considered were structured into a decision tree that represented several strategy issues. These issues were:

- Single source production versus multiple source production
- Optimal second sourcing method
- Scope of second source award
- Timing of second source award
- Selection of the second source
- Design management and enhancement

The decision tree was helpful in developing, evaluating, and explaining various alternative strategies. A simplified breakdown of the thought process is shown in the following figure:

Alternative Acquisition Strategies Analyzed by the JSPO

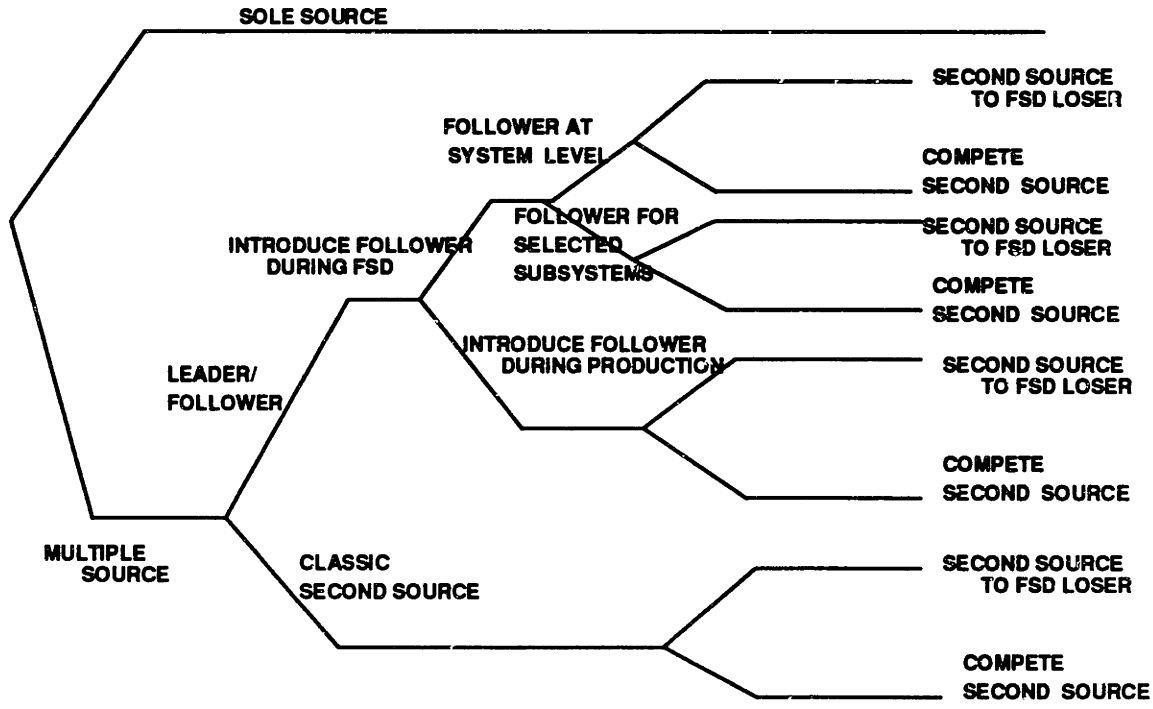

Figure 4.9

Some explanation of where the program was in the 1980 timeframe when these alternatives were developed is appropriate. Recall that the 5 contractors from the Conceptual Phase had been down-selected to 2 contractors for the Validation Phase by the end of 1978. Full-Scale Development was coming up at the end of 1981. Obviously, the most fundamental decision for the AMRAAM Program Director was whether or not to have a second source on the program. Next, if the program director were to elect to have multiple sources, how should the director go about introducing the second source: leader/follower or a classic second sourcing method? If director went to a leader/follower approach (described elsewhere in Section 4), should the director develop a second source for the entire system, or only select the cost driving subsystems for second sourcing?

Both single source and multiple source procurement methods had associated costs and benefits that required significant cost analysis which was conducted to make a relative judgment on cost effectiveness. The first cost improvement curve assumptions used during the analysis were very nominal: 89% initial cost improvement rate for a single source, a leader, or a follower prior to competition. At competition, the leader's and the follower's curves were shifted 12% and rotated 5% (compared to an average observation of 12.5% and 11%, respectively).[102] The analysis then included an extensive variance analysis of all the critical inputs that drove the relative cost effectiveness such as the slope and shifts of learning curves, investment costs, timing of competition, etc. These are some of the results:

- Analysis showed that **multi-source strategies were preferable over the sole source strategy** with the expected level of investment required to bring on the second source and the likely impact on the sole-source learning rate that had been observed very consistently on other missile programs.
- The analysis also showed that **a leader /follower approach was superior** on systems as complex as AMRAAM over classical second sourcing methods.
- **The Follower should be introduced as early in production as possible to maximize savings.** There were other benefits that were identified such as technical data package verification that were known to be valuable to the Government with the early introduction of a second source.
- Due to the large investment in the Validation Phase by both the Government and the contractors, there were **technical and cost benefits to be achieved by the direct award of a second source contract early in FSD** to the Validation Phase contractor not selected for FSD.

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[102]The reasons for selecting low nominal values were twofold. First of all, it was important to be conservative when predicting cost savings. Secondly, it was uncertain how highly capitalized and automated the two contractors might have been when competition was introduced.

4.8.5 Other Second Sourcing Efforts Observed by the AMRAAM JSPO

Other studies that were conducted within the Department of Defense were also monitored very closely by the AMRAAM program office. For example, the Tomahawk Cruise Missile Dual Source Technology Agreement provided for approximately 36 months of exchange of technology between General Dynamics (Convair) and McDonnell Douglas Astronautics. These two contractors were dependent on each other with General Dynamics designing the airframe and McDonnell designing the guidance system. In this way, the two contractors were required to work together to execute the program, and were more likely to be cooperative than the situation that AMRAAM had to work through with one design agent and a follower. Rear Admiral Walter Locke was the director of the Joint Cruise Missile Office and had much previous experience in running competitive programs.[103]

The AIM-7 Sparrow program was extensively studied during the 1981 and 1982 timeframe by many sources. Probably the most extensive was done by Science Applications, Inc. for the Naval Material Command in which they summarized their findings related to the procurement of missiles by dual source competition.[104] Their findings reaffirmed previous AMRAAM efforts in the same area. They also briefly addressed the effects of production rate on system cost, which was another important consideration. SAI's work also confirmed Army Studies into the effect of production rate.[105] There were also refinements studied by the AMRAAM program office regarding how to effectively conduct a competition once two sources were established. An example they followed closely was an Army procurement technique on the Night Vision Goggle program in which careful analysis was used to maintain an industrial mobilization base

[103]Major Donald G. Alducin and James S. Hooker, "Industry and Government Can Jointly Restore US Defense Industrial Base", Military Electronics/Countermeasures, March, 1983

[104]Michael N. Beltramo and David W. Jordan, A Brief Review of Theory, Analytical Methodology, Data and Studies Related to Dual Source Competition in the Procurement of Weapon Systems, August 27, 1982

[105]John C. Bemis, Production Rate as an Affordability Issue, DOD Product Engineering Services Office, Alexandria, Virginia, undated; and, "A Model for Examining the Cost Implications of Production Rate", Concepts, The Journal of Defense Systems Acquisition Management, Volume 4, Number 2, Spring 1981.

with two competitive sources.[106] This technique had the percentage of total procurement for award to each manufacturer as a variable depending on the prices proposed.

4.8.6 Continued Maintenance of AMRAAM's Production Model

AMRAAM maintained the cost improvement model they had developed with The Analytic Sciences Corp. throughout the mid-1980's. The largest change to the model was the incorporation of the impact of changing the production rate as a major variable that must be considered in addition to basic cost improvement theory to reasonably evaluate alternative acquisition strategies.[107]

These models have been reviewed and refined by Government cost analysts and have effectively convinced and satisfied the Office of the Secretary of Defense Comptroller organization and Congressional staffers that the AMRAAM JSPO has an excellent model of their acquisition alternatives.

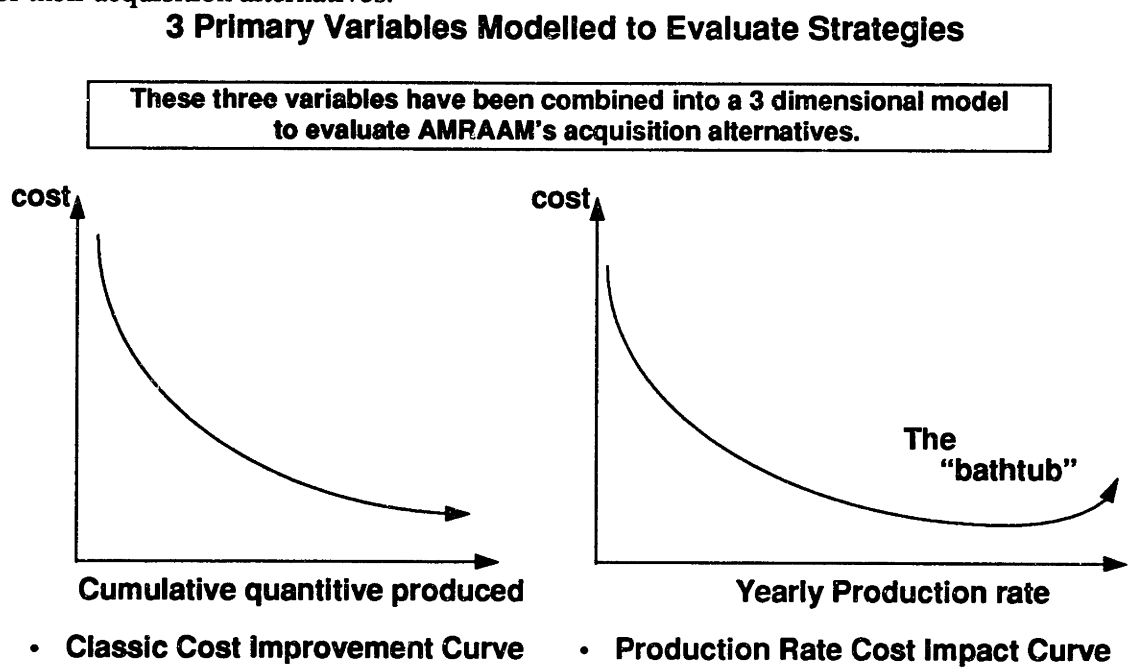

Figure 4.10

[106]Kenneth S. Solinsky, A Procurement Strategy for Achieving Effective Competition while Preserving an Industrial Mobilization Base, US Army Electronics Research and Development Command, undated

[107]Lou Kratz and Larry Cox, The AMRAAM/TASC Cost Improvement and Production Curve Model, February 5, 1982

This figure shows the effects on cost with variation in quantities and the effects on cost with variation in production rates. Low production rates are as not economical, generally, as operating at a higher, more efficient rates that are consistent with capital equipment design and available manpower. The efficient range of production rates are at the flatter area at the bottom of the "bathtub". At some point, production rate can become too high and over-stress factory equipment, as well as skilled labor. (For example, working machinery and test equipment 24 hours a day with no "downtime" for maintenance, or working people for extended periods without sufficient breaks, vacations etc.)

4.9 Summary of AMRAAM Second Source Investments and Benefits

Table 4.6
The Investments in and Benefits from AMRAAM's Second Source

Program Phase	Activity	Investment&Benefit
Full-Scale Development	Hughes Leader Support	Cost- $6.9 million option
	Raytheon FSD Follower Contract	Cost- $17.0 million
Follower Qualification	Raytheon Qual. Contract	Cost- $85.8 million
	Hughes Technical Assistance/Support	Cost- included in FSD and Lot 1
Follower Special Tooling and Test Equipment	Final Assembly and Check-Out Station (HAC)	Cost- $2.1 million
	Chassis Level and Above Contract (Ray)	Cost- $15.4 million - also benefit (Sect 4.10)
	Below Chassis Level STE Contract (Ray)	Cost- $49.0 million
Initial Production	Hughes Lot 1 Technical Assistance to Raytheon	Cost- $1.4 million (Hughes Lot 1 Contract)
	Captive Carry Reliability Program	Benefit - See Section 4.10
	Hughes Lot 2/3 Technical Assistance to Raytheon	Cost- $1.3 million (Ray. Lot 2&3 Contracts)
AMRAAM Producibility Enhancement Program	Raytheon APREP Projects	Benefit- See Section 4.10
	Hughes APREP Projects	Benefit- See Section 4.10
Competitive Production	Lot 5	Cost- Tech. Asst. $0.5 M
		Benefit- 7% average unit cost decrease from Lot 4
	Lot 6	Cost- Tech. Asst. $0.4 M
		Benefit- 15% ave.unit cost decrease from Lot 5
	Lot 7	Benefit- 25% ave. unit cost decrease from Lot 6
	Lot 8	Benefit- 23% ave. unit cost decrease from Lot 7
Support Equipment	Missile Bit Test Set (Ray)	Savings- $10.8 million
Government Resources (All Phases)	Government Staffing	Cost- Approx. $9 million
	Government Testing	Cost- Approx. $3 million

4.10 Discussion of Non-Cost Benefits from AMRAAM's Second Source

When the AMRAAM Joint System Program Office evaluated whether or not to have a competitive second source, the focus was on the monetary savings that might be attained, as opposed to the non-cost and non-quantifiable benefits that the program might realize. Even though the analysis of alternatives always addressed and gave some credit to the following factors, it is likely that no one in the Government, nor even at Raytheon, perceived the key role and the many areas in which the second source might be effective. The following is a recap of areas that are not captured in most economic analyses:

- Procurement Data Package Review- Without a doubt, the value of the data package review that was provided by the second source was worth the price of the Full-Scale Development cost of the follower contractor and the related leader support, even if the second source had never built a missile beyond the Qualification Lot. Even with its best intentions, Government review of data packages are limited to correcting drafting errors and format discrepancies, as opposed to a contractor review by a person that is preparing for competitive production. There are two benefits. The first is back to the original developer as another set of eyes to look for potential problems. The second is to the Government as a level of assurance that the procurement data package is truly sufficient for the Government to openly procure additional missiles from another source as well as compete for spare parts support.
- Acquisition of Special Tooling and Special Test Equipment (ST/STE)- The Government is typically naive in the procurement and control of special test equipment. Whereas good estimates are normally available on the recurring costs of the weapon system, the cost of non-recurring items such as ST/STE have an insufficient experience base from which the Government can negotiate a fair and reasonable cost. The insertion of a follower on the AMRAAM program made the Government become a much more informed buyer. It also allowed the Government to competitively replicate the Chassis Level and Above STE at a large savings over the

cost that Hughes gave the Government in the non-competitive environment. This competition netted over a $30 million savings to the Government, and provided the side benefit that another source was further developed in the understanding of the missile design and testability.

4.11 Second Source Lessons Learned

The lessons learned from AMRAAM's second sourcing program are many. In fact, lessons are continuing as the program has matured into a steady-state production mode. The lessons began as far back as 1978, when the AMRAAM program office discussed with all the players they perceived to be critical to the decision process: the AMRAAM government team; other Government organizations with hands on experience in introducing second sources; higher acquisition authorities within the Government; and the five competing contractors on the Conceptual Phase. This summary will start with a few lessons from these early days, both positive and negative, and will continue up to early 1994:

- **The program office went to extreme measures to review, to understand theoretically, and to select the optimal solution for second-sourcing.**

  Many attempts to introduce a second-source were available and were studied early in the acquisition process to establish the method to be used on AMRAAM. To its credit, the program office did include all the prime players and stakeholders in the strategy development process. However, **the program office left out a key player, representative subcontractors/vendors**, who might very well have offered innovative ideas to the program. Later in the program, discontinuities appeared in such areas as subcontractor special tooling and test equipment that had to be corrected.

- **Contractor commitment to the second sourcing strategy was dependent on the individual contractor's competitive position at any time.**

  When asked in a competitive environment what the advantages and disadvantages were of establishing two sources, senior management from each of the five prime

contractors had consistentlt maintained that two sources were needed and that the second source should be introduced early. After Hughes won the FSD contract, Hughes management no longer supported the second source strategy, and used impediments to delay the technology transfer process they had proposed in the FSD source selection. **Had the Hughes proposed technology transfer plan not been incorporated into the Hughes FSD contract, the AMRAAM leader/follower effort would not have been successful due to the change in attitude that the contractor had after contract award.**

- **Much planning was required before FSD to prepare for a second source.**

  - Investigations of alternatives, cost analyses, discussions and inclusion of many special contract requirements into the competitive Request for Proposal (RFP) were all critical. For example, the requirement for a procurement data package sufficient to support open competition was placed in the FSD RFP, along with the requirement for rights to use the data.

  - Planning and coordination of the second source strategy required an enormous amount of time during the a critical periods throughout the program.[108]

  - Without this planning and preparation, the leader/follower program would have fallen apart.

- **There was no perfect model for AMRAAM to replicate to introduce a second source.**

  Not surprising looking back, but not obvious at the time was that each previous program had idiosyncrasies that made its circumstances vary from the AMRAAM program. These idiosyncrasies were related to such things as the fact that the previous

[108]The Program Director has two responsibilities. The first is to manage the actual acquisition. The second is to communicate (and defend) the program strategy, progress and issues to higher headquarters and audit/oversight activities. The second source strategy development and approval cycle falls into the second category, and dilutes the Program Director's attention to the mainstream development and qualification activities. This is also true of other key Government team members. There has been recent improvement in this area with the introduction of the Program Executive Officer (PEO) structure to provide management oversight to major system acquisitions as described in Section 10 of this thesis.

program did not consider competition until vary late in the acquisition cycle and therefore had poor data or a lack of rights from which to compete. Most programs were much less complicated technically, therefore did not need technical assistance during the second source development/qualification period. In any case, **the AMRAAM program office did the correct thing in designing a strategy that was tailored to the AMRAAM program's circumstances and that incorporated lessons learned from a collection of other programs** rather than copying a particular strategy that had been used on another program.

- **It was apparent that the original source, Hughes, would not perform contract requirements for leader/follower without abnormal Government oversight.**
  The Government and Hughes had a well delineated FSD contract that clearly and comprehensively stated the requirements, but the contract was insufficient to motivate Hughes. In addition, the contract had an award fee provision that was suppose to be used to reward the contractor in identified areas such as the leader/follower program when the minimal requirements of the contract were exceeded. Hughes performed so poorly in the leader/follower area (and certain other areas) that they requested that the award fee incentive be removed from the FSD contract. The fact that they did not receive the award was likely not the issue. The award fee also transmitted a written assessment to Hughes management that was proving embarrassing.
- **Because the Leader/Follower effort was not supported as planned by the developer, the Government was required to fund additional efforts at the second source contractor.**
  Much of the late and incomplete Hughes data had to be reverse-engineered at Raytheon to support the program. The inefficiencies of this redundant work were very frustrating to the Government program office.
- **The second source was willing and able to provide constructive input to the developer during the leader/follower stage.**

However, it was only after Government insistence (and reminder of the contract requirements) that Hughes would use the follower's inputs. The AMRAAM Producibility Enhancement Program (APREP) discussed in Section 5.0 was the first major breakthrough to take more advantage of both contractors' technical resources. By the time the Lot 1 captive carry reliability program had significant problems, Hughes was much more willing to accept another input. However, pockets of resistance in selected technical areas remained.

- **Most of the costs to transfer technology to the follower came from Hughes efforts to protect their competitive advantage rather than from the actual cost of reproduction and explanation.**

  Hughes established a multi-person program office to control the flow of data to Raytheon rather than including Raytheon on normal data transmission systems.

- **The Qualification Lot and directed splits for initial production were appropriately placed to bring on the second source to a level of competence prior to competition.**

  However, original planning was very optimistic by both the Government and the second source. The main causes for delays in introducing the second source were: (1) the basic delays that were experienced on the main FSD program and (2) Hughes delays in providing required data, hardware, software and technical assistance to the second source. In addition, the missile was more complex to produce than planned, and production ramp-up rates could not be achieved by Raytheon.

- **The non-cost benefits of the second-source far exceeded the expectations of the Government.**

  As described in Section 4.10.

- **The cost benefits from introducing a second source were realistic.**

Even after considering the turbulence that the program went through with the delayed FSD program, the cost benefits appear to be as advertised as the competitive lots unfold.

- **Whether or not the AMRAAM program selected the optimal strategy for second-sourcing can only be speculated. It is clear, however, that the strategy employed was beneficial to the program in many areas. It is also arguable that the AMRAAM program would not have survived without the cost and non-cost benefits that the introduction of a second competitive source brought to the program.**
- **An open question would be: In today's environment, were AMRAAM beginning its FSD program, would a similar strategy continue to be effective?**
  Discussions with AMRAAM JSPO personnel point out many changes in today's environment. First of all, with the "peace dividend" from the fall of communism in Europe, the quantity of missiles required has fallen dramatically. Therefore a break-even analysis of the required number of missiles to provide economic benefit from competition, offset against the cost of establishing and maintaining a second source, would be appropriate if the FSD strategy were to be revisited (or examined for another program). Secondly, more Government people are required to manage a leader/follower arrangement than a sole-source arrangement. This increase in personnel levels to accommodate second-source management is in direct conflict with today's environment of growing Government personnel constraints. Regrettably, it appears that living within directed personnel levels will be a major determinant of future Air Force acquisition strategy selections, without regard to overall program economics.

5.0 AMRAAM Producibility Enhancement Program (APREP)

Recall from earlier sections that the Advanced Medium Range Air-to-Air Missile (AMRAAM) concept evolved originally from the emerging technologies in the late 1970's. By the early to mid-1980's, these technologies were in the process of being fully demonstrated in the Full-Scale Development (FSD) program and were confirming that the required levels of performance for AMRAAM would be achieved. The technologies were, in fact, state-of-the-art in design and not yet matured from a producibility standpoint. Affordability in production became perhaps the single most important AMRAAM program issue to be resolved before proceeding into production. Three simultaneous efforts were inserted into the acquisition strategy to reduce AMRAAM's production costs. These included: the second source development strategy (discussed in 4.0 above); the Technical Modernization/ Industrial Modernization Incentive Program (to be discussed below); and AMRAAM Producibility Enhancement Program (APREP). APREP became a major initiative directed at reducing overall program cost after its initiation in May of 1984. The initiative solicited from the industrial community, through the two prime contractors (Hughes and Raytheon), proposals directed at reducing the program cost through a large scale Value Engineering (VE) program. The proposals then went through a competitive selection process, were placed on contract, and completed a thorough design/development/qualification program. The scope of the APREP initiative cannot be fully appreciated without collectively examining:

- The complexity and stability of the AMRAAM design when APREP was initiated,
- The number of APREP projects, their interrelationship and required system integration,
- The dollar values involved in investment, potential savings, and contractor incentives,
- The level and complexity of technologies in the missile manufacturing process,

- The concurrency between completing Full-Scale development on the basic Hughes contract and completing second source qualification on the Raytheon follower contract,
- The simultaneous initiation of production,
- The complexity and sensitivity of the second-source development (leader/follower) effort,
- The general attitude that the program faced toward value engineering within the Government.

5.1 Value Engineering Background:

When the AMRAAM Joint System Program Office examined alternatives to reduce the program cost, it reviewed an acquisition initiative, Value Engineering, that had shown moderate success (on a relatively limited basis) compared to such initiatives as competition. There was a general feeling that, although competition would drive the contractors to achieve rates of learning faster and to be more lean in profit expectations, that there was no incentive that would have the contractors examine alternatives to the basic FSD missile's producibility. In the early 1980's technology was exploding in high tech areas such as electronics and computers. In general, defense contractors like Hughes and Raytheon were well up to speed with the state-of-the-art technologies in the design of weapon systems, but had not been able to keep pace on the producibility side to develop improved and cost-effective manufacturing processes. One tool to incentivize these contractors to invest their time, manpower and financial resources into driving down the cost of manufacturing was the Department of Defense's Value Engineering Program.

A brief review of VE's history shows that it is a relatively new initiative, and is considered a "science" by the strongest advocates. It developed as a result of the material shortages that were prevalent in World War II. These material shortages drove the US Government to press for alternative design approaches and alternative materials to meet wartime demands. It was discovered that many of these new designs that industry brought

forth performed as well or even better than the original product, but were much less costly to produce. One of the earliest leaders in the VE process was General Electric Company (GE). GE has been recognized for formalizing the first attempts to improve efficiency by developing substitute materials to take the place of more expensive materials and methods. After World War II, a much more formalized and structured analytical discipline evolved to systematically examine alternative approaches to design and material selection to find less costly and more producible alternatives. The Air Force was not very aggressive in the VE process until late 1961 when a number of defense contractors showed the results of their internal VE programs. In 1963, a DOD-wide program was established led by the Assistant Secretary of Defense (Installations and Logistics)[109].

DOD Value Engineering programs are of two distinct types. The first type is the in-house efforts by the military and civilian employees of DOD. The second, and the one relevant to the APREP initiative, is the program which was created to stimulate contractors to perform VE and to develop and submit value engineering change proposals (VECP's) to the Government. It is important to note that the only major motivation for cost reductions prior to the formal VE program being set up within DOD was the pressure of competition. In fact, contractors actually have had negative incentives to reduce contract price because fee (profit) was (and is) generally calculated as a proportional function to contract cost. As a result, DOD did implement as policy a contract clause to allow a portion of the savings that resulted from a contractor developed VECP to be returned to the contractor[110].

Over 10 years had passed between the time that DOD instituted the VE clause[111] and the APREP initiative was begun, and yet many Government employees continued to have the mind-set that the contractors were being paid twice if they were given fees for

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[109]Dept. of Defense Manufacturing Management Handbook for Program Managers, 2nd edition, July 1984

[110]Dept. of Defense, Report 4245.8-H, Value Engineering, March 26, 1986

[111]Federal Acquisition Regulations System, Soloicitation Provisions and Contract Clauses, US Government Printing Office, 1979, pp. 52-215

VE efforts. One of the biggest hurdles of the APREP program was to demonstrate to the Government workforce that the economics were clearly in the Government's favor and that the VE effort was above and beyond basic contract responsibilities. The negative Government attitude was changed significantly when aggressive VE proposals were received from each of the contractors. Previous nay-sayers became some of the strongest advocates. In fact, the attitude across DOD changed in the 1983 to 1985 time frame when momentum for the DOD VE program gained strong returns to over $350 Million annually that are shown in the next figure.

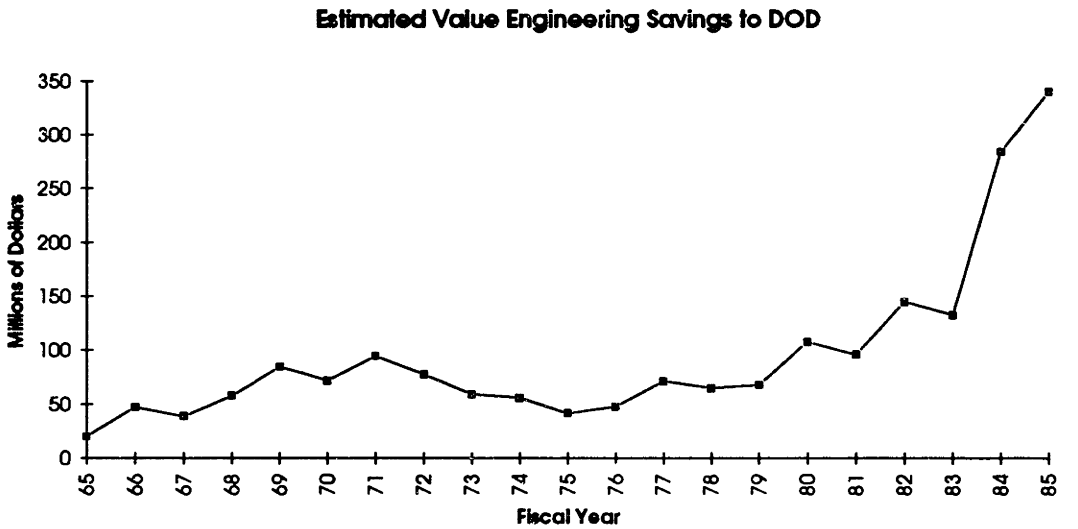

Figure 5.1

The Deputy Secretary of Defense emphasized the potential of the DOD VE program when he stated, "It is evident that there is significant untapped potential in the Contractor Value Engineering Program."[112]

5.2 Defining Value Engineering:

To understand the potential the VE initiative had to reduce cost on the AMRAAM program, a definition of what the value engineering is (and is not limited to) is necessary.

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[112]William Taft, Deputy Secretary of Defense, Department of Defense Memorandum for the Secretaries of the Military Departments 28678, Subject: "Value Engineering", March 26, 1986

First, there are many different interpretations what constitutes VE. A few quotes show this:

"Some call it the 'Wonder Weapon' of Government and industry, with virtually unlimited value."[113]

From the Government Accounting Office (GAO), "Value Engineering is the scientific method of analyzing and redesigning a product or service so that its function can be achieved at the lowest possible cost."[114]

From the Office of the Secretary of Defense, "VE is ... a systematic effort directed at analyzing the functional requirements of DOD systems, equipment, facilities, procedures and supplies for the purpose of achieving the essential functions at the lowest total cost, consistent with required performance, safety, reliability, quality, and maintainability."[115]

A comparison of these definitions highlights an overemphasis on the "low cost" parameter in the GAO's definition compared with the more comprehensive DOD definition, which includes critical considerations such as reliability, supportability, ease of operation, and personnel impacts. These considerations are critical in that total life cycle cost, rather than only production cost, is most important. As will be seen in project selection criteria later on, the Government APREP team was very conscious of this importance, as were the contractors.

Like almost any other design change, the earlier a value engineering change can be introduced, the more likely it will maximize savings. Many of the DOD materials available stress the need for early consideration of VE in the acquisition effort. Figure 8.3 shows the conceptual leverage of this early consideration. At the time APREP was being considered, AMRAAM was in the last 20% of Full-Scale Development. Also, remember that the savings that may potentially accrue are available from not only the production

[113]Don Lee, "Value Engineering," Government Executive, Vol.19, No. 10, November/December 1987, pp. 45-46.
[114]United States General Accounting Office Report, "Value Engineering Should Be Improved as Part of the Defense Department's Approach to Reducing Acquisition Cost" date September 27, 1983
[115]Dept. of Defense, Report 4245.8-H, Value Engineering, March 26, 1986

costs, but also from the logistics savings that can be by-products of higher reliability, reduced parts count, competitive spare parts sources, and improved maintainability.

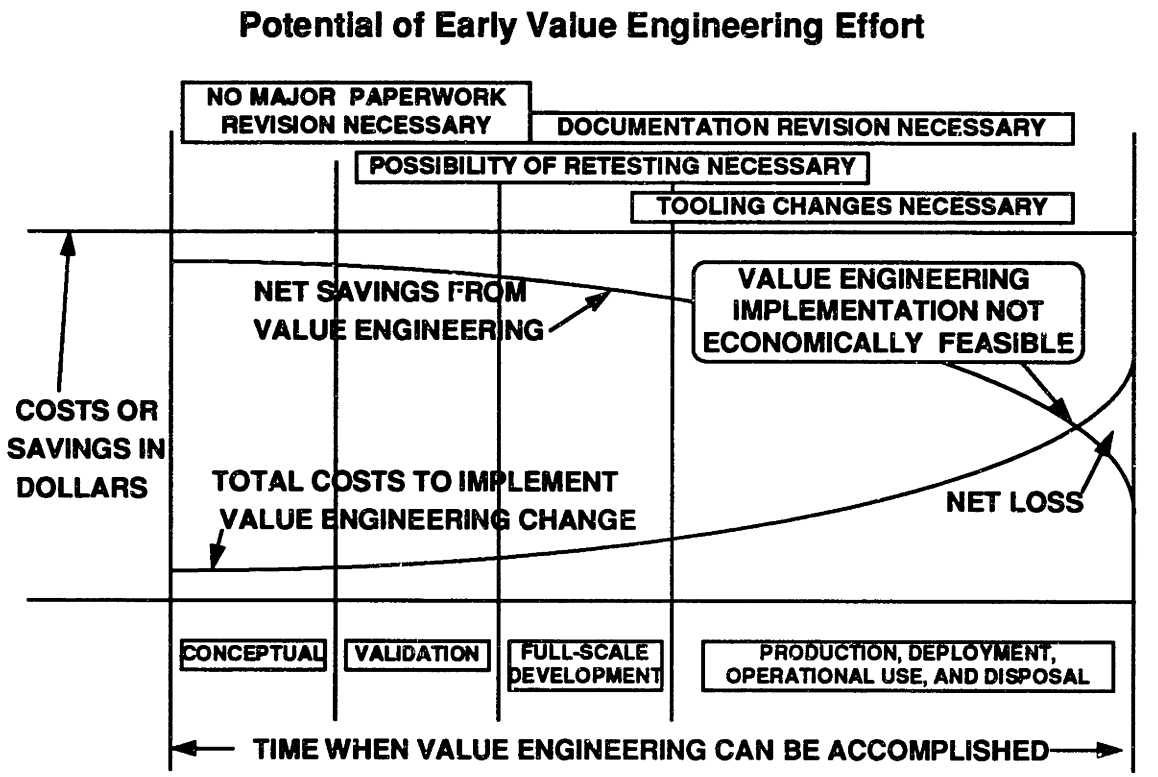

Figure 5.2

Each of the services have goals and policies that reflect their interpretation of the Office of the Secretary of Defense directives. The Air Force and Navy directives have the requirements to:

- Centralize policy direction and responsibility for assuring implementation of overall VE policies.
- Establish VE goals for subordinate commands.
- Initiate procedures for periodic management review of progress and overall status.
- Expedite the objective evaluation of Value Engineering Change Proposals (VECP's).
- Ensure that personnel charged with various facets of the DOD program are adequately trained.

- Provide adequate funding to operate and support VE activities[116].

5.3 APREP Management Concept:

In response to Headquarters of the Air Force direction in May of 1984, APREP was established with the single goal of securing significant cost savings in AMRAAM production and overall life cycle costs without degrading system performance. An ad hoc Producibility Advisory Committee was established to provide guidance to the AMRAAM Program Director on the APREP initiative. The committee, chaired by AD/CZ, consists of senior representatives from throughout the Air Force and Navy, as well as the Hughes and Raytheon AMRAAM Program managers, as shown below:

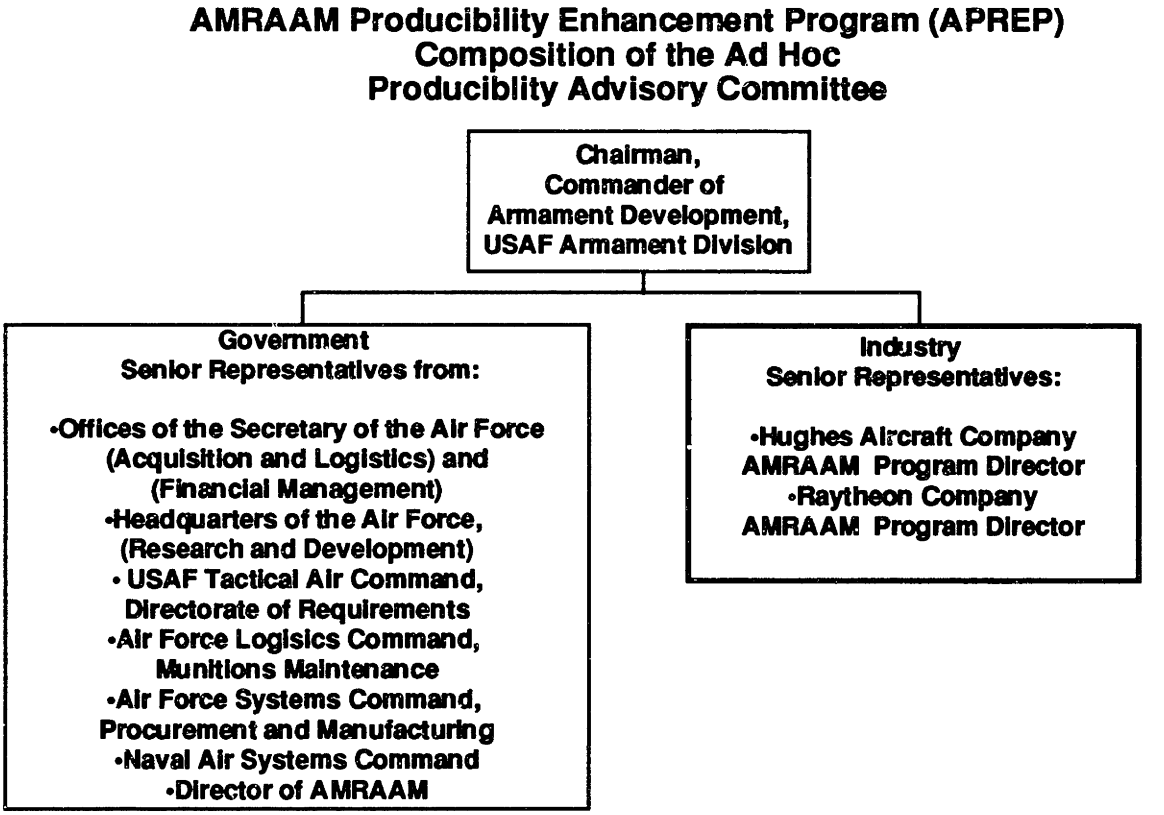

Figure 5.3

This committee endorsed an APREP program to be conducted in four phases: study, project selection, design/qualification, and implementation as shown in Figure 8.2. The

[116]Department of Defense, Defense Technical Information Center, "Technical Report- Subject: Value Engineering," dated January 1982

program schedule was structured to allow the majority of the APREP projects to be available for incorporation into FY89 (Missile Lot 3) production.

5.3.1 Phase I -Study:

The first phase of APREP consisted of contractor and Government study efforts to identify and evaluate candidate producibility projects to reduce the recurring production costs of AMRAAM.

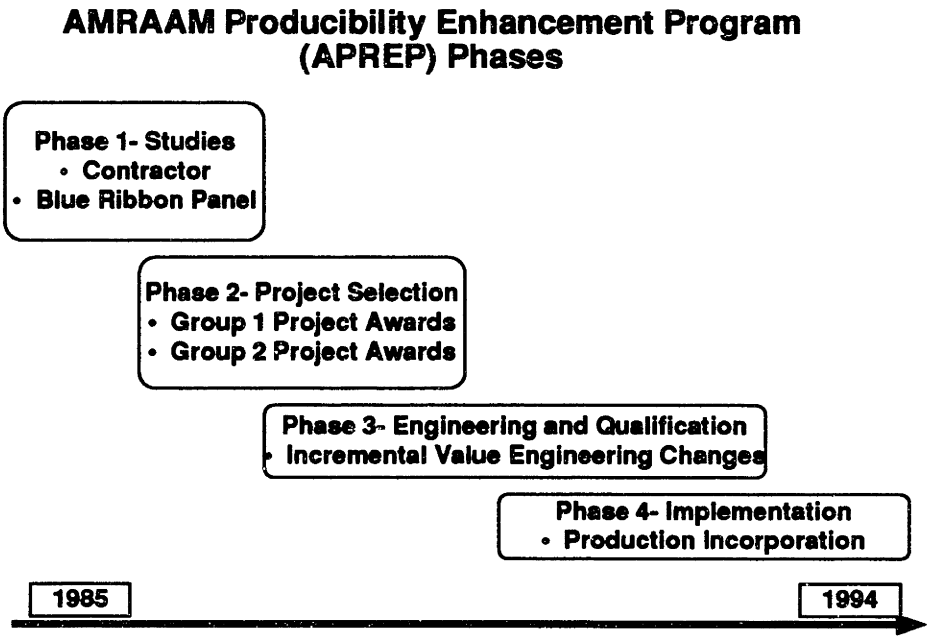

Figure 5.4

5.3.1.1 Contractor Studies:

On February 1, 1985, the Government awarded five-month study contracts to both Hughes and Raytheon. The contractors were directed to consider alternate technologies, alternate designs, and alternate vendors/sources (Figure 8.1). The intent of these contractor study efforts was for each contractor to nominate competitive projects which had high potential for successfully meeting the expectations of cost savings and

development. It was anticipated that the best candidate projects which would not impact form, fit, function (F^3) nor interface specifications of the established production baseline. However, candidate projects with exceptional potential for cost benefit but requiring F^3 and/or interface change were not discouraged. This highly successful effort resulted in approximately 40 competitive projects being proposed by Hughes and Raytheon.

Areas of Producibility Enhancement:
Alternate Designs, Technologies, and Vendors

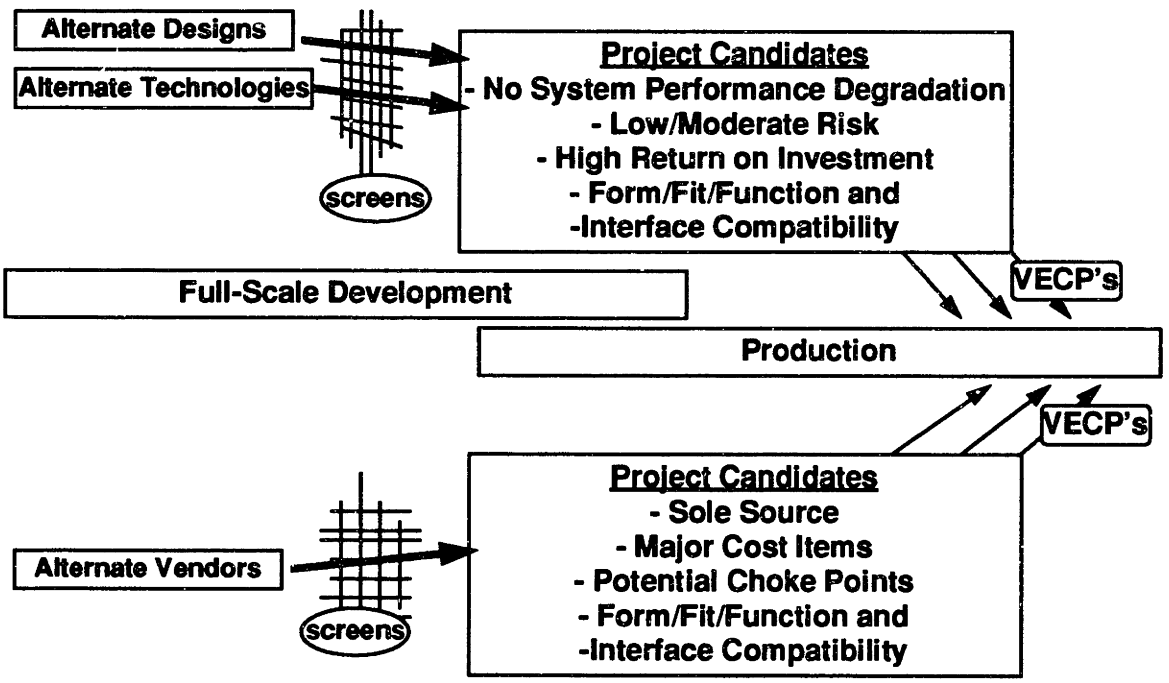

Figure 5.5

5.3.1.2 Government Studies:

Deputy Secretary of Defense directed on January 28, 1985, that the Assistant Secretary of the Air Force (Research, Development, and Logistics) establish an OSD/multi-service Government Blue Ribbon Panel (BRP) to investigate alternative methods for reducing AMRAAM costs. In addition, he directed a high level Air Force and Navy operational requirements group be established to assess the military

consequences, if any, of implementing the cost reduction projects identified by the BRP. Two major conclusions were presented by this panel.

- First, the baseline AMRAAM design was balanced with no "design spikes" needlessly increasing the recurring cost of the missile.[117]
- Secondly, the BRP verified that producibility enhancement projects were available that would result in a recurring production cost savings for AMRAAM of over $1.0 billion.[118]

A detailed briefing of the BRP effort, a comparison of the BRP projects, the representative set of APREP projects used in an Independent Cost Analysis (ICA) estimate, and the currently planned APREP projects, was presented to the Defense Systems Acquisition Review Council (DSARC).

5.3.2 Phase II - APREP Project Selection:

The second phase of the APREP effort was the competitive project source selection. Hughes and Raytheon submitted formal proposals for specific APREP projects in July 1985, following completion of their study efforts. This section discusses the source selection process, defines the criteria used, identifies the projects by the 2 main groups that were awarded, and defines categories of projects.

8.3.2.1 APREP Project Selection Process

The Armament Division structured a comprehensive source selection activity to analyze these proposals from both technical and cost perspectives. The source selection team included top acquisition experts from Air Force and Navy organizations throughout the country. Projects were selected that would result in the maximum overall program benefit to the government. The project selection criteria are shown in Table 5.1:

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[117]In the vernacular of the time, the missile was not "gold-plated" with overly specified performance parameters and actual system requirements were driving the design.
[118]Fiscal Year 1984 dollar value basis

Table 5.1

APREP Project Selection Criteria

- **Technical**

  (1) Impact to Performance and associated Technical Risk

  (2) Producibility and Producibility Risk

  (3) Reliability/Maintainability

  (4) Thoroughness of Product Change Verification

  (5) Production Planning

  (6) Second Source Planning

  (7) Logistics Supportability

  (8) Sufficiency of Data Proposed

- **Costs**

  (1) Production Cost/Savings

  (2) Life Cycle Cost/Savings

  (3) Investment Cost including Instant Contract Cost/Price and Systems Integration Cost

  (4) Technical Assistance Cost/Price

5.3.2.2 APREP Project Awards:

On October 9, 1985, Hughes and Raytheon were informed of the initial project selections. These projects were in two groups: an early-start set of projects (Group I) which were awarded in January 1986; and a second group (Group II) which were planned for award in February/March 1986. This second group consisted of projects primarily in the missile's electronics unit for which the project selection process was completed in December 1985.

5.3.2.3 First Group of Projects Awarded

The APREP projects originally selected (Group I) are shown in the following figure:

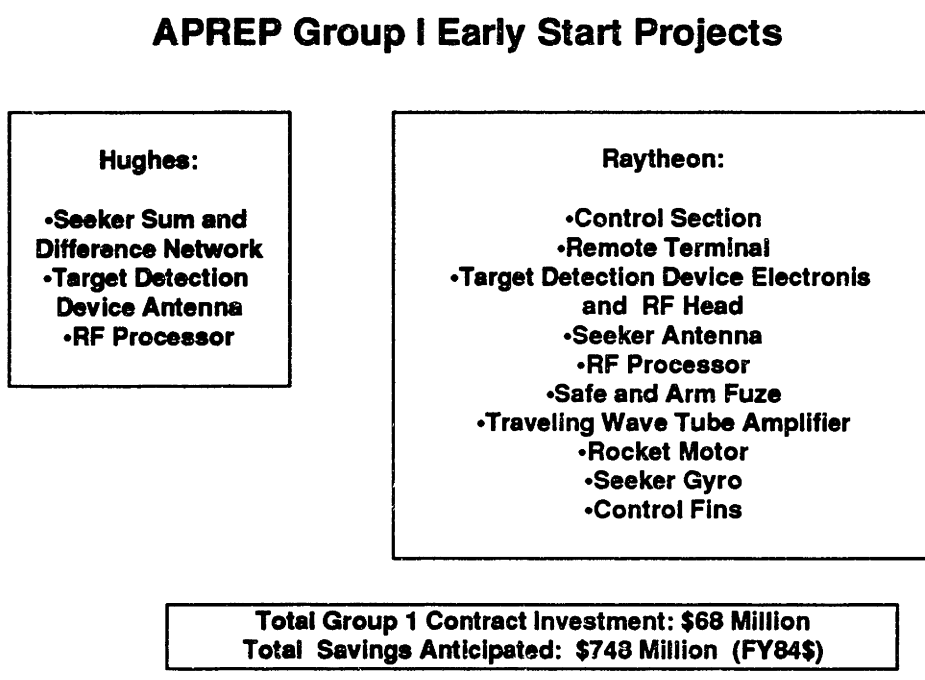

Figure 5.6

Some very interesting developments were taking place. First and most obvious, Raytheon, the follower, was being selected for a much larger number of projects than was Hughes, the Full-Scale Developer and leader on the program. It was apparent, from discussions with the JSPO, that Raytheon was being much more aggressive in the projects that they were proposing, the prices that they were willing to commit to, the terms and conditions that they desired (such as providing the Government with reprocurement data rights), and the flow-down of the APREP initiative to subcontractors and vendors.[119] Another very encouraging finding was available: details of proposed projects revealed that previous

[119]Two reasons discussed for this were that Hughes either was trying to recover from the FSD cost over-run they were experiencing, or were being conservative because their aggressive approach to FSD had gotten them into trouble.

cost projections (investment and savings) were reasonable and that high return on investment was likely.

Sample descriptions of the first group of projects that were awarded are:

- **Hughes Sum and Difference Project:** This project incorporated a change to the manufacturing process for fabrication of the sum and difference network housing. In the previous fabrication process, two machined housings were joined by laser welding. The new process involved electroforming the entire housing which significantly reduced labor content.
- **Hughes RF Processor:** This project was sponsored by Hughes for Watkins-Johnson (a subcontractor) and consisted of changing the mechanical layout and reducing twelve sealed packages of seven types to five sealed packages of four types. Discrete components were exchanged for large-scale integrated circuits and monolithic microwave circuits.
- **Raytheon Control Section:** This project entailed replacement of the electromechanical control section with a pneumatic (cold gas) control section with the work to be performed by the Garrett Corporation. (This project had tremendous cost potential. It was later deleted due to supportability issues of maintaining the cold gas charge reliably.)
- **Raytheon RF Head Project:** This project represented a refined manufacturing process and qualification of Raytheon as a second source producer for the Radio Frequency (RF) Processor, a high cost sole source assembly. Raytheon used a higher degree of integration below the assembly level than did the Watkins-Johnson design.
- **Raytheon Safe and Arm Fuze (SAF):** This project established and qualified Raymond Engineering to manufacture the SAF. Raymond modified an existing SAF design to meet AMRAAM's requirements. Although this project had only a 3 to 1 return on investment, it introduced a second source to a critical bottleneck in the production process.

- **Raytheon Remote Terminal Project:** This project redesigned the existing system to have fewer circuit boards, reduced the number of hybrid circuits from seven to three, and replaced five large scale integrated circuits (LSI)with two very large scale integrated circuits(VLSI).

5.3.2.4 Second Group of Projects Awarded

Eleven projects were originally planned for award in a second group. Five of these eleven projects were selected at the same time as the first group, but had to await the availability of funding and contract negotiations. The remaining six projects were kept in a competitive status for further evaluation. The second group of projects that were originally planned on APREP are shown below:

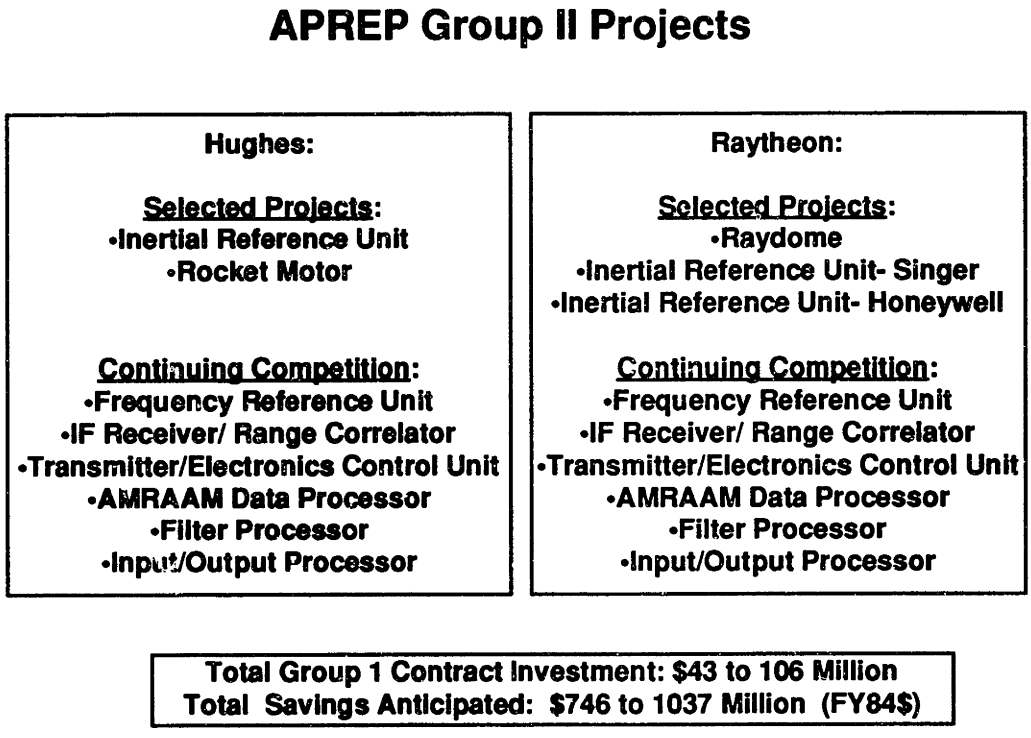

Figure 5.7

Samples of the second group of projects to be awarded are as follows:

- **Hughes Inertial Reference Unit Project:** This project was intended to lower the cost of the FSD AMRAAM inertial reference unit by reducing the cost of the inertial

sensors (gyro's), reducing parts count about one third, and eliminating one printed wiring assembly. Three accelerometers were to be replaced with one new device that the IRU subcontractor, Northrop, had designed. The project was also to attain savings by robotics manufacture and test.

- **Hughes Rocket Motor Project:** This project was to be a manufacturing technique and design refinement that a major subcontractor, Hercules, had proposed. The project was to reduce cost by: 1) substituting a modified version of a Hellfire Armed Firing Device for the FSD design solution; 2) changing the manufacturing process for the rocket motor case; 3) simplifying the igniter assembly; 4) removing the propellant grain restrictor; 5) simplifying and improving the process for insulating the rocket motor case; and 6) changing the 3-piece welded blast tube design to a single piece flow-formed design.
- **Raytheon Radome:** This project was to have established Raytheon as a second source producer of radomes for AMRAAM to compete with the sole-source vendor, Corning. Proprietary materials and processes were available that were proposed to provide a less costly, form/fit/function interchangeable unit at much less cost.
- **Raytheon Inertial Reference Unit Projects:** Raytheon proposed to introduce two new F^3 IRU vendors to expand the vendor base and to reduce cost. Honeywell proposed an advanced ring-laser-gyro and singer proposed a multi-sensor technology.

These examples were relatively easy for the Government to evaluate and make a decision to proceed or put on the shelf. The second subset of the Group II projects were much more complex. These projects were concentrated in the guidance section area and did propose to change the previously baselined interfaces between critical subsystems. The change in interfaces came with a repartitioning and combining of functions to take advantage of improvements in electronics that had occurred in the industry during the course of the FSD program. Examples of the technologies available were: larger gate arrays, custom analog large scale integrated circuits, improved manufacturing technologies

for microwave components, replacement of ceramic circuit cards by printed wiring boards due to the less heat dissipation of new microelectronics, reducing the number and types of subassemblies, and many more improvements in producibilty. It should also be noted that these changes were clearly recognized to potentially drive the inherent reliability of the missile much higher.

5.3.2.5 Project Categorization:

Projects were placed into one or two categories to recognize both contractors may not implement all projects. The reasons that selected projects might not be incorporated by both contractors is that certain producibility improvements were to be below the lowest depot repairable level and unique to one contractor's manufacturing process or design. For example, a change to a Hercules Rocket Motor would not be appropriate to an Aerojet rocket motor, or a Litton IRU change to a Singer-Kearfot IRU. Projects which were likely to be implemented by only the sponsoring contractor were called Category 1. In contrast, Category 2 projects were planned by the Government to be incorporated by both contractors. This categorization was necessary for contractor planning, proposals, and government investment and savings estimates. Figure 5.8 summarizes Category 1 and 2 project characteristics and provides the original categorization for each APREP project.

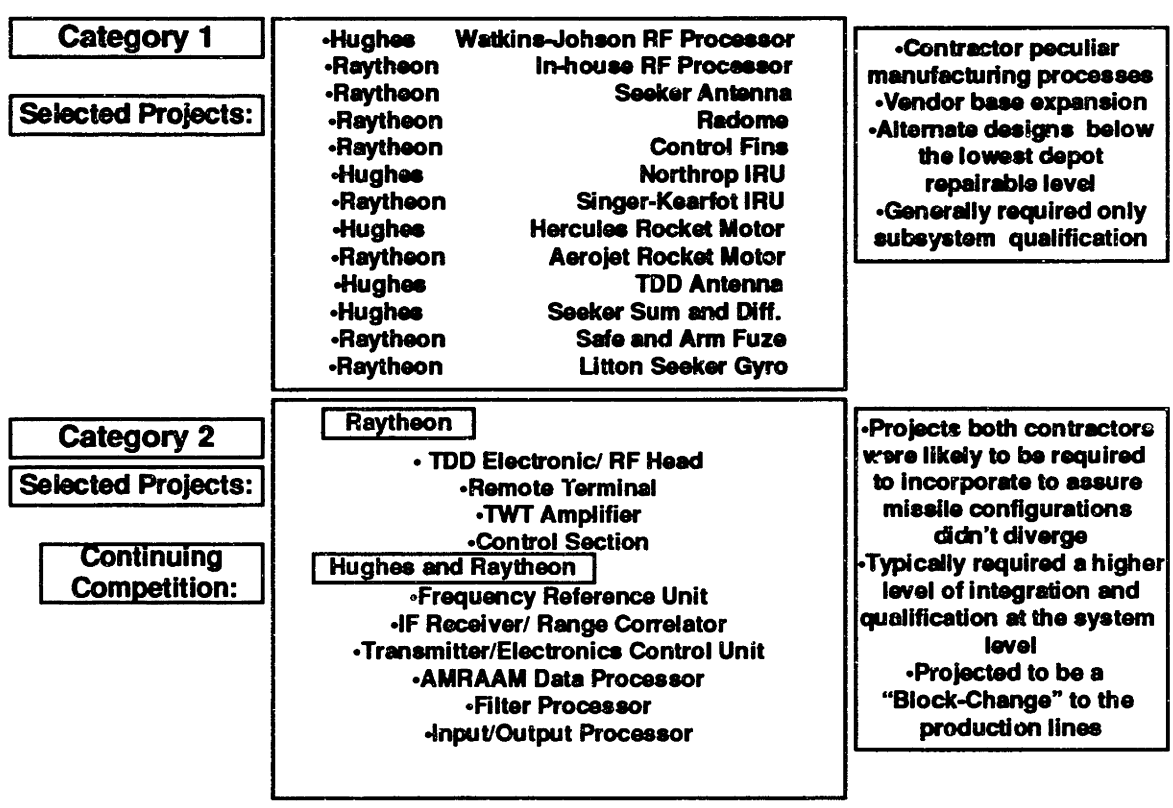

Figure 5.8

Category 1 and 2 projects as shown by the previous figure had different characteristics. These characteristics drove the need for system integration and system-level qualification to the point that a phased approach for inserting the projects into the production lines was planned. The flow of the projection selection, categorization and planned production incorporation is shown in Figure 5.9:

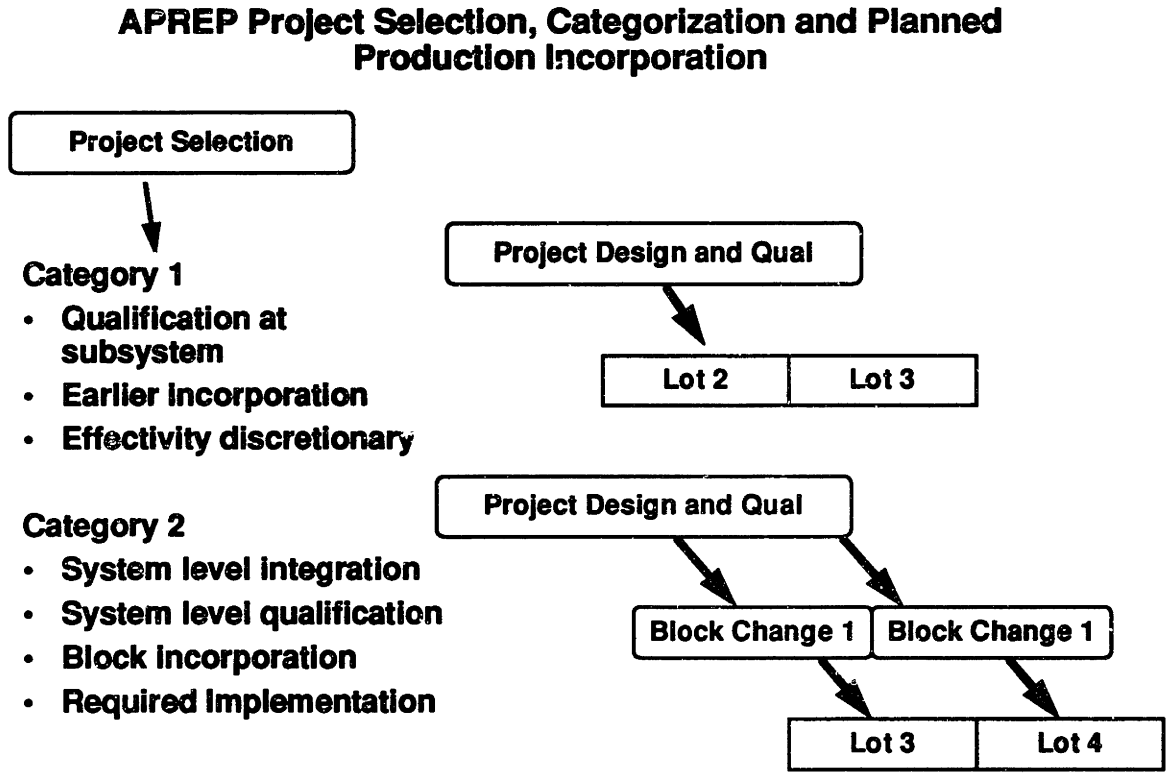

Figure 5.9

5.3.3 Phase III - Projects Design and Qualification:

After all the contractor and government studies and panels, management reviews to approve the program, budget battles to obtain funding, solicitations, proposals and project selections, the APREP program was finally able to fund the design and qualification for a value engineering effort at Hughes and Raytheon. To manage the APREP effort, the Government elected to develop a closely coordinated, cooperative Government/joint-contractor effort. The Air Force maintained the lead management role with full Hughes and Raytheon participation in most major decisions. The Air Force established an APREP management team responsible for the successful conduct of the program within the Directorate of Acquisition. Later, this management team grew to the extent that it was split off to become its own directorate, and also became the lead management organization for the Preplanned Product Improvement activities. To

accommodate contractor interactions, Hughes and Raytheon updated the existing associate contractor agreement (ACA) for the leader/follower program to define mutual responsibilities. Coordination of the concurrent APREP design/qualification activities with each contractor, the Government, and other elements of the AMRAAM program required that an interface control working group be formed and that configuration management discipline be inserted that would minimize breakdowns in communication.

5.3.3.1 Management Control Working Group (MCWG):

A tri-party MCWG was established to oversee the successful coordination of activities on the APREP program. This group included representation from both contractors and the Government. Responsibilities of the group included:

- Formulating overall APREP planning and strategy.
- Ensuring program coordination
- Determining projects priorities, when resource conflicts arose
- Assessing project progress
- Resolving technical interface problems
- Recommending production effectivities

5.3.3.2 APREP Configuration Management and System Engineering Management:

Configuration management of APREP producibility changes included the use of configuration management functions such as identification, control, status accounting, and audits that were on the basic AMRAAM FSD and initial production contracts. A tremendous amount of documentation that was generated by Hughes and Raytheon on the basic FSD, the Follower Qualification and the initial production contracts was used by Hughes and Raytheon for the producibility program. The original configuration baseline for enhanced producibility efforts was been established as the Hughes FSD contractual baseline augmented by the data generated for the Critical Design Review (CDR) that was completed in January 1985. The key documents that were included in the baseline were:

- Specifications associated with the system, functional, and allocated baseline;
- Level II engineering drawings;
- Preliminary Part II (product) specifications;
- Level of Repair Analysis.

Each contractor was required to use these documents as the point of departure for the originally proposed changes. During the conduct of the program, this baseline was changed to reflect the evolving definition and maturity of the technical data package. Each engineering change proposal submitted by the contractors had to reflect changes to the baseline that were to be in effect at the point of production effectivity.[120] The processing of APREP value engineering change proposals required that each contractor and the Government review the proposal to verify that the change would not result in an adverse impact on another area. This process is shown in the figure below:

APREP Value Engineering Change Proposal Process

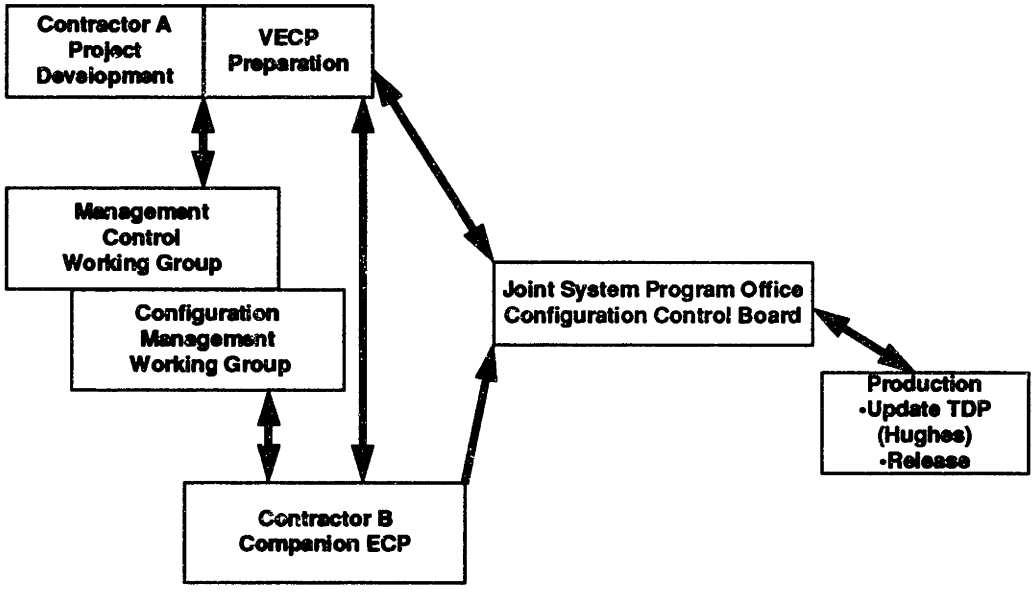

Figure 5.10

[120]In other words, if a project were to be inserted into Lot 3, the configuration baseline for Lot 3 and beyond was required to be modified by the project.

Identification, control status accounting and audits were required during the design/qualification of the APREP projects. System engineering management milestones[121] (See Table 5.2 below) were used to review each contractor's status in designing and qualifying producibility changes. These milestones were synchronized with contract option to verify that the contractors had achieved the level of technical maturity appropriate prior to releasing the contractor to proceed into the next phase.

Table 5.2

APREP System Engineering Management Milestones

MILESTONE	COMPLETED DURING
Interface Baseline Review	----------
System Design Review	**Concept Definition**
Preliminary Design Review	**Detailed Design**
Critical Design Review	**Proof of Design**
Production Readiness Review	**Proof of Manufacturing**
Functional Configuration Audit/ Formal Qualification Review	**Qualification**
Physical Configuration Audit	**First Unit Production**

These milestones were also very effective decision points for the Government to decide whether or not a project were likely to live up to the savings expectations that were originally anticipated. For competitive projects, these points allowed a down-selection to one contractor to be made with a minimal amount of administrative burden. The milestones were also used as a contractual point in time to have formal cost estimates submitted, to have the technical data package updated, and to structure required levels of

[121]Reference Military Standard 1521

qualification and testing to be accomplished commensurate with the level of financial and programmatic commitment that was expected of the Government with the next phase.

At completion of qualification, the Government Joint Configuration Control Board (JCCB)[122] reviewed and approved value engineering change proposals for successfully completed APREP projects. As the earlier figure showed, the Government had to address the change for both the developing (sponsoring) contractor and the companion engineering change proposal from the second (non-sponsoring) contractor. Once this approval had occurred, the change was then a permanent part of the AMRAAM technical data package and could only be changed by an additional JCCB action and approval. Notice also as indicated in the table above that a Physical Configuration Audit (PCA) was conducted during production on the first (or a very early) unit produced. This audit process was used to verify that the production unit was "built to" the approved technical data package and that any deviations were corrected in the data and/or the hardware. This PCA event was especially important with two production contractors making simultaneous changes to both the missile and related special tooling and test equipment.

A general template was established for the design and qualification of APREP projects that included the following activities:

- Concept definition: The first effort under concept definition consisted of an interface baseline review that Hughes, Raytheon and the Government attended. This review established and documented the missile configuration baseline against which the project was being designed. Also the critical physical and functional interfaces between the project, higher levels of assembly, and associated APREP projects was established. The second important concept definition activity was a Systems Design

[122]The Joint Configuration Control Board (JCCB) within the AMRAAM program office consists of senior- level Air Force and Navy representatives from program management, contracting, engineering, test, configuration management, operational, and financial management organizations that have vested interests in reviewing and providing comments on proposed configuration and contract changes that are considered by the program director on the program.

Review in which an assessment was made regarding potential impact to overall missile system performance.

- Detailed design: The detailed design for the projects typically began simultaneously with contract award for the project, because much of the preliminary design work had been completed during the study phase. This effort included not only details of the design itself, but also clear definition of test requirements, specification control drawings, contract format engineering drawings, and a Preliminary Design Review.
- Proof of design: Early in each project the sponsoring contractor procured parts for fabricating Proof of Design engineering units. These parts were assembled into subsystems that were evaluated for design and manufacturability, and functionally tested. These assemblies then typically underwent integration to the next level of assembly and interchangeability testing between the original subsystem and the APREP subsystem were conducted. The sponsoring contractor was required to update engineering drawings and to prepare the Part II (product) specifications for Government and associate contractor use. Proof of Design was completed when the contractor successfully went through a Critical Design Review.
- Proof of manufacturing: The contractor was required to demonstrate its ability to manufacture and test the APREP project subsystem. In addition, to avoid previous problems in transitioning designs from the engineering laboratory to the production floor, the contractor was required to manufacture the Proof of Manufacturing hardware on production representative tooling with the use of factory floor personnel. One other unique requirement existed for Category 2 projects (described above). The contractor was required to provide "kits" to the associate contractor to aid in technology transfer in the second contractor coming up to speed in being able to manufacture the subsystem.
- Qualification: The technical proof of the APREP projects came in a formal qualification program. The level of required qualification was dependent on the

complexity of the change, the interfaces with other subsystems, and the criticality of the subsystem to the system level operational performance of the missile. In the end, virtually every project was flown in flight testing. The end of the Qualification effort was marked by the successful completion of a Functional Configuration Audit and/or a Formal Qualification Review.

- Project integration: There were two levels of responsibility in project integration. For Category 1 projects, a contractor was required to integrate its projects against its own missile baseline. In an expanded responsibility for Category 2 projects, both contractors' projects had to be jointly integrated into the missile configuration baseline. This required a cooperative effort on the part of both contractors.

Template for APREP Project Design and Qualification

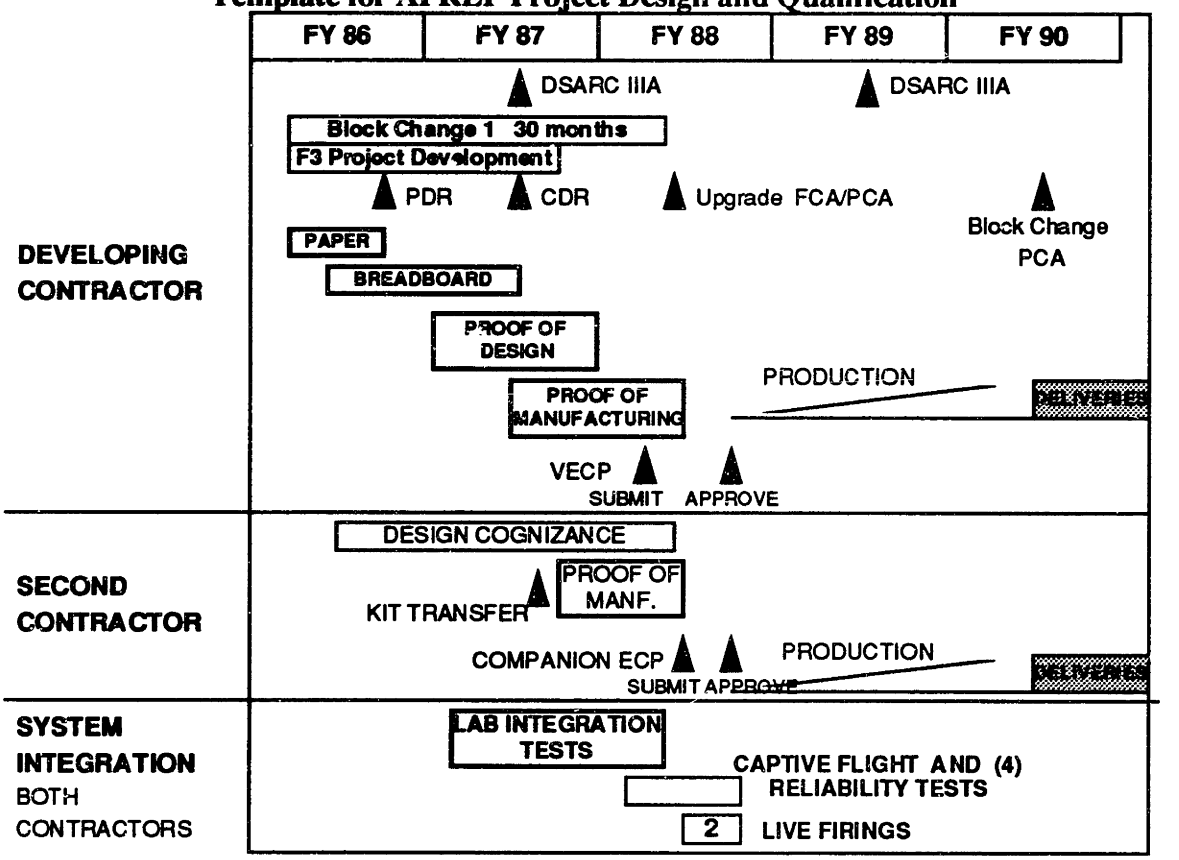

Figure 5.11

The preceding figure (Figure 5.11) shows a template that was used by the Government APREP team to construct an overall schedule relationship between the developing contractor, the second (non-sponsoring) contractor and system integration activities of both contractors.

5.3.3.5 Processing the APREP Value Engineering Proposals for Contractor Shared Savings

After the design and qualification on a project is over, the Government and contractors go through a process to determine and share the savings that has been achieved on the project. This process is very thorough due to the large dollars that are provided to the contractors as incentives. The Federal Acquisition Regulations (FAR) state the share ratio that is used to divide savings. The following chart highlights the two varieties of VE's that are discussed in the FAR.

TYPES OF VALUE ENGINEERING CHANGES

Mandatory

- **Government pays all the development cost**
- **Share ratio = 75% Government / 25% contractor**

  Rationale: The contractor assumes less risk therefore is provided a smaller share of the savings.

Voluntary

- **Government only pays for qualification costs**
- **Share ratio = 50% Government / 50% contractor**

  Rationale: The contractor assumes more risk and therefore is given a higher share.

Figure 5.12

When we discuss the share of savings that are divided between the Government and contractor, these savings are net savings rather than gross savings. In other words all previous and projected future government costs to develop, qualify and implement the change are subtracted from the gross savings number. Also, a savings period is defined

that is typically the first three years of production that has the change incorporated. Payment to the contractor can either be a lump sum, or partitioned out over the three years.

Although the savings are shared for only 3 years and the savings are net rather than gross, there is a very large incentive for contractors to pursue VE's. In AMRAAM's case, the shared savings to date and projected are particularly attractive to the contractors. For example, assume that a level of profit for producing recently awarded Missile Production Lot 7 totals to approximately $75 to 85 million. Contractor APREP incentive awards on projects already completed and savings negotiated are already over $50 million and are expected to grow to over $100 million in the future. This is a strong motivator for both Hughes and Raytheon.

5.4 Original Cost/Benefit Planning on APREP:

When the AMRAAM program office looked at methods to reduce the life cycle cost of the program, many analyses were conducted to understand the cost drivers. The following figure shows the results of these analyses as of 1985. Notice that the majority of the cost for the system is in producing the missile (82%). In addition to considering how to reduce the missile production cost, the program office had to concern itself with the effect any change to the missile production cost might have on the operations and support cost. For example, if the APREP initiative were to generate many versions of the missile, there could well have been a very significant increase in the costs to support these multiple configurations due to stocking of additional types of spare parts, additional test equipment, and perhaps even redundant repair lines. Therefore, a very conscious effort was instituted in the beginning of the program to ensure that incorporation of APREP projects would not reduce front end production costs at the expense of subsequent operations and support costs. In all cases, careful analysis was used to model the impact. As you will see later in this section, most projects undertaken in APREP were directed at

electronic subassemblies. A fall-out benefit of the cost reduction efforts in these electronics generally yielded a reduced parts count and lower heat build-up. This had a direct benefit to the reliability of the missile, and was found to actually significantly reduce missile operations and support costs. The following figure is a first order breakout of AMRAAM program cost that were anticipated by the Government:

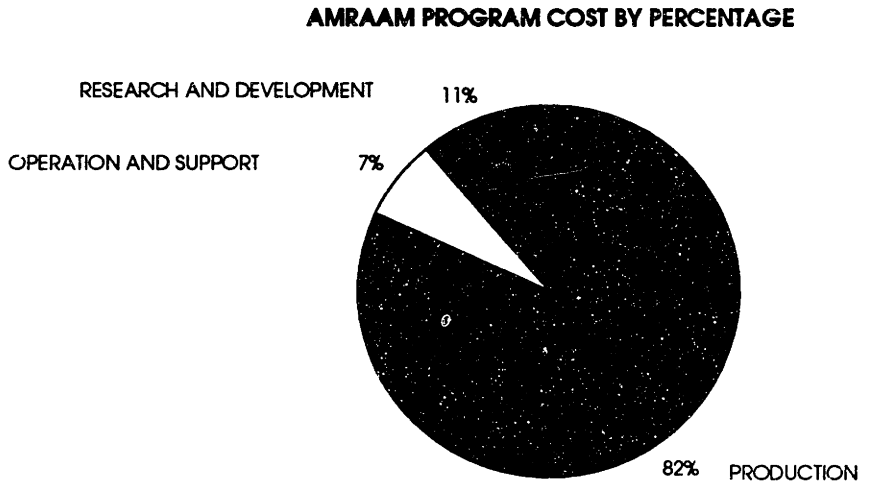

Figure 5.13

Contractor generated Design to Cost reports and Life Cycle Cost analyses as well as independent cost analyses by the Government showed that the majority of the recurring missile production costs were in the areas of the missile that had high density electronics. These areas included the transmitter/electronics control unit and the electronics unit, for example. Other areas of the missile that consistently were identified as cost drivers were the close tolerance precision mechanical devices such as the Inertial Reference Unit, the Seeker/Gyro, and portions of the Control Section with significant electromechanical assemblies. A summary of the percentage of missile production cost by missile section is shown below:

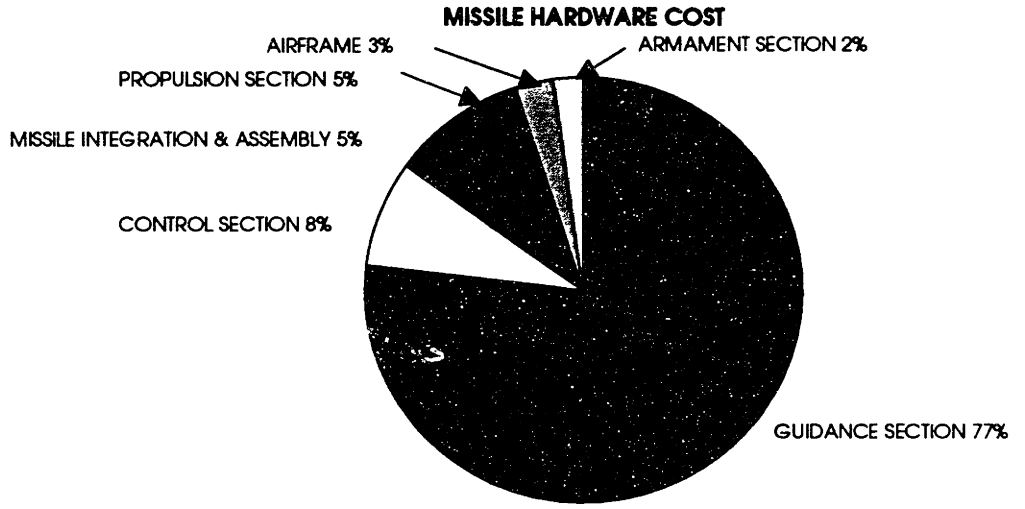

Figure 5.14

With such a large portion of the missile production cost generated in the guidance section area, it was important to break these costs down even further to look for appropriate APREP projects.

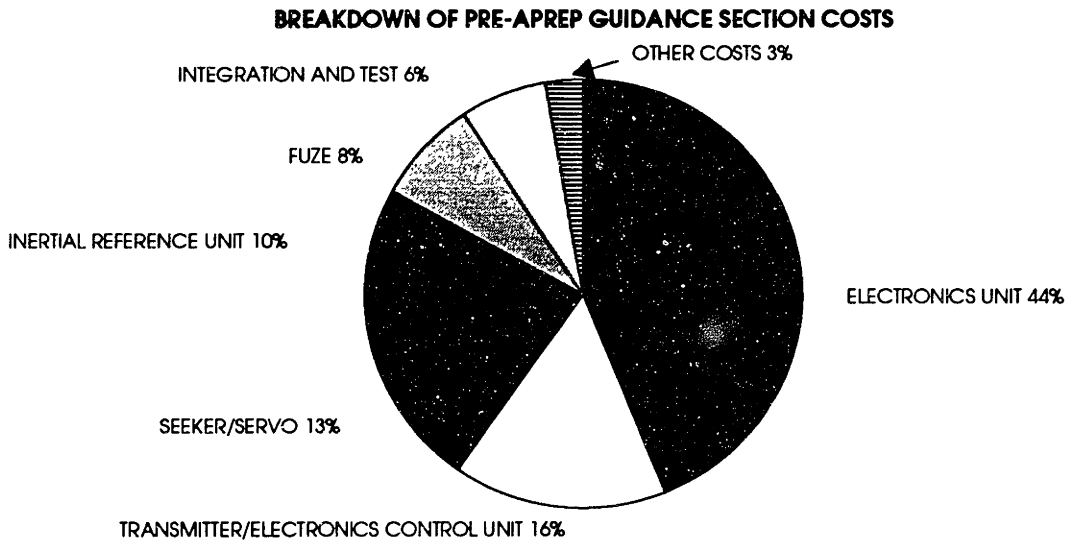

Figure 5.15

The electronics unit, as is shown in Figure 5.15, was by far the largest driver, and resulted in multiple APREP projects by each contractor to reduce its production cost. (These

projects fell basically into the Category II area that became mandatory for both contractors to eventually incorporate.)

The appropriate distribution of APREP projects was planned by the Government and both contractors based on detailed analysis similar to that presented above. A worthwhile question is: "How did the original project selection stack up against the savings potential?"

The answer is remarkably well as can be seen below in a summary of the distribution for originally selected projects shown in Table 5.3 on the next page.

Table 5.3- Distribution of Original APREP Projects by Missile Section

Missile Section		Project	Approximate Investment	Anticipated Savings
Guidance			**$94-157 Million**	**$1230-1530Million**
	1	RF Processor (2)		
	2	Seeker Antenna		
	3	TWT Amplifier		
	4	Seeker Gyro		
	5	Frequency		
	6	Reference Unit		
	7	Transmitter/ECU		
	8	IF Receiver/		
	9	Range Correlator		
	10	Data Processor		
	11	Filter Processor		
	12	Input/Output		
	13	Seeker Sum & Diff.		
	14	Remote Terminal		
	15	TDD Electronics &		
	16	RF Head		
	17	TDD Antenna		
	18	IRU's (3)		
	19	Radome		
Control			**$5 Million**	**$168 Million**
	1	Control Section		
	2	Control Fins		
Warhead			**$1 Million**	**$3 Million**
	1	Safe and Arm Fuze		
Propulsion			**$11 Million**	**$87 Million**
	2	Rocket Motors (2)		
Total:		**24 Projects**	**$111-174 Million**	**$1490-1780Million**

Clearly, the emphasis was placed on the high potential return areas of the missile. It is also apparent that the program office did not overlook the production bottlenecks and potential vulnerabilities. For example, the return on investment for the Safe and Arm Fuze (SAF) was only expected to return $3 million on an investment of $1 million. Although this would appear to be a large return for a typical personal or business investment, it does not have nearly the potential financial leverage as most other projects that were awarded. So, why did the program office pursue the SAF project? In discussions with members of both the Government and contractor APREP organizations, they pointed out the fact that

there were more motives to APREP than purely driving down the missile production cost. Other reasons were the expansion of the vendor base, removal of potential production bottlenecks[123], improved reliability and improved maintainability.

There was another important variable in the cost/benefit analysis that was conducted on the AMRAAM program. This variable was the sensitivity of savings to production quantities and time. Suffice it to say that the project selection process and the management review process of the APREP program went into excruciating details and variance analyses around these issues. The consistent result was that APREP was very sound from a financial investment perspective on the Government's part. One result of a baseline investment analysis was as shown below, and was quite representative of similar results found by the independent review team[124] in preparing for a Defense System Acquisition Review Council (DSARC) decision on the AMRAAM program[125].

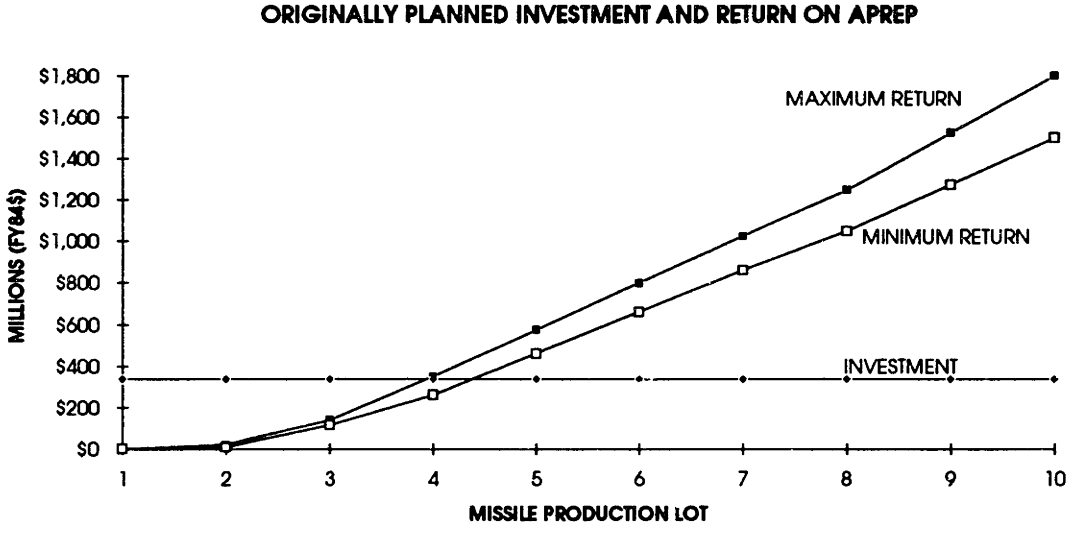

Figure 5.16[126]

[123]This SAF project foresight on the part of the APREP personnel was very important when later in the program the single original source for the AMRAAM fuze ran into financial and legal difficulties and was no longer available as a source.

[124]The Office of the Secretary of Defense Cost Analysis Improvement Group (CAIG)

[125]AMRAAM Decision Coordinating Paper dated November 27, 1985

[126]These costs and savings were predicated on a producing approximately 24,000 missiles in 10 production lots.

5.5 APREP Restructure

Until now we have discussed how APREP was originally planned in the 1985 time-frame and expected outcomes. In meetings with the APREP program manager[127], he stated that the program had retained the original acquisition strategy with minor refinements over the last eight years. The program office had pursued projects from the original list and had made adjustments along the way to add newly identified projects of high potential, and had down-selected competitive projects, and had eliminated certain other projects that proved to be either insufficient in savings, had the potential to impact supportability, or were not as optimal as other alternatives. The major change that Mr. Stoer described was in changing the Government/contractor relationship for the more complex and inter-related projects, primarily in the missile guidance section electronics area.

As was stated earlier in Section 8, certain projects were termed "Category II" if they were mandatory for both contractors to incorporate to keep the missile production lines at the two contractors' plants from diverging. There was another reason that was very related. It was shown that by repartitioning functions of guidance system subsections, even more savings could be achieved. Therefore a closer relationship was necessary between the two contractors to share ideas on projects that might be more effective if the interface boundaries between guidance section subsystems were redefined.

The Government, Hughes and Raytheon then agreed it was in the program's best interest to change the existing contracted relationship to facilitate communications between the two contractors, to optimize the design solution for producibility with a composite contractor approach, and to accelerate the decision making process on areas that crossed the contractor boundaries. Previously, each contractor had direct contracts with the Government on all projects (with an associate contractor relationship linking the two contractors). It was agreed that the new , more effective relationship on these more

[127]Eric Stoer, Leader of the APREP Integrated Product Team

complex, interrelated projects would be a single contract with the Government for one prime contractor with a subcontract to the second contractor. The before and after relationships are shown in the following figure. This change was made and has worked very well to date. It was also successfully used as a pattern on the Preplanned Product Improvement initiative which will be discussed later.

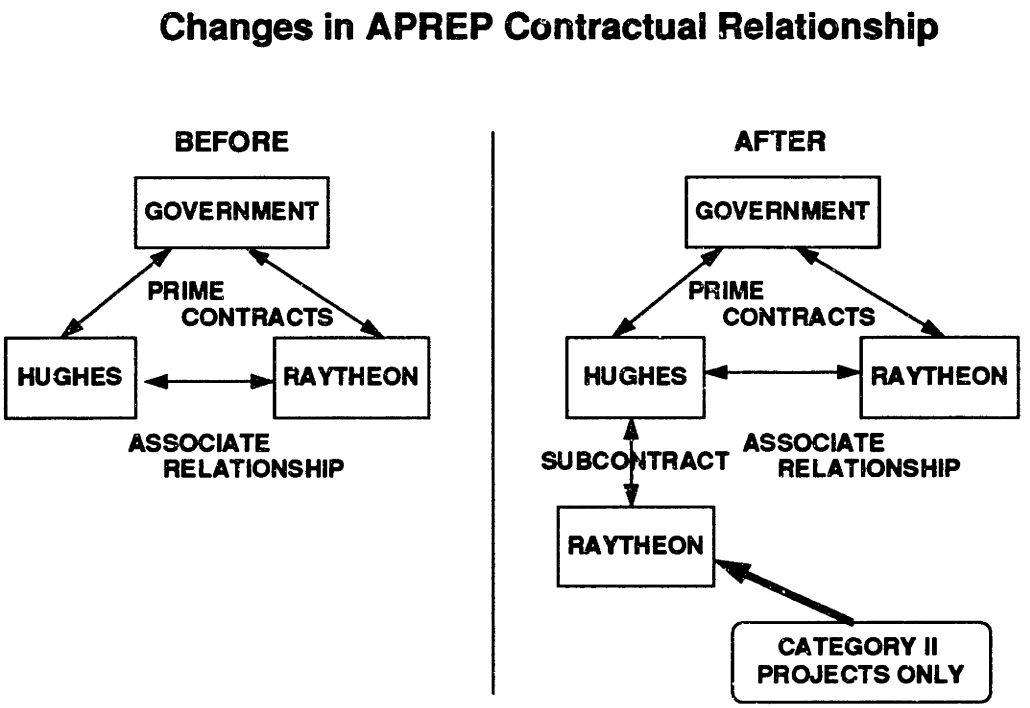

Figure 5.17

5.6 APREP Results to Date

The early concerns that some Government employees had over the appropriateness of a large, Government-directed value engineering initiative on AMRAAM went by the wayside many years ago when the first projects were witnessed on the production line and it became obvious that the effort was worthwhile. The evidence is overwhelming that the initiative has brought strong returns to the taxpayer. A logical question is: "What would have happened if we had not done the program and had relied on competition to drive the cost down?" The results in the following chart attempt to dissect the effects of the competition from the value engineering initiative.

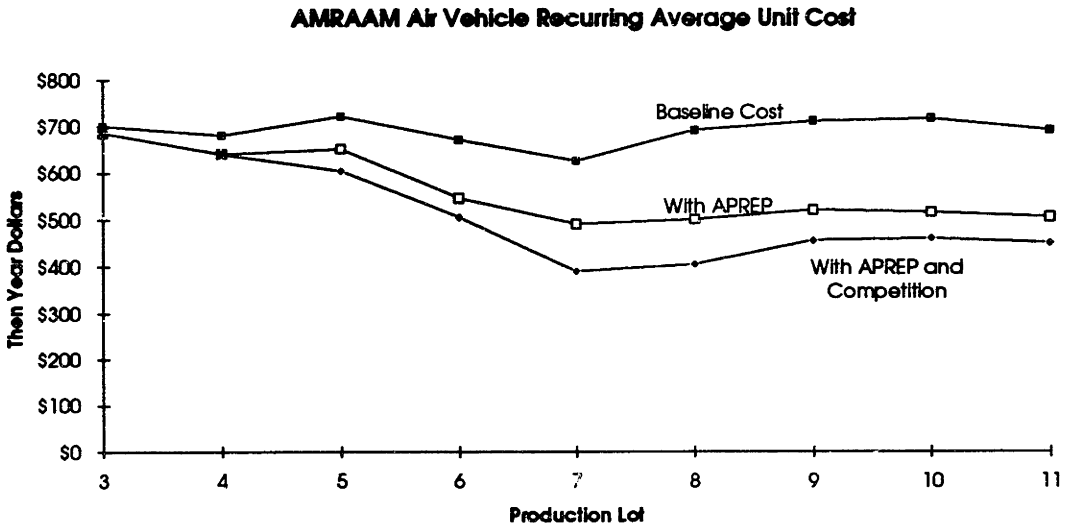

Figure 5.18

Some basic understanding of the program is necessary to understand the shape of these curves. First of all the rise in the baseline curve has the effect of two phenomena. One phenomena is the simple impact of inflation, since the data was provided in then year dollars. The more important impact that sustains the curve at a fixed level is the decrease in quantities that has occurred with the defense down-sizing efforts. Whether or not the program office can truly discriminate between the effects of value engineering and competition is not critical. Obviously, the two effects are synergistic when the phenomenal results are examined.

Another measure of merit of the AMRAAM value engineering initiative is probably how active the program was relative to other programs in soliciting and implementing VE suggestions, and what have been the savings from other programs. The following table will show comparisons with other weapon systems.

Table 5.4
Comparison of AMRAAM's Value Engineering Results to Other Missiles

Program	Total Program Value	Number of VECP's	Missile Quantities	Program Savings
Maverick	$2,347.9 M	121	40k	$520 M
Phoenix	$1,915.0 M	39	3k	$17 M
TOW	$1,588.7 M	192	250k	$165 M
Patriot	$8,385.0 M	36	8.8k	$409 M
AMRAAM	$11,350.0 M	38	13.6k	$1,821 M

These data are very complimentary of each of the programs in attempts to drive down costs and are not likely to be representative of the defense industry in general.[128] Probably the most clear indicator of the exceptional results of the APREP initiative has been its selection as the Most Outstanding Value Engineering Program in DOD by the Secretary of Defense.

5.7 APREP Lessons Learned:

There are many precedent setting elements to the APREP initiative. As the Government and contractor participants described the outcome, the positive points by far outweigh the investments that all parties had to contribute to execute APREP successfully. The following lessons learned are provided:

[128]All of these programs have the common denominator of either Hughes or Raytheon being as at least one of the prime contractors. These contractors have each been much more aggressive in the VE area than the vast majority of contractors that support the Department of Defense.

- **Value engineering should be an integral part of any acquisition from the beginning for two reasons:**

  - First, it creates an atmosphere that improvement is possible and that it is in everyones interest to pursue it independently and collectively. The success within AMRAAM was contagious.

  - Second, the earlier VE is started, the more potential savings may be achieved. Some reluctance existed to starting AMRAAM's program while Full-Scale Development was underway. After it was begun, all sides recognized that opportunities had already been missed due to factory commitments (such as special test equipment) that were too expensive to replace.

- **A dedicated team to focus on Value Engineering can reap benefits.**

  -A major reason that other programs have not pursed VE as aggressively as AMRAAM is the immediate reaction that they could not afford the manpower to run the program. The potential savings far outweigh the cost of the manpower that is required.

  - The biggest reason to dedicate a team is to maintain focus. Attempting to manage a comprehensive VE effort of AMRAAM's scale or Maverick's scale (see previous page Table 5.4) as an additional responsibility would not be possible without degrading performance of other duties. Also, a dedicated team can provide almost an outside look at potential improvements- the forest can be seen as well as the trees.

- **Communication and mutual respect between all parties is critical.**

  - A value engineering team can be most effective if given nearly complete insight into the design and manufacturing process.[129]

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[129]The only reason for qualifying this statement is that Raytheon, who was the second source, was able to contribute extremely well to the VE effort without having total access to the Hughes design process. Raytheon was given much better insight than someone totally new to the program, however, through the leader/follower program.

- Hughes initially didn't want Raytheon to have any role as a design agent. Hughes middle-management actually stated to the Government that Raytheon would not be able to constructively contribute. "Not invented here" attitudes had to be left behind. Hughes higher leadership understood all along that Raytheon could be an important contributor, but it took Raytheon being selected for the majority of the first APREP projects to convince Hughes middle management to recognize the second source's potential.

- Communication is equally important on the Government's side. Openness with the contractors to develop long-term planning, to organize and execute system integration activities, and to effectively perform configuration management activities were key to APREP's success.

- **Be creative with contract structure and consider the total acquisition program strategy when developing the VE acquisition strategy.**

  - APREP broke each project into classic system engineering milestones. This permitted the Government to not commit all project funding up front. Subsequent funding was provided as the contractor made progress that was committed to in the beginning of the project. "Deliverables" during the phase were tied to required milestones during the phase, and completion of the phase was usually based on satisfactory completion of a formal review and related deliverables.

  - Projects were awarded competitively. This not only made the projects more affordable, but also gave the Government the leverage that was necessary to obtain data rights, and other contract special provisions that were key to the larger, longer-term program acquisition strategy.

  - The contract structure made the administration of the numerous projects more manageable. Although the contract had many options (several associated with each project), the administration was much easier after award because projects not being continued for any reason could be stopped simply by not awarding the next phase.

- **Be prepared to "make mistakes".**

  - There was natural attrition of some projects after the development started. The initial attitude was that there had been mistakes in awarding these projects. This was a mindset that did not prevail. It was expected in the beginning by the Blue Ribbon Panel that some projects would fall by the wayside. The project selection criteria included a screen of "low to moderate" risk. By definition, if there is any risk at all, there is a probability that fall-out may occur. Had there been no project fall-out, then the project selection criteria probably would have been too conservative, or projects might have been continued regardless of their potential.[130]

- **Strong cost analysis should be a major driver into the development of the strategy.**

  - AMRAAM had developed and maintained a strong cost baseline through a well coordinated effort in previous program negotiations. It was later augmented by a "should cost" effort that gave the Government even more insight from the bottom up. This allowed the Government to make project selection decisions with much more confidence than would have been possible purely on the contractor's proposals.

  - APKEP projects were required to continuously update cost estimates for both non-recurring (new factory tooling and test equipment or modifications) costs and recurring (missile production costs), and to track these against the baseline missile production program cost. This allowed the negotiations for shared savings to be much more straightforward later on.

- **Every effort should be made to reduce risk for introducing the VE project into the production line and the operational inventory.**

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[130]The Raytheon control section project was an example. This project had the potential to easily save over $100 million. However, technologies required were shown to compromise very critical supportability requirements and would have significantly impacted life cycle cost. It was a tough decision to make, but apparently the right one.

- In FSD, Hughes engineering staff was able to make sufficient quantities of the analog range correlator to deliver the required missiles. However, when it came time for the Hughes or the Raytheon factories to produce for production, it was not possible. In the APREP digital range correlator project, Hughes had much more focus on producibility up front, and was able to make the production line at both contractors much happier from the beginning. The transition planning that took place was much improved over FSD.

- Comprehensive qualification is necessary. Thorough testing, both environmental and performance, should occur prior to releasing new designs to the factory for production. On APREP it did, and no surprises came up after the customer received APREP missiles.

- **The dollar incentives to the contractors can be very large and a great motivator.**

  - APREP will provide over $100 million profit to Hughes and Raytheon over the course of the program.

- **Value Engineering and Competition can be synergistic.**

  - Competition and VE programs have complemented rather than detracted from each other on the AMRAAM program.

  - The second source Raytheon aggressiveness on the APREP initiative provided a strong motivation for Hughes to pursue value engineering.

- **The "Status Quo" Value Engineering program is not sufficient.**

  -At least for the contractors observed on AMRAAM, it is apparent that unless a major motivator exists (such as potential program cancelation or higher Government assumption of risk, both of which were present on AMRAAM), the contractors will likely only use value engineering to a minor portion of its potential.

6.0 Pre-Planned Product Improvement (P^3I) Program

6.1 Purposes of the P^3I Program

The purposes of the AMRAAM Pre-Planned Product Improvement Program are as follows:

- To respond to changes in the threat against which AMRAAM is required to operate.
- To maximize the effectiveness of AMRAAM when integrated with advanced aircraft.
- To enhance readiness and supportability of the system.
- To extend the useful life of the system.

An example of a change in threat might be the introduction of a new Russian MIG fighter that would use multiple engines. Typically, AMRAAM would be able to destroy a single engine fighter aircraft by taking out the engine. With a multi-engine fighter this might not be as likely. Therefore, AMRAAM has looked at advanced warhead techniques that could render other critical elements of the aircraft inoperable.

An example of refining the AMRAAM design to be more effective with an advanced aircraft is the AMRAAM compressed carriage configuration that has been developed under P^3I. This allows the missile to be less visible and to provide less drag to the aircraft. It would also allow tighter compacting for internal carriage. New aircraft such as the F-22 Advanced Tactical Fighter would capitalize on these types of improvements.

6.2 Phased Approach to P^3I

The improvements that are available to the AMRAAM are unending, as new technologies emerge and more capable aircraft platforms are developed. To structure the development, qualification and introduction of the P^3I changes, the JSPO has established a phased approach similar to the producibility changes that were (and are) being made on the AMRAAM Producibility Enhancement Program (APREP). In fact, because of the large scope of the APREP initiative and the fact that the P^3I modifications to the missile would occur to the APREP configured missile, the APREP and P^3I programs have been

managed out of the same special projects group within the JSPO. This allowed close coordination between the two teams. The P3I phased approach allowed the JSPO to manage to yearly funding limitations. The approach provided for immediate emphasis on high priority projects, and allowed the JSPO to refine and investigate other areas of improvement that might be beneficial to counter the evolving threat. Just as in APREP, the P3I effort multi-phased approach will result in "block changes" to the production baseline.

6.3 AMRAAM P3I Schedule and Phase Description

The P3I program looks well beyond the turn of the century. The following schedule shows how the P3I effort is currently structured into 3 phases that will be separately subjected to a Engineering and Manufacturing Development (EMD) Phase.

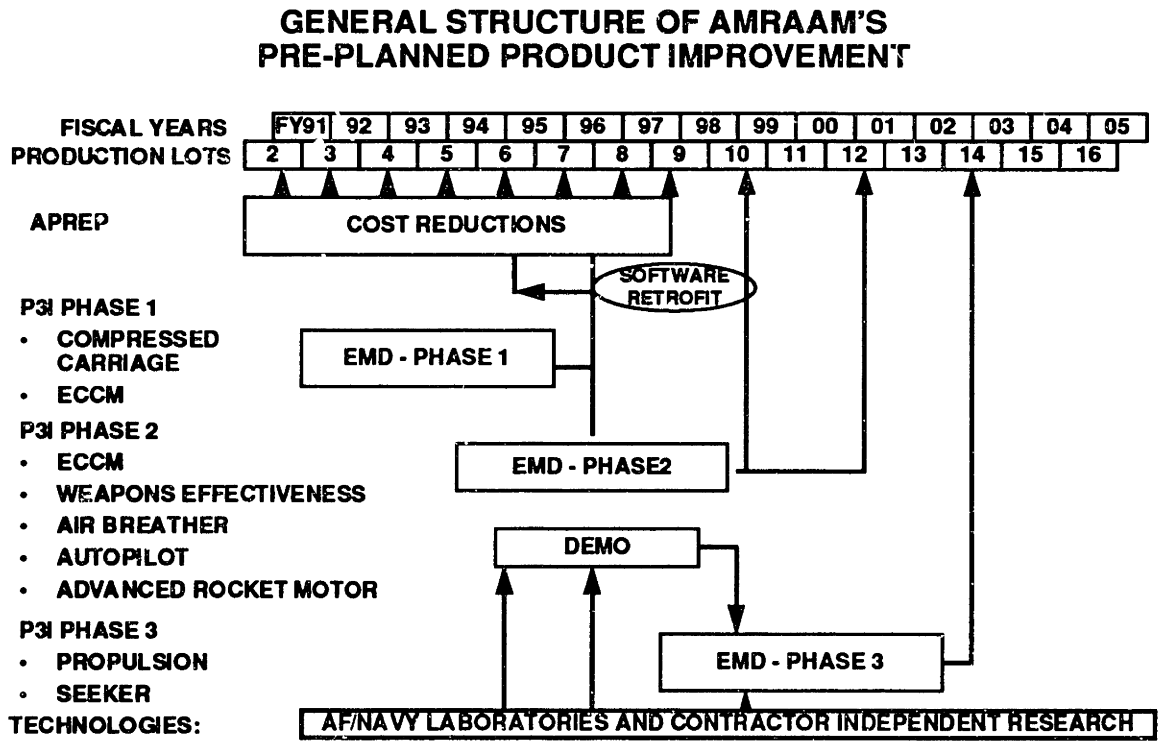

Figure 6.1

The first phase of P3I, consisting of compressed carriage and electronic-counter-counter-measures (ECCM), is well on its way with 33 of a 44 month schedule completed

with excellent progress. The compressed carriage design has been verified through two separation/control test vehicle launches. The ECCM hardware and software is being verified much like the original design with the use of Hardware-in-the-Loop (HWIL) simulation programs. The critical design review for the first phase was completed successfully in January of 1993, and free flight testing may start at any time. Production incorporation is targeted at Lot 8 in July of 1996.

The second phase of P^3I will generate additional improvements to the ECCM, and will demonstrate selected technologies such as bank-to-turn guidance, airbreather propulsion, and advanced solid rocket motors that will improve the range and speed of the missile. This contract should be awarded by the summer of 1994. The demonstration portion of the second phase has two basic objectives:

- To evaluate and demonstrate the most viable technologies for the improved kinematic performance of the missile, and
- To develop the upgraded tactical missile design.

The third phase will build on the second phase demonstration results to meet the evolving operational requirements and will maintain the baseline capabilities while improving seeker and/or propulsion performance.

6.4 AMRAAM P^3I Management Approach

As previously described, the AMRAAM Producibility Enhancement Program (APREP) originally had separate contracts with both Hughes and Raytheon for all projects. Later, the APREP arrangement was modified to award a single contract to Hughes and a directed subcontract to Raytheon for the more complex/interacting projects where interfaces were likely to change to optimize the design. The same relationship was established for the P^3I program. In this arrangement, Hughes is the contractor to the Government and Raytheon is the subcontractor once again. The two companies have developed a share arrangement for new effort that generally splits the hardware

development 50%/50% and Hughes is responsible for virtually all software upgrades. The project managers within the JSPO stated that the relationship is effective.

6.5 P3I Contracts

The prime contract with Hughes for P3I is Contract Number FO8626-91-C-0034 and had a value of $95,464,290 as of March 23, 1994. (Raytheon is a subcontractor.) The P3I Phase 2 Contract (FO8628-93-R-0044) for Full-Scale Development of the P3I changes is not yet definitized.

7.0 AMRAAM Related Technology Modernization (Tech Mod) and Industrial Modernization Incentive Plan (IMIP):

The Technology Modernization (Tech Mod) and Industrial Modernization Incentive Plan (IMIP) were initiatives established by the Office of the Secretary of Defense to improve the efficiency of DOD contractors by investing in improvements that would benefit numerous programs. "Seed" money was provided to contractors from a non-program specific fund to investigate and develop improvements to processes and other areas that would improve factory productivity. The AMRAAM Program supported Tech Mod and IMIP initiatives as far back as the AMRAAM validation phase in 1978. These initiatives were directed to accomplish the following:

a. Identification of new and innovative manufacturing methods and technology to reduce cost.

b. Analysis of AMRAAM prime and subcontractor facilities with focus on productivity, cost savings, and plant modernization.

c. Factory-wide modernization, in concert with both the Army and the Navy. These initiatives were intended to provide a structured business arrangement for incentivizing lower cost production capabilities at AMRAAM prime and subcontractors facilities.

7.1 Examples of Tech Mod and IMIP Projects

By March of 1987 there were 21 AMRAAM Tech Mod projects under contract. The Tech Mod projects were structured into 3 phases. The first phase was a study phase which would propose the contractor's idea for cost savings to the Government. The second phase included design and development (Phase 2A) and manufacture of a working prototype (Phase 2B). The third phase of Tech Mod was the implementation phase. Eleven projects in 1987 were in Phase 2A and ten projects were in Phase 2B when the AMRAAM Blue Ribbon Panel that advocated the APREP program was convened. The

panel studied 12 of the projects and determined that only 7 had sufficient savings to warrant further consideration. Examples of the Tech Mod projects were as follows:

- Wire Bond Pull Tester: All the interconnections in the AMRAAM hybrid microelectronics circuitry had to be pull tested to ensure the integrity of the wire bonds. The test that was conducted consisted of placing a small hook under the center of a wire arc created between the bonds and pulling at a preset force. The Tech Mod project was planned to replace the manual tester with a fully automated machine that would improve productivity and consistency. (This project did provide eventual benefit to the production line.)
- Leadless Chip Carrier (LCC) Placement: LCC devices and component chips were planned to be placed and correctly positioned on ceramic circuit cards prior to soldering. An automated work station was to be designed to populate the ceramic cards with these devices. (This project was overcome by APREP advances in technology.)
- Thermal High-Speed Testing: Hughes planned to perform complete automation for testing and environmental conditioning of a broad category of digital subsystems and components. The automated tester was planned to stabilize the units being tested at high and low temperatures prior to performing functional tests, and was considered to be a significant cost saving measure when high rate production of the missile were to occur.
- Eighteen similar projects at the prime or vendor level: Most of these projects never reached implementation.

7.2 Lessons-learned from Tech Mod and IMIP:

These projects provided only limited benefit to the AMRAAM program. The main problems that occurred are as follows:

- Many of these efforts have targeted processes that became obsolete in the missile design before completion of the improvement project. The length of time that was

necessary to identify a potential project, to obtain Government approval, to develop the project, and to implement the project exceeded the window over which the change would have been cost-effective.

- The program appeared to be supported by AMRAAM alone. Very limited funding was provided from other sources (higher headquarters, other Air Force programs, the Army or the Navy) even though the efforts were selected based on plant-wide benefits to all DOD customers.
- The effort was managed as a low priority effort by both the Government and the Contractors.
- There was a lack of follow-through on many projects due to unrealistic upfront savings projections. Also, several contractors committed to capitalize factory equipment in their proposals to receive funding for their projects, but after the project development no longer would carry through this commitment.
- Much of the cost savings that was planned under these initiatives vanished due to the APREP initiative. APREP also improved manufacturing processes within the prime and subcontractors, and also eliminated many inefficient production processes.

8.0 Joint-Service Participation

8.1 Origin of AMRAAM as a Joint-Service Program

From the generation of the operational requirements beginning in October of 1975 to the present day, the AMRAAM program has been truly multiple-service. The Air Force, Navy and Marine Corps were all side by side in the pre-conceptual phase period when the original studies were being conducted into the requirements that future lightweight radar missiles would have to satisfy. Differences existed, but compromise was reached at the operational level to develop the prioritized set of operational requirements that stand almost totally as written over 15 years ago. The team was visionary in defining requirements in terms of operational needs rather than dictating the design solution to the acquisition community.

8.2 Air Force Designation as Executive Service

After the operational requirement was drafted, the Secretary of Defense designated that the program would be joint-service and that the Air Force, as the major consumer of air-to-air missiles, would be the executive service. The term executive service refers to terminology originating in a joint service regulation[131] that outlines the management of multi-service programs. The regulation establishes joint program management offices with other military departments where a single service, such as the Air Force in the AMRAAM case, is appointed as executive agent. The regulation was intended to establish policies for implementing the early Department of Defense directive[132] for acquiring major defense systems. This joint-service regulation states that the service designated as the executive agent shall have the authority to manage the program under the policies used by that service. Therefore, the AMRAAM JSPO has almost always used the Air Force regulations and methods in executing the program.

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[131]Air Force Systems Command/Air Force Logistics Command Regulation 800-2, Army Material Command Regulation 70-59, and Naval Material Command Instruction 5000.10A, Subject: Acquisition Management: Management of Multi-Service Systems, Programs, and Projects, dated September 4, 1975

[132]DOD Directive 5000.1, "Acquisition of Major Defense Systems", dated July 13, 1971

8.3 Responsibilities of Executive and Participating Services

There are defined responsibilities assigned to both the executive service and participating service, such as the Navy in AMRAAM's case. The executive service is required to:

- Assign the Program Manager.
- Establish a joint-service staffing document that incorporates positions that will be occupied by personnel from the participation services, and includes a senior representative from each of the participating services.[133]
- Staff the Program Management Office in accordance with the staffing document.
- Be responsible for the administrative support of the Program Management Office.
- Delineate the functional tasks to be accomplished by all participants.

There are complementary responsibilities for the participating services such as:

- Assigning qualified personnel to the program as defined in the staffing documents.
- Having the senior representative report directly to, or have access to the executive service program manager, typically as the deputy to the program manager.
- The senior representative is, in turn, responsible to speak for the participating service and insure proper coordination within the participating service.
- Provide travel funds and support for their own (participating) service representatives.

8.4 Evolution of Program Management Charters for AMRAAM

The executive service is required to prepare, negotiate and issue a jointly approved charter for multi-service programs such as AMRAAM. The charter identifies the program manager and establishes the program office. The charter also describes and assigns responsibility for satisfying any peculiar management requirements.

The first official charter on the AMRAAM program was signed in September of 1978.[134] This charter identified two charismatic leaders, Colonel Luke H. Boykin from the

[133]In AMRAAM's case the only other service considered to be "participating" was the Navy, who was to also represent the Marine Corps.

[134]Program Management Charter, Advanced Medium Range Air-to-Air Missile, dated September 12, 1978.

Air Force to serve as the Program Director, and Captain Burton L. Munger from the Navy to serve as Deputy Program Director. The charter identified Col. Boykin as the single central executive responsible for the successful management of the program. The charter went on to identify his specific authority to manage the program, tailor the organization, tailor the application of regulations to the needs of the program, make technical and business decisions, assess and identify program resource requirements, maintain continuous assessment of program status, and report problems to proper higher echelons. The charter also defined how the Air Force program director would evaluate/rate all Air Force personnel, and would prepare letters of evaluation on Navy personnel.

The Navy Deputy's responsibilities were: to act for the Air Force Program Director on joint-service matters in his absence, to insure that Navy program needs were brought to the attention of the Air Force Program Director, to provide inputs into program issues and policies, to manage unique Navy requirements, to provide status to the Navy upper management, and to serve as the Navy liaison on the program.

A unique requirement on the AMRAAM program identified in the charter was to establish an AMRAAM Steering Group which would be chaired by the Under Secretary of Defense for Research and Engineering and have members from the Office of the Secretary of Defense, the Air Force and the Navy. This senior group was used to discuss and attempt to resolve AMRAAM-related program issues beyond the control of the AMRAAM program director.

One of the most critical agreements in the charter identified which service was responsible for funding which program requirements. The agreement called for the services to equally fund the Validation Phase[135], and for the Air Force to fund the Full-Scale Development Phase with the exception of : Navy unique requirements, Navy travel, and Navy aircraft modification development and fleet installation. For production, the

[135]By this time, the Conceptual Phase was within its last few months of being complete.

services would each pay costs prorated to the number of missiles each service were to buy.

The next charter update[136], occurring in 1985, remained very much the same except for the following:

- Specific names of the Air Force Program Director and the Navy Deputy Program Director were deleted.
- No mention of the fact that the Air Force Program Director would prepare a letter of evaluation on the Navy Deputy.
- The funding agreements were changed and became more specific in identifying the relative funding from each service for FSD and aircraft integration.
- Joint operating procedures were put into place in the areas of Test and Evaluation, Configuration Management, and Financial Management.

In 1987, the Joint USAF/USN Program Management Charter for AMRAAM was once again signed[137] by the top military acquisition authorities within the Air Force and Navy. This version of the charter had no changes over the 1985 charter, and remained in place until 1993. In 1993, the AMRAAM P^{3}I program made it prudent to update the responsibilities of each service in defining requirements, staffing, funding and general coordination in an updated charter.[138] The update is also an official endorsement of the P^{3}I program by both services.[139] Another new feature of the 1993 charter is that the recent Program Executive Officer structure for major programs has been included.'[140] The

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[136]Updated charter dated November 21, 1985.
[137]Updated charter dated July 30, 1987.
[138]Updated charter dated August 2, 1993.
[139]This endorsement was politically necessary to show joint service support for the AMRAAM P^{3}I program. The Navy had been pursuing development of a new, longer range missile to replace their aging Phoenix systems that protect the fleet. Although Congress continued to not fund the effort, the Navy was able to sustain the program through the Naval Weapon Center technology efforts in China Lake, California for several years. Finally, Congress directed that the program be stopped. This endorsement by senior Air Force and Navy members gave credence to the commitment that AMRAAM's P^{3}I effort would also address extended ranges more suitable to the Navy's needs.
[140]The Program Executive Officer management structure was directed by the Secretary of Defense to be put in place for all major programs as defined by DOD Instruction 5000.1. This structure greatly

new charter also states funding responsibilities for establishment of depots for missile repairs and upgrades. Finally, the charter states that the services will jointly fund the P^3I program, and that neither service will unilaterally make budget decisions that would preclude program execution.

8.5 Joint Service Effectiveness on AMRAAM from the Participating Services Perspective

AMRAAM is the current "best-practices" example of how to respond to Congressional and Office of the Secretary of Defense demands for more truly joint-service acquisitions. The AMRAAM program office personnel are continuously being requested by other programs from all three services to provide insight into what has made the Air Force and Navy marriage work in the case of AMRAAM . Captain Bill Walker, the Navy Deputy Program Director, and Richard C. Calano, the senior Navy civilian on the program, provided this assessment: "Jointness became the AMRAAM culture and the basis for AMRAAM philosophy. There are no Air Force issues, there are no Navy issues, there are only AMRAAM issues."[141]

8.6 Joint-Service Lessons-Learned on AMRAAM

The following are both positive and negative lessons-learned regarding the joint-service relationship:

- **A joint-service program is like a marriage- it is a permanent relationship.** This has far-reaching implications. First of all there is an early need for understanding and commitment. Second, there is a need for compatibility of all key personnel within a joint system program office. They will live and work together on very challenging issues for many years. "Personalities" can make a difference.
- **"The faintest ink is better than the best memory."** The process of defining, documenting, and coordinating the program charter is the most beneficial activity to

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streamlined the reporting chain from the Program Director through a PEO (who acts as a "Godfather" in the Pentagon) and then directly to the senior acquisition official within the service.

[141]Naval Air Systems Command, Team Forum, Volume II No. 12, December, 1993, "Partnerships, AMRAAM Leads the Way To Joint Success"

set the stage for joint-service success or failure. Putting agreements down in writing forces issues to be staffed and committed to by higher management. It also retains a basic understanding for future personnel newly assigned to the program to refer to when making program decisions and resolving issues.

- **There are many more resources available to a joint-service program, and their use fortifies the relationship.** The AMRAAM program draws on a broad base of support from both the Air Force and Navy developmental laboratory, test and logistics support structure. For instance, in addition to the JSPO at Eglin Air Force Base in Florida, the AMRAAM program obtains support from:

  -the Naval Air Systems Command in Crystal City, Virginia;

  -the Naval Air Warfare Center in China Lake, California;

  -the Navy's Point Mugu Test Center, also in California;

  -the three Naval Weapons Stations in Falbrook, California, Yorktown, Virginia, and Earle, Pennsylvania; and

  -the Naval Surface Weapons Center in Dahlgren, Virginia.

- **The Charter should be a living document and should be updated periodically to address new issues.** A prime example is in the area of program funding for production. If one service modifies its plan to acquire missiles without prior coordination of the other service, havoc can (and is) wrecked on the program's budgeting and contracting process. AMRAAM's charter was modified in 1993 to include an agreement not to make such unilateral changes.
- **The best people will wear a "purple" suit, not Air Force Blue or Navy Blue.** Teamwork, trust, and commitment are all essential to successfully plan, budget for, execute, modify, and re-modify the acquisition strategy for a joint-service effort.
- **Stability in both services is critical. (Also true for single service programs.) The appropriate personnel stability and turnover ratio combination raises the probability of success.** First, stability of personnel filling certain key positions of

both the Air Force and Navy on the AMRAAM program allowed joint-service professional relationships to develop that facilitated communications and rapid resolution of problems. Second, selected turnover of other key personnel (primarily but not exclusively military) facilitated transfusion of lessons-learned from other programs from each service and current operational user experience to effectively influence AMRAAM's acquisition. The right mix of corporate memory and cross-feeding from other programs and the user was a major challenge that was turned into an AMRAAM program attribute.

- **Integrate participating service personnel throughout the Program Office.** Do not establish separate co-located offices. In AMRAAM, the Navy had limited resources applied to the program, therefore they had to be (and were) strategically located to maximize their visibility and contribution to program issues.
- **The joint system program office should be a team and a family.** The AMRAAM program office was fortunate that key personnel in both the Air Force and Navy recognized the need to develop as a team and a family to effectively work together. In addition to handling the challenging workload as a team, there were many other activities that were used to pull the JSPO together such as: tension relievers including social gatherings (both with and without family members); great emphasis on physical fitness and athletic events; planned and spontaneous individual and team recognition of accomplishments; and Commander's Calls for direct communication between JSPO leadership to all JSPO personnel to provide status of the program and where it was going.

9.0 International Involvement and Programs

AMRAAM has been a multi-national program since its inception. One of the most important issues addressed in the initial meeting of the Defense Systems Acquisition Review Council (DSARC) on AMRAAM was the evaluation of all alternatives to meet the US need, including purchase of allied weapons. A careful analysis was conducted on each foreign system, and it was determined (and agreed by the allies) that AMRAAM was a necessary new effort. The documentation that was developed to support this decision process was very thorough.[142] The DSARC had an active staff that supported Ambassador Komer, who represented North Atlantic Treaty Organization (NATO) influence on the committee, and carefully examined and approved the plans for AMRAAM.

9.1 The Memorandum of Understanding (MOU) for Air-to-Air Missiles

In 1978 and through today, the Office of the Secretary of Defense (OSD) has provided basic guidance to the effect that Rationalization, Standardization, and Interoperability (RSI) with our Allies must be fully explored with regard to the development, production, and ultimate deployment of weapon systems, including air-to-air missile systems. OSD's guidance to the acquisition workforce is intended to further national policies to exploit the military, economic, and political advantages which can result when research and development resources are shared, and when weapon commonality allows operational flexibility to US and Allied forces. RSI is a fundamental consideration in the AMRAAM program.

AMRAAM was designed to be compatible with the F-16, which is being used by several NATO countries. AMRAAM is required to be compatible with several other allied aircraft including the German F-4F, the British Sea Harrier FRS2, Tornado F-2, and F-3 aircraft.

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[142]AMRAAM Rationalization, Standardization and Interoperability Plan dated September, 1978; and the AMRAAM Allied Participation Plan dated November, 1980

The government of France (FR), the Federal Republic of Germany (GE), the United Kingdom (UK), and the United States (US) signed an MOU in August of 1980 concerning the development and production of the AMRAAM system and the advanced shorted Range Air to Air Missile (ASRAAM) system. Although FR is a signatory to the MOU, they are a non-participating government under the MOU.[143]

The MOU recognized the need for a new generation of advanced air-to-air missile systems to meet established operational requirements for countering the military threat to the parties of the North Atlantic Treaty Organization. The threat to NATO closely paralleled the threat that was postulated by the US Joint Service Operational Requirements Document (JSOR).

Under the MOU, the US was responsible to develop and produce the AMRAAM system. A European consortium was responsible to develop and produce a short range system (that will be discussed later in this section). The European participating governments (GE and the UK) were given the option to determine how they would proceed to acquire AMRAAM. GE and UK had the opportunity to acquire AMRAAM through a direct purchase from the AMRAAM production contractors, or via a foreign military sales (FMS) purchase as part of a US production contract. The countries also had the opportunity to purchase selected subsystems from the US and coassemble in Europe; or could develop an autonomous capability to dual-produce in Europe. In the mid-1980's a European industrial team was chartered by the GE and UK governments to determine if Europe would be capable of producing an AMRAAM. The team came to a preliminary conclusion that European industry had or could obtain the necessary expertise to produce the missile. The governments (GE and UK) then proceeded to establish a participating prime contractor (PPC)[144] team with industry representatives from each country to

[143]A "non-participating government" had rights under the MOU to become a participant at a later time. Also, France was not bound by the limitations of the MOU in sales of its air-to-air weaponry as was the US, the UK and FRG.

[144]This participating prime contractor role was delineated in the MOU.

undertake further exploration of Europe's ability to produce a cost-effective missile. Cooperative governmental and industrial arrangements between the US and European participants were encouraged to further the success of these NATO RSI efforts.

US and European interfaces on the AMRAAM were structured at several levels. Responsibility for overseeing the implementation of the Air-to-Air MOU was assigned to a Program Steering Committee (PSC). The PSC served as a formal point of contact among the participating governments for matters arising from the MOU. Much more actively, per the MOU, the participating governments each assigned representatives to the AMRAAM program office at the outset of FSD. Their purpose was to follow the progress of the program, to ensure continuous liaison and cooperation with their national governments, and to facilitate a European decision as to which acquisition approach they should proceed with to later obtain the AMRAAM system. A fall-out benefit was that the Europeans were able to obtain significant AMRAAM technology through monitoring the program.

During the Validation Phase of AMRAAM, aircraft/missile interface data exchanges took place and the aircraft/avionics modifications necessary for compatibility with NATO aircraft were analyzed and documented to the extent that mechanical and electrical subsystem data were available. There was an exchange of information on generic simulations which addressed the missile performance that was to be expected from varying aircraft flight profiles. Both GE and the UK agreed that the preliminary information revealed no major obstacles to the interoperability of AMRAAM with their respective candidate aircraft.

In the FSD Phase, the data transfer to the Europeans was expanded to include logistics planning information. The European participating prime contractors also began to interact directly with the FSD contractor (Hughes Aircraft Company). Hughes initiated efforts to finalize specifications for NATO standardization agreements for the

aircraft/missile avionics interface, missile/rail launcher interface, and missile/eject launcher interface.

A critical success factor for co-production or dual production lies in achieving a workable arrangement for technology transfer. Under the AMRAAM program, technology transfer was structured to safeguard information and technology for security and industry proprietary reasons. The need existed to release enough information for the Europeans to make an informed decision on which way to proceed, yet to control the flow for the purposes described above. The AMRAAM JSPO, with input from US industry, identified critical technologies and data that needed to be protected. This information/data was segmented and release controlled accordingly. Aircraft interface data was released very early in the process, because every alternative that called for the Europeans to use AMRAAM would require aircraft integration activities to be initiated early to reduce cost and risk.

The primary approach for data transfer contemplated under the MOU was that the US prime contractor (Hughes Aircraft Company) and a European participating prime contractor would enter into a licensing agreement on an industry-to-industry basis. Alternative license arrangements were also contemplated by the MOU that would have included the European subcontractors and US contractors.

A major legal battle erupted between Hughes and the Government and Raytheon regarding the right to sell AMRAAM overseas. After several years of debate, Hughes Aircraft Company opted to form a partnership with Raytheon Company to form AMRAAM International Licensing Company (AILC) to collaborate on the licensing of AMRAAM European coassembly or co-production contemplated in the MOU. GE's Mersserschmitt-Boekow-Blohem (MBB) was identified to be responsible for negotiating manufacturing rights and access for AMRAAM production within the Federal Republic of Germany.

After much debate between the United Kingdom and the Federal Republic of Germany, the countries elected not to proceed with plans to coassemble or co-produce AMRAAM. Each country now has efforts underway to obtain AMRAAM through the US Foreign Military Sales (FMS) program. In total, Hughes is contracted to produce approximately 170 tactical missiles and Raytheon approximately 120 missiles for US Allies in Lot 7. For Lot 8, Raytheon (who won the larger portion of the US missile production split) was awarded 120 FMS missiles; and Hughes was awarded 80 FMS missiles.

9.2 The Other Side of the Air-to-Air Missile Memorandum of Understanding- The Advanced Short Range Air-to-Air Missile (ASRAAM)

The Air-to-Air MOU between the United States, the UK and GE had another important element beyond the agreement that the US would develop the next generation medium range missile. It also provided that the Europeans would develop the next generation of short range missiles- to be known as the Advanced Short Range Air-to-Air Missile (ASRAAM). This was an important concession on the part of the US, in that previously the US had not been dependent on another country for air-to-air weapons.

ASRAAM was to be funded by the European governments, developed by a European team, monitored by the US, and provide the equivalent acquisition options to the US that were provided to the Europeans on AMRAAM. The program became very political between the Europeans. Two concepts competed, one from the UK and one from GE. After a very protracted period of negotiations, the Europeans were able to form a joint-company specifically formed for ASRAAM's acquisition. Funding issues developed when the program failed to achieve technical progress and the schedule stretched beyond acceptable limits to the European governments.

The European partnership went on hold finally, and ASRAAM progress dwindled to a virtual standstill, leaving only a token amount of support and confidence left in

Europe or in the United States that ASRAAM would ever become reality. When the Europeans backed out of continued development of ASRAAM, the MOU was abrogated.

The United States had taken on the much more complicated and expensive AMRAAM program and had by this time gone through all phases of development and were solidly into production with two competitive sources. In addition, the US had hosted the European representatives in the AMRAAM JSPO for approximately 10 years, and had provided substantial access to technologies that emerged and were fully developed on AMRAAM. In summary, the US had fully lived up to its end of the MOU, whereas the Europeans had been unsuccessful.

9.3 Lessons Learned from the Air-to-Air Memorandum of Understanding Experience:

- The concept of sharing the responsibilities in weapon system acquisition with our allies is excellent. Obviously there is more of a need in today's environment than ever to find more affordable methods to acquire our military capabilities.
- Agreements with our allies need to have technical, cost and schedule controls in place to assure all parties needs are met. That is not to say that one country should control the resources of another, but that thresholds would be established and progress would be tracked in each area to inform everyone of the health of the program. As it was, the ASRAAM was unhealthy long before the European company or governments were willing to recognize it. The US had agreed not to develop its own next-generation short range system, and was limited for many years to making improvements to the existing systems.
- Acquisitions through true partnerships are extremely difficult between governments. Although the commercial industry has been very successful, military efforts have had limited success. With the best of intentions, forming a joint company and having to put up with two sets of government oversight might be overwhelming.

- On the positive side, the Air-to-Air MOU might be considered a success. The US did not dilute its resources by undertaking a new short-range effort at the same time it was going through the AMRAAM effort. Likewise the probability that the Europeans could have successfully executed ASRAAM was probably much enhanced by not having to take on a European AMRAAM.
- There have been other benefits to the US. Although much technology might have "escaped" for free to the Europeans, there is not much doubt that the US openness about the technical status and test results on AMRAAM gave the Europeans confidence that it was the appropriate missile for their future air combat. The intent of the MOU was that resources might be saved, as has been emphasized, but also that interoperability be truly present where a US fighter can land at an air base in Europe and use their missiles in an emergency, and that a European fighter might do the same at a US installation.
- Although the US committed precious manpower to the international operations in addition to hosting the European representatives, this relationship was not all one-sided. In discussions with a former director of AMRAAM's test program, he stated that one of the top contributors to the US developmental test program was a European representative who "rolled up his sleeves and dug in" to the overwhelming work load.
- One of the most critical aspects to the European participation (as well as participation by other allies) is that by increasing the quantity that the US is ordering from the AMRAAM producers, the unit price has dropped dramatically, and sufficient quantities have been acquired each year to sustain two competitive sources.

9.4 Another AMRAAM-related International Program

Previous air-to-air missiles, such as the AIM-7, have been adapted to shipboard launch. A similar effort is underway at the request of one of our European allies that shows the potential to exploit AMRAAM's effectiveness in a new role. This could further expand the production requirements for AMRAAM subsystems and drive down cost.

9.5 The Future of AMRAAM's International Program

There is little question that AMRAAM will be one of the most desired weapons in the world for air combat. Orders for approximately 800 missiles have already been signed[145] and another 900 are projected within the next few years. These projections were made before the recent cost reduction results of Lot 8, and are probably conservative. Another important reason AMRAAM has a strong international future is the key performance advantage it gives US tactical aircraft. Therefore, future competition for aircraft sales might very well be tied to the ability of an ally to obtain AMRAAM.

[145]Letters of Agreement

10.0 Technical Support Contracts during Production

There is technical support that is required during the conduct of the production program that is over and above the mainstream production engineering tasks. This support includes Systems Engineering, Software Maintenance, Maintenance of the Non-production Test and Simulation Stations, Maintenance of the AMRAAM Technical Data Package, and the Logistics Requirements unique to each of the AMRAAM co-producers.

10.1 Contracting Approach to Obtain Technical Support

Hughes-provided technical support has been established and sustained on a separate contract from the basic missile production contracts. The primary reason is likely that, because these tasks are sole-source to Hughes and the dollar values are quite large, the Government needs the ability to have a much more detailed proposal than would be provided with the competitive missile production proposals. Having the technical support effort contracted separately also permits detailed discussions and negotiations to take place, without fear of holding up the much larger production contracts.

The Hughes Technical Support requirements are found in a basic contract[146] that covered the period from January 1, 1993 until December 31, 1993. This basic contract had two annual options, the first of which has now been exercised and will cover the Hughes technical support needs until December 31, 1994.

A different approach has been used to contract for technical support for Raytheon. Rather than issuing a separate contract, the JSPO requested and obtained a task change proposal to the existing missile production contract. Raytheon technical support requirements have been integrated into a Program Analysis/Studies and Technical Data Package Maintenance contract line item. The efforts for 1994 and 1995 have been made parts of the Lot 7 and 8 missile production contracts, respectively.

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[146]Contract FO8635-93-C-0016, Advanced Medium Range Air-to-Air Missile Technical Support, value as of March 23, 1994 was $34,200,000.

10.2 Description of Technical Support Tasks

Examples of the support activities that Hughes and Raytheon perform are summarized in the following list. (H = Hughes and R = Raytheon)

- Elimination of Class I Ozone depleting substances studies (H & R)
- Systems engineering support to include hardware studies, system safety and integration support. (H)
- Maintenance and modification of AMRAAM test stations (non-production) and simulation facilities. (H)
- Software support to include maintenance of the missile production software, the guidance section test station software, and the final assembly and check-out station software (Fully Automated System Test software). (H)
- Test and integration support to the Air Force and Navy that includes field test team support, special test assets, and aircraft integration support. The aircraft integration support includes hosting the AMRAAM Interface Control Working Group (ICWG) and participating in interface meetings. (H)
- Technical Data package maintenance to include update of drawings, specifications, manufacturing process planning, etc. (H & R)
- Integrated logistics support to include Logistics support analysis and the maintenance of the AMRAAM Logistics Support Analysis Record, spare/repair parts provisioning documentation (data and screening), logistics on-call support, and technical publications for the user community to operate and maintain the missile system. (H)
- Foreign military sales support to include test and integration. (H)
- Special studies to determine the impact of potential changes to the Raytheon production line. (R)

10.3 Approximate Scope of Technical Support Tasks

An approximate magnitude of the technical support that is required to perform the above tasks is currently $15 to 20 million annually to Hughes and $1 million annually to Raytheon.

10.4 Rationale and Ramifications of the AMRAAM Technical Support Tasking

Hughes as the Full-Scale Development contractor has unique capabilities to perform almost any technical support task that the Government requires. This accounts for the large portion of tasking and associated funding that goes to Hughes each year. Raytheon also has unique capabilities that only they could perform, such as analysis of the potential impact to the Raytheon production line if a system change were to be made. Therefore, these tasks do not lend themselves to be competitively acquired.

There are certain tasks that might be sustained as sole-source in a protective strategy by the contractors. In particular, the software tasks that Hughes performs have evolved out of the original software development efforts on the FSD program. During FSD, software was continuously late in development and in documentation. The Government Accounting Office has been particularly critical of Hughes and the JSPO management of the software development. The strategic advantage Hughes obtains from controlling software development and documentation is in constraining any effective alternative that the Government might have for a "winner-take-all buy-out" in the missile production line if the program ever gets within sight of filling inventory requirements. This is discussed again in the analysis of future program alternatives in the last section of the thesis.

On the positive side, the large technical staff that is available at Hughes provides the technical corporate knowledge necessary to sustain the AMRAAM program as the premiere air-to-air weapon system of our time. The relative cost, comparing $20 million

for support to $1 billion for annual missile procurement, is certainly a reasonable sustaining investment.

11.0 Government Program Office Organizational and Reporting Chain Evolution

It is very interesting to follow through the changes that have occurred within the AMRAAM Joint System Program Office (JSPO) and in the reporting chain of the JSPO up through the higher Government echelons. There are many questions that might be addressed:

- Did the JSPO grow over time due to required workload and other value-added activities, or did the organization grow due to the tendency of organizations to become more bureaucratic (and "empire building")?
- Did (and does) the JSPO have the appropriate numbers and skills of personnel to perform their responsibilities during the various phases of the program?
- Were the various organizational structures that were put in place over the life of the program effective? ...Optimal?
- Was there sufficient manpower available to the Navy as a participating service on an Air Force led program, and was this manpower effectively placed in position and responsibility?
- What was (and should be) the appropriate role of support contractors to the program?
- What has been the relative personnel mix of military, civil service and support contractors?
- What were the management styles and personalities of the leaders (especially the Program Directors), and how did they influence the organizational effectiveness and morale?
- How participative has the management structure been over the course of the program? Has a total quality program been implemented and is it effective?
- What have been the sources of manpower resources and what has been the reporting chain for the Program Director regarding program execution over the course of the program?

- Finally, what should be the future structure of the JSPO- its size, organization, composition of military/civil service/support contractors?

These questions address tough decisions that the Program Director has been required to make over the course of the AMRAAM program. Although the questions cannot be answered in detail within the scope of this thesis, observations are provided in each area after the following description of the AMRAAM JSPO evolution.

11.1 Evolution of the JSPO

11.1.1 Pre-Conceptual and Conceptual Phase:

In 1977, prior to awarding the Conceptual Phase contracts, a small group of Air Force and Navy military and civilians were formed into the Advanced Medium Range Air-to-Air Missile (AMRAAM) Joint System Program Office (JSPO). The office numbered less than 30 people, and was led by Air Force Colonel Luke Boykin. His Deputy Program Director was Navy Captain Burt Munger. These two men established the joint-service relationship that is described in Section 8.0 of this thesis. In these early years, the main tasks within the JSPO were:

- to provide the operational needs in terms of requirements to the aerospace industry
- to evaluate the results of the industry technology assessments and potential design solutions to meet the requirements
- to prepare the near- and long-term acquisition strategies to acquire the system
- to prepare cost estimates and budget submissions to fund the effort
- and, as with any major program, to communicate the results of the previously described tasks to higher headquarters and operational users to obtain support and approval for the program.

During this early, formative part of the program, the organization was loosely defined, and everyone assigned to the program participated in almost every task. The five contracts that were awarded to the Conceptual Phase contractors did not require

significant management oversight because they were basically competitive studies. There were no Government tests to speak of, therefore only preliminary test planning activities to support the Validation Phase activities were required. However, during the mid- to late-1978 period, the five contractors had submitted proposals for the Validation Phase competition, and a challenging source-selection process was underway. Simultaneously, management oversight from the Air Force, Navy and the Office of the Secretary of Defense (OSD) was requiring exhaustive program planning and formal/informal reviews. Also, because the next phase (Validation) would require many test assets such as aircraft, test ranges, wind tunnels, and the like, much time had to be spent coordinating and obtaining commitments for these resources.

An additional issue came forward- the four aircraft industry organizations that were responsible for the F-14, F-15, F-16 and F-18 did not want to deal with the five Conceptual Phase AMRAAM competitors independently when they were putting together the Validation Phase proposals and aircraft interface designs. Therefore the Government became the "integrator" to provide necessary data between the aircraft and the missile.

These many simultaneous, mandatory activities drove an increase in the number of people required to staff the JSPO during Validation Phase.

11.1.2 Validation Phase

The Validation Phase had two contractors, Hughes and Raytheon, who were required to design, fabricate, develop specifications for, and flight test missiles to "prove the concept" of a self-contained lightweight radar missile. In addition to managing these contractor activities, the JSPO was required to expand and refine the long-term planning and cost estimates on the program. The JSPO was also required to continuously provide this planning along with Validation status reports to upper service and OSD management for review and approval.

By the latter part of 1981, the JSPO had an organization led by Air Force Brigadier General Gerald Schwankl that was structured as shown in Figure 11.1:

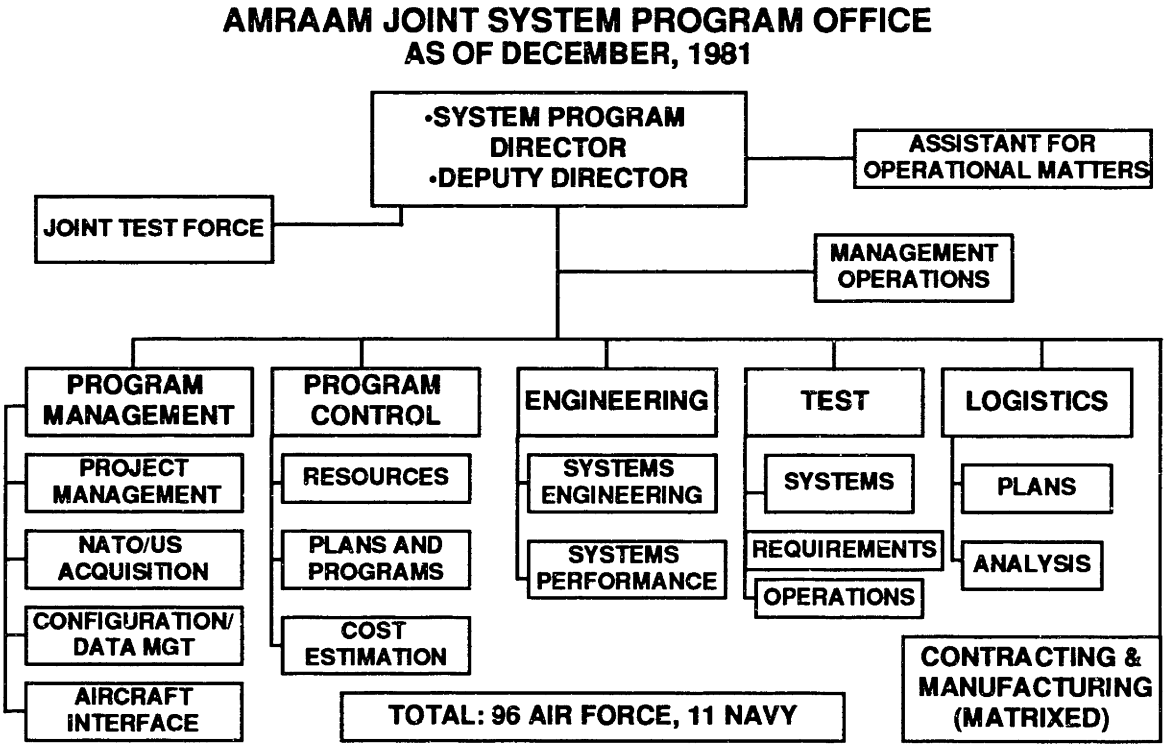

Figure 11.1

This organization consisted of 107 people (96 Air Force and 11 Navy). Five of the six divisions reported only to the Program Director. Division Chiefs in all organizations were responsible for not only the organizational functions, but also for the performance ratings and training of assigned personnel. The sixth division, Contracting and Manufacturing, was "co-located" within the program office, but reported to the Eglin Armament Division procurement organization management in a matrix fashion.

It is also important to understand the Program Director reporting chain. Recall that AMRAAM had been designated a major program.[147] With this designation came the responsibility to go through a series of service and OSD reviews to support every major milestone decision, such as going from one program phase to the other. The chain from the program director to the milestone decision approval authority is shown in Figure 11.2.

[147]In accordance with Office of Management and Budget Circular A-109 and Department of Defense Instruction 5000.1.

Program Director Management Chain in 1981

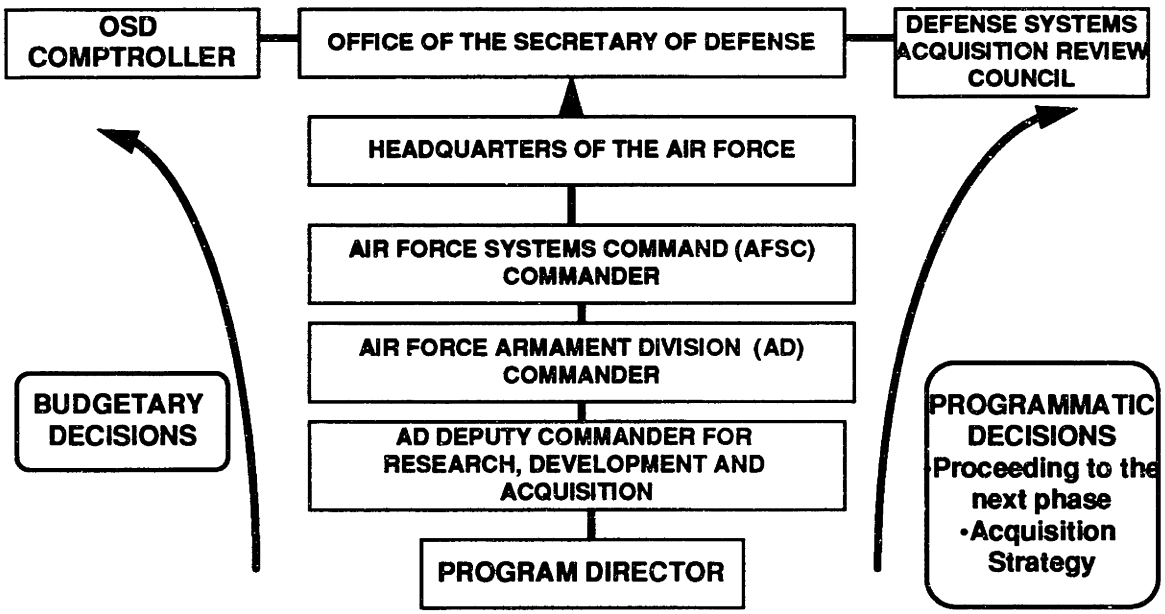

Figure 11.2

There were two types of major programmatic decisions. The first type included decisions that would approve the program acquisition strategy (program structure, contracting plans, etc.). The second type related to the approval of the program to move from one program phase to the next. Figure 10.2 shows that the program director was required to obtain approval on any major decision from six layers of management before any major program decision could occur. The final decision which would typically come from the Defense Systems Acquisition Review Council (DSARC).

There was another chain that had almost the equivalent impact on the program. This was the comptroller chain for the budgetary decision process. Whereas basic programmatic decisions were made as shown on the right side of Figure 11.2, the comptroller organization within OSD did not endorse and was not directed as an outcome of the DSARC decisions. The OSD comptroller chain is shown on the left side of Figure 11.2. Thus the program was in a constant state of conflict between programmatic

direction and budget authority. This problem has been improved over the last few years[148], but continues to be a major disconnect in the DOD bureaucracy.

Figure 11.2 also oversimplifies the necessary coordination that needed to and did take place with the Navy. The Navy had a large vested interest in the program in that AMRAAM was intended to eventually replace the AIM-7 series of missiles that were used throughout the Navy fleet. Also, the Navy had many major acquisitions on-going with industry that were relevant inputs to the program decisions that the AMRAAM JSPO faced. Therefore another important informal chain of coordination was through the Naval Air Systems Command and the Department of the Navy.

There are two points in going into so much detail of the external management structures that the Program Director and the JSPO dealt with on a daily basis: The first is to provide some insight into the manpower that was required to interact to such a degree with such a complicated and layered management structure above the JSPO. The second point is to raise the following question: With so much program oversight and need to interact with higher management, how was it possible for the Program Director to manage the program itself?

The latter part of the Validation Phase was very taxing on the available manpower within the JSPO. The program had to simultaneously execute the competitive flight test of two contractors, had to conduct a source-selection involving hundreds of people, had to plan in detail the FSD program and the second-sourcing strategy, and had to obtain approvals for moving forward into the FSD program.

11.1.3 Full-Scale Development Phase

With the FSD contract having been awarded in December of 1981, you might have thought that the program would have been through sufficient management reviews to last for a few years. Not so. As described Section 4.4.3, the FSD decision and the second-

[148]Improvement has come through the introduction of the Program Executive Officer concept discussed in Section 11.1.4.

source decisions were separated to minimize the possibility of either Validation contractor attempting to game the source selection and become the follower rather than the leader. This second-sourcing decision process took almost as much management time as the basic decision process for proceeding into the FSD program. The FSD decision is estimated to have taken the JSPO 60 and 80 major meetings and briefings over a 6-month period prior to December of 1981. The second-sourcing strategy development and approval cycle is estimated to have taken between 40 and 50 meetings/briefings over the 5-month period following the FSD contract award. These meetings were required to obtain approval for the leader/follower program and the selection of Raytheon as the second source (follower). All of these activities occurred immediately after FSD contract award in December of 1981. The FSD contract post-award conference, Systems Requirements Review, preparation for the Systems Design Review and test and evaluation master planning were all occurring in this same period, along with detailed reviews of contractor configuration management documentation such as system and subsystem specifications.

To a large degree, the personalities of the various AMRAAM program directors have determined how successful the JSPO was in interacting with higher headquarters at any point in time. In researching this thesis, two members of the JSPO recalled that in the first staff meeting that Colonel (later Brigadier General) Schwankl called in the JSPO, he opened the meeting with a prayer. (This was very unusual in a US Government organization.) It is rumored that he needed "divine guidance" to understand the management structure that stood between him and the executing the program. (True story- and the only attempt at humor within this thesis.)

As if the Program Director didn't have enough to do, in mid-1982 it was decided that the AMRAAM JSPO would expand its role to be the responsible organization for all Air Force counterair programs[149] and was named the Deputate for Counterair. This added

[149]Counterair would include air-to-air missiles as well as the aerial targets that are used for air-to-air missile developmental tests and training of operational forces.

the responsibilities for acquiring aerial targets as well as AIM-7 Sparrow missiles and AIM-9 Sidewinder missiles for the Air Force Security Assistance program to other countries. The organization was modified to accommodate these acquisition responsibilities through the addition of two more directorates in the JSPO.

Another wrinkle had been added to the organizational make-up. Not only were the contracting and manufacturing personnel matrixed, but also engineering and logistics personnel were now matrixed into the organization. Figure 11.3 points out that the manufacturing organization had moved to become its own directorate that reported to the Program Director. It also shows that NATO representatives had moved within the office to monitor the FSD program as described in Section 9.1.

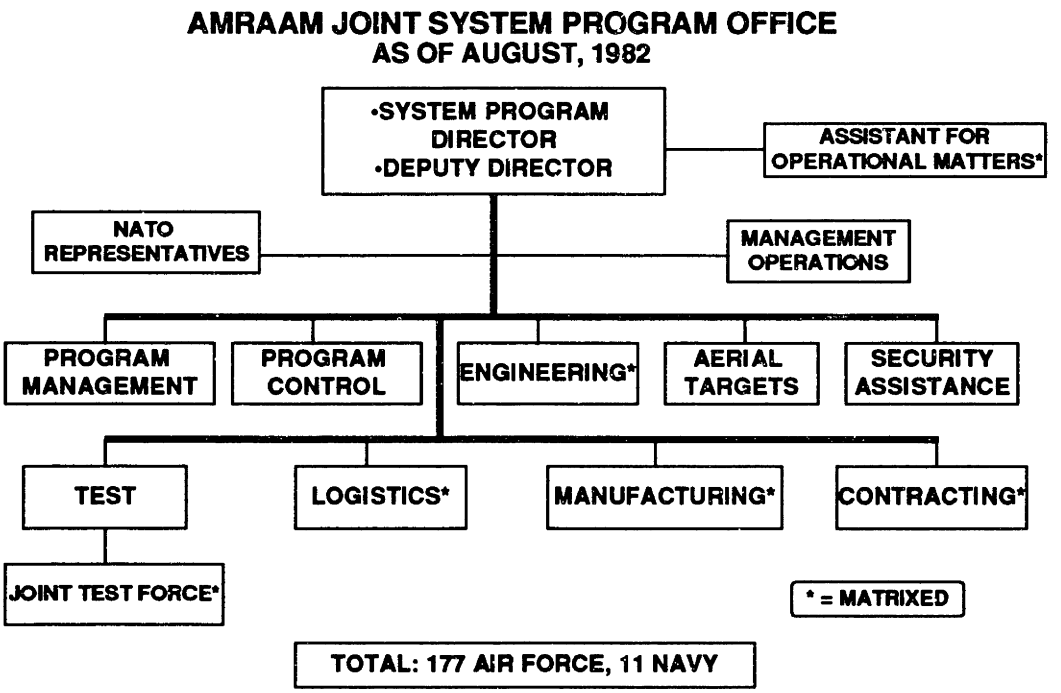

Figure 11.3

Notice that the organization grew rapidly (from 107 in December of 1981 to 188 in August of 1982), that it gained responsibilities beyond AMRAAM, and that there was a trend toward matrix management. These changes were done under the Program

Directorship of Air Force Colonel Henry B. Fisher, who was with the program less than a year.[150]

Colonel Leon Redenbacher took the AMRAAM program helm after Colonel Fisher's departure and focused on the problems that were being seen with the Hughes performance on the FSD contract. Organizationally, he took action to pare down the workload that diluted the JSPO's attention. He was successful in transferring the responsibility for the aerial target development and acquisition to another organization by October of 1983.

In the summer of 1984, another transition occurred in the Air Force leadership of the program. Colonel Thomas R. Ferguson, Jr., formerly the Program Director of the Maverick Air-to-Ground System Program Office at the Aeronautical Systems Division in Wright-Patterson Air Force Base in Ohio, replaced Colonel Redenbacher as the AMRAAM Program Director.[151] (Colonel Ferguson was promoted to Brigadier General and Major General while assigned as the AMRAAM program director.) General Ferguson brought a new set of talents to the front office of the JSPO. He was creative in conflict resolution that had developed over the execution of the FSD contract with Hughes. He was able to see beyond the immediate issues of missile deliveries and cost overruns, and to look for innovative methods to control the growing recurring cost estimates that plagued the program. Under his leadership the vision and implementation of the AMRAAM Producibility Enhancement Program (APREP)[152] was born. The relationship between the Hughes and the Government was at an all-time low when General Ferguson

[150]While not expanded on here, the turnover of Program Director at this critical phase of the program left the JSPO without continuity at an important juncture. It was during this period that the Hughes FSD technical and schedule problems were coming to light. Colonel Fisher was replaced by a strong leader, Colonel Leon Redenbacher. Colonel Redenbacher regained Hughes' attention on the contract and program requirements. The front office stability during this period of change in Air Force leadership of the program came from Navy Captain Raymond D. Slingerland, who served as the Deputy Program Director during the entire period.

[151]Colonel Ferguson later went on to become the "Lt. General Ferguson" who commanded the Aeronautical Systems Center at Wright-Patterson AFB until the summer of 1993, and made his mark in DOD acquisition with innovative management techniques and business practices.

[152]See Section 5 of this thesis.

took over the program. Further, the relationship between the Government and Raytheon, and between Hughes and Raytheon, were equally poor when General Ferguson arrived.

General Ferguson's leadership and the APREP initiative breathed new life into the program. These two factors, coupled with the flight test successes that began to occur during FSD, gave both the Government and the contractors confidence that the Air Force, Navy, OSD and Congress would support the program into production.

General Ferguson made further organizational moves to focus available resources and management attention specifically on AMRAAM. He transferred air-to-air programs other than AMRAAM out of the JSPO, and made the organization "purely AMRAAM" once again. During this period, program control personnel became a "matrixed" group. (Therefore, all functional areas in the organization were then matrixed with the exception of program management, configuration management and test.) By March of 1985, the director had also moved the Configuration and Data Management function out of the Program Management organization into its own directorate as shown in Figure 11.4.

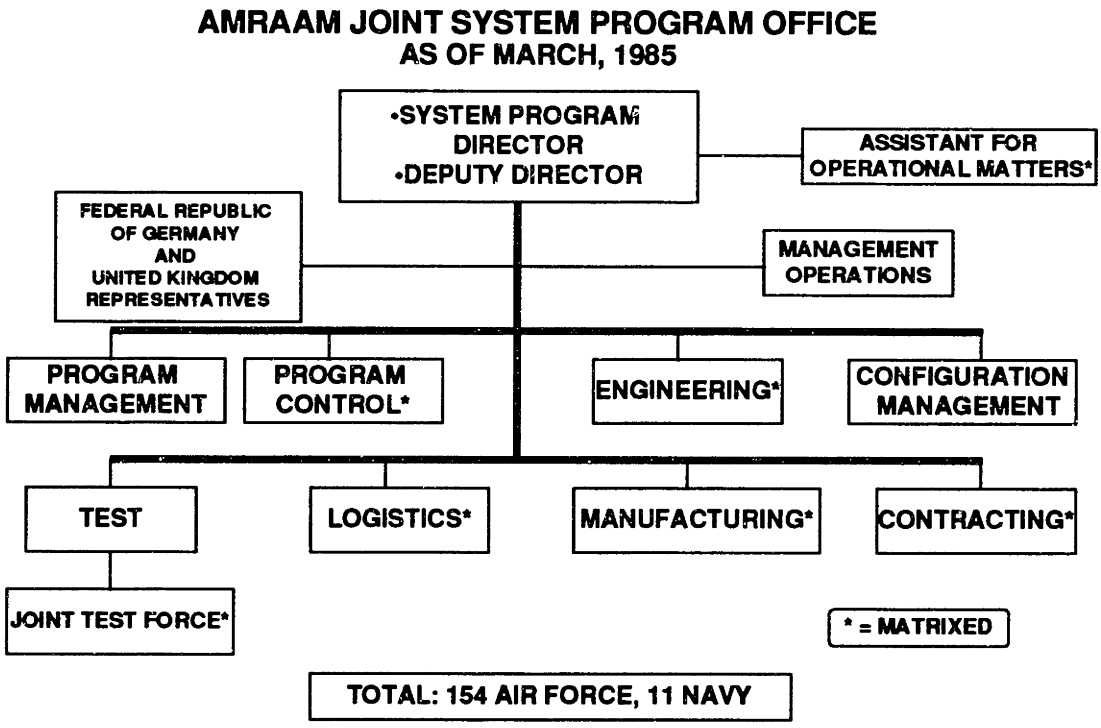

Figure 11.4

Notice that the total number of military and civilians within the program office was now 165 people. The Government program office size and structure remained relatively stable through General Ferguson's remaining time on the program. The General implemented another source of manning for the JSPO, which was the use of support contractors. He was aware of support contractor capabilities that could be very effectively brought to bear on program issues. For example, the program was directed by OSD to perform a "should cost" analysis on the missile production. This analysis was very manpower intensive and required extensive on-site work for well over 100 people for many months. There were (and are) contractors who specialize in management and technical support services to organizations with work overload such as this. An example is Wallace and Company of Dayton, Ohio, who were experts in manufacturing and special tooling and test equipment. They provided expertise that was not available within the Government.

AMRAAM program activities that were ongoing in the 1985 through 1988 timeframe are mind-boggling. Think of the following:

- Completion of a 120 plus missile FSD flight test program.
- Management of the Leader/Follower Program.
- Initiation and management of the APREP initiative.
- Initiation of the Follower Qualification contract.
- Aircraft integration on 4 aircraft simultaneously.
- Development of the AMRAAM Foreign Military Sales program.
- Initial production solicitations, negotiations, contract awards, and management.
- Satisfaction of the Defense Systems Acquisition Review Council (DSARC) process to proceed with the program.
- and many more.

Over the years, the program had been managed with far fewer people than an equivalent system program office at Wright-Patterson Air Force Base (WPAFB) in

Ohio.[153] Various independent and in-house manpower analyses indicated that a much greater number of people were needed to perform the list of activities that AMRAAM was required to accomplish. With this overwhelming workload and the fact that more manpower positions were not to be forthcoming, the Armament Division at Eglin Air Force Base in Florida began using more and more support contractors. Although not the preferred solution, this was the only method to staff program offices at Eglin.[154]

11.1.4 Production Phase

It is somewhat misleading to divide up the program by major phases to describe the organizational staffing that was available, because the program had concurrent phases of Full-Scale Development and production. This section continues on with the chronology established in previous sections that bring us up through 1988.

By the middle of 1988, Major General Ferguson had departed the program for Headquarters, Air Force Systems Command, and Brigadier General Charles E. Franklin[155] became the program director. The JSPO was in for a rapid awakening. Whereas General Ferguson had been a top-level manager, and had delegated much of the program management responsibilities to his management within the JSPO, General Franklin had the opposite management style. His first day in the JSPO he made it very clear when he stated, "I'll tell you upfront. I'm a micro-manager. I've tried it both ways, and the other way doesn't work for me".[156]

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[153]WPAFB is considered by many to be the "Mother Church" and model for acquisition within the Air Force.

[154]Rather than have each office separately contract for these management support tasks, central contracts were competitively awarded for technical support and management/other functional support. AMRAAM JSPO continues to use these contract vehicles today. Precedents for support contracting came from both the Electronics System Division in the Boston suburbs and the Space Division in the Los Angeles area that obtained a majority of their acquisition expertise through support contracts. Eglin's use is very small in proportion to these areas.

[155]Now Lt. General Franklin, Commander of the Electronics System Center, Hanscom Air Force Base, Ma.

[156] His announcement was no surprise to the JSPO. The Air Force informal network had already given the JSPO a "heads-up" for what to expect.

The JSPO didn't have time for long to worry about the change in management. The train derailed when serious problems occurred in AMRAAM captive carriage on the F-15. This was the first show-stopping technical problem that had occurred on the program since much earlier in FSD. General Franklin had a remarkable and unique ability to work the program through this catastrophe. He had a persistence that neither the program office nor the contractors had ever witnessed to find the root causes of problems- both technical and managerial. He was extremely disciplined in his work-process, and expected the same from all members of the AMRAAM team- Government and industry.

The organization structure remained relatively stable with General Franklin, but personnel did not. He expected a level of performance and follow-through on responsibilities that many of his key Government personnel and contractors either didn't understand, or chose not to provide. He replaced several directors and key managers.

Just as he was very direct in making changes in personnel assignments, he was equally willing to give as much responsibility and workload to a person of any rank or an organization that proved itself. For example, Hughes had problems with the Missile Rail Launcher design for years. It was not reliable in the field and was an unbelievable headache to the Government as well as the contractor. After months of frustration, General Franklin found that a junior officer, Captain Greg Egan, in the JSPO engineering organization had an idea on how to fix the major problem. He directed that Captain Egan go to Hughes to allow Hughes to take a look at the Captain's idea. Hughes met with the Captain briefly, and basically dismissed his idea as not worthwhile. General Franklin gave the Captain access to the very small amount of funding that he thought he would need to prove and qualify the concept, and the Captain was successful where millions in investment at Hughes had failed.[157]

[157]A "good news" story was that General Franklin sponsored Captain Egan for the top engineering award within Air Force Systems Command for the year, which he won. A similar example of General Franklin recognizing talent occurred when an F-15 had a failed starter for its engine and the most critical test in AMRAAM's history was scheduled to take place. Millions of dollars of test preparation would have been wasted, and the AMRAAM program would have undergone a significant setback. All the procedures and

Similarly, when Hughes was not able to find the reliability problems with the missile as rapidly as needed, General Franklin sought help from Raytheon (the second source) as well as other independent, but technically strong organizations. He went so far as to send Hughes hardware to Raytheon for failure analysis, a move much stronger than had ever been made on the AMRAAM program to involve the second source in Hughes problems. In the end, he forged a superior working relationship between Hughes and Raytheon on issues of mutual interest.

Without a doubt, General Franklin's assignment to the program came at a time that could not have been more useful to the Air Force. Under his leadership, the captive carry problems were resolved, and AMRAAM went on to achieve its first operational capability and success in combat.

One major external change came about during General Franklin's leadership of the program. The Program Executive Officer (PEO) role was established within the Headquarters of the Air Force by Secretary of Defense direction to streamline the reporting chain for major programs. This change is a major improvement in removing the many layers of management that formerly were involved in making program decisions. One drawback remains- the manpower resources that the major programs use are owned and controlled by the same management that was taken out of the decision process. The jury is still out on whether or not the owners of these organizational positions will continue to attempt to manage the programs. The following figure shows the new PEO reporting chain.

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advice from senior Air Force said the mission would have to be canceled. One sergeant had an idea that he could crawl into the engine and save the mission. He was successful and General Franklin brought him up to meet the Chief of Staff of the Air Force to receive honors.

Program Director Management Chain from 1991 until Today

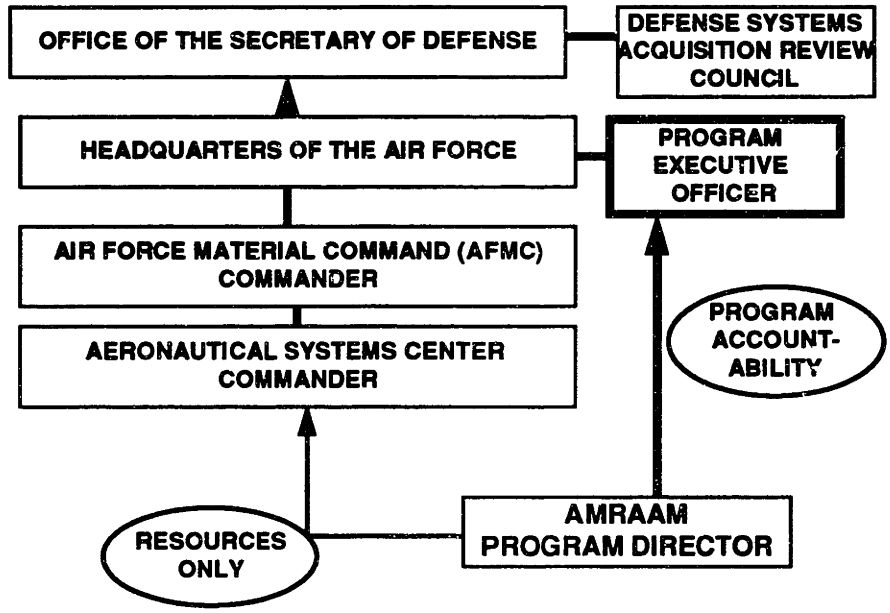

Figure 11.5

In contrast to General Franklin with his self-selected micro-management style, the next program director was a civilian, Mr. Harry E. Schulte[158], who came to AMRAAM from managing another Eglin program office. Mr. Schulte's style was a complete reversal to General Franklin's. Like the General, he demanded performance from the Government and contractor personnel, but also was a strong believer in delegation. His rule was very simple: If you have the responsibility, go off and do it; don't bother him unless you get into trouble or need advice. He also provided a sense of relief after the period of problems the program had to resolve during General Franklin's tenure. Morale improved dramatically under Mr. Schulte. One other major event regarding the organization occurred. The Commander of the Aeronautical System Center (Lt. General Ferguson) decided to once again turn the AMRAAM JSPO into the overall Air-to-Air JSPO, adding significant program content to the JSPO workload.

[158]Mr. Schulte is a member of the Senior Executive Service of the Federal Government.

11.2 Today's JSPO Organization and its Challenges

This brings us up to March of 1993, with Colonel Rick Dickson having been being assigned as Program Director for less than a year. Colonel Dickson faces a new set of problems with which other directors have not had to deal. In the past, the program was typically understaffed, but always had a degree of freedom to fortify the organization with support contractors when necessary. This is no longer true. With recent "peace dividends", the AMRAAM program and all other programs are being forced to reduce the number of military, civilian and support contractor positions. At the same time that he is being directed to draw down these personnel levels, Colonel Dickson is required to manage AMRAAM's competitive missile production, the APREP initiative and production transition, the Foreign Military Sales activities, the Pre-Planned Product Improvement (P^3I), and new workload. He also has been made responsible for all Air Force air-to-air missile acquisitions. Therefore, the AMRAAM JSPO has once again become the Air-to-Air JSPO, responsible for:

- the Advanced Medium Range Air-to-Air Missile System.
- the AIM-9X Short Range Missile System.
- numerous other weapon systems, including supporting hardware such as aerospace ground equipment for maintenance and loading of weapons.

All of these programs are very complex and require a highly-motivated, professional group of military and civilian personnel to perform necessary Government functions.

The scope of the workload is awesome. The programs total over $25 billion. There are approximately 30 major prime contractors and 60 very active contracts. Programs are both single- and dual-sourced, and range in all contract types from firm-fixed-price to cost-plus-award fee[159]. Over the past twelve months, the JSPO approved

[159]The relevance of the number of sources on a program, and the type contract on a program is that these factors are two of the most critical in determining the workload and required manpower within a program office. Simplistically, it can be assumed that dual-sources require approximately 150 % of the manpower over a single source program. Likewise, a fixed-price type contract should require fewer personnel to manage than a cost type contract.

and managed well over 200 major engineering changes to the these programs, as well as almost 800 contract actions (awarding contracts, modifying contracts, etc.). The JSPO is also responsible for assuring that the missiles are compatible with required aircraft such as the F-15, F-16, and the F-22 (Advanced Tactical Fighter) from the Air Force and the F-14 and F/A-18 from the Navy.

JSPO customers are literally from around the world. The Air Force itself has a variety of customers from the Air Combat Command, the Pacific Air Force (PACAF), the US Air Force in Europe (USAFE), the Air National Guard and the Air Force Reserve. There are US Navy and Marine Corps customers, as well as United Kingdom, Norway, Korea, Turkey and Finland customers. In addition to challenges from AMRAAM and all these additional programs, Colonel Dickson has recently been directed to move the program organizational structure to integrated product teams (IPT's), which he is now in the process of implementing.

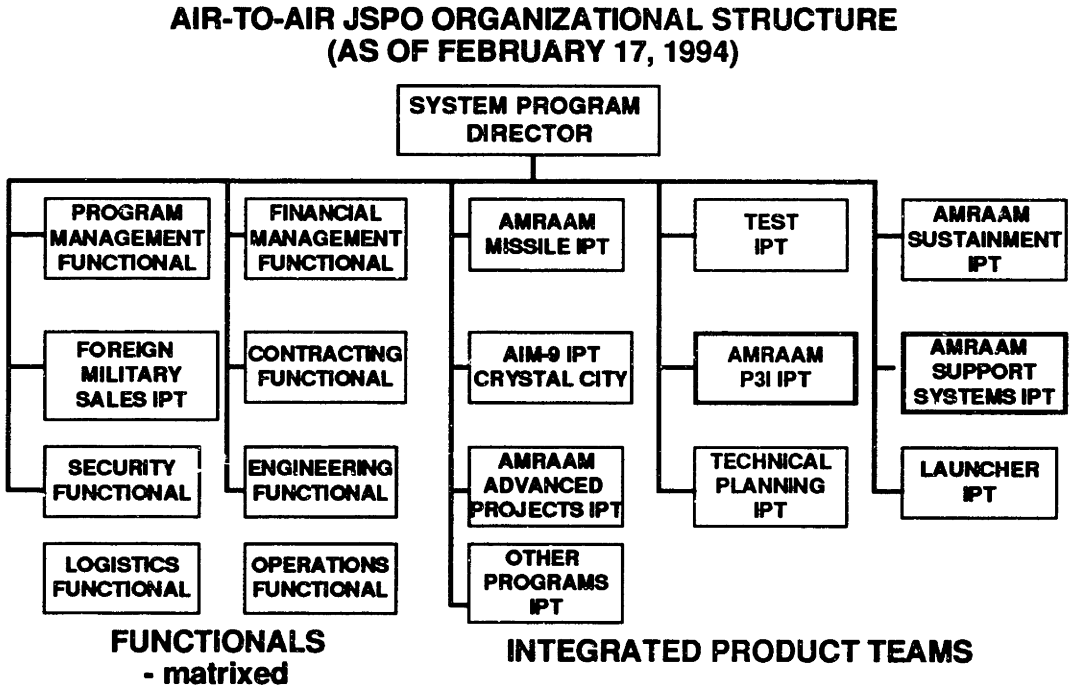

Figure 11.6

There were 265 Government and 194 support contractor people assigned to the Air-to-Air JSPO on February 17, 1994.

11.3 Definition and Philosophy of the Integrated Product Team (IPT) Structure

The Air Force Material Command has published a pamphlet[160] that discusses Integrated Product Development (IPD) and Integrated Product Teams. This document describes how people that are assigned to IPT's need a variety of functional and interpersonal skills to effectively work as a team. It also goes on to show how teams must be able to identify problems and opportunities that can resolve root causes and common causes of problems. Numerous training sources for IPT skills have been established that the Air-to-Air JSPO teams have either gone through or are in the process of obtaining. The following diagram (Figure 10.7) from AFMCP 800-60 (C1) Attachment A shows where IPT's fit within the generic IPD model tailored for weapon system acquisition.

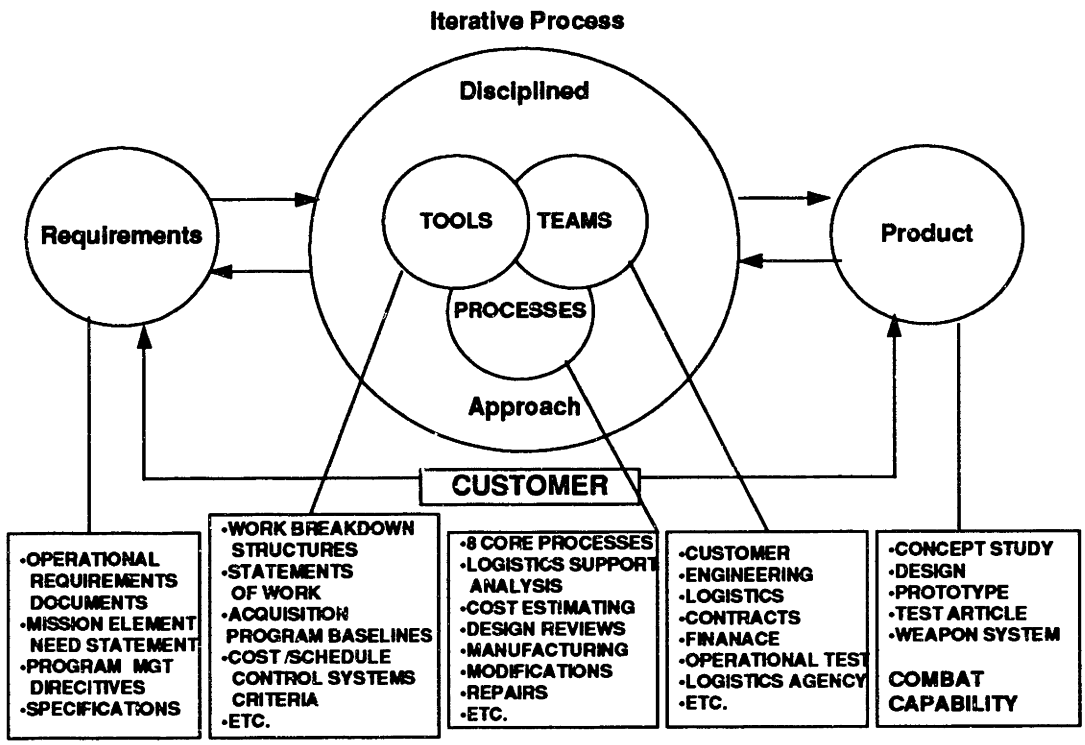

Figure 11.7

[160]AFMC Pamphlet 800-60 (Change 1) dated October 1, 1993.

Teams are defined as the ingredient that make all the elements of integrated product development to fit together. People who comprise the teams are the decision makers that can effectively make the acquisition a success or failure. During different phases of the program, or in different projects within the Air-to-Air JSPO, various functional roles will require more or less emphasis as the life cycle evolves. Lead members of the teams will change during this process.

11.4 Assessment of the Recent Change to IPT's

On the positive side, the JSPO IPT-based organizational structure provides a balance between a functional organization and a totally self-directed, integrated product team organization. However, the new organization has many issues to deal with:

- There is no solution identified to handle the conflict between day-to-day supervision of the IPT members and the functional chiefs having rating responsibility and authority.
- There has been no customer involvement and acceptance of the new organization. The JSPO had a reputation for being very responsive to the operational users. New bridges will have to be built between the new organization and the customers.
- The civilian personnel system has not accepted the previous grade structure for the new organization. As mentioned previously, grade levels for civil service are determined in part by numbers supervised, which will change dramatically if the IPT structure is retained.
- Co-location has now occurred which has IPT members sitting side by side. Some critical assets are available only to a single IPT, whereas before these assets were providing assistance to multiple teams.
- There is a growing workload within the air-to-air missile arena, at least in the JSPO. How do will the JSPO accommodate more work while we are downsizing, without sacrificing the quality of our products?

- Many personnel issues such as performance planning, appraisals, awards, and training must be worked cooperatively between the IPT chiefs and the functional leads to establish procedures that can accommodate the needs of the organization and the individual in both the short- and long-term.
- This is only the most recent cut in personnel levels. Downsizing is likely to become even more severe. The organization must position itself to be agile in its organizational structure and methods/processes of doing business to survive abolished positions and mismatched skills. The JSPO must establish contingency plans to be able to shore-up teams that get into trouble with their new empowerment.

11.5 Summary of Assessment of the JSPO Organization

In the beginning of Section 11 several questions were posed to stimulate the thoughts of readers as they review the evolution of the AMRAAM JSPO and the management chain of command with which the Program Director was required to satisfy. To summarize the analysis of the JSPO organization, the following briefly addresses each question:

- **Did the JSPO grow over time due to required workload and other value-added activities, or did the organization grow due to the tendency of organizations to become more bureaucratic (and "empire building")?**

  There are no apparent signs of "empire building" when the staffing levels and organization of the JSPO are reviewed carefully. There are areas that could have been fortified at the expense of other less priority or critical efforts, but this is an observation after the fact and would not have been evident at the time.
- **Did (and does) the JSPO have the appropriate numbers and skills of personnel to perform their responsibilities during the various phases of the program?**

  There are never enough people to perform all the tasks that a system program office is responsible for. However, a true talent of the AMRAAM JSPO seems to have been

an ability to appropriately prioritize workload. There were shortfalls and continue to be shortfalls in certain functional areas that have impacted the program progress, such as software engineering and management.

- **Were the various organizational structures that were put in place over the life of the program effective? ...Optimal?**

  It is beyond the scope of this thesis to determine if the organizational structures were optimum. However, it is apparent that the organizational structure were sufficiently effective in the past to allow the program to succeed. The recent change to Integrated Product Teams is likely to be an improvement, given the issues that are stated in Section 10.4 are satisfactorily resolved.

- **Was there sufficient manpower available to the Navy as a participating service on an Air Force led program, and was this manpower effectively placed in position and responsibility?**

  Discussion with the Navy leaders says yes, there was a minimally acceptable number of Navy people assigned to the JSPO to consider the Navy's interests, and that the Air Force leadership showed no bias in putting the best people, Air Force or Navy, in the most critical positions.

- **What was (and should be) the appropriate role of support contractors to the program?**

  The role that the JSPO would like to see the support contractors play is to fill in critical shortfalls in program office expertise that is due to either missing skills or limitations in Government authorized positions. While the author agrees with the JSPO position, there is a philosophical argument that is likely to be made that if the intent of Congress is to get people off the Defense payroll: using support contractors circumvents this intent. On the other hand, Congress has expected levels of acquisition excellence that it demands, and if the only way sufficient manpower is

available to execute approved programs is through support contractor assistance, so be it.

- **What has been the relative personnel mix of military, civil service and support contractors?**

  As Government manpower positions have decreased over the years, the percentage of support contractors has increased. As of February 17, 1994, there were 194 support contractors (42%) compared with 265 military and civil service workers (58%) in the JSPO. This ratio appears to workable. Other Air Force systems centers have a much larger percentage of support contractors without any apparent mission impact, but likely with less cost effectiveness. The military/civilian ratio within the JSPO appears to be a good mix. Military personnel tend to bring other program and operational experience into the JSPO, while the civilian workforce adds stability and corporate knowledge.

- **What were the management styles and personalities of the leaders (especially the Program Directors), and how did they influence the organizational effectiveness and morale?**

  Although management styles varied greatly from program director to program director, by accident or by design each management style seemed to meet the program needs at the time. Air Force upper management is either good at picking program directors, or is lucky. Morale also varied significantly from program director to program director, but this seemed to correlate more closely to the issues and pressures the program was facing than who actually occupied the leader position.

- **How participative has the management structure been over the course of the program? Has a total quality program been implemented and is it effective?**

  The JSPO has always had a fairly open door policy and was willing to receive ideas from anyone. However, there is a marked improvement within the JSPO over the last few years. While this thesis does not address the total quality program of the JSPO,

interviews with people within the JSPO showed genuine interest and excitement in the Total Quality initiatives that the JSPO has undertaken. The JSPO is in its second annual self-assessment using criteria from the Malcolm Baldridge Award, and has an outstanding team approach in this assessment. The JSPO was in the top ten of 41 Aeronautical System Center ratings last year, and is confident that they are much better improved this year with the active program they were able to implement. The JSPO is ahead of its peer organizations in bench-marking, and has a very energetic and motivating person assigned as focal point to coordinate the organization's total quality efforts.

- **What have been the sources of manpower resources and what has been the reporting chain for the Program Director regarding program execution over the course of the program?**

  The reporting lines for the Program Director have been tremendously improved over the last few years due to the Program Executive Officer structure. There is a potential problem with the provider of resources wanting to dictate the use of resources within the JSPO. However, current management discussions are directed toward a workable solution for both the program execution side and the resource balancing sides of the equation.

- **Finally, what should be the future structure of the JSPO- its size, organization, composition of military/civil service/support contractors?**

  This is the question of the hour for the Program Director, Colonel Rick Dickson, to answer. The author doesn't have an academic solution.

12.0 Summary Analysis of Acquisition Strategy and Alternatives for the Future

The most interesting and difficult task in studying the AMRAAM program is to "score" its overall success. On the surface, this would appear to be an easy task. The user requirements were challenging: performance, cost, supportability, and schedule.

1. The general consensus in 1978 from Government acquisition executives would have been that risk to achieve missile performance was moderate, optimistically. **Without question, the AMRAAM system is now a performance success.**
2. The general consensus in 1978 from the same executives would have been that the cost was high risk. The largest overall contributor to program life cycle cost was missile production cost. **In the current production contract with Raytheon, the missile price is well under $300 thousand- far, far better than these experienced acquisition leaders have ever expected. Hughes cost results are also impressive.**
3. In 1978 the operational users and support community hoped but had never been able to field a missile that was as supportable as AMRAAM is today. **AMRAAM is exceeding all Government requirements and projections for reliability and supportability. The missile has exceeded reliability performance so far that both contractors are now providing a 10-year warranty, whereas at the beginning of the program the contractors thought that a 3-year warranty to a lower performance standard was excessive and cost prohibitive.**
4. In 1978, the Government determined that the threat in Europe to the F-16 was so great that it was necessary to dictate a schedule approximately a year and one half better than the most likely estimate that the Joint System Program Office and independent groups projected. **The program was not successful in achieving the schedule that was directed,** but was reasonably close to expectations.

Therefore, the simple grade is that the program would receive an "A" in the first three and perhaps a "C^{+}" or "B" on the fourth (or would have the 4th thrown out as unrealistic). Likely, if the true customer, the operational user, was to evaluate the

acquisition program they would give it a high "B" or low "A", but if they were to evaluate the product, they would give it a healthy "A". But this is not the nature of the analysis that is most meaningful at this stage of the program.

More important, perhaps, is to assess whether or not the Government, and the AMRAAM Joint System Program Office (JSPO) in particular, has evolved closer to being a "learning organization". Dr. Peter Senge describes the characteristic of the learning organization as having the ability to continually expand its capacity to create its future.[161] No doubt, this is the challenge that the JSPO faces. The JSPO is the future Air Force and Navy team for acquiring missiles to counter evolving air threats. But why can't the JSPO continue to perform business as usual? Many acquisition and policy issues are likely to change the way DOD acquisition will be performed in the future. One reason this thesis provides a fairly comprehensive background of previous AMRAAM acquisition strategy development has been to show that the JSPO has been creative in the past and has led the DOD pack of major programs with its innovation. But the program is now in competitive production. Will it sustain this creativity?

Examples of the acquisition strategy issues of today that will dictate why the AMRAAM JSPO must be adaptable and innovative were first introduced in Section 1.2 of this thesis. Issues, constraints and major considerations are as follows:

12.1 Program Stretch-out:

This issue revolves around the question of how many lots beyond Lot 8 does the Government need to continue to acquire AMRAAM. Recent planning included production through 16 lots. However, the Air Force Chief of Staff has now directed the program to analyze stretching the production schedule beyond the current 16 lots of planned production. The purpose of this stretch-out is to sustain the production and

[161]Peter M. Senge, The Fifth Discipline, the Art and Practice of the Learning Organization, August, 1990, pg.10.

technology base of the missile. The longer schedule will cause inefficiencies in both the industry and the Government as fewer missiles per year will increase overhead rates.

12.2 Yearly Production Rate and Sustaining Two Competitive Producers:

The overall quantity of required missiles for the US is relatively fixed. Therefore, program stretch-out would further reduce the yearly quantity to be acquired. As such, a question enters whether or not the quantity to be produced each year will sustain two production sources at the prime contractor level. It should be noted that the reasons other than cost-competition for a second source in the first place continue to provide important benefits. The allied missile requirements are entering the equation now as a much bigger factor. Recall that the allies are now ordering more missiles per year than is the US Navy.

This question requires a fundamental review of our relationship with our primary missile sources, Hughes and Raytheon, as well as many of their suppliers. Rather than having a strategy based almost entirely on competition, the Government and industry might need to look at relationships such as are established in the modern automobile industry. The successful theory of "lean production" has been applied primarily by the Japanese manufacturers, but now has taken hold in American industry as well.[162] There are fundamental differences between the automobile industry and the US DOD armament industry that will remain. But many of the successes in the lean production world appear to come from cultural changes in business practices- relationships between customers and manufacturers that are more open; trust between the manufacturers and suppliers that is earned and maintained without threat; a commitment to quality and performance on the manufacturer's part that is unprecedented and provides for continuous improvement; and empowerment to make decisions at the level where the most appropriate knowledge exists.

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[162]James P. Womack, Daniel T. Jones, and Daniel Roos, The Machine That Changed The World, The Story of Lean Production, 1990.

In the first section of this thesis, the original goal of the AMRAAM program was stated to be to develop, acquire and support the world's most effective air-to-air missile system for the United States tactical air forces and important allies beyond the year 2000. There is not much question that without cost constraints, the JSPO would desire to have technical resources from both sources at the prime contractor level available to improve the missile and to resolve problems that arise on the missile. In other words, there is a perception on the Government's part that these two sources in a cooperative mode could offer a better product than a single contractor, but that two sources are likely not to be affordable with reduced quantities.

Another Government fear is how to control cost in a sustained procurement of the missile if only one source is retained, and a "winner take all buy-out" is not feasible.[163]

12.3 Future Improvements to AMRAAM:

There will continue to be a requirement to upgrade the missile's performance to counter evolving electronic countermeasures, to integrate on new aircraft, and to improve producibility for further cost reductions. AMRAAM will continue to need pre-planned product improvements to continue to sustain its performance advantage over enemy systems and to be compatible with advanced aircraft such as the F-22. At present, Hughes and Raytheon both participate in these activities through direct or indirect (sub-) contracts with the Government. If there are not sufficient quantities to economically justify two production sources, there would also be acquisition strategy ramifications for future improvements to the missile system. The following figure uses a simplified systems dynamics pictorial to show the relationship between the customer and the acquisition community, and the process/acquisition cycle relevant to AMRAAM.

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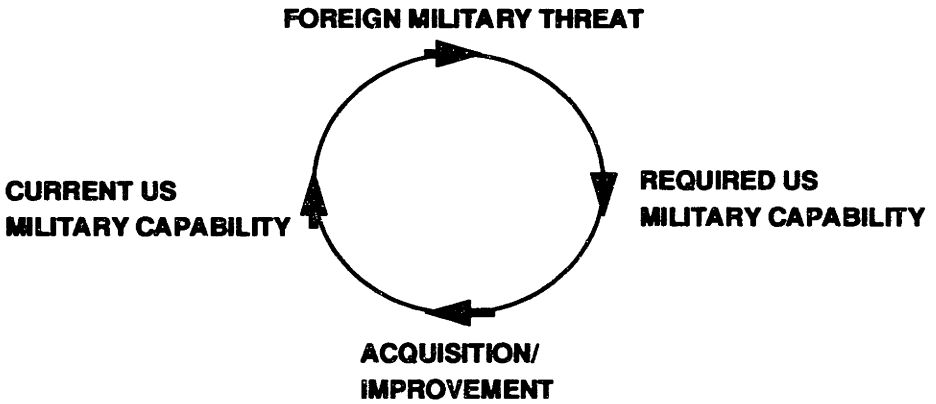
[163]A "winner take all buy-out" is the strategy that would likely be used if only 2 or 3 lots of production missiles remained, and one final competition could be held. However, due to the desire to sustain the technology base for future improvements, and the firm requirement in excess of 16 lots (8 additional lots beyond those currently awarded), there is not much likelihood that a buy-out is within reach of a single procurement action. In addition, Hughes has exclusive control of critical software tools that would need to be maintained for missile upgrades and diagnoses, and there is little chance that the competition for the remaining missiles would be on a level playing field.

The Foreign Military Threat/US Military Capability Cycle



- **The existence or likelyhood of a foreign military threat drives a requirement for a US military capability.**
- **A comparison of current US military capability and required US military capability reveals the need for a new acquisition or some other form of operational improvement (such as enhanced training).**
- **The operational user determines that AMRAAM is required to counter perceived, continuously evolving, foreign military threats**

Figure 12.1

To analyze where we are today in Figure 12.1, the initial answer would probably be that we have recognized a threat and developed a system with performance to counter today's threat. Therefore, all we have to do is to continue to produce enough missiles to equip our forces, and our duty is complete. The world is not so simple. Notice that the threat is recognized to be evolving- the threat is improving in performance. (The threat is also proliferating, with more and more countries having modern air-to-air weaponry.) As these foreign military threats improve and proliferate, the US military needs also change in performance and quantity. To AMRAAM, this might also mean that we require additional configurations to be compatible with an F-22 Advanced Tactical Fighter or allied aircraft.

One legitimate answer to the "Where is AMRAAM in the cycle?" question is "everywhere". Certainly we have met today's threat with a number of missiles, but we

haven't fully equipped our forces such that every US pilot has the missiles he needs to enter combat. Therefore we are currently in acquisition of more missiles.

We also do recognize that our competitive advantage in the air-to-air missile world over our enemies is our performance advantage. We must therefore look downstream beyond the year 2000 and recognize the gap between the missiles we have today (and would project to have in 2000) and the threat of tomorrow. The AMRAAM P^3I program is directed and critical to counter that threat. We therefore never anticipate getting out of the cycle, we only try to minimize the gap between required and actual operational capability at any time. This drives the continuous acquisition cycle on the AMRAAM program.[164] The following figure (Figure 12.2) shows the acquisition cycle in relation to the requirements cycle:

The Integration of Threat/Requirement and Acquisition Cycles

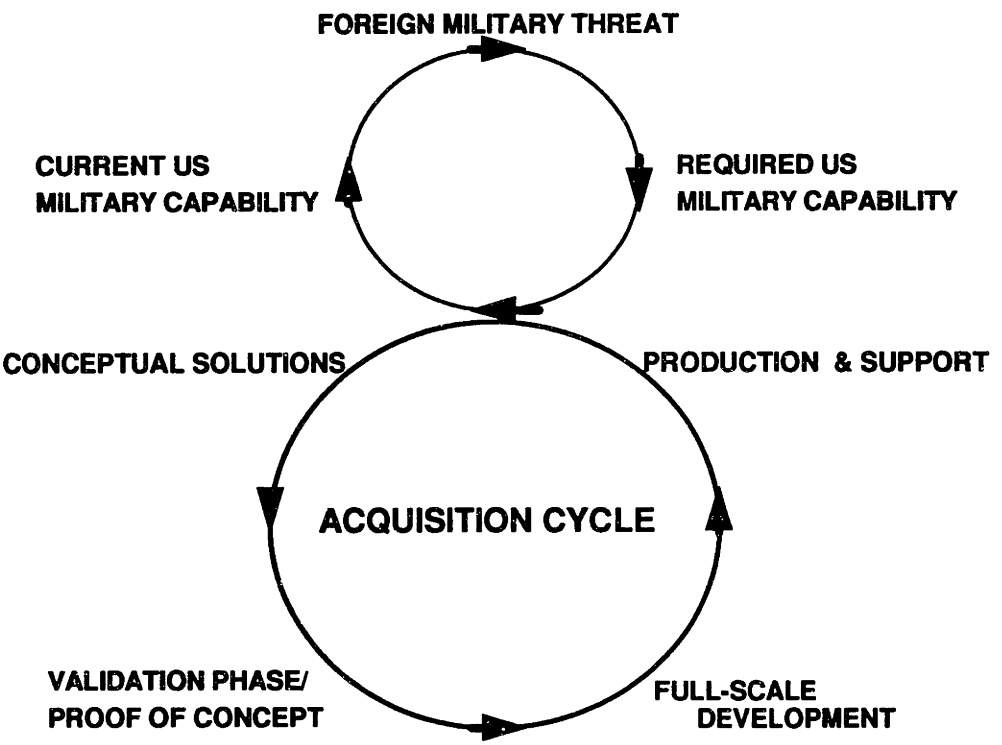


Figure 12.2

[164]This also drives the continuous improvements of our threats. That is, if they perceive that the US and/or its allies have an improved capability, the are obliged to also add capability and/or quantity. This process was shown in Peter Senge's The Fifth Discipline in several examples.

Note that these phases are those that AMRAAM went through on the original cycle to provide an operational capability to the user. For performance improvements that are developed on the Pre-planned Product Improvement (P^3I) program, these same steps will once again occur. Perhaps the steps will not be in clearly distinct phases, but they will certainly occur. Remember that AMRAAM's first cycle was approximately 10.5 years. For follow-on versions from P^3I, this cycle must be shrunk to 2 or 3 years for straight forward changes, and probably 5 or 6 years for more complicated changes. There will be multiple changes being developed and managed on concurrent schedules. These changes will require verification through various levels of test, including operationally realistic testing, to verify that performance of other features and reliability has not been degraded. The environment that the P^3I changes and APREP changes to the missile will also include the support environment. Picture new block changes being introduced in the AMRAAM program with perhaps 7 or 8 major groups over a 5 year period. In addition to the challenge of development, the challenge to manage the configurations[165]becomes critical. The support aspects of the system are even more difficult. Different spare parts and documentation are generally required for each configuration, and special tooling and test equipment must be maintained for each configuration. With these numerous configurations, process control also becomes even more important.

Thus, the most likely product improvement scenario is set: acquisition of continuously improving AMRAAM configurations, and simultaneous supportand upgrade of a growing quantity of older, multiple-configurations of AMRAAM. These activities will bring an increasingly challenging set of problems for the JSPO to handle.

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[165]Configuration management is the functional discipline in which the Government and industry document and control the various configurations of items that the Government acquires. The discipline is necessary to make sure performance is maintained and that items are supportable for repair and upgrade. When many changes occur, the degree of difficulty for the configuration management world increases exponentially.

12.4 Government Program Office Personnel Constraints:

By the end of Fiscal Year 1994, the AMRAAM JSPO will lose an estimated 50 personnel in a top down directed cut. Even with its program priority, the AMRAAM Joint System Program Office (JSPO) has not been immune and will not be immune in the future to the overall reduction of our military forces. The number of people required to effectively manage the acquisition of a system is clearly dependent to a degree on the complexity of the acquisition strategy. Therefore, matrix organizations that control staffing levels for the JSPO have the motivation to influence the acquisition strategy to free personnel resources for reassignment, independent of the macro-level economics that would justify sustaining two competitive contractor sources for production and/or improvements.

A bold experiment with integrated product teams (IPT's) is underway within the JSPO (and throughout Air Force Material Command) to organize more effectively to meet these challenges. (A simplified diagram of the organization was shown back in Figure 10.6.) This IPT change has the potential to free-up resources through streamlining and other efficiencies that have not been available within the Air Force culture for many years except on special high priority programs.

This IPT initiative shows that the Air Force is trying very hard to be a "learning organization". The jury is still out on whether or not sufficient training has taken place to change the culture within the workforce to the learning mode. As Peter Senge states,

> "Organizations learn only through individuals who learn. Individual learning does not guarantee organizational learning. But without it no organizational learning occurs."

Another more serious challenge is facing AMRAAM and all other Government program offices- improved relationships with their industry counterparts. The relationship over the years has been cooperative to some degree. But a tension has existed between the Government perception that "the contractor is in business to make as much as the market

will bear" and the contractor's perception that "the Government is here to try to drive us out of business and is not sensitive to real world cost and risk". Even though more experienced Government personnel have overcome this over-generalized situation, there is not much question that this is the most common attitude. As a result, contractors are likely to submit proposals in a non-competitive environment that are not as efficient as might be required to perform a task, and the Government is likely to establish an arbitrary cut to the contractor's proposal "based on negotiating experience". It is the inability to resolve this fundamental conflict that drives the inefficient use of competition in some situations- such as the one that the AMRAAM program is likely to face in the next few years.

Hopefully, the team approach to acquisition and sustainment will expand beyond the "Government team" versus the "Industry team", to genuinely cement a Government/contractor learning organization.

12.5 AMRAAM Program Alternative Acquisition Strategies

This brings us to the point at which we can consider the alternatives that are available now and in the future for the US Air Force and Navy to acquire and sustain AMRAAM. The basic alternatives are:

A. Continue with yearly competitive production buys with Hughes and Raytheon

B. Attempt multi-year competitive production buys with Hughes and Raytheon

C. Attempt a "winner take all buy-out" with a multi-year buy

D. Attempt a "winner take all buy-out" with pre-priced options for the next few years

E. Facilitate a composite Hughes/Raytheon team for future buys (yearly or multi-year)

12.5.1 Alternative A- Continue with yearly competitive production buys with Hughes and Raytheon

Description: This alternative would sustain the currently employed strategy of having the two prime contractors compete on an annual basis for the majority of the missiles. Both contractors would also maintain the same team relationship in the APREP and P^3I areas. When (and if) the program draws closer to completely fulfilling operational inventory requirements, a one-time competitive buy-out could be used. Currently, Lot 8 is the most recent contract award. With at least 16 lots anticipated, a competitive buy-out would not be planned until approximately Lot 13 or 14.

Advantages-

- Sustains competition at the prime contractor level
- Sustains cooperative producibilty enhancement efforts (APREP)
- Sustains cooperative pre-planned product improvements (P^3I)
- Permits downstream "Winner take all buy-out"

Disadvantages-

- Pushes prime contractors closer to their minimum economic sustaining rate

12.5.2 Alternative B- Attempt multi-year competitive production buys with Hughes and Raytheon

Description: The multi-year approach removes significant program uncertainty and related economic risk from the prime contractors and the subcontractors by allowing longer than annual commitments to be made. Multi-year contracts might be for 3 to 5 years. This option as described would retain both prime contractors and would recompete at the 3 or 5 year points. Typically the primes would buy subsystems and components in larger lots from subcontractors to press for savings from economies of scale. Going to fewer subcontractors would probably trim down the vendor base, which may be economical in the short run, but expensive in the long run. Higher costs in the long run would be due to erosion of the vendor base competition and requalification costs if subcontractors and vendors "build-out" quicker than the prime missile deliveries and have to restart and requalify the production line.

Advantages-

- Sustains competition at the prime contractor level
- Sustains cooperative producibilty enhancement efforts (APREP)
- Sustains cooperative pre-planned product improvements (P^3I)
- Permits downstream "Winner take all buy-out"
- Permits near-term savings due to vendor economy of scale production

Disadvantages-

- Pushes prime contractors closer to their minimum economic sustaining rate
- Removes much of the competitive vendor base for future acquisitions (3 or 5 year point)
- Will require significant subcontractor/vendor requalification program for breaks in production
- Tends to increase size of inventory and runs risk of scrap/rework in the event of engineering changes.

12.5.3 Alternative C- Attempt a "winner take all buy-out" with a multi-year buy

Description: This alternative differs from the previous in that only one prime contractor would be retained. There are major disadvantages in addition the those of Alternative B because only one prime missile production contractor would be involved in producibility, P^3I, and production efforts. Competition would go away and require negotiated procurements after 3 to 5 years. Also, because Hughes controls critical software tools, it is questionable whether or not the Government could award the entire remaining program to Raytheon. Therefore, the competition would likely not be on a level playing field and might present a dilemma to the Government that would not be readily resolved.

Advantages-

- Would provide for a large one-time savings due to competition
- Permits near-term savings due to vendor economy of scale production
- Removes the issue of minimum sustaining rate at the prime contractor level

Disadvantages-

- Eliminates competition at the prime contractor level beyond the window of the multi-year (3 or 5 years) procurement.
- Questionable initial competition due to "unlevel playing field"
- Eliminates cooperative producibilty enhancement efforts (APREP)
- Eliminates cooperative pre-planned product improvements (P^3I)
- Removes much of the competitive vendor base for future acquisitions (3 or 5 year point)
- Will require significant subcontractor/vendor requal program for breaks in production

12.5.4 Alternative D- Attempt a "winner take all buy-out" with pre-priced options for the next few years

Description: This alternative is much like Alternative C in that the Government would award the basic (first year) production contract to a single source competitively. Whereas

the multi-year would commit procurement dollars beyond the first year, this alternative would not. Options that were pre-priced in the competitive environment would be used to award subsequent years of missile acquisitions. Although this alternative would not generate the multi-year economies of scale, it would eliminate subcontractor requalification costs and would likely sustain the competitive vendor base due to the annual procurements.

Advantages-

- Would provide for a large one-time savings due to competition
- Removes the issue of minimum sustaining rate at the prime contractor level
- Sustains competitive vendor base
- Avoids subcontractor/vendor requalification

Disadvantages-

- Eliminates competition at the prime contractor level beyond the window of the basic contract and its options (4 to 5 years)
- Questionable initial competition due to "unlevel playing field"
- Eliminates cooperative producibilty enhancement efforts (APREP)
- Eliminates cooperative pre-planned product improvements (P^3I)
- Does not benefit from near-term economies of scale available to multi-year buys

12.5.5 Alternative E- Facilitate a composite Hughes/Raytheon team for future buys (yearly or multi-year)

Description: This option is much more radical than Alternatives A through D. In this alternative, the Government would agree to a teaming arrangement with Hughes and Raytheon to allow the prime level cooperation that has been successful in the program in the APREP, P^3I and reliability areas to be extrapolated to the production program. This would allow the prime contractors to partition production efforts in any way that makes sense. For example, there are Final Assembly and check-out facilities at Tucson, Az. for

Hughes and Letterkenney, Pa. for Raytheon. With the new production rates that are likely to occur with program stretch-out, either facility could easily handle assembly and check-out of all the missiles. A likely choice might be Tucson due to its proximity to the Hughes plant versus the remoteness of the Letterkenney facility from Raytheon. Another area is vendor management. Right now both contractors request bids, negotiate, monitor, and perform acceptance testing or other product assurance measures on every subcontractor and vendor within the missile. This workload could be divided either by product area or by geographical area to be done by one, rather than both, prime contractors. The last and most important difference between this and other alternatives would be the atmosphere that might be created that would optimize the "learning organization" philosophy that has been so successful in the automobile industry. It is being attempted within the Government and within industry, but today's Government/industry relationship is still very much at arms length. Of course the big disadvantage of this approach is the elimination of competition at the prime level, and this is a very large concern. From its inception, the AMRAAM program has very successfully relied on the use of competition to obtain the best ideas available from any one contractor at the most competitive prices. The unknown is whether this alternative would offer root-level advantages that would offset the benefits of sustained competition. Could fair and reasonable prices be obtained from a Hughes/Raytheon team? Would "the best talent" that the two contractors have be placed on the program in a non-competitive environment? This alternative raises questions that would have to be answered. But, fundamentally, there is a philosophical argument that states that true teamwork could be inherently more creative, effective, and efficient in providing the operational missile systems they require.

Advantages-

- Sustains cooperative producibilty enhancement efforts (APREP)
- Sustains cooperative pre-planned product improvements (P^3I) and would likely provide the best performing missile.

- Permits downstream "Winner take all buy-out"
- Better coordinated subcontractor/vendor utilization and management
- Provides the potential to manage the prime-level (Hughes/Raytheon) minimum sustaining rate by distributive management
- Offers the potential to eliminate redundant prime contractor tasks (Final assembly and check-out, vendor management, etc.)
- Creates the atmosphere conducive to a "learning organization"
- Minimizes Government management responsibilities (and personnel requirements)

Disadvantages-

- Removes prime contractor level competition and requires negotiated procurements
- Requires a fundamental mind-shift from current competition based strategies

12.6 Recommendation

Clearly, the alternatives available to the Government and the contractors on AMRAAM all have strong advantages and disadvantages. Philosophically, I would prefer the teaming of Alternative E based on "gut feel" after having witnessed the tremendous accomplishments that Hughes has brought to the program in development and production, and the complementary technical and production capabilities that Raytheon has also contributed. Hughes and Raytheon cooperation began with a very rocky start. Improvement required true Governmental leadership from program directors such as General Ferguson and General Franklin, as well as their industry counterparts, to be the forcing functions to join two competing organizations to accomplish what many said was impossible:

- Solving reliability problems,
- Implementing long-term cooperative efforts to improve the inherent producibilty and lower the cost of the missile, and
- Cooperatively expanding AMRAAM's performance to higher and higher levels.

When the program is examined in detail as I did in preparing this thesis, it is very evident that both contractors have made in the past and will continue to make outstanding contributions.

On the other hand, no one expected to continue to see the benefits of competition in Lot 8 (23% improvement over Lot 7) after the savings that were achieved in Lot 7 (25% improvement over Lot 6). And 10 year warranties! Who really knows where it might end? Therefore, one position that would be easy to take is, "If it's not broken, don't fix it", and stay with Alternative A (annual competitive procurements with each contractor).

At this point were I the program director, I think I would be careful not to outrun my headlights. The aerospace community is in a period of flux with the DOD spending cutbacks. Hughes has acquired another missile production contractor in a corporate

acquisition. Raytheon is in the process of consolidating its manufacturing facilities to remain cost effective. Major subcontractors are attempting to transition to commercial areas. All these things could have either positive or negative effects on the AMRAAM program, and could well influence the appropriate choice of strategies.

I think for the next two years' procurements (Lots 9 and 10), I would plan on using the same strategies that were used for the Lot 5/6 contracts and the Lot 7/8 contracts. This competition for the basic contract, with a downward adjustable option for the second year, buys the time necessary to truly evaluate new approaches such as Alternative E's teaming arrangement. In parallel with moving forward with the Lot 9/10 acquisition planning, I would perform cost analyses of every alternative to attempt to ascertain cost advantages and disadvantages. I would also challenge a team to consider both cost and non-cost advantages and disadvantages of other approaches, and to look for barriers to and potential solutions for contractor teaming.

The End.

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