A STUDY OF THE EFFECTS OF ACQUISITION POLICY ON THE CLIMATE FOR TECHNOLOGICAL INNOVATION IN THE PROCUREMENT OF U.S. AIR FORCE WEAPON SYSTEMS

by

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ABSTRACT

This thesis examines the effects of current Department of Defense and U.S. Air Force procurement policies on the development of advanced technology and the application of technology to new weapon systems. Areas investigated include attempts to increase and maintain competition during the weapons acquisition life cycle, prime contractor cost sharing with the government during system development, use of prototyping, increased emphasis on system support and readiness, the use of performance-oriented specifications, and increased requirements for commonality between systems.

The research is based on a series of interviews with senior U.S. Air Force and industry personnel who are directly involved in some aspect of the acquisition process. All of these individuals have extensive experience in weapon system or advanced technology development.

The interviews indicate that high costs of system development to the prime contractors and increased uncertainties in achieving returns on investment are creating disincentives to technical leadership in the defense aerospace industry. In addition, pressures on prime contractors to share development costs are encouraging the diversion of resources from long-term technology development into efforts to support current business. Government and industry managers alike are seen to favor policies which are tailored to the needs of individual programs, and which ensure reasonable economic returns to contractors from efforts to advance the technological state-of-the-art.

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I would also like to thank my thesis advisor, Dr. Russell Olive, whose guidance and help significantly improved the quality of this effort. I have found our association to have been both personally and academically rewarding.

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CHAPTER ONE

INTRODUCTION

BACKGROUND

It is difficult to think of an area of public policy in the United States which has been the source of more sustained controversy than the development and acquisition of new weapons systems for the military services. Nowhere has this been more true than in the procurement of aeronautical systems (aircraft and missiles which operate in the air, as opposed to space) where the general public has been barraged with a steady stream of news reports detailing apparent flagrant abuses in various Department of Defense (DOD) weapons procurement programs since the early 1960s. Performance shortcomings and cost overruns of the Air Force TFX/F-111 and C-5A programs during the mid-1960s are well-known cases in point. Performance and durability problems with the F100 fighter engine developed to power the USAF F-15 (and later F-16) fighters during the early 1970s also attracted widespread attention and criticism. More recently, during the early 1980s, there have been widespread allegations of overpricing and fraud in the defense industry, with reports of $2500 aircraft toilet seats and $900 hammers. One does not have to review the literature on the subject very extensively to identify many other examples of allegedly excessive industry profits, weapon system cost growth, deficient performance, and lack of durability in service.

EFFORTS AT ACQUISITION REFORM

The result of these much publicized cases is a general impression in the minds of the public that the entire defense acquisition process is badly in need of reform. Responses from various governmental bodies to correct the situation have been many and varied. The Judicial Branch of the Federal Government has recently been involved with criminal trials of industry officials charged with various kinds of malfeasance. More pertinent to this investigation, the Congressional and Executive Branches have conducted numerous studies of the apparent problems and have, over a continuing period of time, implemented a wide variety of evolutionary reforms aimed at improving the efficiency and decreasing the cost of weapons development and acquisition.

Some specific recent examples are worthy of note. One specially chartered Congressional Commission, the Grace Commission[1/], made numerous recommendations aimed at forcing the defense acquisition process to function more nearly like a commercial market between buyer and sellers. On the Executive Branch side, the President's Blue Ribbon Commission on Defense Acquisition[2/], or Packard Commission (named for its Chairman, former Under Secretary of Defense David Packard), in 1986 submitted its final report which recommended increased emphasis on prototyping, streamlining of the acquisition process, and the creation of a high level Defense Department Acquisition "czar" to better control procurement activity. There have also been several internal DOD task force studies on improving the acquisition process, such as the 1981 study performed by the Office of the Under Secretary of Defense for Research and Engineering[3/] and a study by the Defense Science Board (DSB) chaired by the Vice President (now CEO) of Martin Marietta Aerospace and a former DOD official, Norman Augustine[4/]. The result of these studies was the formulation of the so-called Carlucci Initiatives[5/] for defense acquisition reform which were a comprehensive set of proposals covering the entire spectrum of defense procurement issues. These initiatives were implemented by the Deputy Secretary of Defense (now Secretary of Defense) Frank Carlucci in the early years of the Reagan Administration and still form the basic structure of current DOD acquisition policy.

TECHNOLOGY AND REFORM

One might well ask whether the "DOD acquisition mess" is actually as bad as the press reports and the continual efforts at reform would seem to indicate. At least a few informed observers apparently do not think so. Michael Rich and Edmund Dews of the Rand Corporation[6/] have reported that

> ...in terms of the three most generally accepted measures for judging the acquisition process--cost growth, schedule slippage, and functional performance shortfalls-- there has been steady improvement in program outcomes over time.

They go on to note that weapon system programs which began full-scale development (FSD) in the decade of the 1970s exhibited less cost growth than those begun in the 1960s, and indications are that programs entering FSD in the 1980s are experiencing less cost growth than the 1970s programs. They conclude that "cost growth in defense programs is now no greater than in civil programs of similar character and complexity and is probably a good deal less."

It may be that this apparent improvement in the efficiency of weapons acquisition is in fact due to the repeated attempts to revise and reform the procurement process. There is, however, another possibility. The basic acquisition structure which has been in place for the past two decades may not be as fundamentally flawed as some of its critics maintain. It is certainly difficult to point to any specific and consistently applied set of policy revisions over this time period which could account for the results reported by the Rand Corporation researchers. Granted, there are certainly specific examples (some already noted) in which the acquisition/development process has functioned poorly. These failures could be due more to problems in implementing general policy guidelines in particular cases than to fundamental flaws in the overall process. In general, it is possible that the apparent gradual improvement in the quality of the weapons acquisition process (somewhat in contrast with the popular perception) is the result of continuous evolution and refinement of the procurement system and not the result of major policy initiatives.

It is not the intent of this particular investigation to prove or disprove the adequacy of the present acquisition process and the reasons for same. Rather, it is to examine another, potentially dangerous element which appears to have entered the weapons procurement equation as a result of recent acquisition policy changes. All of the major studies and policy reforms identified have concentrated mainly on the issues of procurement efficiency and cost and have addressed the issue of system performance only peripherally. There is now a growing sentiment in both the defense industry and the DOD that the collective zeal on the part of Congress and the Executive Branch to increase competition, reduce costs, and eliminate abuses in the acquisition process may have reached unwarranted extremes, and may in fact be having the unintended effect of discouraging the development and utilization of advanced technology in new weapons systems.

The national defense posture of the United States since the end of World War II has been critically dependent on continual advances in the quality and capability of our weapons to offset the numerical superiority of our adversaries. These advances in capability have come about as a direct result of the development and application of sophisticated new technologies. Any set of broadly applied policies which have a significant negative effect on our national ability to effectively utilize advanced technologies in new military systems could therefore have far-reaching adverse national consequences.

INDUSTRY AND GOVERNMENT CONCERNS

An excellent barometer of the health of any industry is the industry trade press. There have recently begun to appear in the aerospace and defense industry press a number of articles which indicate a growing concern on the part of both the aerospace contractor firms and the Department of Defense (DOD) regarding the potential negative effects of current procurement policies and strategies on technology and innovation in the industry.

A recent article in Aviation Week and Space Technology magazine[7/] is illustrative of this point. It concludes that

> ...government policy reforms meant to trim profit margins in defense contracting and make companies bear more costs and investment requirements are undermining the U.S. defense industrial base . . . a rising number of companies are reevaluating their participation in defense contracting, and multi-product corporations are reluctant to commit prime technologies with commercial potential to defense work.

The article further expresses the view that

> ...Congress and the Defense Department overreacted to allegations of overpricing and fraud . . . too many corrective measures were imposed, resulting in excessive reductions in returns to contractors . . . A further disincentive to defense work is the risk of forfeiting valuable technology, especially to a competitor, without compensation as a result of second-sourcing or teaming.

A quote from Gerald W. Ebker, President of IBM's Federal Systems Division, in the same article is sobering in its implications. He states that:

> IBM is careful not to let Federal Systems Division activities contaminate technologies elsewhere in the corporation. In the present environment, the government does not get the best technology.

Another item from Aviation Week[8/] is even more specific. It notes that in the Air Force's Advanced Tactical Fighter (ATF) program

> ...risk-sharing provisions are severely affecting the funding of other participating contractor corporate activities, especially independent research and development . . . Contractors are becoming increasingly concerned that government cost-sharing programs may be undermining the industry's ability to develop new technologies needed for future military aircraft and avionic systems."

These concerns are not confined only to the aerospace contractors. The military customer side of the market is also uneasy about current trends. In response to industry concerns noted above, the Air Force's new Assistant Secretary for Acquisition, John Welch, is examining the possibility of changing the contracting rules in the ATF program to compensate the participating contractors for their investment in the program. Welch states, "We need to understand the investment of both the eventual winners and losers... It does not do any good if we shrink our competitive base and drive people out of business."[9/] Clearly, significant reductions in the number of firms willing or able to participate in advanced weapon system development programs will also reduce the potential for innovative ideas and new technology which can be brought to bear on the weapon system design problem.

THESIS HYPOTHESIS

It is the purpose of this investigation to examine in detail the hypothesis that current DOD acquisition policies, both those explicitly stated as well as those derived from general policy guidelines, are becoming counterproductive in their effect on the climate for technological innovation in new weapons development programs, and in their effect on the development of advanced technology in general. Both the sources of new technology and the ability or willingness of the weapons contractors to apply new technology to a particular system application are of primary interest, since technology must be both available and applied to specific products before any utility can be gained. No assertion will be made here that the climate for technological innovation is the only (or even the single most important) criterion that should be applied when weighing the benefits and liabilities of specific acquisition policies. It is asserted, however, that this is a highly important criterion which can be ignored only at substantial risk, for reasons examined in detail in the next chapter.

CHAPTER TWO

ADVANCED TECHNOLOGY AND DEFENSE

TECHNOLOGY AND DEFENSE PHILOSOPHY

Technology is the cornerstone of the national defense philosophy of the United States. This is true at present and has been so since the end of World War II. The origins of this philosophy are rooted in the war itself; the Manhattan Project to develop the atomic bomb represents the embodiment of the technological approach to warfare. Former Secretary of Defense Harold Brown has noted[10/]:

> ....during the war the United States was behind at the start in quality and sophistication of most military equipment. Never during that conflict did the United States outdistance the Germans in quality of basic military hardware . . . It was primarily the quantity, not the quality, of equipment that gave the United States its advantage.

Clearly, this reliance on quantity rather than technological superiority was changed radically with the advent of nuclear weapons. These overwhelmingly powerful weapons, which the United States alone possessed from 1945 to 1949, not only brought a swift end to the war, but also "nurtured the comforting belief that the bomb was not only the 'winning weapon' but also something that would permit reduced expenditures for the military services."[11/] Thus, in the expanding post-war consumer economy and the simultaneous beginnings of the cold war, it was felt possible to have both guns and butter.

Reliance on technological advancements in weapons became more than an economic convenience in 1949 when the Soviet Union exploded its first fission bomb. From that point onward, the pursuit of ever more sophisticated and capable weapons has been regarded as an essential element of national security and the deterrence of aggression. This philosophy has not been confined to the arena of strategic nuclear weapons, but has carried over into all aspects of tactical and conventional (i.e., non-nuclear) weapons. Throughout this process, however, the cost effectiveness aspects of advanced technology have remained an important element. As Secretary Brown again notes,

> If the United States looks for comparative advantages against a potential Soviet adversary with superior numbers of forces, one of the most obvious is the relatively lower cost of incorporating high technology into U.S. military equipment . . . In contrast, a low technology - high manpower mix is more advantageous to the Soviets, who are behind on technology but have greater numbers.

He goes on to explain that to match the level of Soviet military expenditures (approximately double the U.S. percentage of GNP) the United States would have to double the number of weapon systems in development and production, an approach which is not politically acceptable or realistic.[12/]

Unfortunately, the national defense problem is not as simple as countering a numerically superior adversary with a modest continuing investment in new technology. Thomas Cooper, Assistant Secretary of the Air Force for Research, Development, and Logistics has recently stated in Congressional testimony[13/] that

> The U.S. no longer enjoys the vast superiority in weapon system quality which, in the past, was the counterbalance to the significant Soviet advantage in weapon system quantity. The rapidly narrowing U.S. technology lead over the Soviets is primarily due to the science and technology budget level and the covert acquisition of advanced technologies by the Soviets. Given the assumption that the Soviets will continue to build their weapon systems in large quantities, the U.S. is faced with the option of achieving equality in weapon system numbers, or reestablishing unquestionable technological superiority. Since the U.S. has traditionally relied on its quality of weapons systems to offset quantity disparities, we must maintain a broad based Science and Technology Program that addresses all assigned Air Force mission areas . . .

Other Defense Department officials have repeatedly made the same point. In his discussion of proposed acquisition reform measures before the Senate Armed Services Committee[14/] in 1981, then Under Secretary of Defense Frank Carlucci prefaced his testimony with the following remarks:

> The Soviets . . . up until the past few years, have relied on sheer numbers, bigger missiles, heavier payloads, more tanks, and so on. The general idea behind our approach to building weapons has been to counter this preponderance of numbers with a superiority of design, speed, maneuverability, and firepower. This makes good sense because it draws on our traditional genius for innovation, and I cannot imagine any responsible critic arguing that we should rest our defense on producing the same kind and number of weapons the Soviets do. But, the truly alarming piece of news about the Soviets is that for the past two decades or so they have been showing every sign of taking advanced technology seriously, too . . . Our new systems are designed to meet today's threats; the simpler and cheaper systems they replace can no longer counter the advanced weaponry of our potential adversaries. But many of the advances we will employ are not available to us for seven or eight years because of the time required to plan and produce them. And that makes it all the more imperative that we continue to recognize the importance of superior technology.

Thus the necessity of maintaining a clear technological advantage in military equipment is apparent. This approach is also one which has been largely free of political partisanship; debates have raged long and hard regarding the best means to bring about the desired result, but the basic policy has been supported by Democratic and Republican administrations alike, and is firmly entrenched in the national psyche.

Harold Brown also points out[15/] that part of the advantage currently enjoyed by the United States over the Soviet Union comes about not from across-the-board technological superiority, but rather from superiority in several critical areas. Many of these areas (e.g., advanced electronics and computers, integrated circuitry, and high speed data processing) are ones in which military capability has come about due to technology transfer from the civilian economy; these are also technologies which are not currently available to the Soviets. He recognizes that technology can only go so far in offsetting overwhelming numerical advantages, and that other factors such as strategy, tactics, leadership, and training are vitally important in any armed conflict. Nevertheless, it would be foolish to throw away the advantages of anything which is a "major equalizing factor, much of whose cost has already been paid in any event, because . . . the United States has a large civilian and a relatively small military sector in its industrial economy." Secretary Brown concludes that the United States has no real choice but to adopt advanced technology for its weapon systems, given the relative advantages it can provide over potential adversaries, and the fact that the American public and its political leaders are willing to maintain only a certain level of defense spending. Moreover, if correctly handled, U.S. reliance on advanced technology is likely to produce a more effective military capability.

THE QUANTITY VERSUS QUALITY ISSUE

In recent years there have arisen a number of prominent defense critics who have popularized the argument that the pursuit of complex advanced technology weapons is a fundamental part of the alleged problems with the U.S. defense establishment. Their argument is that there exists a firmly entrenched research and development bureaucracy in the DOD, the military services, and the defense contractors whose principle objective is to ensure the continued development of high technology weaponry and the continued existence of the high-tech establishment. The result of this "R&D culture", it is claimed, is the procurement of overly complex weapons incorporating immature leading-edge technologies which do not perform as advertised, break too often, cost too much, take too long to develop and produce, and would be inadequate to defeat the simpler, more numerous weapons of adversaries even if the U. S. weapons functioned as well as initially claimed. The solution to this situation, in these critics' opinion, is for the United States military to produce more weapons of simpler, less complex design, having somewhat less capability but which are more reliable, easier to operate and maintain, and which would exhibit more overall military utility due to increased numbers. This argument often also includes the notion that large numbers of more specialized (cheaper) weapons are preferable to smaller numbers of general purpose "do everything" type systems.

Several of these critics have published widely read books which advance this "quantity vs. quality" argument, among them Richard Stubbing[16/], James Fallows[17/], and Edward Luttwak[18/]. A central theme of these arguments is that (relatively) simple, cheap weapons systems are synonymous with modest or low levels of technology, and that high technology automatically translates to high cost, complexity, and reliability/maintenance problems in the field. A case which both Fallows and Stubbing cite as illustrative of the problem is the Air Force's F-16 fighter, which they compare favorably with the larger, more expensive, and more capable F-15. The conclusion is drawn that even though the "technology advocates" in the Air Force development/ acquisition bureaucracy were successful in adding some needless complexity during development to the rather simple and austere lightweight fighter (LWF) concept which the F-16 started out to be, the system which eventually was produced still is far preferable to the more sophisticated F-15 because of the F-16's lower cost, greater numbers, better reliability, and modest technology.

These arguments are not germane to the real issue, which is one of military capability, not technology. To address these criticisms in sequence, first consider the issue of the additions made to the F-16 during its development. These basically consisted of adding a radar, fire control system, and a fuselage extension (for additional fuel) to the YF-16 prototype which had been successfully flown during the so-called lightweight fighter competition. Structural changes were also made for the purpose of converting a hand-built prototype aircraft designed to last only a few hundred flight hours into a viable weapon system which would withstand several thousand hours of operational use and which could be economically produced in large quantities. This resulted in some weight growth and increased cost, as did the other additions. However, the claims of the critics that these additions were unnecessary and are purely the product of the vested R&D establishment are simply not supportable. For example, the assertion that the use of a radar system in aerial combat is the equivalent of shining a flashlight in a dark room (and thereby pinpointing the exact location where the opposition should shoot), is a better justification for the judicious use of radar, rather than a valid argument for its deliberate omission. The option to have the capability and not employ it in some situations seems far preferable to its total absence in other cases where it may be vitally important. Arguments for simplicity of design and function may stand on their own merits, but a fighter which lacks range and the ability to operate in an intensely hostile modern air combat environment in anything other than a close-in visual-only mode is not likely to survive for very long. This limitation could perhaps be overcome if all potential opponents would agree in advance to engage in hostilities only in clear weather with no ground based radar detection and intercept control, and firing only at short range after each aircraft's identity is established beyond all doubt; such a scenario is clearly not realistic.

As to the second part of the critics' argument, there is a widespread misconception that the F-16 is not a high technology aircraft, and that this accounts for its relative simplicity. In fact, the F-16 is a highly sophisticated piece of aircraft engineering and design, incorporating the following features which were unique at the time of its development, and which still in many ways represent the state-of-the-art of fighter aircraft technology:

(1) Relaxed Static Stability and Fly-By-Wire Flight Control System. The F-16 was the first operational aircraft to incorporate the concept of reduced or negative longitudinal stability. This means that in certain flight regimes, the aircraft is actually unstable in the pitch, or elevation, axis, and would go out of control very quickly without computer aided control. A human pilot is simply not capable of responding fast enough to control the aircraft under these conditions. The advantage of such a design is reduced drag and better maneuverability. This concept is mechanized with a fly-by-wire flight control design in which there are no mechanical links between the pilot's control stick and the moveable flight control surfaces. In this arrangement, a computer takes control inputs from the pilot, along with data from various velocity and acceleration sensors, and provides a signal to control actuators which move the control surfaces. Fly-by-wire

control is an efficient complement to relaxed stability because the flight control computer is fully utilized (and essential) in both cases.

(2) Vortex Aerodynamics.

In the F-16 forward extensions of the wing roots at the wing/fuselage intersections (called strakes) are used to induce strong vortices in the airflow over the wings at high lift combat maneuvering conditions. These vortices enhance the lift characteristics of the wings and improve combat maneuverability.

(3) Variable Camber Wing.

The wing design of the F-16 incorporates moveable leading (forward) and trailing (rear) edge surfaces which are computer controlled and move according to a pre-set schedule to optimize the curvature of the wings at different flight conditions. This creates a more efficient lift/drag ratio over a wide range of velocities/altitudes/lift conditions than if the wing were optimized to only one design point.

(4) Composite Primary Tail Structure.

The horizontal tail structure of the F-16 is constructed of a light weight graphite/epoxy composite material, rather than metal. While composites have been employed in other aircraft prior to the F-16 in constructing secondary structures such as doors and access panels, the F-16 was the first U.S. production military aircraft to employ composites in primary load carrying flight critical structure.

(5) Digital Avionic Technology.

The offensive avionics (electronics) systems of the F-16 represented the current state-of-the-art of digital electronic technology. The system employs a high-speed data bus and a distributed computer architecture to multiplex and transmit a large quantity of digital information, efficiently integrating the operation of radar, navigation, and fire control systems.

The F-16 is in many ways technologically more advanced than the larger, more expensive, and slightly older F-15. The two systems simply incorporate the technology which was available when each was in design/development. The primary difference between the two is the amount of capability desired. The F-15 was intended to be capable of night/all weather operation, long range, and high maximum speeds, and was designed to provide this capability. The F-16 was designed as a day fighter and had a correspondingly different design approach. Both incorporate, of necessity, a high degree of advanced technology to perform their respective missions.

The complexity issue was summed up very succinctly by Norman Augustine in testimony before the House of Representatives Armed Services Committee[19/]. When asked if he felt the United States military relies too heavily on high technology, the response was as follows:

> Clearly, one makes a trade; as you introduce more technology you usually get more capability and you usually get more problems and sometimes wind up with more costly items. The mistake that is commonly made in the media . . . is to equate high technology with complexity, and that does not have to be true. One can also use technology to produce simplicity.

Continuing at a slightly later point, he added with regard to quantities of weapons:

> In fairness, though, I have to say that to have twice as many aircraft as an example, that can fight only in the day and in fair weather may not be a good trade if the enemy chooses to fight at night in bad weather. So, clearly, one has to make that very difficult judgment.

Is there, then, really a choice to be made regarding the use or non-use of advanced technology? It would seem not. High technology and simplicity are not mutually exclusive. Informed and thoughtful policy makers will (and should) debate the issue of the amount of capability which is desirable and affordable in new weapon systems. The issue of the amount of technology that should be employed in any of these systems should be largely academic, since the use of the best possible technology in all cases represents a benefit which should not be lightly thrown away.

Senator John Tower addressed the issue directly in remarks prefacing a discussion of the Carlucci Initiatives for Acquisition Reform in 1981 in Senate Armed Services Committee hearings[20/]:

> We have gotten quite a bit of unfavorable press for defense lately. I think some of it has been unfair and reflects rather shallow investigation. I think that some stories and perhaps some books being written have been misleading. It is sometimes suggested that we can get by on a lot of cheap systems and therefore save money. An assertion by a major network that the Soviet philosophy is to buy great numbers of simple systems is simply untrue. In fact they are making technological improvements in their systems all the time.

The argument has also been advanced that the pursuit of "leading edge" technology in new systems and the increased difficulty of making such advanced technology work results in increased development times and delays in deploying new weapons. Smith and Friedman of the Rand Corporation refute this contention in an analysis of weapons acquisition intervals[21/]. After a detailed study of historical trends in acquisition times, they conclude that development times for military aircraft and missiles have remained essentially constant since the late 1950s. Some portions of the acquisition cycle have admittedly lengthened substantially; these are the requirements formulation and concept validation phases (due to increased time debating the need for and the specific development approach of new systems) and the production phase (due to program stretch-outs resulting from budgetary considerations). These are political and monetary issues, not technical ones.

CURRENT TECHNOLOGY TRENDS

Military aviation has been a technology-intensive activity from its very inception. Advancements in capability have occurred in such quantity and at such a rate as to progress from a near-universal rejection of the possibility of heavier-than-air flight to travel at velocities measured in multiples of the speed of sound in less than fifty years. This is only one example of the tremendous increase in capability of military aircraft during the brief history of the industry. There are countless others. Many industry experts believe that there are currently on the horizon a number of new technologies which, if properly matured and harnessed will lead to the next quantum jump in aeronautical systems capability in the near future. It should be noted that in this instance capability is defined much more broadly than in the past when it was often interpreted to mean aerodynamic performance (how high, high fast?). This set of enabling technologies will potentially span the entire spectrum of performance attributes, including reliability, maintainability, simplicity, size, and weight, in addition to the more standard measures of functional performance. A brief summary of these potentially high payoff technologies is as follows:

(1) Low Observables (LO). Techniques for reducing the detectability or "signature" of aircraft have been in development for over twenty years. They were first applied in the early 1960s in the Lockheed/USAF SR-71 high speed/high altitude reconnaissance aircraft. In recent years these techniques have become far more sophisticated and capable and are now being utilized in the B-2 "stealth" bomber, the Navy Advanced Tactical Aircraft (ATA) and the USAF Advanced Tactical Fighter (ATF). What was previously viewed as a highly

specialized technology of limited application is becoming pervasive and has the potential to be used to greater or lesser extent on most new military aircraft programs. The advantages of this technology are a significantly increased ability to attack ground based or airborne enemy targets with greatly reduced risk of being effectively attacked in return.

(2) Advanced Structural Materials. Utilization of fiber reinforced non-metallic composite materials in load carrying primary aircraft structure has been an accomplished fact for about ten years. However, these materials have suffered from several disadvantages which tend to offset their primary advantage of reduced structural weight. These include temperature limitations, susceptibility to low energy impact damage, and difficulties in maintenance and repair. There are now a new class of composites becoming available which offer considerable improvements in these areas due to the use of new resin systems which form the matrix keeping the reinforcing fibers in place. These new resins are thermoplastic rather than thermoset types, meaning that they are processed using elevated temperatures instead of a chemical reaction to "cure" the material to its final properties. Thermoplastics are therefore more easily repaired because the material can be reconstituted using heat (the one-time chemical reaction to form thermoset materials is irreversible); this is in addition to better high temperature resistance and greater toughness (critical properties in high performance aircraft applications). This class of materials opens up a multitude of new options for aircraft designers.

(3) Advanced Microelectronics. The continuing advances in electronics technology in the areas of Very High Speed Integrated Circuits (VSHIC) and gallium arsenide (GaAs) semi-conductors offer additional reductions in weight and volume of aircraft avionics (or increased capability for the same space and cost), as well as increased speed and reliability, and easier maintenance.

(4) Sensor and Information Fusion. The proliferation of electronics systems on modern aircraft and their associated single purpose sensors (for both signal transmission and reception) are threatening to turn a very large fraction of the skin surface of military aircraft into antennas (clearly an impractical design concept). Emerging technologies offer the potential of multipurpose wide bandwidth sensors which will reduce part counts and greatly simplify electronic (avionic) system designs. At the other end of the avionics systems improved information processing capability resulting from improved microelectronics will allow real time information updates and selective presentation to a pilot to reduce complexity of operation and avoid pilot information overload.

(5) Artificial Intelligence (AI). Advances in AI capability will make feasible automation of many tasks now done manually by a pilot. In a rapidly changing combat environment with many decisions to be made in very short times, this will relieve the pilot of the burden of routine decision-making and allow him to concentrate on critical combat tasks.

(6) Built-In-Test (BIT) and Embedded Training. Improved hardware and software technologies may contribute to large reductions in system support functions and cost. Self diagnosing and BIT capability in electronics systems, and the ability to provide on-board operations and maintenance training could reduce ground support personnel and hardware requirements considerably.

The above list enumerates only what might be termed the more revolutionary technology advancements and applications which are on the horizon. In addition, there are many more evolutionary improvements which are continuing in the areas of aerodynamics, propulsion, and flight control techniques.

None of these technologies are yet mature enough to be applied broadly to system design applications with an acceptable degree of risk. Considerable money and effort will be required to fully develop these technologies and to apply them innovatively in new system applications. It would be wasteful and probably dangerous to squander the opportunities they represent by engaging in procurement practices which discourage or make impossible the full utilization of these capabilities. Further, a short-term focus which allows the maturation of these technologies at the expense of others more far reaching and as yet not envisioned would be just as bad. The recently concluded summit meeting between President Reagan and Soviet General Secretary Gorbachev and the signing of the intermediate nuclear forces (INF) reduction treaty portend a greater emphasis on advanced conventional weapons and exotic non-nuclear weapons technologies; this trend will probably continue for the foreseeable future. It is imperative that the United States defense establishment continue the historical trend of the military aerospace industry and remain in the forefront of technological advancement and innovative design. The desire to develop a comprehensive understanding of the probable effects of current acquisition policies in achieving these ends is the underlying motivation for conducting the investigation described in the following chapters.

CHAPTER THREE

RESEARCH METHODS

RESEARCH SCOPE

The objective of this research was to develop a more complete understanding of current DOD acquisition policies and their effects, and to acquire data which would either support or refute the premise that these policies are presently creating significant disincentives to the development and utilization of advanced technology in new weapons systems. Because this subject area is rather broad and extremely complex, it was necessary to limit the scope of the investigation in order to fully explore the relevant issues.

It was decided at the outset that the investigation would be limited to a study of large, expensive (in terms of unit and total costs), highly complex weapons systems incorporating a wide diversity of applicable technologies. No attempt was made to include two other major acquisition areas, namely smaller, less expensive and more technologically narrowly focused systems (e.g. air-to-air missiles) and reprocurement of spare parts for existing systems. The latter category is not technologically intensive and is driven by an entirely different set of factors. The former category is not subject to many of the constraints which profoundly effect the acquisition of "major" weapons programs, mainly cost (this subject will be addressed in some depth subsequently in this chapter when the rationale for specific subject areas of investigation is discussed). The research was also confined to one specific category of weapon system in order to ensure uniformity in the data and to expedite the information gathering process. Thus, the decision was made to address only the acquisition of aeronautical systems (military aircraft), rather than other types of military equipment such as ballistic missiles or space systems. It was felt that this would not unduly limit the applicability of the data, and that any significant conclusions drawn in the subject area would be generally applicable to any large and complex DOD weapons program.

The data-gathering effort was also targeted at systems being developed for the U.S. Air Force. Here again, the rationale was that this would make the research effort more tractable and yield a higher quality, more uniform set of data. It should be noted, however, that in examining applicable acquisition policies for inclusion in the study, some policies which are currently in use only by the U.S. Navy were included, since presumably these could be adopted by the other services at some point in the future.

Another broad area of investigation which was not dealt with explicitly in this research is the matter of the relationship of subcontractors to major weapon system prime contractors. This is an area which could well be the subject of a separate investigation.

While subcontractor contributions to weapon system development form an important portion of this study, these are examined here from the vantage point of the prime contractors who act as the system integrators and assemble the complete weapon system in all its diversity and complexity, and from the point of view of the military customers who acquire and use the final product.

SELECTION OF A RESEARCH METHOD

Several alternative methods of research were considered. Ultimately, the method chosen to conduct the investigation was the use of in-depth interviews. The rationale for the choice of interviews, rather than some other method (e.g. a survey questionnaire) was three-fold. First, it was felt that a survey questionnaire would be excessively constraining, limiting the respondents to a set of inquiries chosen solely by the investigator. In a highly complex subject area such as acquisition policy, which has many diverse aspects and subtle nuances, the use of in-depth interviews seemed to offer the greatest potential to fully explore all relevant subject areas.

Second, interviews were believed to provide the flexibility to inquire more deeply into areas which the interviewees might believe to be particularly important. In the event that significant issues might be raised which had not been anticipated beforehand (as subsequently proved to be the case), these would not be lost *a priori* because they had not been included in the list of questions.

Lastly, since the opinions of individuals with a wide range of backgrounds and experience within the overall development/acquisition function were desired, it seemed clear that the use of interviews would allow maximum opportunity for individual opinions and insights to be included in the results, and that the underlying reasons supporting a particular opinion could be examined in some depth. This consideration later provided an excellent criteria for gauging the relative merit of some responses which were offered by only one or two individuals. Some of these opinions turned out to be extremely valuable in this author's opinion. (This aspect will be discussed more fully in the next chapter).

INTERVIEWEE SELECTION

The selection of people to be interviewed was based on three distinct criteria. These criteria were organizational affiliation, direct involvement in the acquisition process, and significant responsibility within the organizational hierarchy. Based on these criteria, high-ranking managers from the large aerospace contractor firms and corresponding senior government acquisition personnel were targeted as interview subjects.

Organizational affiliation was thought to be an extremely important factor in influencing the point of view of potential interviewees. Since the investigation was aimed at the effects of government policies (as evidenced by the actual conduct of technology and weapon system development), personnel from the large aerospace contractor firms who actually perform the design, development, and production functions became the group of primary interest for obtaining information. As the implementing organization in weapon system development, these prime contractors must operate as successful business enterprises within the constraints of established USAF procurement policy. It was therefore essential to obtain the industry view of the factors which drive technical and programmatic decisions in specific directions.

It was recognized at the outset that an industry-only view could well be a biased perspective. For this reason it was also of paramount importance to obtain the opinions of people from the government side of the acquisition function. The basic rationale was that similarity of government and industry views would provide a high confidence level in the validity of the opinions expressed. In the event that the two views were in substantial disagreement, it would be necessary to attempt to discover the underlying reasons for the diversity of views, and in so doing come to a more complete understanding of the issues.

Direct involvement in the acquisition process was also considered to be an essential element in obtaining high quality data. This consideration limited the selection of both government and industry personnel to those in "front line" acquisition organizations which are currently engaged in on-going development programs. In the case of government personnel, those targeted were from the Aeronautical Systems Division (ASD) at Wright-Patterson Air Force Base. This is the USAF organization responsible for the development and acquisition of new aircraft and some specialized missile systems, and is one of five "product" divisions within the Air Force Systems Command (AFSC). While the ultimate "customers" for new aircraft are the operational commands such as Tactical Air Command (TAC), Strategic Air Command (SAC), and Military Airlift Command (MAC), AFSC and its product divisions are the actual purchasers of weapons systems and are responsible for research, development, and the implementation of acquisition policy. ASD maintains a large permanent staff of military and civilian acquisition specialists, including experts in the functions of contracting, manufacturing, engineering, and program management. It was this group of professional acquisition personnel who were of primary interest for participation in the interviews.

On the prime contractor side, those individuals currently engaged in active system development programs or who had broad responsibility for advanced technology efforts were of primary interest as prospective interviewees. It was felt that individuals engaged in presently on-going major programs would have the best visibility into and appreciation of current policy ramifications.

The selection process also targeted senior personnel with significant decision-making responsibility in their respective organizations, both contractor and government. This research activity was not meant to be a case study. Rather than surveying participants in development programs subsequent to completion of a project, the intent here was to solicit the opinions of actual decision makers during a period of intense programmatic activity so that near real-time decision rationale (as a result of the current acquisition environment) could be obtained. This approach was thought to provide a more accurate picture of the results of specific procurement policies than an after-the-fact attempt at recall of the relevant factors.

The final list of interview subjects totaled twenty-six persons, of which twenty were from industry and six were affiliated with the government. Government personnel were all from the Aeronautical Systems Division, Wright-Patterson AFB. Industry participants were drawn from five different prime contractor firms currently engaged in major system development efforts contracted by ASD. Several of the participants requested anonymity when agreeing to be interviewed; upon some reflection it was deemed appropriate to withhold the identities of all of the participants to encourage candor in the responses.

Although specific names and titles will not be identified, representative information is as follows:

(1) Interview participants represented three basic categories of expertise: engineering/technical, program management, and procurement/contracting.

(2) Air Force interview subjects included four senior acquisition managers or staff who were general officers or civilians of equivalent rank.

(3) A total of six industry vice presidents were interviewed, including two executive vice presidents/general managers.

(4) A total of six government and industry weapon system program managers or deputy program managers were included in the interviews.

(5) A total of nine government and industry chief engineers, directors of engineering or deputy engineering managers participated.

(6) Other typical position titles of interview participants were Director of Program Control, Director of Procurement, USAF Contracting Officer, Director of Finance, and Director of System Engineering.

(7) Two individuals responsible for corporate-wide technology development and advanced design efforts were included as interview subjects.

INTERVIEW SUBJECT AREAS

The subject areas to be addressed in the interview questions were chosen with the intent of treating those policy areas which might be expected to have a significant impact on technology development and utilization in major USAF weapons programs. A review of the relevant academic literature (some of which has already been mentioned) was very useful in identifying areas of continuing concern in the weapons acquisition process, as expressed by members of the DOD, Congress, and numerous defense acquisition critics. In addition, articles in the trade press tended to highlight areas in which the defense/aerospace industry is beginning to voice serious concerns as to the impacts of current policies.

The combination of these two general sources plus the author's experience in the defense R&D/ acquisition community were used to identify specific acquisition policy areas thought to have a significant influence on the climate for technological innovation in the military aircraft industry at the present time. Specific policies identified fell into seven basic areas as follows:

(1) Effects of Increased Competition During the Weapons Development/ Acquisition Life Cycle. This area of inquiry addressed attempts by DOD and the military services to maintain the involvement of more than one prime contractor firm throughout the development and production phases of weapons programs for the purpose of reducing costs and improving product quality/capability.

(2) Effects of Prime Contractor Teaming. Questions in this area dealt with the relatively new acquisition phenomenon of alliances between large contractor firms for weapon system development.

(3) Effects of Prime Contractor Cost Sharing. The current procurement environment is one that strongly encourages increased contractor investment in the development of new weapons systems. This may have an impact on technology development/application now and in the future.

(4) Effects of Prototyping. Prototyping is a frequently used device in new weapons development. There appears to be renewed interest in this approach at the present time; this may or may not have an influence on technical innovation.

(5) Effects of Increased Emphasis on System Support and Readiness. Reliability, maintainability, and supportability in the field are all subjects of great interest to the DOD at the present time. The relationship between these areas and technology was the subject of interest here.

(6) Effects of New Development Specifications. Questions in this area were formulated with the intent of determining whether or not new performance-oriented (as opposed to design prescriptive) specifications are expected to encourage increased innovation.

(7) Effects of Commonality Requirements. DOD efforts to reduce costs by requiring varying degrees of commonality between weapons systems seem to be undergoing a resurgence similar to the use of prototyping. Questions were posed in this area to determine the

expected effects (if any) on the application of technology to new weapon systems.

Each of these policy areas are described in detail in the following sections.

(1) Effects of Increased Competition During the Weapons Development/Acquisition Life Cycle

The current DOD acquisition process is structured into four distinct phases. These are Concept Definition (CD), Demonstration/Validation (D/V), Full Scale Development (FSD), and production. This listing is in chronological order with each succeeding phase exhibiting substantially increased total cost and correspondingly decreased technical risk than the preceding program phase (refer to Figure 3-1 for a graphic presentation of the acquisition time line and associated risk assessment). As can be seen in Figure 3-1, formal DOD approval (often at the Secretary of Defense or SECDEF level) is required before a new development program can progress from one phase to the next. The milestones shown in the figure coincide with these major review and approval points and are an important part of the acquisition process.

As each succeeding phase of the acquisition cycle is executed, flexibility and uncertainty in the specific design characteristics of the weapon system are reduced. Typically, during the CD phase a relatively large number of prime contractors are involved, utilizing (comparatively) small dollar value contracts to explore the

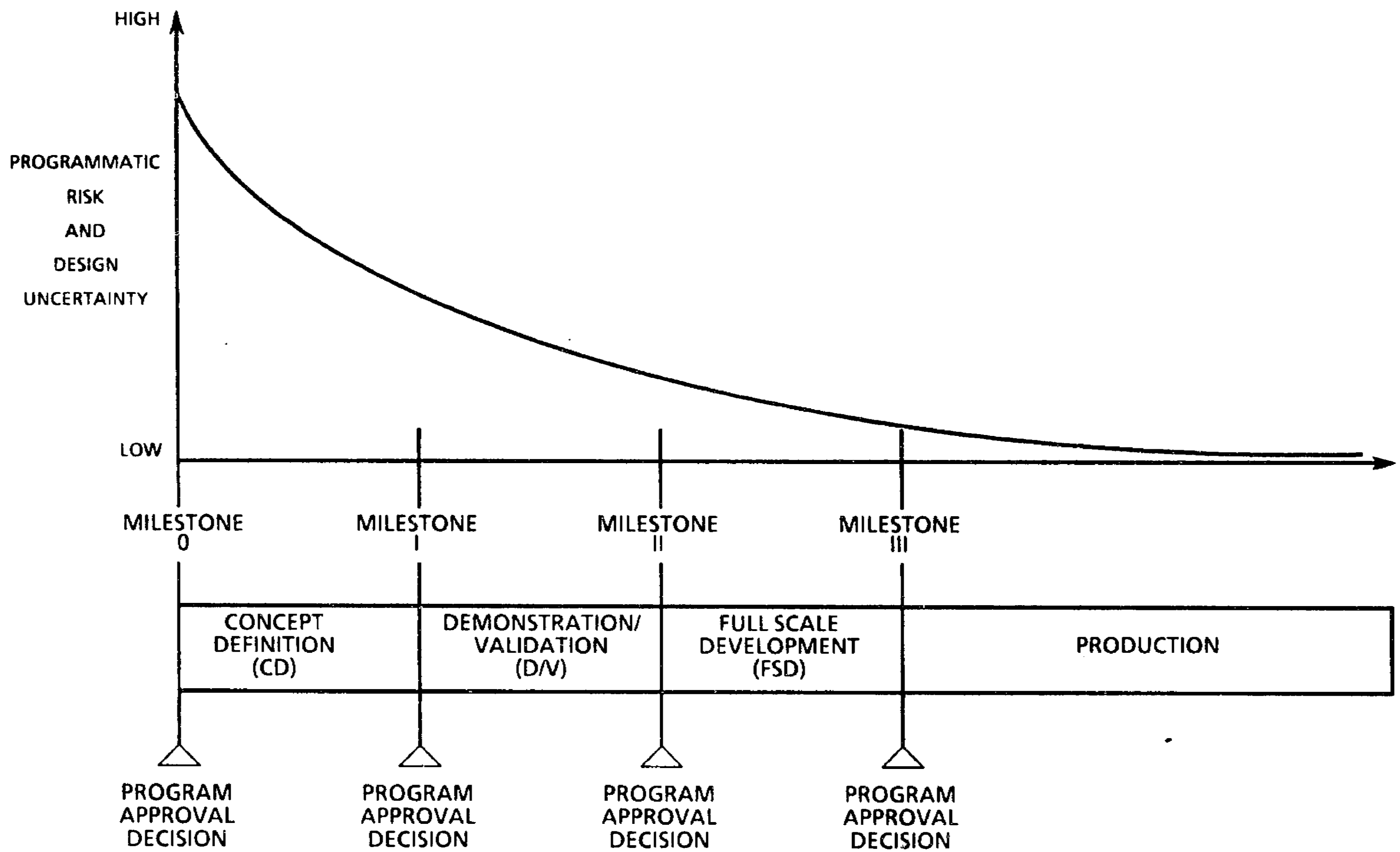

Figure 3-1. THE GENERIC DEFENSE ACQUISITION PROCESS

feasibility of a wide variety of design concepts in response to a Statement of Need (SON) issued by an operational command and a Mission Element Need Statement (MENS) generated internally by the Department of Defense. These "need" statements are fairly general in nature and allow for a large degree of latitude in selecting design concepts.

Competition among prime contractors begins during the CD phase and escalates as the program progresses into the D/V phase. The procuring agency (e.g., the USAF product division) will, after review of the CD phase studies and some additional refinement of the weapon system performance requirements, issue a Request For Proposal (RFP) to industry, inviting submittal of proposals for the conduct of the D/V phase. Proposals are required to contain descriptions of the technical and managerial approaches for the conduct of the D/V phase, and associated costs. After submittal by the prospective prime contractors, the proposals are reviewed and evaluated in a formal process called a source selection evaluation. The Source Selection Authority (SSA), usually the Service Secretary if the program is a "major" weapon system, will then select several of the proposing firms to be awarded contracts for the D/V phase. This phase is considerably more expensive than concept definition, and involves extensive efforts to validate and prove the feasibility of the design concepts formulated during CD. As a result of the increased costs the number of competitors which can be funded during this phase is smaller than the original number of contenders, usually in the range of two to four firms.

The entire RFP/Proposal/Evaluation/Contract Award cycle is repeated at the conclusion of D/V to select the contractor(s) for the FSD phase. FSD is considerably more expensive than either CD or D/V, since it involves construction and extensive tests of full scale flight articles intended to be as representative of the final production system as possible. During FSD, detailed design is completed, full-scale vehicles are constructed and tested, necessary modifications are accomplished as a result of testing, performance characteristics are verified, and acquisition of "long lead" materials and tooling for production is accomplished. In some cases, low rate initial production (LRIP) may even be initiated if the need for the weapon system is judged sufficiently critical to justify a compressed time schedule and greater concurrence in development and production.

The high cost of FSD for large and complex weapons systems effectively precludes the possibility of funding more than one contractor during this program phase in most cases. As a result, the often fierce competition between the contending firms culminates with the award of the FSD contract. Up to this point multiple competitors are involved, and presumably the quality of the technical product is enhanced and costs are held down. Competitive pressures are intense, since losing out in an early phase of a development program effectively eliminates a firm from participation in subsequent phases, unless the firm is successful in negotiating a subcontract arrangement with a winning competitor. Once the winning firm has successfully completed FSD, it and it alone has usually developed the necessary expertise to produce the highly complex system and to ensure that the nominal performance requirements will be met.

Prominent defense critics such as former DOD official Jacques Gansler attribute many of the perceived problems in the acquisition process to the "locking in" of a single prime contractor at the award of the FSD contract.[22/] Gansler and others argue that from this point forward the prime contractor is in a monopoly position and can control most aspects of the program to his satisfaction and advantage. It is further argued that competitive pressures prior to FSD contract award provide great incentives to the competitors to "buy in," or purposely understate the costs and technical difficulty of FSD and production. The competition thus becomes a "liar's contest" to win FSD, with the contractors knowing full well that the government will have no choice after FSD award but to cover the inevitable increased costs or incur a severe schedule slippage by re-opening the competition. This, it is argued, is the basis for the cost overruns occurring in many DOD acquisition programs.

The problem of maintaining competition during the entire acquisition life cycle has been one of the major subjects of procurement reform debate. Efforts in this area were one of the primary areas of emphasis of the Carlucci Initiatives in 1981. The difficulty, in the case of major weapons programs, has always been the high cost of FSD. It is not economically feasible in most cases to carry two prime contractor efforts through FSD and then either "throw away" one of them or carry both into production. While the Carlucci Initiatives stopped short of endorsing a single approach to the solution of the competition problem, their general thrust was to greatly increase pressure on the military services to enhance competition in the acquisition process. This has led, in turn, to a number of specific policy initiatives on the part of the services.

One outcome of the general drive to increase competition has been the establishment of a "Competition Advocate" position at a high level in the hierarchy of each of the three uniformed services. Each service competition advocate is charged with the responsibility of identifying opportunities for awarding more development contracts on a competitive basis (i.e., multiple sources) and not to a single or sole source. The services are now frequently called upon in Congressional testimony to provide statistics as to the overall percentage of new contracts awarded under both competitive and sole source situations.

The individual services have tended to go their own separate ways (within the overall constraints established by the Defense Department) in the specific implementation of policies to increase competition. The Navy, for example, at the direction of former Secretary of the Navy John Lehman, in November 1985 issued formal new acquisition policies requiring that each new R&D program begin with a minimum of two contractor teams performing separate development up to the start of FSD, extensive risk reduction efforts be conducted prior to FSD, and that first production be apportioned between two contractors.

This was an attempt to move a portion of the development activity to the left (earlier) on the time line into a program phase where multiple contractors are still involved. The intent was also to qualify more than one source for initial production, the so-called "split production" approach.

The Air Force has taken a somewhat different approach in efforts to increase competition. The USAF approach is not as formal, but has had the same basic intent. For example, in the Advanced Tactical Fighter (ATF) program the D/V phase is 48 months long and involves extensive risk reduction and performance verification efforts to "front load" some development activity into a more competitive program phase. While the length of each program phase is at the discretion of the services and the individual program manager, this is a relatively lengthy duration for a D/V phase.

The Air Force has, however, generally tended to avoid the Navy approach of multiple competitors in the production phase. Whereas the Navy has shown a willingness to adopt a policy of opening production contracts up to recompetition among multiple competitors as a matter of course, the Air Force seemingly has done so only on programs that have experienced serious developmental problems, are relatively inexpensive to develop and produce, and that are somewhat narrowly focused technologically. The Navy preference for "second sourcing" appears more pervasive and was apparent in actions taken to force General Electric to license production of the highly successful F404 engine (which powers the F-18 fighter) to Pratt & Whitney, a major competitor. The overall success of this initiative is yet to be determined.

Another approach to increasing competition during the production phase when only a single contractor is involved is the establishment of requirements for continued competition among subcontractors and vendors to the prime contractor. Since 60-80% of the cost of major weapon system production is in subcontractor/vendor procurement, this is an area believed to have significant potential for reduced cost as a result of competition. To cite the case of the USAF ATF once again, one of the criteria for the selection of prime contractor(s) to win the FSD contract award has been identified to be the degree to which the primes plan to ensure on-going subcontractor/ vendor competition during the production program.

While efforts to increase competition in the weapons development life cycle are usually claimed to reduce costs and improve the overall quality of the final product, there has surfaced some concern that the specific policy manifestations of these efforts may be detrimental to adoption of the best technologies. In particular, the adoption of strategies such as split production awards, recompetition during production at both the system (prime contractor) and subsystem (vendor) levels, and second source licensing may have the effect of limiting the economic returns of extensive technology investment efforts to contractors, or worse, may result in the forced sharing of proprietary technologies with competitors. The intent of interview questions in the area of competition enhancement was to solicit views as to the extent to which contractors might be reluctant to apply the best technologies to the weapon system design effort as a result of specific policy initiatives such as the ones discussed above.

(2) Effects of Prime Contractor Teaming

A trend which seems to have become quite popular in recent years with all of the military services is teaming of prime contractors during the development cycle. Once again, several different approaches have been implemented by different services in several major programs.

Teaming is thought to have several advantages for the military weapons customer. The major one is that teams composed of several prime contractor firms will constitute an enlarged technological base as compared with a single contractor. Different companies have different areas of special expertise, both in product design and manufacturing technologies. A team composed of members having differentiated and complementary skills and know-how will theoretically have the potential to design and produce a more capable, and perhaps cheaper, product.

Teaming is also purported to have other more subtle benefits. It keeps more firms involved in major programs for a longer time period as the number of major new system starts continues to decline and the interval between programs increases. By "sharing the business" among several firms, the production base is assumed to be preserved and a larger number of firms remain viable in the industry than could otherwise exist in a shrinking market. Thus, the ability to effect a "surge" in weapons design and production in the event of a national defense emergency is presumably protected. This approach also tends to avoid concentration in the industry, it is argued, and eliminates dependence on a few sources of supply. Teaming has also been suggested to create a broader political base in support of major programs since the participation of several contractors in widely scattered geographical locations will tend to increase the number of congressmen and senators voting to continue a major development effort. Teaming is thought to offer advantages to the prime contractors as well since, although it reduces the rewards (total profits) accruing to a single company, it also spreads the technical and financial risk incurred by individual firms in very controversial and/or difficult programs.

Figure 3-2(a) illustrates a typical single-contractor-take-all acquisition program; this is in contrast to the approach shown in Figure 3-2(b) which illustrates a similar effort with teams of contractors. Note that the only significant difference between the two approaches is the number of firms involved during FSD and production; the military customer is still "locked in" to a single contractor entity for the high cost portions of the program. This is

TEAMING OPTIONS IN ACQUISITION LIFE CYCLE

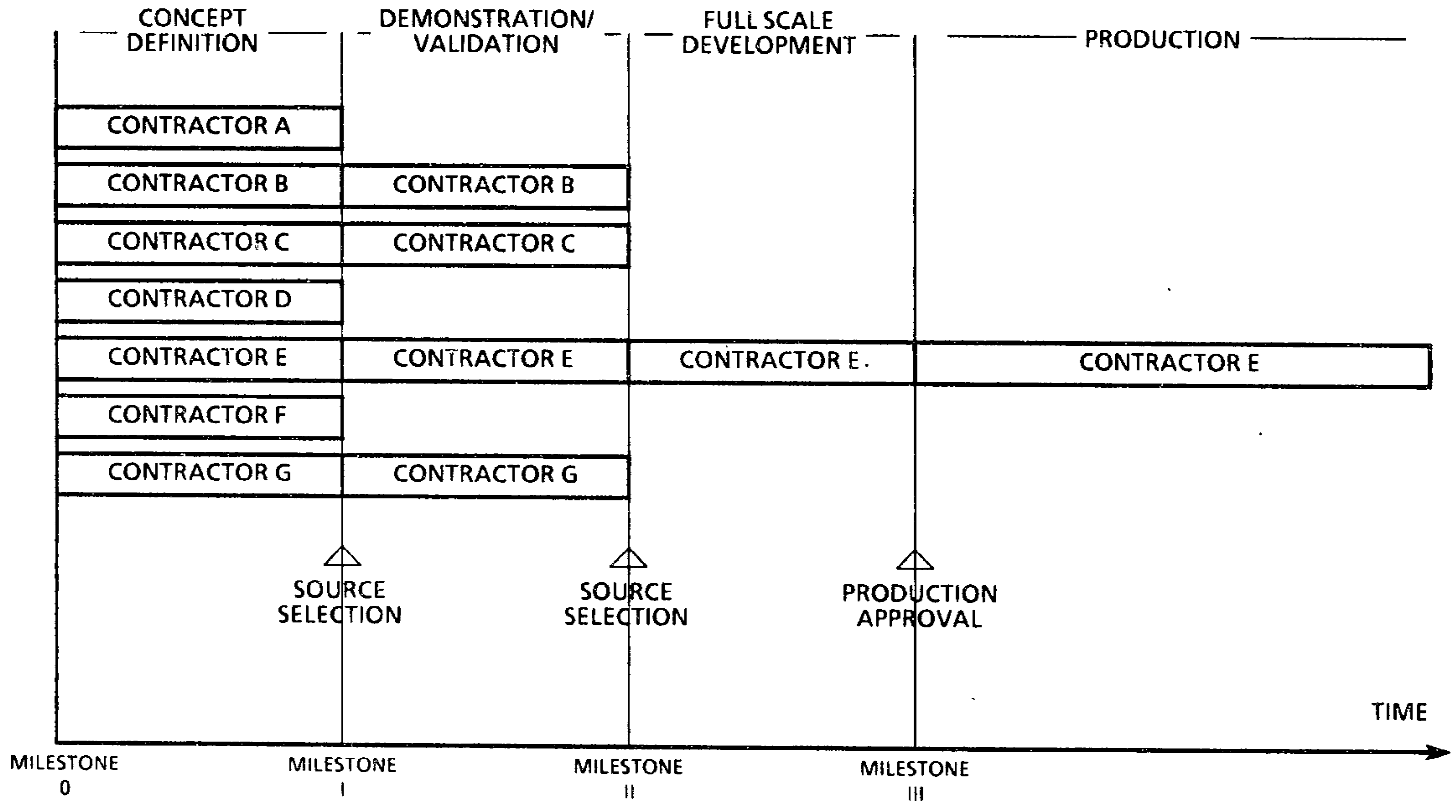

Figure 3-2 (A) TYPICAL SINGLE CONTRACTOR ACQUISITION PROGRAM

TEAMING OPTIONS IN ACQUISITION LIFE CYCLE

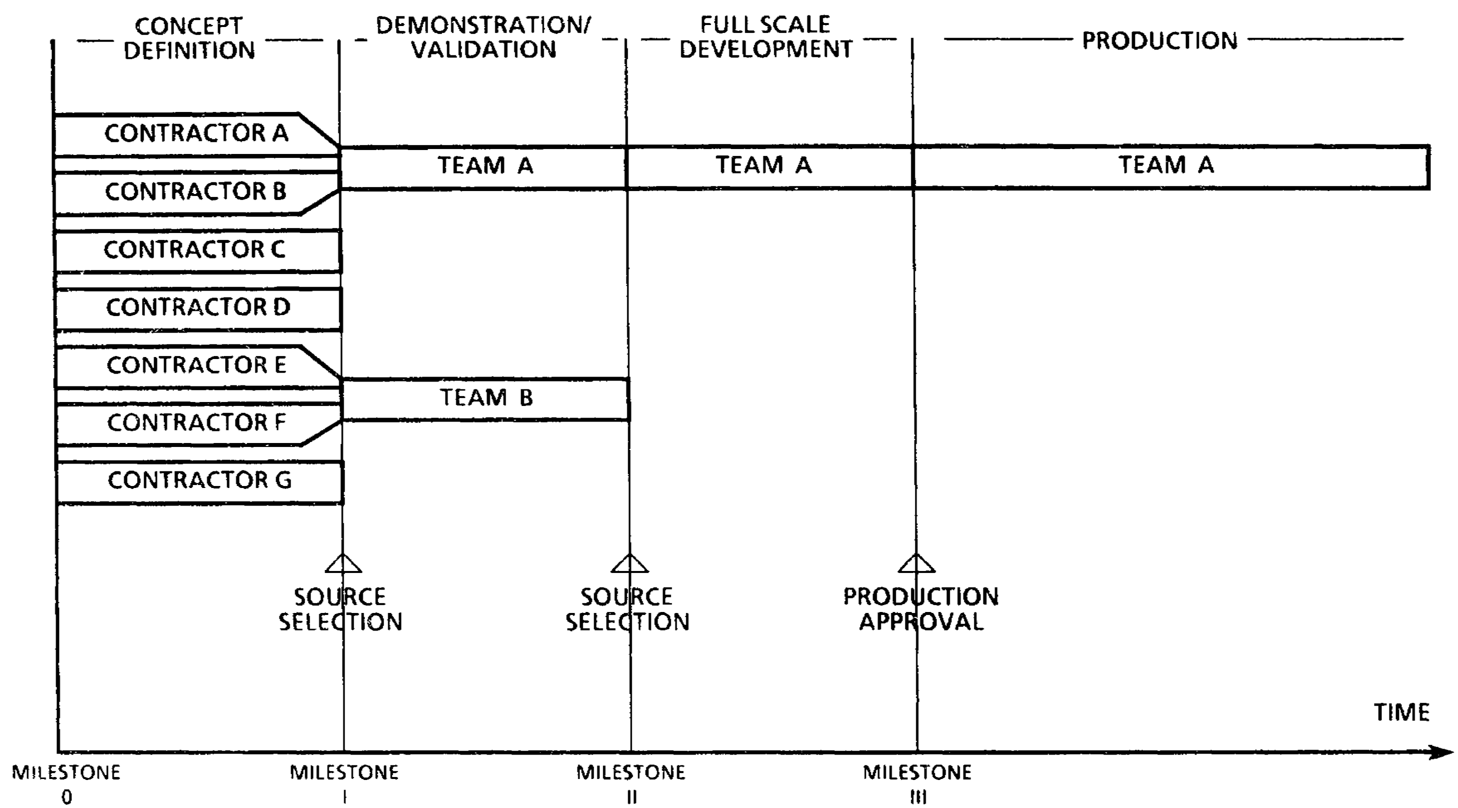

Figure 3-2 (B) ACQUISITION PROGRAM WITH CONTRACTOR TEAMING

essentially the approach which was recently followed in the Air Force's Advanced Tactical Fighter (ATF) program. In this instance, the prospective prime contractors were "highly encouraged" to form teams for the D/V program phase, although this was stated not to be a requirement.[23/] Two separate teams did eventually form, one with three members (Lockheed, Boeing, and General Dynamics) and one with two members (Northrop and McDonnell-Douglas). The teaming agreements in both cases were commercial agreements reached without the involvement of the Air Force customer. Five separate contractors (out of seven original contenders) therefore wound up participating in the D/V program.

The Navy approach to teaming has been (again) somewhat different. In the Advanced Tactical Aircraft (ATA) program which recently entered FSD, teaming of prime contractor participants was a requirement. In an attempt to address the issue of maintaining competition into the production phase of the program (and in consonance with the policy initiatives adopted in 1985 which were described previously), the Navy also adopted an approach of splitting the winning FSD team apart prior to production, and competing the individual team members against each other. In this way two single firms (General Dynamics and McDonnell-Douglas) will both share in the risk reduction activities of FSD, and both will be prepared to perform the production program, presumably at a lower cost to the government since neither will be in a monopoly position subsequent to development. This approach is illustrated generically in Figure 3-2(c).

TEAMING OPTIONS IN ACQUISITION LIFE CYCLE

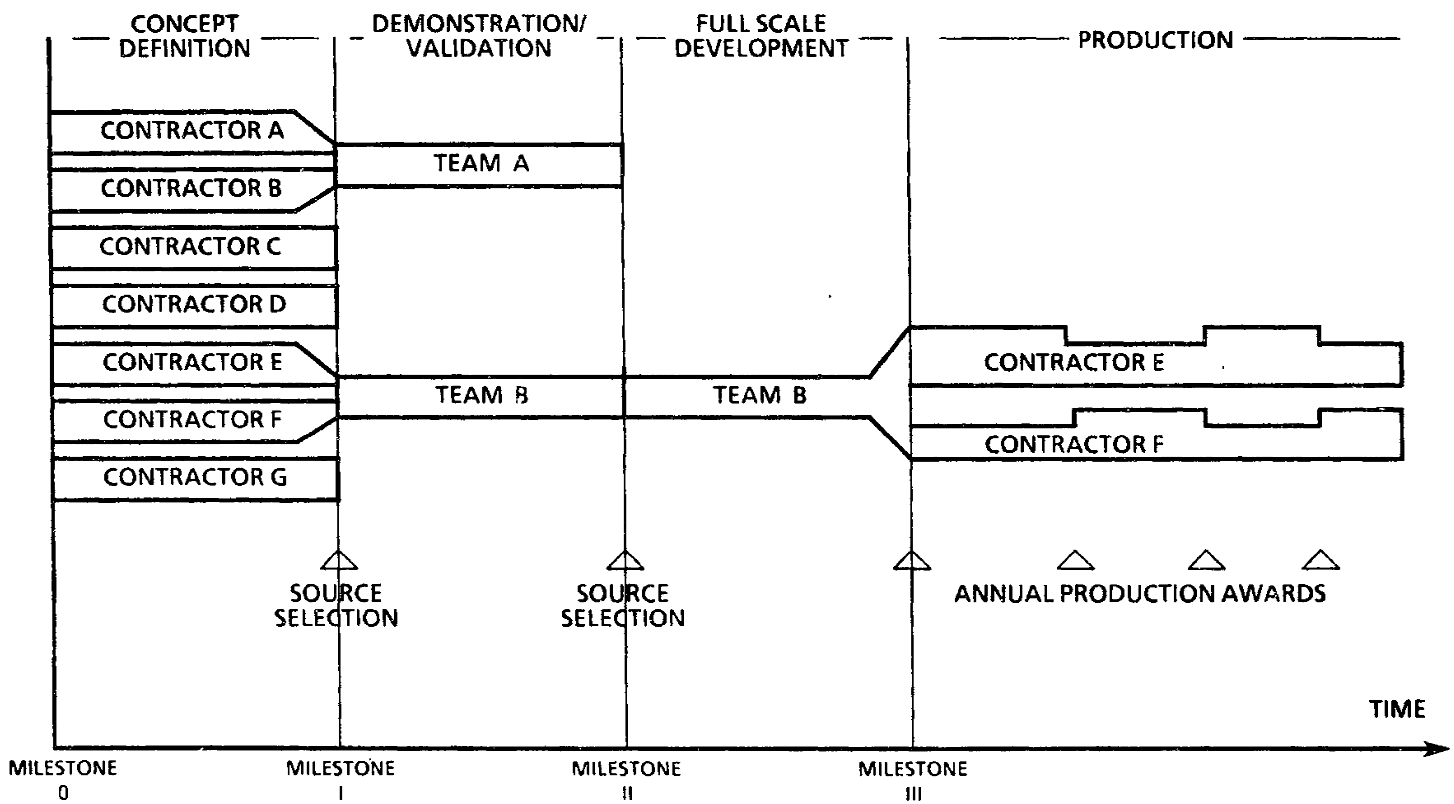

Figure 3-2 (C) ACQUISITION PROGRAM WITH SPLIT TEAMING IN PRODUCTION

Teaming arrangements such as those described above are believed to have significant implications in the areas of technology sharing between firms and protection of proprietary data and intellectual property. Interview questions in this area were intended to address the willingness of prime contractors to apply their best technological and innovative efforts to the system design problem in the teaming environment, especially in light of the fact that some contractors now find themselves in the position of being partners on one active program, and competitors on another. The effects of teaming in general, voluntary (contractor selected) teaming, forced (customer dictated) teaming, and split teams for production were addressed in the interview questions.

(3) Effects of Prime Contractor Cost Sharing

Scherer, in his definitive study of the defense acquisition process[24/] has noted that the major difference between the commercial and military aerospace markets is the degree of technical risk involved in new product development, and the manner in which new developments are funded. Historically, the military services and DOD have funded very nearly the entire cost of new weapons R&D. The rationale behind this approach has to do with the desired capability of new weapon systems. The history of new weapons development, especially in the areas of military aviation and space systems, has shown a continual and rapid advancement in sophistication and performance. With very few exceptions, each new weapon system developed and deployed in the last fifty years has represented a significant improvement in capability as compared with its functionally equivalent predecessor. This is attributable to the fact that technology has been advancing steadily, while at the same time system performance requirements have grown progressively more challenging in order to maintain a performance advantage over adversaries. It is not clear which of these factors is the cause and which is the effect. The fact remains, however, that whatever the cause, each new generation of weapons has tended to be on the "leading edge" of the current technology, with the result that there are usually great uncertainties at the beginning of a new program whether the desired capability (and enabling technology) can be successfully developed at all. This factor, plus the extremely high cost of new aircraft development, have tended to support the argument that the development risks are too great to be borne by the individual contractors alone, and that customer funding for new efforts is justified and necessary. (Of course, the quid pro quo in this equation is extensive government customer involvement in, and control of, the new product development process).

Many of the current defense critics argue vigorously against this policy. They attempt to make the case that under the full funding situation the contractors are incurring almost no risks at all. It is further charged that, in addition to funding the full costs of new system development, the government also owns many of the production facilities and equipment used by the prime contractors. While the critics admit that defense aerospace profits (which are controlled by the government procuring agencies as a percent of costs incurred) are low in comparison to other industries in terms of return on sales, they argue that the return on investment in military aerospace is inordinately high. Studies of actual return on investment to the contractors by various groups such as the Rand Corporation have yielded ambiguous results.

There currently exists no explicit DOD policy which calls for greater investment on the part of the prime contractors in the new weapons development process. In fact, one of the clearly stated components of the 1981 Carlucci Initiatives for acquisition reform was a continued policy of full government funding for weapons development and acquisition. Nevertheless, there appears to be a trend in the DOD over the past few years to implicitly encourage substantial contractor financial contributions to the development process. This seems to be the result of two separate factors. First, contractor cost sharing requirements may be a response to the critics who maintain that full funding of development efforts represents a virtual "free ride" for the prime contractors since none of their funds are at risk. Second, the current leveling off and actual decline in real terms of the defense budget has created some very difficult choices for policy makers in the DOD and the uniformed services. Contractor cost sharing may represent a means to "get more for less", i.e., it may be possible to avoid outright program cancellations if the contractors make up the difference between the actual cost of new system development and the reduced funding now available. While "stretch-out" of programs is an alternative that can be, and is, frequently used, this approach is far more attractive for systems which are already in production. The savings realized for systems in development is probably much smaller.

Once again, the Air Force's ATF program provides an illustrative example. Each contractor team participating in the D/V program phase (two teams, five contractors total) will receive a total reimbursement of $691 million for the four year long effort. Some industry managers have estimated that the costs of a high-quality D/V effort may be on the order of $1 billion. In order to remain competitive for the winning-team-take-all FSD award, each contractor team may choose to invest a substantial amount of corporate funds in the development effort. There are suggestions in the trade press that other classified DOD programs are encouraging a significant amount of contractor cost sharing. It has also been estimated that the contractor-to-government funding ratio in the National Aerospace Plane (NASP) program is currently four-to-one.

The type of contract used for development activities is a closely related aspect of the cost issue. The debate between the use of fixed price and cost reimbursement type contracts has raged for some years. The pendulum in DOD has swung back and forth in preference for on type or the other. During the 1960s, cost reimbursement contracts predominated. As the cost overrun revelations of the F-111 and C-5A programs surfaced, the pendulum swung sharply to the side of fixed price contracts during the late 1970s and early 1980s. There now appears to be some movement back away from the fixed price approach since this does not seem to have eliminated the cost overrun problem. Defense critics continue to argue that a cost reimbursement contract is virtually a license to steal for the contractors, while industry continues to maintain that large complex programs employing leading edge technology are far too risky to be done on a fixed price basis.

The cost-sharing and type-of-contract issues can have significant implications if they result in a reluctance on the part of industry to develop and apply the best possible technology in the system design/development process. This is the most visible area of concern which one finds in reviewing the current trade press and various defense publications. Interview questions in this area were designed to explore the ramifications of cost sharing in current programs, possible long-term effects on the overall technology base, the effects (if any) of fixed price versus cost reimbursement development contracts, and the implications for subcontractors who might be affected by possible flowdown of cost sharing requirements from the primes.

4. Effects of Prototyping

Prototyping has a long history of use in military aviation. It is usually employed during the D/V program phase and can take many forms. The purpose of prototyping has always been to put realism into system development, to provide objective means of performance verification not possible by analytical means alone, and to do this prior to a commitment to a costly FSD and production program. This has generally been interpreted as a "fly before you buy" approach, but this is not always the case. Risk reduction and feasibility demonstration of various design concepts can be accomplished in many ways during the D/V program phase. These can range from wind tunnel tests of aerodynamic and stability characteristics, to laboratory bench testing of hydraulic and electrical components, to strength and fatigue testing of structural elements and sections, to airborne laboratory tests of electronic subsystems and sensors. Flight demonstration of full-scale or near full-scale prototype aircraft can also be included if it is judged that other "subsystem" prototype tests are insufficiently definitive in demonstrating that technical (and/or cost) risk has been reduced to an acceptable level.

System level (i.e., whole aircraft) prototyping was used extensively during the 1950s, particularly in the development of the so-called "century series" of fighters from the F-100 to the F-106. It enjoyed a resurgence during the early 1970s when Under Secretary of Defense David Packard endorsed its use generally to avoid "paper" competitions during source selection. During this period three major prototype programs were undertaken, the Attack-Experimental or AX Program, the Light Weight Fighter or LWF Program, and the Advanced Medium STOL (Short Take-Off and Landing) Transport or AMST Program. Of these, two actually led to full blown production programs: the AX resulted in the USAF A-10, and the LWF program turned in to the USAF F-16. The "loser" in the USAF LWF competition, the YF-17, later was developed into the current Navy F-18. More recently (1986), the President's Blue Ribbon Commission on Defense Acquisition Reform chaired by former Under Secretary Packard recommended that DOD once again return to increased use of prototyping during system acquisition. (It is interesting to note, however, that the Packard Commission endorsed many varieties of prototyping including the full scale variety, and not the exclusive use of system level prototyping as is widely believed in DOD and the defense industry.) As a direct consequence of the Packard Commission report, system level prototyping was added to the USAF ATF program during the source selection for the D/V program phase; previously the ATF program had incorporated only subsystem level prototyping during D/V.

Proponents of system level prototyping argue that it is advantageous from a technological point of view because it focuses technical efforts on "practical" technology, it provides a clear demonstration of capability and eliminates "paper" competitions, and that it is necessary because subsystem demonstrations and analyses are inadequate to discover all potential problem areas needing resolution during development. Opponents argue vigorously in return that system prototyping is generally unnecessary because of the accuracy of currently available analysis and subsystem test tools, it wastes time and increases development costs, and that it tends to result in adoption of highly visible "gee whiz" technologies at the expense of more intrinsic, but ultimately more effective design characteristics. Interview questions in this subject area were designed to elicit opinions on the value and technological ramifications of procuring agency requirements for both subsystem and system level prototyping during development.

(5) Effects of Increased Emphasis on System Support and Readiness

A major component of criticisms of the current defense acquisition process is the argument that present policies focus on the traditional measures of functional performance, such as speed, acceleration, and agility in military aircraft systems, at the expense of other less quantitative attributes such as reliability, maintainability, and ease of logistical support (hereafter referred to as R, M, & S) in the field which may ultimately prove more important than pure performance in a protracted conflict. The military services have responded to these criticisms with substantially increased emphasis on weapon system support and readiness.

The Air Force, for example, has adopted an initiative called Reliability & Maintainability (R & M) 2000 in an attempt to encourage the development and adoption of technologies contributing to improvements in new weapon system R & M. The Air Force Systems Command (AFSC), as the command responsible for research, development, and acquisition of new weapons, in 1986 adopted a policy of ranking R, M, & S equal to system performance in source selection evaluations of contractor proposals. Statements of system capability and requirements are beginning to reflect these considerations, as evidenced by the ATF program SON and System Requirements Document (SRD). These efforts have received generally favorable comment, as witnessed by a recent Rand Corporation study.[25/]

There is an admittedly arguable point of view that present technology trends are generally contributing to improvements in R, M, & S with each successive new system deployment without the necessity of resorting to such explicit and formal methods. First-hand interviews conducted by this author in early 1987 with maintenance personnel at three operational fighter bases in Europe would tend to support this position. However, it may be that increased formal emphasis on R, M, & S during development is necessary to fully achieve the improvements in this area which are now possible.

Interview questions in this area were designed to determine the general opinions of USAF acquisition officials and industry managers regarding the effects of increased emphasis of R, M, and S on technology development and adoption and whether this emphasis will tend to encourage new innovations necessary to meet more stringent and challenging requirements, or whether such policies will favor the use of well known "tried and true" designs to reduce uncertainty and risk.

(6) Effects of New Development Specifications

Many defense critics maintain that the military services are too restrictive in their approach to writing weapon specifications. This view holds that there are usually too many requirements levied on the prime contractors, and that these often are written in a manner which dictate the exact design approach which must be used. The net result, in this view, is increased costs caused by largely unnecessary and narrowly focused requirements. Former Secretary of Defense Harold Brown takes a similar view[26/] and recommends that the services adopt flexible performance oriented specifications which define required capabilities, but not specific design solutions as is now frequently the case.

The Aeronautical Systems Division (ASD) has initiated just such a policy, and is now in the process of rewriting the current military specifications (MIL-SPECS) for which it has responsibility to a so-called MIL-PRIME format. The objective is to eliminate the design prescriptive approach, and allow more flexibility for the contractors to employ new and innovative design solutions.

Interview questions in this area were aimed at discovering if such an approach is likely to have the desired effect of promoting (or at least not prohibiting) unique and innovative solutions to weapon system design problems.

(7) Effects of Commonality Requirements

The use of nearly identical subsystems in a multitude of different weapon system applications and similar higher-level approaches of acquiring the same weapon system to satisfy multiple service (e.g., Air Force/Navy) needs represent two different approaches to commonality which have been employed in DOD over the years, with mixed results. The foremost example of the latter is the much publicized case of the F-111 in which then Secretary of Defense Robert McNamara attempted to force the Air Force and the Navy to acquire (nearly) the same fighter/bomber aircraft. The result was prolonged controversy and much acrimonious debate between the two services. A less well-known example of the former situation is the use of the F100 fighter engine as the powerplant for both the USAF F-15 and F-16 fighters.

More recent attempts at commonality at both levels involve the two most current tactical aircraft development programs, namely the Air Force ATF and the Navy ATA. At the system level, Congress has directed each service to pursue plans to adapt the other service's aircraft for its use, i.e., the Air Force will look at using some variant of the ATA as a future USAF attack aircraft, and the Navy will examine the feasibility of using an ATF variant to fill its future fighter needs. At the subsystem level, former Secretary of the Navy John Lehman suggested that there ought to be upwards of 90% commonality of avionics (electronic systems) between the ATF and the ATA. This suggestion is now being pursued by the Navy and the Air Force at the direction of DOD.

The motivation for pursuing commonality strategies at both levels is obviously cost reduction. However, a contrary point of view is that attempts to force a singular solution to incompatible requirements could result in low grade "consensus" type designs and a sacrifice of both technology and capability.

Interview questions in the commonality requirements subject area were intended to discern any projected effects on technology adoption and innovation as a result of the policies described above.

CONDUCT OF INTERVIEWS

All interviews were conducted during the period 11-22 January 1988 at the Aeronautical Systems Division, Wright-Patterson AFB and at several prime contractor facilities. The content of the interview questions was as described above. Exhibit 1 outlines the subject areas covered by the interview questions. No attempt was made to follow the outline exactly or to ask identical questions of each participant. The interviews were structured more in the form of discussions which averaged approximately one hour in length (the shortest was about 45 minutes, the longest almost 2 hours). Initial inquiries in each subject area were purposely kept general in nature, so as not to bias the results by asking "leading" questions. The

Exhibit 1

Interview Subject Area Outline

1. Effects of increased competition
   - Longer competitions prior to FSD
   - Split production awards
   - Second Sourcing
   - Requirements for Subcontractor/vendor competition

2. Effects of prime contractor teaming
   - Contractor selected teaming/partners
   - Acquisition agency required teaming/partners
   - Split teams for production

3. Effects of prime contractor cost sharing
   - Weapon system development investments
   - Current program impacts
   - Long-term effects on technology base
   - Fixed price vs. cost reimbursement contracts
   - Implications for subcontractors

4. Effects of prototyping
   - System level (flight demonstration)
   - Subsystem level

5. Effects of increased emphasis on system support and readiness
   - Reliability
   - Maintainability
   - Supportability & logistics

6. Effects of development specifications
   - Functional (performance specified)
   - Prescriptive (design specified)

7. Effects of commonality requirements
   - System level
   - Subsystem level

discussions then became more specific as the initial responses led to follow-up questions. Since many of the subject areas are closely related, questions in one area would invariably lead to discussions covering issues in other subject areas. The only attempt made to constrain the discussion was to make sure that all the subject areas were eventually covered, regardless of sequence. The amount of time spent on a specific subject area varied substantially from interview to interview since different individuals had different areas of interest and expertise. The intent was to elicit the maximum amount of relevant information and opinion from each individual, based on their particular area of competence and experience in the defense acquisition activity.

The results and the procedures used to interpret them are described in detail in Chapter 4.

CHAPTER FOUR

FINDINGS

ANALYSIS OF INTERVIEW DATA

The output of the in-depth industry and government personnel interviews was a voluminous set of notes which were examined for trends, areas of significant divergence of opinion, and noteworthy individual opinions which were unique, but well substantiated. The results of this examination are characterized by ten separate, but closely related, findings which will be described in detail in this chapter.

Before proceeding with this discussion, however, it is important to first comment on the data analysis process itself. No attempt was made to keep a "scorecard" of the total fraction of the interviewee population who took a particular position versus those who might have expressed a differing point of view. Such an approach was not possible due to the highly individual nature of each interview and the wide spectrum of experience and expertise represented by the total population. As a result, the presentation of the findings will be qualitative in nature, and is based on the author's judgement of the significance of particular opinions and points of view. This judgement was based on the degree to which a particular opinion was shared among all the interviewees, as well as on how well a unique observation was supported by a rational argument and personal expertise of the individual concerned. Both of these factors were weighed in the context of the author's experience in the defense acquisition business to arrive at the final list of findings.

In summary, the findings are characterized as falling into three major areas: nearly universally held opinions, distinctly divided opinions, and minority opinions identified by only a small number of individuals (or a single individual) which were well supported and thought to be highly significant. Six of the ten findings may be said to be widely shared by the interview subjects. These findings are that present policies are:

(1) providing economic disincentives to remaining a prime contractor;

(2) discouraging contractor technical leadership;

(3) encouraging short-term consumption of resources at the expense of long-range technology development;

(4) producing inefficiencies in weapons program management as a result of prime contractor alliances;

(5) discouraging subcontractor innovation and long-term viability;

(6) emphasizing the importance of appropriate weapon system requirements.

One of the findings--effects of system level prototyping--was viewed by the interviewees in two distinctly different ways. Opinions were split nearly evenly as to whether this would be a positive or a negative influence on technology and innovation. The remaining three findings were well-argued minority views. These are that present policies will tend to:

(1) produce a loss of contractor technical differentiability over the long term;

(2) reduce technical flexibility during weapon system development;

(3) encourage abuses during the procurement process.

The detailed discussion which follows describes each finding, identifies which of the three basic characterizations are applicable to the finding, and attempts to convey a sense of why the finding is significant. The degree to which government and industry respondents held similar or opposing views in a particular area is also addressed.

ECONOMIC DISINCENTIVES TO PRIME CONTRACTING

The first finding is an opinion shared by nearly all respondents, government and industry alike, that the combination of increased competition, forced contractor cost sharing, and lack of program stability in the current acquisition environment are creating substantial disincentives to remaining a military weapon system prime contractor. A significant number of the interview subjects expressed the opinion that the historical trend (since World War II) of steadily increasing industry concentration will continue with the voluntary or involuntary exit of several more prime contractor firms from the defense industry in the next five years. Such an eventuality will also result in a corresponding reduction in the size and diversity of the existing technology base.

The responses suggest a chronology of investment necessary to win new weapons programs which tends to refute the position taken by many acquisition critics that industry investment is minimal. This chronology starts with technology base development required to compete for a major program award, and continues through development and into production, sometimes to the completion of the production program.

Contractor cost sharing in the development of generic technology has been a way of life in defense R&D community for some time, and appears to be growing more pervasive in the opinion of several USAF and industry officials. Firms wishing to pursue particular avenues of technological endeavor so as to develop areas of expertise thought to be important in future systems development are faced with increasing requirements to invest corporate resources in amounts sometimes matching or exceeding the value of contracts (hopefully) obtained from a government R&D laboratory. Several industry officials were of the opinion that willingness to cost share in technology development contracts has a direct bearing on a firm's probability of winning such contracts. There is limited recourse if the technology area is of substantial importance; other alternatives to develop the technology are independent research and development (IR&D) in which a portion of the contractor investment is reimburseable by the government as an overhead expense, and discretionary contractor R&D which is funded totally out of corporate profits.

Contractor cost sharing requirements escalate rapidly with the start of a major weapon system program. Direct investment required during the D/V phase alone in the current acquisition environment is on the order of $300-400 million for a major program. Additional investments are required as the system progresses into FSD. Substantial investments in tooling are usually necessary, much of which must be done (to meet schedule) under conditions of high uncertainty when multiple firms are competing for award of the FSD contract. As technology has progressed and weapons have become more complex, it has also become necessary for prime contractors to invest heavily in plant and facilities to maintain a competitive position. Examples are elaborate and expensive flight simulators, large very high-speed computers and support facilities, and complicated software of all kinds (such as CAD/CAM programs, non-linear structural analysis routines, and computational fluid dynamics (CFD) airflow and performance analysis programs). Sufficient numbers of appropriately trained and qualified engineering, management, financial, and manufacturing personnel must also be in place (and drawing salary) ready to begin work if an FSD or production contract is won (this is usually a government requirement stated in the RFP; the contractor must demonstrate in his proposal that this capability is in place prior to contract award).

The result of the large required "up front" investment is a substantial negative cash flow for the entire period of system development (on the order of seven to eight years) and well into the production phase. Recovery of this investment cannot occur until after a substantial portion of the production program has been completed; the reason for this is that there are strict legal prohibitions against recovery of losses incurred under one (development) contract by higher profits under a subsequent related contract. Thus, pay-back of the initial investment must come from regular profit rates, and the total absolute profits to do this are only large enough during the production phase. Several industry officials pointed out that DOD has recently instituted other policy changes which exacerbate the pay-back problem. These changes are a one to two percent across the board reduction in negotiated profit rates (negotiated for each contract as a percentage of costs), and a reduction from 90% to 75% in progress payments (incremental payments over time to cover costs incurred in partial completion of a contract). One senior industry official expressed concern that the Air Force might adopt the current Navy policy of requiring the prime contractor(s) to buy all of the production tooling at the beginning of the production contract and amortize the cost over the life of the expected production run.

The total "cost risk" or amount of funds invested by a prime contractor prior to FSD start was estimated by one senior industry official to be between $500 and $600 million, and the cost risk prior to production start to be on the order of a billion dollars for a major program. This was pointed out to be the primary reason for prime contractor teaming, even in programs where it is not required. Teaming spreads the financial risk among several contractors in the event that a program is cancelled or that a contractor (or team) loses out at some stage in the competition. While the total profits accruing to an individual contractor are reduced under a teaming arrangement, the persons interviewed felt that the risks of "going it alone" are too great.

Industry officials noted that the cost-sharing situation would be tolerable if the substantial financial risks were not coupled so strongly with uncertainties in the future business base. Weapons programs are notoriously subject to cancellation and stretch-out. In addition, the current environment of second sourcing, production licensing of competitors, and recompeted production awards leads to an expectation that the projected production volume will not be realized, and that break-even will be delayed in time (and might not be reached at all). It was noted that this was a substantial difference between the defense business and the commercial marketplace, where the financial risk may be just as high, but the eventual production volume is somewhat more predictable, and not as subject to sudden severe fluctuations and cuts.

In general, there was a recognition by the Air Force personnel interviewed of the considerable financial pressures on the prime contractors as a result of current policies. Only one individual expressed the view that the issue was one of contractor willingness to invest, and not one of ability to invest; no supporting argument was offered to justify this position, however. The majority expressed the opinion that prime contractors' ability to cost share was directly tied to their current business base; those with profitable production programs currently underway were believed to be substantially more able to make substantial contributions to system development and to survive the effects of a major cost sharing program. One senior Air Force official suggested the need for the government to be very selective in deciding what programs are appropriate for cost sharing. The suggestion was that only relatively low unit cost programs with associated large production volumes (fighters) should be cost shared, and that other programs with high unit costs and low total production volumes (e.g., bombers) should not be cost shared. In this individuals opinion, the cost sharing option should be adopted only with an associated commitment on the part of the Air Force customer to program stability (multi-year funding, minimum guaranteed production volume) so as to ensure the contractor(s) an adequate return on investment. This official also pointed out the danger of shrinking the prime contractor base and "locking in" firms to a single program because of the constraints imposed by cost sharing. The danger here would be the creation of a few "specialty" firms with a narrow technology base. The need for up-front government commitments to program stability was echoed widely by industry officials. On the more positive side, several Air Force officials observed that cost sharing requirements provided incentives to the contractors to spend limited development dollars wisely and only in the potentially highest pay-off technology areas.

Several industry officials pointed out that the cumulative effect of current DOD efforts to minimize industry profits had reduced rates of return to less than long-term U.S. Government Treasury Bill rates; this return would occur only in situations in which contractors were generally successful in winning production programs. This would not hold true, it was pointed out, if a major cost shared system development program was lost after the D/V phase, for example. In this situation, costs incurred would be largely unrecoverable, and corporate financial health would suffer accordingly. It was also noted that the contractors incur a substantial opportunity cost of having hundreds of millions of dollars tied up in one major program (which could later prove to be a "loser") when the funds could be more profitably invested elsewhere. There are also opportunity costs of the large up-front investments in major system development, even when the firms are ultimately successful in winning a production program. One government official noted the costs of program cancellation as well, since negotiated termination costs to the government cover only direct costs, and not those previously noted which are associated with maintaining a competitive position in the industry.

The current situation of reduced total profits to industry, delayed breakeven points, and increased early cost risk are shown graphically in Figure 4-1. It should be noted that the situation depicted in the figure applies only to the winning contractor/team. A firm or team that is eliminated from the competition at the end of the D/V phase has no mechanism available to recover its substantial investment. This situation is believed by a number of industry and Air Force personnel interviewed to be likely to lead to decisions on the part of several current prime contractors to exit the industry (as least as prime contractors) in the near future, due to an inability to compete under present ground rules. Several industry officials expressed the opinion that, despite enormous pressures to compete on every new program, even those primes planning to remain active in the industry might have serious second thoughts about embarking on a second cost shared program having participated in a previous one. Those who anticipated further shrinkage in the number of prime contractors also saw a general reduction in the quality of the available technology base as a result.

DISINCENTIVES TO PRIME CONTRACTOR TECHNOLOGICAL LEADERSHIP

The second finding is closely related to the first. There was a strong body of opinion, shared between industry and government personnel alike for the most part, that current economic disincentives coupled with efforts to increase competition are having the effect of discouraging technology leadership in the defense industry at the prime contractor level. A substantial number of the interviewees expressed the view that technical followers tend to fare far better

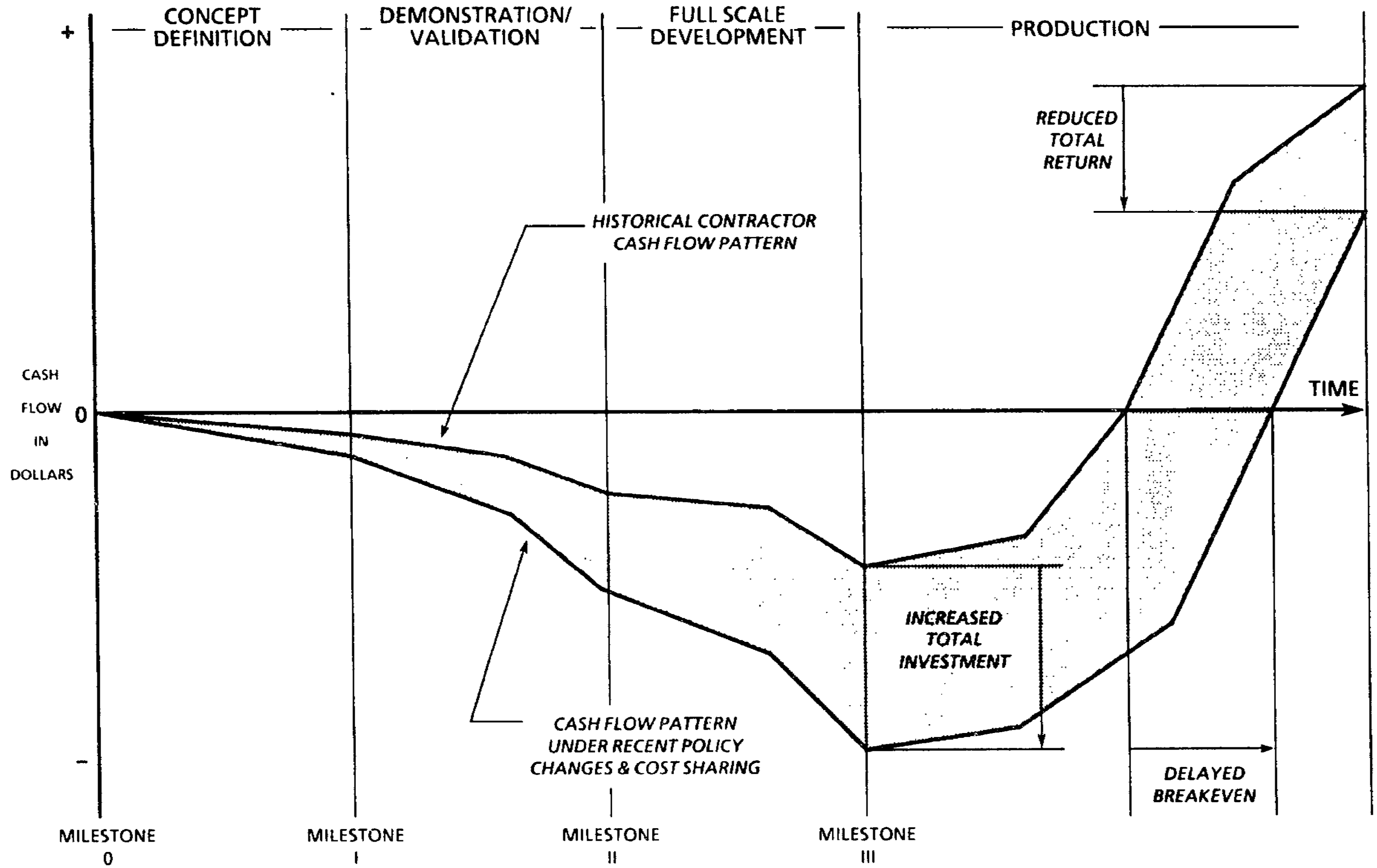

Figure 4-1. CONTRACTOR CASH FLOW DURING SYSTEM ACQUISITION

(Source: Financial Executives Institute) economically under present conditions than technical leaders; this will have the inevitable effect, it was predicted, of causing subtle but very real degradation in the overall technology level of new weapon systems over time, along with an associated slowing of the rate of technological advancement in general.

In order to put the discussion in the proper context, it is important to note at the outset that industry officials were nearly unanimous in agreeing with their government counterparts that true competition is essential to foster a high rate of technological advancement. Industry officials included in this sample were quite willing to concede the point that efforts to enhance competition, if done properly, would be likely to improve the technical quality of new weapon systems, as well as reduce their cost. However, both Air Force and industry officials were in basic agreement that some aspects of current acquisition policy have gone too far and are now becoming counterproductive.

Several government and industry technical specialists noted that the benefit/cost ratio of investing in new technology has decreased in recent years. Contractor costs have risen as a result of cost sharing in both the generic technology base and system development areas. The benefits accruing to prime contractors as a result of decisions to invest in new technology have simultaneously been reduced, as a result of teaming (required by the government or made almost unavoidable by economic risks), second source licensing, and recompetition during production. The net effect, in this view, is to lower the threshold at which industry decision makers decide to quit investing in new technology and opt for a "good enough" strategy. If true, the obvious result would be a general decrease in the pursuit of high pay-off technical advancements.

One senior Air Force official was particularly forthright in expressing the opinion that present policies are tending to make prime contractors timid in their technical approaches, and are providing incentives to lose, rather than win development competitions. It was noted that split-teaming approaches in production, forced licensing, and second sourcing all increase uncertainties for prime contractors that they will receive the economic benefits of innovative approaches in sufficient measure to justify initial investments. Furthermore, a prime contractor who wishes to win a major program award is forced to develop (at significant cost) expertise in a wide variety of highly diverse and complex technical areas. A prime contractor aiming at a second-source award, on the other hand, has the luxury of being able to focus to a large degree on production related technologies. This singular focus is clearly less costly, and is likely to reap great dividends if a second source production award is based on reduced manufacturing costs. In this scenario, there is little incentive to invest to win, since economic returns will likely be higher for a "near miss" and subsequent second source award. Likewise, the incentive in this case is for the second source to gain the benefits of the innovator's technology through a sharing arrangement forced by the government, rather than developing the technology independently. If enough prime contractors adopt this approach, there is a substantial probability that the most innovative ideas will be lost to the military customer. This view was echoed by several industry management officials in different firms.

Air Force and industry officials having visibility into actual program costs also expressed doubt that split production awards and second sourcing were effective in reducing unit costs of major weapons, and might actually have the effect of raising overall program costs. The reason given is that the total production volume of most major systems is sufficiently low to start with that splitting the award between two contractors prevents either from achieving full benefits of the production learning curve. Neither producer ever reaches a volume where learning in production is sufficient to offset the increased cost of opening the second line. Several individuals noted that once the government has incurred the cost of establishing a second production line with a second source contractor, it is virtually committed to keeping both production lines open. It is clearly not possible to award a one hundred/zero percent production split in any given year. No contractor can afford to allow a large and expensive production facility and associated skilled personnel to sit idle for a year in anticipation of the next award. Likewise, the procuring agency cannot stand to subsidize such a wasteful approach in either budgetary or political terms. Each contractor is therefore assured of a minimum annual production volume (historically not less than 30% share, according to one Air Force official). In addition, the potential benefit of winning a small marginal gain in production volume for any given year (e.g., a 55/45 split vs. a 50/50 split) may not be economically justifiable if a substantial investment in more efficient production technology and equipment is required. There is, therefore, little incentive for either contractor to pursue the most advanced and efficient production technology.

A more subtle aspect of this situation was noted by several government and industry officials. If this "assured production share" situation is perceived by the contractors from the outset as being very likely, oligopolistic competition sets in, and the technical quality of the system design is likely to suffer, with the result that the product incorporates basic capability only, but nothing highly innovative or advanced.

No strong consensus was apparent from either the Air Force or the industry participants as to which of two opposing effects would be the more dominant--the desire among competing firms to win weapon system competitions by incorporating their best (and possibly proprietary) technology, or a corresponding desire to "hold back" in the fear that proprietary technology and trade secrets would be shared with competitors by the government in split production and second source licensing situations. It was generally recognized that "holding back" the best technology would make it impossible for a contractor to obtain any benefit from its development. However, most of the interviewees felt that advance knowledge of future technology sharing with competitors would almost certainly exert subtle pressure on potential innovators to be somewhat less aggressive in general approach. It was noted by several government officials that the issue of protection of proprietary data rights in government contracts has historically been a controversial subject. Data and know-how developed under a government funded activity are by definition open and available to all competitors. The difficulty in a cost sharing environment is determining what should be open and what should be proprietary, given that both the private firms and the government have contributed financially to the development of the technology. Some industry officials expressed dismay that these considerations are sometimes ignored when decisions to second source and recompete production awards are made.

LOSS OF PRIME CONTRACTOR TECHNICAL DIFFERENTIABILITY

The next finding concerns a theme which permeated the discussion with several industry officials who, understandably, were especially sensitive to this particular issue. Their concern has to do with a perceived loss of the ability of prime contractors to differentiate themselves from their competitors on the basis of particular technical expertise in the eyes of the military customer. This is feared to have a substantial negative effect on the development of advanced technology in the future in similar fashion to the previously noted disincentives to technology leadership. Indeed, the loss of technical differentiability could be considered to be another dimension of the second finding; however, the issue is significant enough in its own right to be discussed separately.

Historically, the aerospace defense contractors have exhibited highly specialized and individual areas of expertise. This has been recognized by their military customers, and extends from the level of system capability (e.g., fighter "expert", bomber "expert", etc.) down to the level of highly specialized technologies ("stealth", avionics integration, and advanced materials expertise, for example). While it may be argued that actual specialized know-how coupled with customer perceptions of individual contractor capability have tended to narrow the apparent technology base to a few firms in each major area, the ability of firms to develop particular technologies and exploit this know-how in system development competitions has generally served to provide incentives for the pursuit of advanced technology and innovative designs.

A number of industry officials expressed the view that current acquisition policies which explicitly or implicitly require technology sharing between prime contractors will produce a general technical leveling of competitors, with the result that incentives to innovate will be lost. Teaming of contractors for joint system development was viewed as the largest influence here, with second source licensing being of somewhat lesser impact. It was noted that firms usually develop specialized technologies over an extended period of time through the pursuit of government funded R&D efforts, as well as through IR&D and purely contractor funded programs. The attainment of a level of maturity sufficient to be exploitable in a major weapon system program can require five to ten years. Presumably, in a teaming arrangement, firms bring complementary technologies "to the table" so that the overall technical level of the weapon system is improved, and all firms contribute an approximately equal share of specialized knowledge. This does not obviate the fact that other firms now quickly acquire the benefits of technology which has been developed at considerable effort and expense over a substantial period of time. Competitive pressures to win require a very high degree of open sharing among team members (who are former, as well as possible future, competitors) of proprietary technology and general know-how which would ordinarily be closely guarded within a firm. It was predicted that, over a period of time, one result of present teaming and second-source licensing policies will be to create a situation in which all major prime contractors have the same basic technology base; thus there will be no more "secrets" and little to differentiate between firms. Technology becomes, in effect, a commodity item, and mediocre levels of capability are the result, since there is little to be gained from high intensity efforts to develop new capability. The prevailing attitude was that, in the short run, the combination of complementary areas of expertise resulting from current teaming strategies will likely result in some improvement in the technical product of those programs in which teaming is being used. The cost of this improvement was predicted to be a general lowering of contractor technological capability over the longer term, if present trends continue.

Several of the same industry officials who voiced concern regarding the probability of technical leveling in the industry also saw an undesirable connection between this problem and the economic problems of remaining in the defense business. These individuals expressed the opinion that the defense aerospace industry is currently in an overcapacity situation, and that a reduction in the number of prime contractors is inevitable in the next few years owing to the lack of sufficient new business to support the present number of firms. A substantial danger exists, it was suggested, that this inevitability of industry contraction, coupled with loss of technical differentiability, would combine to produce elimination of prime contractors by governmental fiat. In this scenario, the government would make semi-arbitrary choices to eliminate prime contractors based on a perception of indistinguishable firms, rather than letting the "marketplace" decide through the mechanism of contract awards based on an overall level of technical, manufacturing, and management skills. The result could be elimination of the potentially most innovative and technically capable firms, with a further reduction in the quality of the industry as a whole.

INCENTIVES FOR SHORT-TERM VERSUS LONG-TERM TECHNOLOGY DEVELOPMENT

Many of the individuals interviewed who were primarily concerned with technical matters (as opposed to general program management) were quite emphatic in making the point that the current acquisition environment encourages prime contractors to focus on short-term technology issues necessary to win near term programs and maintain the present business base, at the expense of longer-term generic technology development efforts which will be important to future business. The technical specialists were by no means alone in this view, however, as a substantial number of the other interviewees (including most senior government and industry officials) were in basic agreement with this assertion.

The thrust of the argument is that most (if not all) of prime contractors' resources will be required to support cost sharing in major weapons development programs if present policies are maintained. Major systems currently in development (e.g., ATF) are already having a substantial impact on the ability of firms to invest in technology base programs. One senior industry official noted that one major cost shared system development program "wipes out" ten important general R&D efforts in his company, and effectively dries up flexibility to invest in new technology using discretionary corporate funds (coming directly off the profit bottom line). A program manager from another firm indicated that the selection of Air Force laboratory-funded R&D contracts (CRAD, or contracted research and development) which his company was deciding to pursue is starting to be made on the basis of whether or not cost sharing is required. This is due to the funding "squeeze" being exerted by cost sharing on a major program, and would result, in this individual's opinion, in the neglect of technological areas judged by his firm as very important to future business simply because the company could not afford to do both system and technology development simultaneously. A number of industry officials pointed out that major program cost sharing is also reducing investment in Independent Research and Development (IRAD) which is partly reimbursed by the government, and is a popular and effective vehicle for new technology development. This is because contractors are legally barred from using IRAD funds for technology development specific to a particular weapon system application; heavy required investments in an ongoing system development activity thus draw funds away from IRAD even though IRAD is a more cost-effective vehicle from a contractor's standpoint. In a long system development effort, this could also adversely affect the choice of technology to be included in the system (in addition to the longer-term impacts) if the generic IRAD efforts being sacrificed have some near-term payoff.

The majority view by far of the technical personnel surveyed was that near-term efforts to support current programs would always take precedence over future technology concerns. The probable result is that little impact will be seen on the technology inherent in systems presently in the D/V or FSD phases of development. One engineering manager on a major system program reflected that he would push as hard as possible to obtain the resources believed necessary to win a currently ongoing development competition, assuming that corporate officials and program managers would "put the brakes on" technology investments at an appropriate point. He noted, however, that he believed he could get whatever funds were necessary, since the consequences of losing would be very severe given the amount already invested. Another engineering manager from a different firm referred to the present situation as "the raping of the technology base." Still another senior official responsible for corporate R&D planning and resource allocation offered the opinion that industry is now "eating its future seed corn", and acting richer than it is by continuing to participate in weapons development programs with potentially crippling cost-sharing requirements. The result will be, it was predicted, the consumption of resources now and the loss of ability to continue technological advancement in the future, with a prolonged period of retrenchment necessary to recoup the loss. He noted further that the question was one of time as well as of money; once the rate of technological advance is slowed or stopped, regaining a competitive position will require a finite period of time regardless of the amount of money which is applied to the problem.

The overwhelming majority of the interview subjects expressed the view that current system development programs will probably continue with little or no apparent adverse impacts due to enormous pressures on contractors to participate and win. The cost of current policies, however, was predicted to be a serious undermining of the future technology base; this is already becoming apparent to those actively involved and was noted by individuals on the system development and application side as well as those in primarily technology development activities.

LOSS OF FLEXIBILITY IN SYSTEM DEVELOPMENT

One possible exception to the expectation that the technological quality of weapon system development would not be adversely affected to any great degree in the near term was noted by several Air Force and industry managers. This is the possibility that a reduction in the flexibility of resource allocation (as a result of financial pressures) will lead to technical conservatism in weapon system design and development.

Two factors were noted here. One is the fact that a substantial degree of cost sharing during system development reduces the amount of funds that are theoretically available to the contractor(s) to resolve unexpected technical problems encountered during development. These are not unusual, owing to the desire of the military customer to achieve significant performance advances in new weapons; this results in pressure on the contractors to press hard on the current "state-of-the-art" and undertake often risky technological solutions to solve design problems. Several contractor personnel also noted the extreme difficulty of accurately predicting the actual cost in production of unique designs incorporating new technology (e.g., new materials, software). If available contingency funds have already been expended to finance significant cost-sharing commitments, contractors may be reluctant to pursue advanced technologies (which may be high pay-off), knowing that the military customer has a limited budget and may be unwilling or unable to fund additional efforts to mature the design, and that the contractor may have to "eat" the additional cost.

This factor is exacerbated by a second factor, which is the preference of the DOD for fixed price contracts. A strong theme which ran through many of the discussions was the belief that fixed-price contracts are not appropriate for development programs involving significant degrees of risk. The constraints imposed on the contractors by the demands of delivering a specified product under a fixed price arrangement with substantial up-front cost sharing are believed by many of the interviewees to encourage a conservative approach to system design.

Interestingly, both government and industry officials demonstrated a substantial appreciation of the problems of their opposite numbers regarding this issue. Industry respondents were aware of the difficulty which government procurement agencies have in obtaining approval to use cost-type contracts, given the history of abuses which these have engendered. They further noted that the use of cost reimbursement contracts is not generally appropriate because these do not provide incentives to industry to produce the best product at the best price. On the other hand, Air Force representatives demonstrated that they were very much aware of the financial pressures exerted on the contractors as a result of the use of fixed price contracts. Those individuals who were knowledgeable in this particular area suggested that the issue was not black and white, but resolvable on some middle ground. They noted that fixed price contracts with incentive fees (FPIF) have much more flexibility for both parties than firm fixed price (FFP) contracts, and provide the means of finding an acceptable compromise. An opinion expressed by a number of Air Force and industry people in all specialties was the need to match the type of contract employed to the level of risk inherent in a specific program at each major stage of its development. In this way an appropriate level of risk sharing can be established between the contractors and the government, while at the same time providing incentives to the contractors to achieve good cost and technical performance.

INEFFICIENCIES ASSOCIATED WITH PRIME CONTRACTOR TEAMING

A widely held view of the interview participants regardless of organizational affiliation or area of expertise was that current teaming arrangements (either contractor-selected or DOD-directed) are making the acquisition process much less efficient, and will generally reduce the resources devoted to technical endeavors. While this general opinion was expressed by the majority of respondents, several unique manifestations of this effect were predicted by specific individuals.

The major point shared by the interviewees was that the combination of two or more large prime contractor firms into a joint team for the purpose of developing a major weapon system significantly increases the complexity of an already difficult task. Many resources (time and personnel) which would ordinarily be devoted to productive developmental activities must now be expended in complicated coordination tasks, often involving facilities and people scattered over a widely dispersed and separated geographic area. The result is that, for a fixed program budget and schedule, less useful work generally is produced. More players are involved, the management task is more difficult, and an increased waste of resources is incurred. Estimates of the additional "cost" of teaming by industry and government officials ranged from 15 to 50 percent. It was recognized that complementary capabilities of team members would provide a benefit; whether or not the increased cost justified this benefit was an open and unresolved question.

Several industry officials believed that clashes of diverse corporate cultures resulting from teaming can result in additional inefficiencies and conflicts, with a corresponding reduction in the quality of technical product. In particular, the approach to the development of new technology was cited as an area of differing corporate attitudes. In several instances it was suggested that teaming can result in a marriage of two opposing viewpoints; one a highly organized bureaucratic/efficiency optimizing approach, and the other a less structured risk taking/entrepreneurial approach. In this view, the conflict between these two approaches could have a subtle impact on the decision making process involved in choosing the team's overall technical approach, and carries a danger of "homogenization" and the loss of an open climate for innovation.

Another view of the teaming issue was concerned with the process of technical approach formulation. It was pointed out that in a traditional prime/subcontractor relationship, the prime contractor generally controls the process of dispute resolution. In a teaming arrangement, this is no longer necessarily the case. The process of resolving differences in approach may involve considerable negotiation among partners, with a corresponding loss of efficiency and an increase in time required to make decisions. Program cost sharing and uncertainty in the competitive environment were also predicted to encourage "failure avoidance" behavior during this process. Such an environment is not conducive to innovative efforts, in the opinion of those who anticipated such a scenario.

RESULTS OF PROTOTYPING

The subject of system prototyping during development was one of the few areas of investigation which elicited sharply conflicting responses from the interview participants. The difference in views followed no discernible pattern; the population sampled was approximately evenly split in their opinions, and no correlation was apparent with organizational affiliation, position, or area of expertise. In contrast, however, there was just about unanimous agreement that prototyping at the subsystem level is extremely desirable and beneficial.

One distinct school of thought on the system prototyping issue was that such an approach is nearly indispensible in the current acquisition environment. Proponents of this approach advanced several arguments in favor of the position that system prototyping tends to encourage a high level of technological excellence. One of the most significant is that it forces a focus on useful and practical technology rather than "blue sky" or unrealistic technical approaches. This comes about as a direct result of the requirement to "publicly" demonstrate the workability of the system during flight demonstration and evaluation. Quantifiable measures of performance can be used to eliminate the "liar's contest" aspects of paper design competitions, in this view; many uncertainties and extravagant claims of capability can be eliminated from the proposal evaluation and contract award process. It was also asserted that the "threat of flight" imposed by a prototyping approach encourages an efficient allocation of (scarce) resources by the contractors, especially in a cost-sharing environment. One senior Air Force official expressed the opinion that the combination of prototyping and competition during weapon system development is the single most important factor contributing to technical excellence and low cost in the final product. Several individuals pointed out that system level prototyping is a singularly visible activity which tends to encourage and maintain interest in a new weapons program, thereby enhancing the probability of the program "staying alive" during budget deliberations. The adherents of system level prototyping were certainly not lukewarm in their support, but were very aggressive in their advocacy of this approach.

The opponents of system prototyping were nearly as vocal as the supporters, and advanced at least as many arguments against such as an approach as the supporters offered in its favor. The contrary arguments were that prototyping is expensive, unnecessary, wasteful, and discourages the adoption of the best technology. This school of thought maintains that in most cases other less costly development and performance verification tools (wind tunnel test, flight simulation, laboratory component tests) yield sufficiently accurate results that construction and test of an entire vehicle is not necessary during early development. Opponents argue that this is wasteful duplication of efforts which must be done during FSD, and may be counterproductive, since focus on the prototype diverts resources from more fundamental small-scale development activities which may have higher payoff. They noted that once the commitment to an entire vehicle is made (an expensive undertaking) it is extremely difficult and even more expensive to incorporate fundamental changes identified as necessary by subsequent testing and evaluation. Because such "locking in" of the basic design occurs so early in the development program, a premature "technology freeze" takes place using the know-how available at the time of the prototype design. There is great reluctance to make changes later during FSD when better techniques and definitive test results have become available. It was also suggested that system prototyping and "fly-offs" tend to encourage the adoption of highly visible performance enhancing technologies, often at the expense of those which contribute to reductions in life cycle cost and enhance reliability and supportability in the field.

There appeared to be little common ground on which to reconcile these two opposing points of view. It is interesting to note, however, that several of the system prototyping advocates recognized that adoption of this approach tends to aggravate the problems associated with cost sharing, since prototyping increases costs early in the system development program (although, it is argued, the total acquisition cost should go down because of reduced uncertainty and waste). It was pointed out several times in the discussions that the initial cost of prototyping can be a key factor in raising the economic stakes in a competitive program to the point where teaming is nearly imperative (in order to share the risk among several companies). Otherwise, the consequences of losing must be borne by a single firm, and this cost could be great enough to bankrupt the contractor if his design is not selected for production.

Several government and industry officials believed that system prototyping in a cost sharing environment encourages "technological buying-in", or concentrating all available resources on the prototype effort in an attempt to maximize functional (quantitative) performance of the prototype vehicles. This would, with high probability, result in neglect of other technical areas important to the development of the system (e.g., manufacturing technology, reliability, cost of operation). These latter areas would then become "add-ons" later rather than being part of the system design process, with a corresponding reduction in the quality of the overall weapon system.

Other industry representatives stated that system prototyping in a long early development phase (typical of attempts to increase competition) will increase the "waste" in the acquisition life cycle in the sense that eventually one contractor's (or team's) design concept is "thrown away" when a final winner is selected. More money and effort expended prior to this point results in a larger "loss" to the government in non-utilized developmental effort (unless the loser is eventually selected to produce his design in another program, similarly to the YF-17/F-18 case). Individuals expressing this point of view were of the opinion that such efforts represented precious time, money, and capability which could be far better utilized elsewhere; they were, in effect, advocating shorter competitive development efforts.

The one related area on which nearly everyone agreed was that prototyping at the subsystem level, (particularly for avionics subsystems) is not only desirable, but essential. Prototyping at this level was thought to pay large dividends in that a test-fix-test approach can be employed to identify and cure performance deficiencies. This is because modifications are relatively easy and cheap to accomplish and can continue until the desired level of performance is realized. Several technical specialists pointed out that increasing reliance on software in digital technology electronic systems effectively mandates the use of a subsystem prototyping approach to achieve the necessary degree of integration. Another individual believed that subsystem prototypes are effective in demonstrating reliability, maintainability, and supportability aspects of designs and encourage the use of appropriate technologies in these areas.

DISINCENTIVES TO SUBCONTRACTOR TECHNICAL PERFORMANCE

A result which was readily apparent from the vast majority of the interviews was the expectation that the combination of increased cost sharing and efforts to enhance competition at all levels will have significant adverse technological consequences at the subcontractor/vendor level in the defense aerospace industry. Most of the disincentives to technical innovation noted previously at the prime contractor level are expected to apply to the subcontractors as well, with the additional complication that, in many cases, the subcontractors are even less equipped to deal with the problems than are the primes. The overall result was expected to be a reduction in the number of suppliers generally, and a loss of true competition and desire to innovate over time.

The view from both the government and industry perspectives was that the subcontractors are caught in the same financial "squeeze" as the primes. The prime contractor personnel indicated that, to a large degree, cost-sharing requirements levied on them by the government are passed on to their subcontractors and vendors to the maximum degree possible, in order to help minimize prime contractor cost risk. The degree to which the primes are able to successfully leverage cost sharing with their subs varies widely, depending on the criticality and complexity of the subsystem, the number of potential suppliers, and the size/financial position of the suppliers involved. In some cases subsystem hardware is being supplied to the primes at cost plus a small margin; in other cases where more customer leverage is available, developmental hardware is supplied free of charge (100 percent cost share).

The ability of subcontractors and vendors to cost share varies widely in the opinion of the primes. Three distinct categories of supplier firms were identified; these tend to prescribe the willingness/ability of the subs to contribute financially to system development. First, there are the larger firms which are generally able (and somewhat willing) to share costs with the primes. Next, there are firms which recognize the risks of cost sharing and probable recompetition during production and choose, in many cases, not to participate due to a combination of the uncertainties and inability to withstand the financial hardships. Last, there are firms (many times small companies) which are hard pressed economically and recognize the risks, but choose to participate anyway because they have very little choice; their entire business is based on the prime contractor customers. These latter cases are candidates for serious financial problems, in the opinion of several of the interviewees.

A number of negative effects were either predicted or cited as currently taking place. First, "no bids" from some supplier firms have already occurred in some cases. This was thought to deny the benefits of specialized expertise and technology to specific weapons development programs. Industry representatives noted that in several cases decisions by subs not to participate had come from the smaller and potentially most innovative firms. In other cases the financial pressures and risks of reduced future returns have resulted in only one or two suppliers working on a particular subsystem. In this situation, real competition is drastically reduced, and the general sense of both government and industry officials was that the technical quality of products will suffer as a result. In still other cases where only a few large vendors exist to begin with (usually for relatively complex and costly subsystems incorporating high levels of technology, e.g., electronics) the effect of cost sharing and increased competitive pressure has been to drive the few large and capable suppliers into teaming arrangements with each other, in similar fashion to teaming at the prime contractor level. These arrangements were also predicted to substantially reduce the motivation to develop innovative approaches. Several interviewees also mentioned instances where only one vendor was supplying all the primes competing in a major program. Since the vendor wins in any case, concerted efforts on his part to innovate were not expected.

Finally, casualties among some of the smaller firms which participate because they are highly specialized and need the business were expected to occur in increasing numbers during the next several years as a result of current conditions in the industry.

There was no strong belief apparent from the interviews that subcontractors were "holding back" their best technology because of fears of forced future sharing and technical leveling, although a number of individuals believed that there could well be subtle movements in this direction. However, some additional and non-obvious ramifications of the current subcontractor situation were cited by several industry officials. In some cases, a "quid pro quo" was necessary to gain critical vendor participation in a major program and to cost share in a meaningful way. The nature of this trade is that, in return for cost shared participation and early competition the vendor receives a commitment from the prime that no additional competition will take place during the FSD and/or production phase. In essence, once on the "team", the vendor stays for the life of the program. This situation represents a substantial reduction in competition during later program phases where the prime is in a monopoly position with respect to the government customer and vendor competition may be the only effective means to reduce costs.

Another aspect of cost sharing impacts at the vendor level concerns control over the sources and nature of innovation. Several industry officials felt that in the normal course of system development the primes are able to exert a strong guiding and controlling influence on their suppliers. This was seen as a critical task because one of the major functions of the prime contractors is to act as a system integrator to ensure that all constituent parts function harmoniously as a whole. These officials suggested that cost sharing by major vendors significantly increases their independence and simultaneously reduces the control which the primes can apply to force (if necessary) a system compatible technical solution. What results is a "bottom-to-top" design process in which the system design may have to change to accommodate a sub-optimal component. This is the direct antithesis of the systems engineering approach in which component and subsystem designs derive from the higher level weapon system performance requirements.

Another sidelight of the whole cost-sharing issue was mentioned by several industry officials. In some limited cases, the ability of the prime contractor to "track" more than one supplier for a particular subsystem is severely constrained by limited financial resources (in a cost-sharing and/or teaming environment) and the heavy time and personnel requirements associated with maintaining a detailed engineering and design interface with a subcontractor. It was noted that this has resulted in situations where a second supplier was willing to participate in a major program on a 100% cost-shared basis (free to the prime), but had to be turned down because of the inability of the prime to devote the necessary resources to the task.

IMPORTANCE OF APPROPRIATE REQUIREMENTS FOR WEAPON SYSTEMS

A finding which emerged from the discussions on the impacts of commonality and increased emphasis on reliability, maintainability, and supportability (R, M, & S) was the importance of establishing appropriate weapon system requirements. This theme was also evident in the discussions on the general effects of increased competition, and was an issue raised by both government and industry representatives. The prevailing attitude was that the quality and type of requirements at both the higher (system) levels and the detailed (subsystem) levels can make or break a weapons acquisition program.

Requirements which specify levels of performance and capability but leave the exact solution approach and method of implementation to the imagination of the contractor(s) were viewed as far superior to those which dictate exact methods of solution, specific designs, and otherwise constrain the contractor's approach and reduce flexibility. At the same time, it was pointed out that flexible requirements must be quantifiable and enforceable so that performance against a standard can be measured. Specific performance requirements with "teeth" were generally thought to promote better technical solutions and act as a motivator for innovation. Several Air Force officials noted that the combination of true competition and challenging (but flexible) requirements is a key factor in producing optimum contractor performance.

Specific requirements for R, M, & S were viewed as either technology neutral or somewhat positive. One view of this subject held that R, M, & S specifications were merely an expansion of the present performance requirements matrix and would not have much effect on inherent levels of technology. Another view held that specific quantitative R, M & S specifications which are strictly enforced would tend to encourage new and innovative solutions which could at the same time reduce complexity and increase performance. Both camps seemed to agree that both loosely written or vague requirements and overly restrictive specifications were probably counterproductive, and would be disincentives to new ideas.

The avoidance of design prescriptive type specifications was seen as particularly important in consideration of commonality issues. It was repeatedly pointed out that requirements for identicality of design and "build-to-print" specifications are strong disincentives to innovation and foster a routine "push it out the door" mentality on the part of prime contractors and vendors alike. Several individuals questioned whether such an environment would even encourage the adoption of low-cost manufacturing technologies since contractors could adopt subtle quality reduction measures to gain advantage in price competitions. Requirements for nearly exact commonality were also viewed as encouraging "lowest common denominator" type solutions at both the system and subsystem levels, resulting in mediocre or even substandard performance. On the other hand, adoption of F^3I strategies--identicality of form, fit, function and interface (the latter primarily for software)--were seen as distinct incentives to both product design and manufacturing technologies. Requirements for similar items having essentially identical functions across several weapon system lines were seen as expanding the potential production volume and business base while allowing flexibility for the individual tailoring of designs. This approach was thought to have positive incentives for innovation because of the potential applicability to many product lines.

Use of hard-to-achieve (but still realistic) system performance requirements which "set the hurdle high enough" were generally regarded as a very positive influence on technical quality of product in major weapon development competitions. ASD's MIL-PRIME specifications were almost universally viewed as beneficial in allowing design flexibility; several individuals recommended that this concept be extended formally to high level system specification applications across the board.

ENCOURAGEMENT OF "TECHNICAL ABUSES"

The last finding summarizes some predictions of the deleterious effects of certain aspects of current acquisition policy which were offered by a few individuals. These effects can be characterized as reduced or sub-optimal levels of technical performance in new weapon systems.

A singular observation by one official was that in the current acquisition environment, weapon system program managers are responsible only for contractor performance as regards acquisition cost, and are not measured in any meaningful way relative to weapon system lifecycle costs. In the opinion of this individual, this one-dimensional approach results in an undue emphasis on technologies which hold down the "up-front" cost of system development, and to a somewhat lesser extent, production. Approaches which minimize acquisition cost often result in increased costs of maintenance and operation, and discourage the adoption of technical approaches which cost a little more initially, but reduce total life cycle costs and improve readiness. Increased emphasis on R, M, & S requirements was viewed as a general improvement in this regard, but there seemed to be a fair amount of skepticism that these would continue to be rigorously pursued and enforced in a budget cutting/deficit reduction environment.

Another aspect of cost sharing at the prime contractor level closely parallels the "control of the sources of innovation" issues discussed previously at the prime contractor/subcontractor interface. Several industry representatives believed that cost sharing during weapon system development reduces the ability of the government procurement agency to exert control over the risk-reduction process and generally lessens the customer's influence in guiding the acquisition activity. In the opinion of these individuals, the cost-sharing environment allows contractors to "fence off" certain activities from the view of the government customer, encouraging abuses and "surprises" later in subsequent program phases. This is because the contractors cannot be forced to divulge or discuss activities which are being funded purely out of corporate funds. It was suggested that such an environment encourages mediocre or "good enough" type approaches, since activities appearing highly ambitious and advanced may not have any real substance because of financial pressures; fallback to a much lower capability solution occurs later after the government is committed. It was asserted that the end result is a "shifting of the locus of control" from the government to the contractors. Concern was expressed that all contractors might have to engage in such practices to avoid losing out to better appearing competitors.

SUMMARY OF FINDINGS

In summary, the findings may be said to reflect government and industry concerns regarding the effects of acquisition policy over two different time horizons.

First, there are concerns regarding near-term effects of present acquisition policies on existing weapons development programs. It was predicted that loss of flexibility in system development and inefficiencies associated with contractor teaming could result in subtle but real degradations in the technical quality of products. To a somewhat lesser extent, disincentives to subcontractors and inadvertent encouragement of technical abuses were also seen as having similar effects, although these were expected to have long-term impacts as well.

Findings expected to have significant long-term impacts are economic disincentives to prime contracting and technological leadership, loss of contractor differentiability, and encouragement of a short-term technical focus at the expense of long-term technology development. These expected long-term effects were viewed as the far more serious of the two categories.

Opinion was split over the issue of system-level prototyping. Those in favor of this approach saw short- and long-term benefits, while those opposed saw liabilities across the board. The view of subsystem prototpying was universally positive.

Finally, the importance of verifiable but flexible weapon system requirements and specifications was noted by almost everyone interviewed. Present USAF approaches to this area were generally viewed in a favorable light and were thought to have a beneficial influence on technology and innovation in both the short and the long term.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

ANALYSIS OF FINDINGS

The individual findings discussed in the previous chapter are fairly self explanatory in identifying potential effects on the climate for innovation in the development of new USAF weapon systems; therefore a great deal more need not be said, except to emphasize and highlight several key points.

The first point is that two specific areas of current acquisition policy seem to dominate all others, and indeed permeate every aspect of weapon systems development/acquisition. There are efforts to enhance competition throughout the weapon acquisition life cycle and policies aimed at increasing contractor investment in the development process and at reducing overall industry profits. The preponderance of opinion among those surveyed seems to be that the short-term effects of these two general policies, while significant and pervasive, are not such that an immediate or drastic reduction in the technical quality of weapon systems currently in the development/procurement "pipeline" is likely to be noticed. In this context, the original thesis is supported, but no strong statements can be made as to the immediate effects of present policies.

On the other hand, there is evident a substantial body of opinion that the long-term effects of these two policy areas (especially cost sharing) will be extremely damaging to the long-term health of the aerospace defense industry and the level of both technology and capability which will be exhibited by future weapon systems. Increased economic risks coupled with heightened uncertainties in the magnitude and timing of economic returns are likely to drive some prime contractors and subcontractors/vendors out of the defense business (with a corresponding reduction in the diversity of the technology base), as well as to increase conservatism and reluctance to take technical risks of those contractors which remain. By far the most insidious and strongly felt effect, however, is that the future technology base will very probably be substantially reduced by the present diversion of funds and resources necessary to support the current (cost shared) business base. Continuation of policies effectively requiring large contractor investments in current weapons development programs are consuming the limited resources necessary to ensure future technological vitality, in the view of most of the interview participants. The lack of an available technology base will undoubtedly mandate a reduction in future weapons capability, even if significant policy changes are implemented which increase the motivations of contractors to innovate.

A fact which is particularly striking is that there was a substantial degree of agreement between Air Force acquisition managers and their industry counterparts as to the probable results of current policies. Given the singularity and unequivocal nature of the industry view, a somewhat contrary opinion might have been expected from the other side of the acquisition equation. This was generally not the case. Although the opinions of the government personnel were not as forcefully stated as those of industry managers (for the most part), it was apparent that both groups were in fundamental agreement. Further, a remarkable degree of comprehension and understanding of the factors which constrain and motivate the contractors operating in an business environment were demonstrated by the Air Force representatives, while the contractors showed great appreciation and knowledge of the needs and goals of the military weapons customer. In this context, the "front line" organizational entities which interface with each other on a regular continuing basis (i.e., the government program offices within the Air Force product divisions and the prime contractors) do so in a fundamentally cooperative and non-adversarial role.

CONCLUSIONS

Two major current policy areas, cost sharing and competition enhancement initiatives, are likely to have profound and adverse effects on the future ability of the Department of Defense to successfully develop and procure weapon systems incorporating a level of technology consistent with national defense policies and needs. Of these, one (cost sharing) is a de facto approach not explicitly identified as DOD policy; the other (competition enhancement) is a formally stated policy of the DOD, but its specific implementation is subject to a wide diversity of approach.

The Department of Defense and the military services are attempting, for the most laudable of motives, to "get more for less" in the current national environment. As budget deficits mount and the defense budget has begun to decline (in both absolute and real terms), the DOD has attempted in the procurement area to maintain the same level of "output" (i.e., number of different weapon systems and quantity of each type) resulting from a reduced level of "input" (acquisition dollars). The specific manifestations of this general trend are most obvious in the attempts of the military services to force the weapons contractors to contribute corporate funds to make up for the budgetary shortfall associated with the spreading of reduced resources over a fixed number of programs, and efforts to increase the efficiency of the acquisition process through enhanced competition. Unfortunately, actions taken for the best of motives are now becoming counterproductive, and threaten to severely handicap future development efforts. Present policies in both of the subject areas have indeed "gone too far."

It is perhaps sadly ironic that the present Secretary of Defense, Frank Carlucci, has recently inherited a DOD employing procurement policies which are the direct antithesis of those initiatives which he was responsible for putting in place in 1981 when Mr. Carlucci was the

Deputy Secretary of Defense. Review of the 32-point "Carlucci Initiatives" reveals three very significant points[27/]:

(1) They endorse full funding of R&D and procurement "at levels sufficient to ensure efficient cost, supportability, and schedule performance."

(2) They eschew "across-the-board" type policy implementations that mandate a single approach to increasing contractor competition.

(3) They seek greater program stability through the use of multi-year procurements and the use of "most likely cost" budgeting to reduce overruns.

The DOD has, in the face of enormous conflicting pressures, unfortunately fallen victim to the "consume now, pay later" mentality which seems to afflict a sizeable portion of American society at the present time. The adoption of excessive cost-sharing strategies for major system development allows the short-term maintenance of the procurement "living standard" at the sacrifice of a loss of long-term technical health and competitiveness. Likewise, universally applied policies designed to enhance competition are reducing stability by generating increased uncertainties for return of investment, are promoting technology leveling and technical followship strategies, and in many cases are fostering the very effect they were meant to correct, namely the reduction or outright elimination of true competition. By raising the costs of failure to prohibitive levels, present policies create an environment where contractors literally cannot afford to lose. This, in turn, encourages the contractors to engage in the very "financial and technical buying in" abuses which are so decried by critics inside and outside of the DOD. In addition, an attitude is created which is destructive of innovation. As noted by Robert Hayes and William Abernathy[28/] innovation "is best encouraged by an environment that does not unduly penalize failure." The current acquisition environment does precisely that.

One senior official put the problem very succinctly during the interviews. He summarized the current acquisition environment as one which lacks "technical integrity"; his description clearly was one which defined the word technical in the broadest possible terms. He pointed out that both the military services and the prime contractors are strongly motivated to understate the costs and the difficulties of advanced weapons development and acquisition in order to keep programs alive in the face of mounting budgetary pressure and the absolute need for firms to win competitions in order to survive as viable business entities. This, in turn, leads to many of the abuses so publicized in the past, and undermines one of the basic underpinnings of the defense aerospace industry, which has historically been a willingness and ability to achieve rapid technological advancement and produce innovative solutions. A number of officials reflected basic agreement with this position.

Of the two policy areas which threaten to have profound technological effects, present strategies to enhance competition seem to exert the more subtle and insidious influence through technical leveling and encouragement of technical follower strategies. The effects are therefore likely to become apparent only slowly over an extended period of time. On the other hand, excessive cost sharing appears to be having adverse consequences which, if not immediately felt, are certainly quite apparent at the present time and are easily predictable to substantially degrade technical efforts in the future. It is also evident that in addition to clearly discernable direct effects, cost-sharing policies aggravate other problem areas, and threaten to turn possibly technology-neutral policies into substantially negative ones. System level prototyping comes to mind here; opinion was evenly split as whether such a policy is an incentive or a disincentive to innovative design. However, done in a cost-shared system development environment it seems likely to lead to substantial procurement abuses and inefficiencies. Cost sharing is a policy which is extremely attractive because it helps to alleviate short term budgetary problems and silence defense critics; when adopted in modest amounts in selective cases the technological effects are probably not that significant. However, as a broadly applied long-term strategy the adverse effects will be truly devastating.

RECOMMENDATIONS

Norman Augustine, in testimony before the U.S. House of Representatives Armed Services Committee in 1981,[29/] addressed the fundamental issue in defense acquisition:

> It is instructive to begin by asking, how good or how bad is the defense acquisition process?... The data I have collected over the years indicate that the acquisition process in general does moderately well in assuring that performance goals are met. About three-fourths of the time these goals are met or exceeded, and in no more than approximately one-tenth of the cases does the process fall short of performance goals by more than 20 percent. On the other hand, these same data reveal that schedule overruns of one-third or more occur fully half the time. The most recalcitrant problem, however, is the matter of cost control...the chances of a major program being completed within its initial cost estimate (R&D plus procurement) is found to have been about 9 percent. The chances of a program being completed with no more than a 50 percent overrun are no better than 70 percent, and the median...overrun is approximately 32 percent. The average overrun...is in fact nearly 52 percent. Clearly we must do better. Fortunately, we can do better. In fact, the trend for each of the past three decades has, as least as best as I can determine from an examination of the data, been one of gradual improvement.

One of the fundamental causes of these overruns is the tendency on the part of both the military services and the contractors to purposely understate the true costs of weapons procurement. This results in public perceptions of incompetence, or worse, of contractor attempts to deliberately realize excessive profits at public expense. Cost sharing strategies, implemented with the best of intentions, are but another outgrowth of this attitude that it is possible to avoid the true costs of new weapons development and have the additional drawback of seriously undermining the technology base. The resultant abuses which come from "mortgaging the future" through deliberate underestimation of the true costs (not all of them purely economic) in turn fuel additional efforts to reform the acquisition process and generate further pressures on the DOD to adopt more restrictive and centralized control of the weapons procurement function.

It is time for realism in the estimation of weapons system costs. This is hardly an original thought; the suggestion that the DOD adopt a policy of conducting independent cost assessments of most likely costs or "should cost estimates" has been offered by many acquisition experts, including Mr. Augustine. Some might consider such a recommendation naive or unrealistic, given the pressures for, and apparent short term political benefits of, underestimation. Nevertheless, consider the ramifications of such an approach. Full funding of weapons R&D and procurement at a conservative level (estimated by independent studies within the DOD), coupled with a contract award criteria based on technical quality of approach (not cost) for <u>development</u> phase efforts, would remove incentives to "buy in" and maximize contractor motivation to pursue superior technical products. It would remove current disincentives to prime contractor technical leadership, and reduce the present prohibitively high penalties of "failure" (losing out during system development competition). It would eliminate the diversion of resources from long-term generic technology efforts into specific system development activities, and would stop the sacrifice of the future technology base which seems to be now taking place. It would reduce or eliminate the tremendous pressure for prime contractors to team for risk sharing purposes, and eliminate much of the technology leveling and loss of differentiability which appears to act as a disincentive to contractors to pursue unique and individual avenues of investigation (a necessary adjunct approach is to eliminate government directed teaming at the same time. Directed subcontracts to the primes could be required in selected cases where a particular area of expertise known to be critical to a program exists outside of the prime contractor's in-house capability). This would also eliminate the inefficiencies and hidden costs of prime contractor teaming. Realistic development funding would reduce the "flowdown" of economic pressures to the subcontractor/vendor tier of the defense industry and the probable future reductions in the number of these firms (with associated narrowing of the technology base). It would increase technical flexibility during the development process and allow for more reasoned decisions to resolve unexpected technical problems. It would allow for much more pressure to be applied during production to the prime contractor and subcontractors to reduce manufacturing costs and produce real cost savings. It would reduce many of the current procurement abuses and improve prospects for the long term technical health of the industry.

Institution of realistic weapons program budgets and funding levels is the first and most fundamental step in an overall process needed to return the acquisition process to a more appropriate structure. The basic framework already exists, and is defined by the original 32-point Carlucci acquisition initiatives. Research for this thesis, as well as a number of years of experience in the weapons acquisition activity have convinced this author that the present acquisition process is not fundamentally flawed. Many of the current DOD procurement initiatives and policies represent an overreaction to past perceived abuses, and may well in the long term encourage the very kinds of abuses which they were meant to correct. At the same time, a very high technological price will have been paid. H.L. Mencken once observed that "For every problem there is one solution which is simple, neat, and wrong". The DOD must come to terms with present realities and adopt a selective, flexible approach to weapons acquisition, rather than blanket prescriptions. The evolutionary refinements represented by the original Carlucci initiatives offer the framework and the means to improve the procurement process while at the same time eliminating the current drift into counterproductive areas of acquisition reform. A return to these extremely logical and well reasoned guidelines is essential.

In light of the findings revealed by the current research, some specific recommendations (in addition to realistic program budgets and funding) are in order. The first of these concerns the competition issue. Strategies to enhance competition during the acquisition life cycle should continue, but must be selectively applied depending on the needs of a specific program. Efforts must be made to resist and/or reverse tendencies to adopt panaceas. Forced teaming, second source licensing, and frequent recompetition in production all tend to result in technical leveling, loss of differentiability, and disincentives to innovate. The issue is not one of eliminating competition; the prime contractor representatives surveyed all recognized the potential benefit to the military customer and the taxpayers of true competition which encourages product improvements and reduces prices. However, competition enhancement strategies must be applied thoughtfully, and in such a way as to guarantee a winning contractor emerging from a competitive effort a recovery of whatever investments have taken place plus a reasonable profit. This, in effect, requires up-front government commitments to the funding and production volume of the system. Subsequent recompetition should take place only after the winning contractor (or subcontractor) has realized an adequate return. An integral part of such an approach is the fostering and establishment of long term and stable customer/ supplier relationships between the government and the primes and between the primes and their subs. Such relationships would bring DOD procedures more in line with commercial practice (which many reformers inside and outside of DOD seem to believe desireable), and would result in far better and more cost effective products than continual and frequent competitions which can result in a loss of business to adequately performing firms on the basis of small (near term) cost reductions.

This author tends to share the opinion of many of the interview participants that further reductions in the number of prime contractor firms doing defense business will occur over the next several years. The crucial question which remains to be answered is, "What mechanism will be employed to accomplish the necessary contraction?" Many of those surveyed believed that the mechanism could well be extremely arbitrary and disruptive of product quality if present trends continue unaltered. Significant potential exists for technical homogenization of the industry and/or for some firms with greater financial resources to "swallow up" competitors through unfriendly takeovers and acquisitions. Any mechanism which relies on happenstance or semi-arbitrary governmental fiat (based on perceptions of similarity) is believed to be inferior to true competitive winnowing in the marketplace, and carries substantial dangers that the most technically capable and innovative firms will be eliminated or reduced to a mediocre level of capability. A far more desirable situation is one of maintaining true competition through the judicious use of strategy, and let the "chips" (award of lucrative contracts) fall where they may.

Consideration of government commitments to stable program funding and production levels, along with the establishment of cooperative long term relationships between DOD and industry lead to another, more general, recommendation. It is that the entire weapons development/acquisition function must begin to take place in an overall more cooperative environment. Both the DOD and industry should adopt a non-adversarial approach to their relationship in the future if the historical trend of technological advancement is to continue. There is a growing awareness that the U.S. is facing unprecedented global competitiveness challenges that will not be solved by a continuation of past confrontational relationships between management and labor. The parallels in DOD and industry relations are almost inescapable. It is interesting to note that there is currently some recognition of the benefits which can be realized by a cooperative approach. The Sematech initiative, jointly funded by the DOD and an industry consortium to develop a domestic advanced semiconductor manufacturing capability serves as a case in point. This philosophy of government/industry cooperation must be carried over into the procurement arena as well; little is being gained by either side by a continuation of adversarial attitudes. An "arms-length" but largely cooperative relationship between the prime contractors and the government customer already exists to a substantial degree at the program management level; this attitude should be striven for at all policy-making levels in the DOD. The DOD should also strive for more consistency with governmental attitudes in general. It is unfortunate that the forced sharing of knowledge and proprietary expertise which often results from current competition enhancement strategies comes at a time of heightened awareness of the importance of preserving intellectual property rights. Recent federal court rulings extending copyright protection to software are illustrative of this trend. A thorough re-examination of competition enhancement strategies and selective revisions would serve notice that DOD is interested in a more cooperative approach.

This thesis investigation has been a qualitative study which strongly suggests that present procurement policies will have serious negative long-term effects on the defense aerospace industry. Further quantitative research into the economic and financial aspects of the defense acquisition process from an industry perspective could shed additional light on the questions of actual investment required and rates of return. This would require a substantial degree of cooperation on the part of industry, with an independent researcher to fully document the economics of weapons development and production. In addition, comprehensive studies in a similar vein at the subcontractor level of the industry are recommended. This is an exceedingly important portion of the industry, and the health of this segment may ultimately prove to be at least as important to the technical quality of future weapons as that of the prime contractors. Both DOD policymakers and the prime contractors need to have a more complete understanding of this area than currently exists. Detailed studies at both of these levels would be extremely valuable in dispelling the current confusion and conflicting opinions regarding the financial health and attractiveness of the defense aerospace industry.

SUMMARY

The prevailing view of those individuals interviewed in this investigation is that current procurement policies are likely to have a number of adverse long-term effects. These individuals did not view the basic acquisition structure as significantly in need of reform, and made a credible case for the position that current initiatives aimed at increasing contractor investment in the system development process, plus blanket prescriptions intended to increase competition throughout the procurement life cycle, represent overreactions to perceived past abuses and may contribute to further abuses while undermining the technological (and possibly economic) health of the defense aerospace industry.

The situation is not totally bleak, however. At the primary interface between the military customer and the prime contractors, there is apparently a basic understanding of the factors which motivate and constrain each of these entities. This understanding can be built upon to refine the acquisition process in truly productive ways, achieving greater efficiency without indulging in counter-productive excesses.

To quote once again from Hayes and Abernathy[30/];

> Our experience suggests that, to an unprecedented degree, success in most industries today requires organizational commitment to compete in the marketplace on technological grounds - that is, to compete over the long run by offering superior products. Yet guided by what they took to be the newest and best principles of management, American managers have increasingly directed their attention elsewhere.

The same may be said for the current state of the weapons acquisition activity. Current policies are providing significant disincentives to industry managers to pursue strategies of technological leadership and innovation, and are threatening to reverse a historical trend which has served both the military services and the civilian economy (in the form of commercial spin-offs) well in the past. Technological superiority is not a luxury; it is a necessity in a dangerous world. The DOD must resist the advice and pressure of well meaning, but misinformed, critics and politicians who confuse healthy debate over the appropriate level of weapons capability with issues of technology and technical excellence. Likewise, the DOD must not slip further into the comforting, but ultimately costly, delusion that it is possible to obtain the same quantity and quality of weapons for a substantially smaller budget over the long term. Short-term benefits of such a policy cannot justify the high price which will ultimately have to be paid. It is essential that a return to previously articulated policy initiatives and carefully reasoned implementations be accomplished as rapidly as possible in order to reverse adverse current trends. Once lost, the technological health and vitality of the military aerospace industry will not be easy to regain.

FOOTNOTES

1. "Analysis of the Grace Commission's Major Proposals for Cost Control," Joint Study by the Congressional Budget Office and General Accounting Office, January 1984.

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4. Norman R. Augustine, "Defense Procurement Policies and Procedures: Cost Management and Control," Testimony before the Special Panel on Defense Procurement Procedures of the House of Representatives Committee on Armed Services, October 27, 1981.

5. Frank C. Carlucci, "Defense Procurement Policy and Management"; Testimony during Hearings before the Senate Committee on Armed Services, July 28, 1981.

6. Michael Rich, Edmund Dews, and C.L. Batten, Jr., "Improving the Military Acquisition Process," Rand Corporation Report R-3373-AF/RC, Feb. 1986.

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10. Harold Brown, Thinking About National Security - Defense and Foreign Policy in a Dangerous World, Boulder, CO: Westview Press, 1983, pp. 227-228.

11. Richard D. Challener, "The National Security Policy from Truman to Eisenhower," in N. Graebner (ed.), The National Security, Its Theory and Practice 1945-1960, London: Oxford University Press, 1986.

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13. Thomas E. Cooper, "Department of Defense Appropriations for 1987," Testimony in Hearings before the House of Representatives Subcommittee on Defense, USAF Acquisition Statement, March 12, 1986.

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20. Sen. John Tower, "Defense Procurement Policy and Management", remarks in Hearings before the Senate Armed Services Committee, July 28, 1981.

21. G.K. Smith and E.T. Friedmann, "An Analysis of Weapon System Acquisition Intervals Past and Present," Rand Report No. R-2605-DR & E/AF; The Rand Corporation, Nov., 1980.

22. Jacques S. Gansler, The Defense Industry, Cambridge, MA: MIT Press, 1980.

23. "Request For Proposal, Advanced Tactical Fighter (ATF) Demonstration/Validation Program," Headquarters Aeronautical Systems Division, Wright-Patterson AFB, 8 October, 1985.

24. F.M. Scherer and M.J. Peck, The Weapons Acquisition Process, An Economic Analysis, Harvard University Graduate School of Business Administration, Cambridge, MA, 1964.

25. W.L. Stanley and J.L. Birkler, "Improving Operational Suitability Through Better Requirements and Testing," Rand Report R-3333-AF, The Rand Corporation, November 1986.

26. Brown, op. cit., p. 242.

27. Memorandum from Frank C. Carlucci, Deputy Secretary of Defense, to Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, Under Secretaries of Defense, Assistant Secretaries of Defense, General Counsel, Assistants to the Secretary of Defense, April 30, 1981.

28. Robert H. Hayes and William J. Abernathy, "Managing Our Way to Economic Decline", Harvard Business Review, July-August 1980, p.70.

29. Augustine, op. cit., pp. 1058-1059.

30. Hayes and Abernathy, op. cit., p.68.

APPENDIX A

LIST OF ACRONYMS

ACM - Advanced Cruise Missile Program

AFSC - Air Force Systems Command

AI - Artificial Intelligence

AMRAAM - Advanced Medium Range Air-to-Air Missile Program

AMST - USAF Advanced Medium STOL Transport Program

ASD - U. S. Air Force Aeronautical Systems Division

ATA - U.S. Navy Advanced Tactical Aircraft

ATF - USAF Advanced Tactical Fighter Program

AX - USAF Attack Experimental Program

BIT - Built-In-Test

CAD/CAM - Computer Aided Design/Computer Aided Manufacturing

CD - Concept Definition

CEO - Chief Executive Officer

CFD - Computational Fluid Dynamics

CRAD - Contracted Research and Development

D/V - Demonstration/Validation

DOD - Department of Defense

DSB - Defense Science Board

F^3I - Form, Fit, Function, and Interface

FBW - Fly-By-Wire

FFP - Firm Fixed Price

FPIF - Fixed Price, Incentive Fee

FSD - Full Scale Development

INF - Intermediate Nuclear Forces

IRAD (or IR&D) - Independent Research and Development

LO - Low Observeables

LRIP - Low Rate Initial Production

LWF - USAF Light Weight Fighter Program

MAC - U.S. Air Force Military Airlift Command

MENS - Mission Element Need Statement

MIL-SPECS - Military Specifications

R & D - Research and Development

LIST OF ACRONYMS (continued)

R & M - Reliability and Maintainability

R,M, & S - Reliability, Maintainability and Supportability

RFP - Request for Proposal

RSS - Relaxed Static Stability

SAC - U.S. Air Force Strategic Air Command

SECDEF - Secretary of Defense

SON - Statement of Need

SRD - System Requirements Document

SSA - Source Selection Authority

STOL - Short Take-Off and Landing

TAC - U.S. Air Force Tactical Air Command

USAF - United States Air Force

VSHIC - Very High Speed Integrated Circuits

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