ARE NEW ACQUISITION PROGRAMS TAKING LONGER TO DEVELOP/FIELD AND IF SO, WHY?

Graduate Systems Engineering Capstone Project

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AFIT/IGSE-05J

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Graduate Systems Engineering Capstone Project

Presented to the Faculty

Department of Aeronautics and Astronautics

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Engineering

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June 2005

Abstract

This study analyzes the Air Force fighter aircraft development and acquisition environment to determine if current aircraft acquisitions have longer development cycles than in the past and if so, why? This report directly compares the programs and acquisition environment of the early 1970's to the programs and acquisition environment of today. Specific examples studied were the F-15, F-16, F/A-22, and F-35. The subcategories examined include technology, schedule, budget, acquisition processes and acquisition climate.

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1 Introduction

It would probably be accurate to say that for as long as the Department of Defense (DoD) has been acquiring weapon systems, there have been complaints and criticisms as to how the process was run, how much it cost, and how long items took to acquire. Just as there is no shortage of military acronyms, there also is no lack of military acquisition reforms throughout the DoD's history designed to squelch these critics. With the two latest fighter acquisition programs, the F/A-22 Raptor and the F-35 Joint Strike Fighter (JSF), we see the same old criticisms about cost and schedule, but are these the same magnitudes of cost and schedule increases we have observed in the past? Could these two programs simply be statistical outliers or anomalies in the grand scheme, or are aircraft acquisition programs taking a serious turn for the worse? Our group set out to answer the simple question; are the fighter acquisition programs of today, namely the F/A-22 and F-35, taking longer to develop than acquisition programs of the past? The original plan used the F-15 and F-16 acquisition programs as comparative standards.

We quickly arrived at the simple answer of yes but did not uncover significant statistical evidence to back up our answer. We, in turn, concluded that simple calendar time is not adequate to analyze and pass judgments on acquisition programs. Our group re-attacked the issue of expanding acquisition times by applying a systems thinking approach. We identified a series of categories that affect acquisition programs and researched what historically has caused longer acquisition times and increasing costs. We focused on Budget, Technology, Climate, the Acquisition process, and Schedules. Due to the nature of our findings, we recommend this initial research project act as a baton to be passed on to our IDE successors for further development and analysis. The goal should be to help others grasp the true complexity of the acquisition process and to stress the use of real "systems thinking" to ensure the entire process is held accountable for successes or failures and not just simplistic, standalone scapegoat categories. The acquisition process is complex and surrounds every program with numerous symbiotic externalities. We all must understand this.

2 Background

Is it taking longer to develop new aircraft now than in the early 1970s?

Yes.

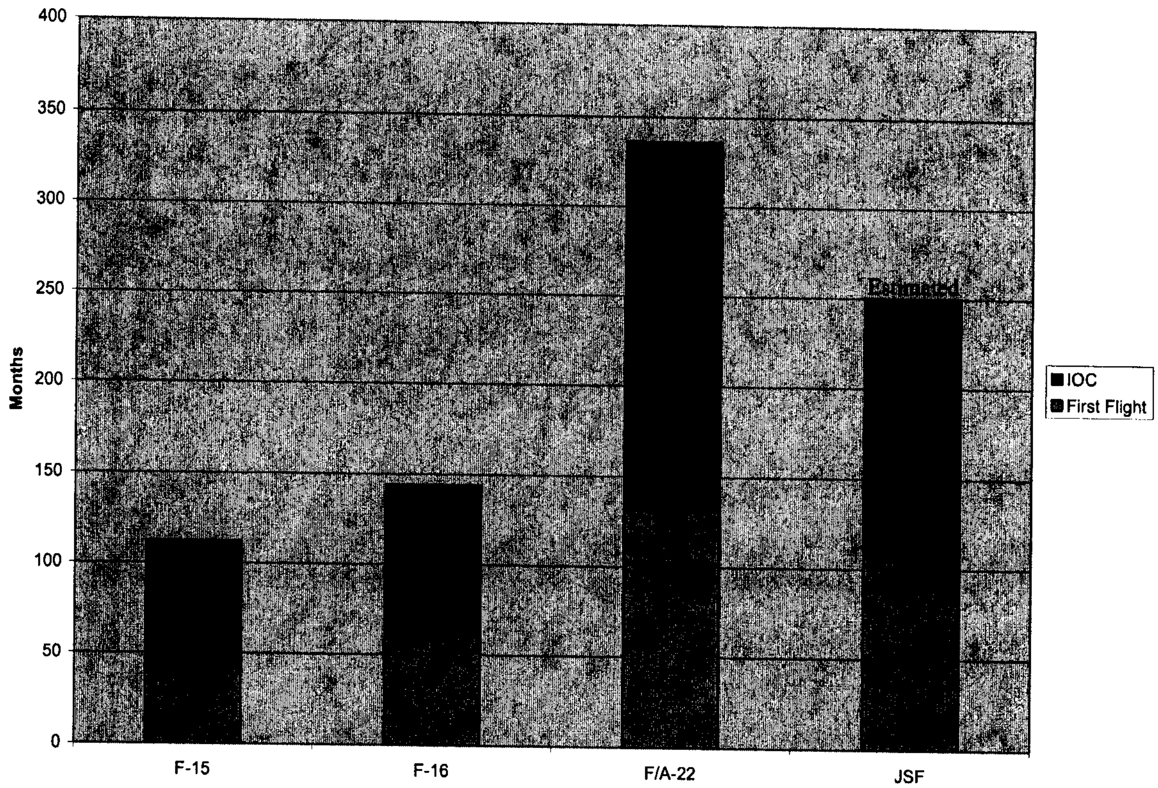
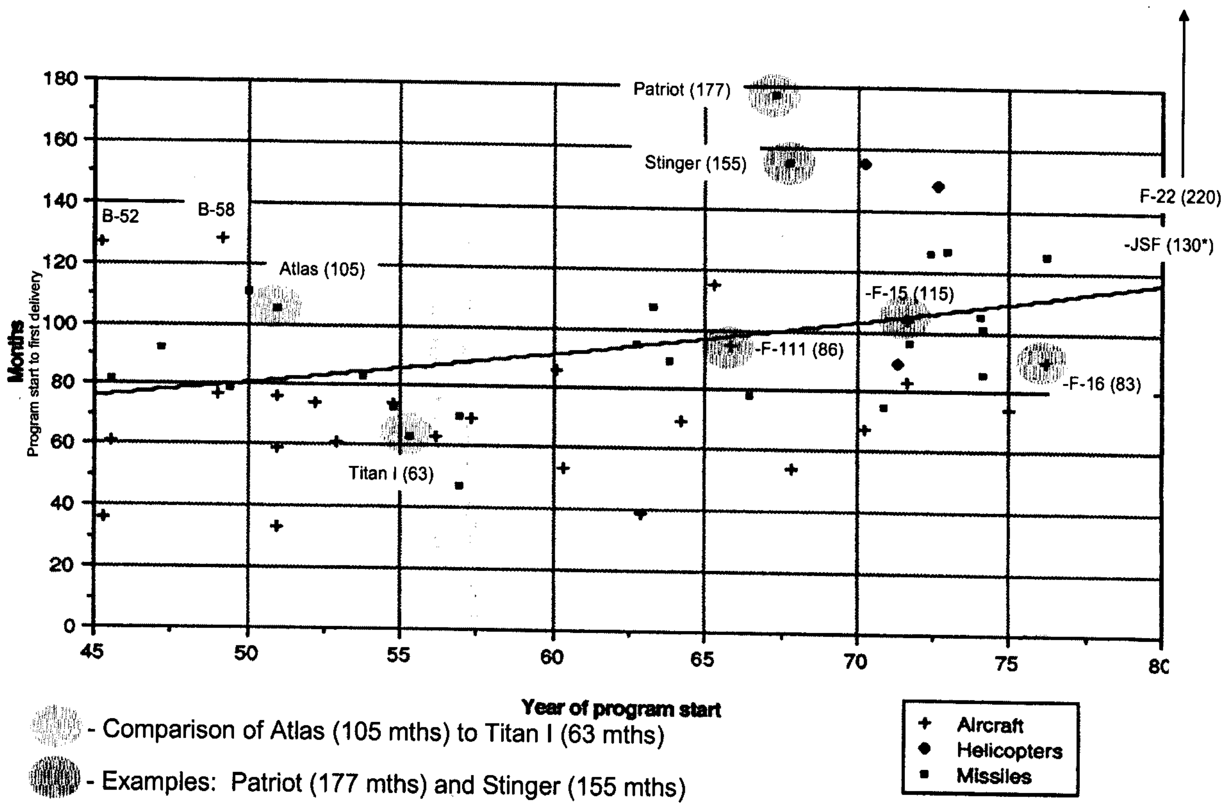


Figure 1: Fighter Aircraft Development Times (Gebhard, 2005)

We can clearly see from figure 1 that the F/A-22 and the F-35 are taking longer to develop than it took to develop the F-15 and the F-16. Can we simplistically take these two points and use them to pass judgment on the entire Air Force acquisition process? In other words, is this a statistically significant sample size, or could these two data points simply be outliers? To help understand the point, figure 2 shows data collected by the RAND Corporation for Aerospace

Weapon System Acquisition Milestones covering a time period from 1945 to 1980. This chart clearly shows how scattered the data points are even back to the 1940s where the B-52 and B-58 both exceeded 10 year development cycles.

Time from program start to first delivery with exponential fit line: all systems



RAND N-2599-ACQ Pg 27

Figure 2: Program Timelines (1945 – 1980)

In an effort to expand the number of total samples, RAND choose to analyze aircraft, helicopter, and missile acquisition programs from this period. The study analyzed over 51 programs and made comparisons between programs that occurred prior to and after 1960. This date was chosen because the late 50s and early 60s is the time period where the DoD dictated centralization of acquisition management. This report, as with our project, was designed to compare program durations between two different time periods to identify improvement or degradation of the acquisition process. RAND used the "Mann-Whitney U" test statistic which represents the distributional differences between two sets that are not normally distributed. None of the probabilities were even close to the 5% significance level. Figure 3 shows one of many figures in their extensive study. This figure is very typical of the others though. The distribution charts portray just how scattered the data are. RAND reported "these data cannot be well approximated with a function whose only independent variable is calendar date." (Rothman, 1987) They concluded that "In all categories there is no significant relationship in the period from FSD (Full Scale Development) start to first delivery."

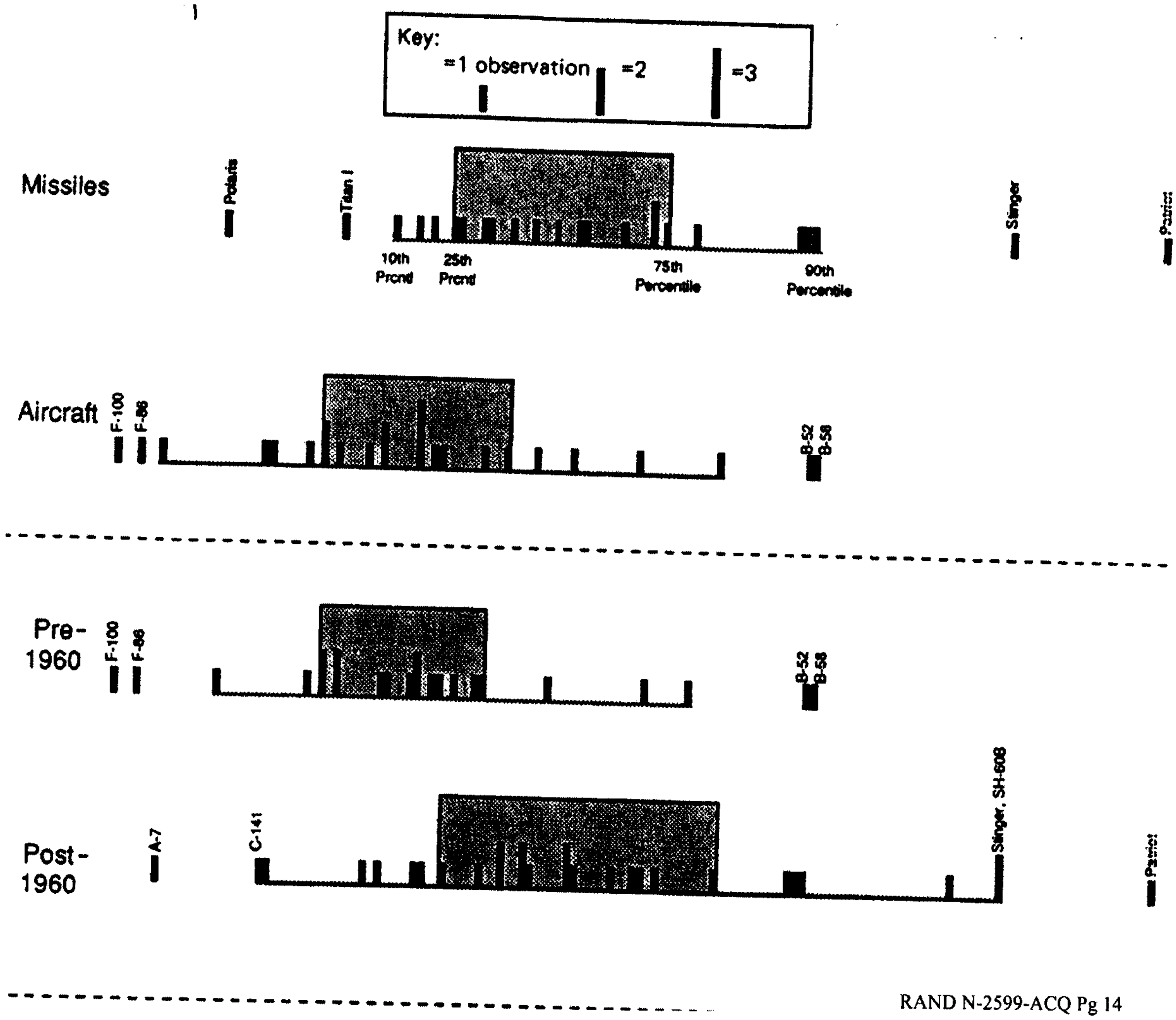


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Figure 3: Distribution of months from FSD start to first delivery (1945 – 1980)

"The most important finding of this work is that calendar time does not adequately account for the variance in the data on development time...Experts on acquisition have always believed that the mechanisms affecting development time are more complex than this simple model, and this analysis confirms this belief." (Rothman, 1987)

What we can take away from Figure 2 is that although statistically, the data are too scattered to prove significant conclusions, the visual best fit line drawn in figure 2 certainly shows an upward trend.

At this point, we know the answer to our initial question is yes with unknown statistical significance. The statistical significance of our planned comparison between the F-15/F-16 and the F/A-22/F-35 was deemed trivial due to the original desire to use calendar time so the focus of our study was adjusted to address the more important question; what causes acquisition programs to take longer to complete in today's environment than they took in the early 1970s?

3 Method

The process we used to attack the problem was first to brainstorm possible reasons for increased acquisition development times. We conducted an extensive literature search, and made several trips to the Aeronautical Systems Center (ASC) History Office to attain documents on earlier programs. It was a challenge to maintain an unclassified report as many of the requirements documents for the F/A-22 and F-35 are classified. We utilized subject matter experts (SME) when possible. We conducted interviews both in person, and over e-mail.

The list of contributing factors we deemed significant are listed on the below "Fishbone" diagram.

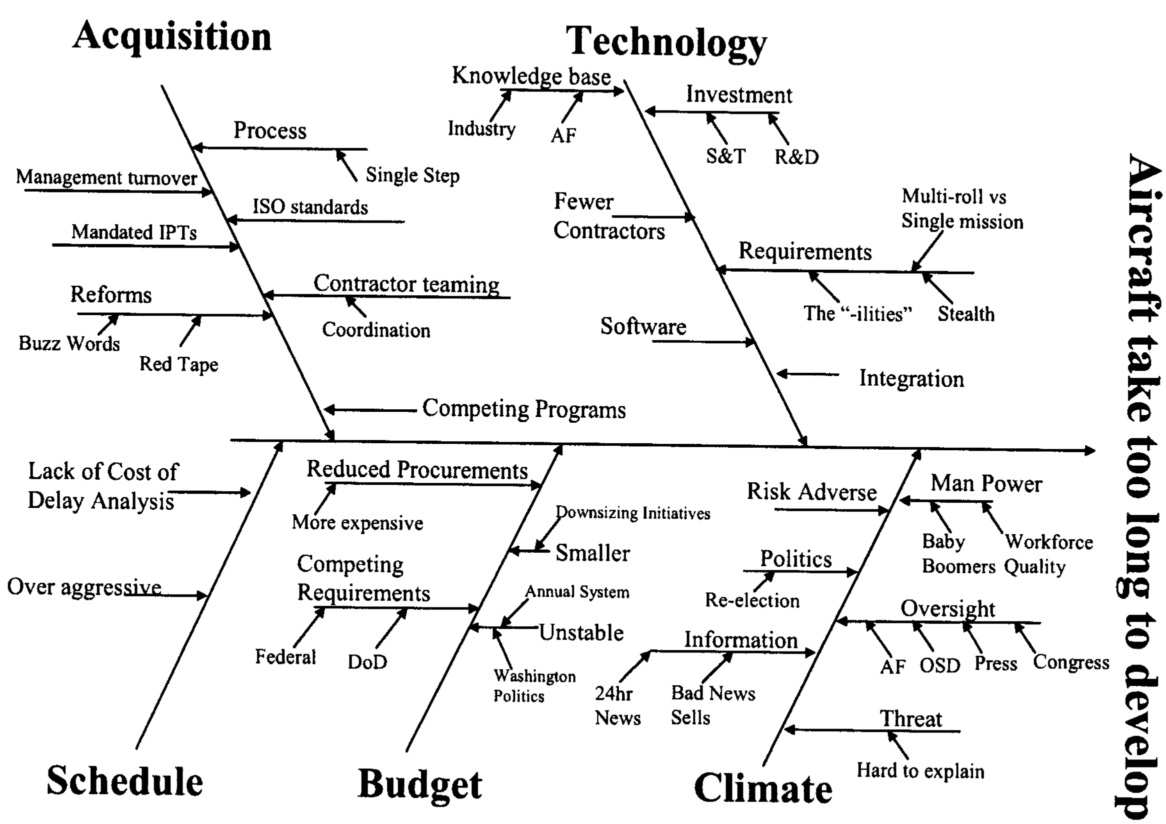

Figure 4: Fishbone causal map of acquisition program delays

4 Result / Findings

4.1 Budget:

The most common programmatic challenge uncovered by our literature review and SME interviews was the supply of money or simply put, the budget. The budget is the basic structure that drives all else in an acquisition program. Essentially nothing affects a program as much as the budget. The world of budgets is a turbulent one. It sways under the effects of competing requirements, between both within the non-military federal concerns and the DoD. There are also variations in budgets dictated by financial initiatives, usually calling for a downsizing of the military. Another powerful factor causing instability in the bedrock of budgets is good old fashioned Washington D.C. politics. And last, but not least, the budgetary system itself dictates an annual reauthorization of program monies which causes self-inflicted inefficiencies.

4.1.1 Historical Budget Comparison

A useful starting point is a "big picture" comparison between the DoD budget of 1969 and that of 2002. Figure 5 shows budgetary variations over the last 30 years. The budget is plotted as a percentage of the gross national product of the United States. The DoD budget was nearly 10% of our GNP in 1969 and has progressively fallen to just over 3% as of 2002. During the Ronald Reagan presidency there was a considerable buildup, which is generally credited with winning the cold war, followed by a drastic decline due to the demand for "Peace Dividends." This effect is reflected by the camel back shape in the curve between 1981 and 1993. The rest of the decline is due to the continued Defense spending cuts of the Clinton administration. It is important to look at the DoD as a whole because the Air Force is not a stand alone entity. Acquisition communities across the DoD have a direct affect on each other. If funding is reduced in any one, or in this case, all of the DoD components, there are negative ramifications across the board.

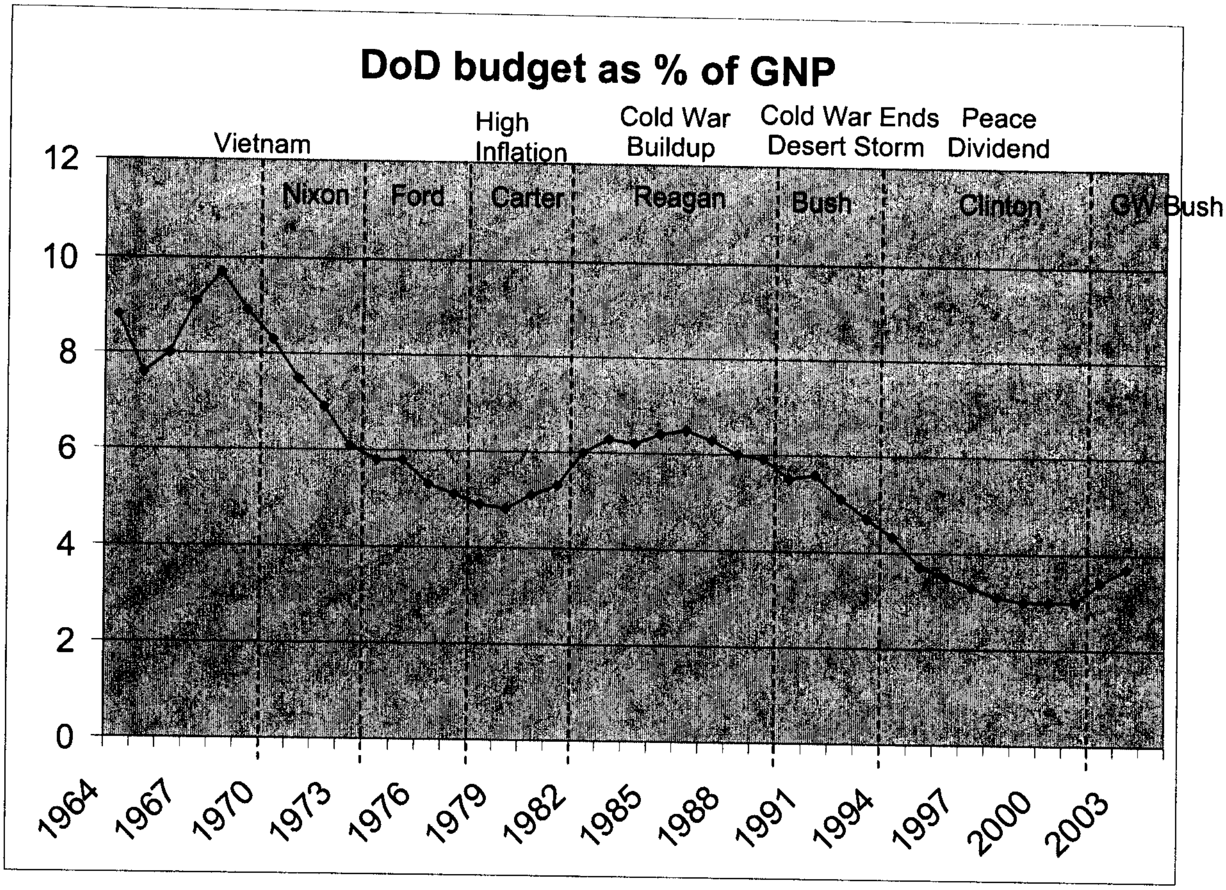

Figure 5: DoD Budget as a Percent of Gross National Product

4.1.2 Industry Health

Every acquisition program has the potential to advance our nations technology base as well as our nation's industrial base. Contractors do not care which component of the Armed Forces money comes from, they enthusiastically compete for any contract they are qualified to win, therefore the more contracts on the market, the healthier the industrial base becomes. The defense industry's health in the era of the F-15 and F-16 acquisition programs was far superior to today's sorely under-nourished environment. In a general sense, the aircraft industry's health can be analyzed by observing annual military aircraft production rates as shown in figure 6.

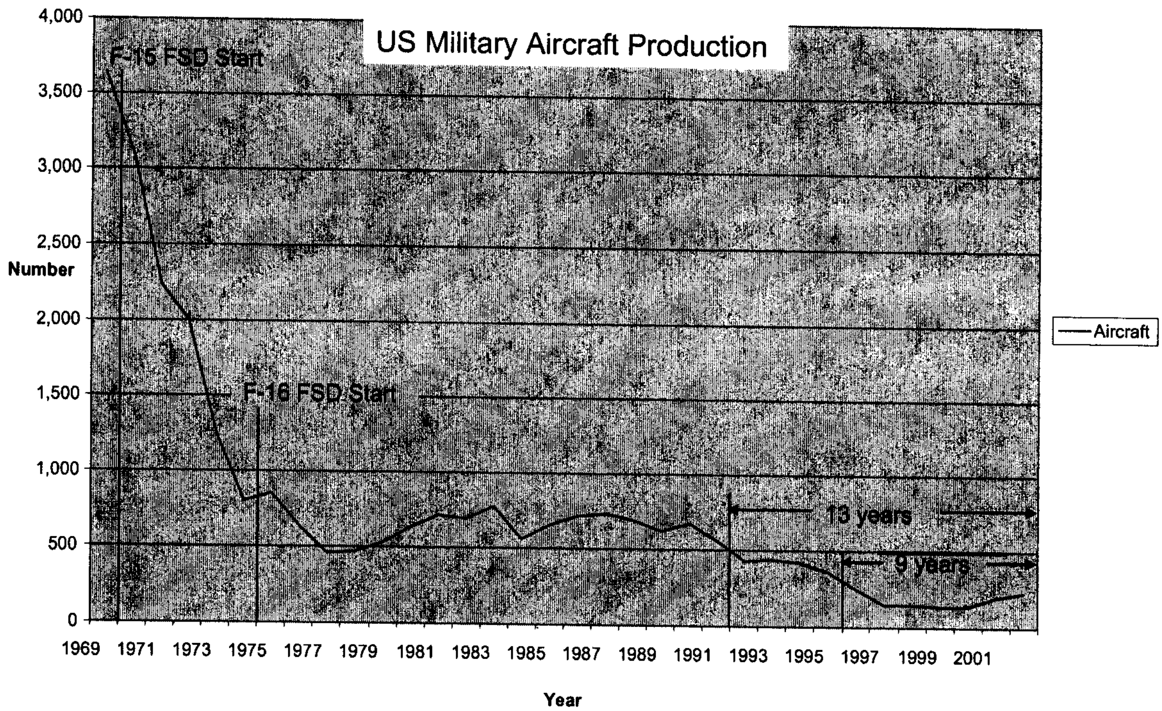

Figure 6: US Military Aircraft Production (Aerospace Industries Association)

When the U.S. began producing the F-15, arguably the most successful fighter procurement program in our nation's history, the country was just ramping down production rates in conjunction with the end of the Vietnam War. Notice that the production rates peaked at over 3,500 aircraft per year. When decreasing production rates, the industry not only sees excesses in experienced, highly trained workers, but also in production capability. Workers and companies are highly motivated by the pursuit to maintain their jobs in a rapidly declining market (excess in skilled workers + excess production capacity + excess motivation = Great environment for a customer to develop new weapon systems). The F-16 was slightly more displaced from the largest rates of reduced production but still close enough on the timeline that the benefits were still available. If you look at the DoD budget and it's decline in magnitude, which is directly tied to the reduction in production rates, the industry was left in a state that could be called a "buyer's market." The companies were in tip-top shape from the late 60s and were each ready to fight tooth and nail to win a piece of the rapidly decreasing defense budget dollars.

The right half of Figure 6 illustrates an important point. What we have in today's industry is a collection of battered, merged, and bought out corporations that have survived 30 years of competition in a market where the DoD has not purchased more than 750 aircraft in any one year. For that matter, the military has not purchased more than 500 aircraft in any one year for the last 13 years and, since 1996, has not purchased more than 250 aircraft in any one year!

4.1.3 Economies of Scale

"Economies of scale" is an old economic principle that still applies, even to the mighty United States military juggernaut. If you take the external budgetary constraints and variations placed on the F/A-22 program, it does not matter how many TQM charts you publish or IPTs you establish you will never be able to produce an aircraft on schedule and below budget. The F/A-22 program was started in 1986, was scheduled to complete development in 1995, reach IOC in 1996 with a planned total production of 750 aircraft. What has ended up happening is the development and IOC have been stretched out to 2005 and the total planned production was reduced to 177 aircraft. It is up for debate as to the exact cause (of which there are many) but, it should be no surprise that the "per unit" cost has tripled. This is clearly demonstrated in figure 7 below.

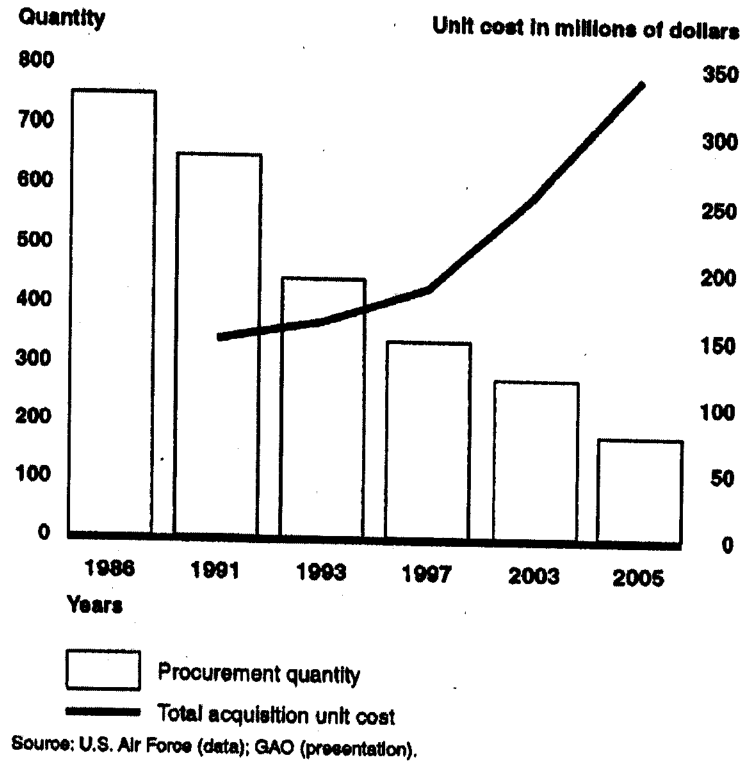

Figure 7: Quantity versus Unit Cost (GAO-05-390T, pg 6)

"Decreased procurement quantities, along with increased development and production costs and increased costs to modernize and enhance capabilities, have led to rising acquisition costs. This figure illustrates the downward trend in procurement quantities and the upward trend in acquisition unit costs." (Sullivan, 2005) Needless to say, the reduction in total number produced in conjunction with an extended developmental period does not have a negative affect that is linear, it is parabolic. In the case of the F/A-22, "congress placed a cost limitation on both development and production budgets in 1997." (Sullivan, 2005) This cost cap slowed down the entire acquisition process to such an extent that it was eventually removed to help alleviate the negative ramifications. The negative affects of this years production won't truly be displayed on the accounting sheets for several years. Again, we should not be surprised at the inflated price (I am sure the F/A-22s opponents are counting on it) per unit but rest assured our ever present critics will claim that the program manager ran the program inefficiently, the contractors were milking the government out of money and a new acquisition reform bill should be passed to solve the acquisition community's ineptitude.

4.1.4 Cost of Delay Analysis

Lt Col Ross McNutt is a member of the AFIT faculty and a former member of the Pentagon's Acquisition Cycle Time Reduction Task Force and is an expert on the topic of Cost of Delay Analysis (CoDA). In his dissertation, *Reducing DoD Product Development Time: The Role of the Schedule Development Process,* Lt Col McNutt points out that "...the funding process is the dominant influence on development and on the creation and execution of project schedules." (McNutt, 1998). He cites the unstable nature of defense procurement budgets as one of the reasons development projects take so long. Specifically, he asserts that our acquisition system is characterized by product development being driven by available funding instead of the other way around. His surveys of program managers and program element monitors showed that these professionals are confident that, "...with full funding and a strong emphasis on short development time, a project could be completed in half the scheduled time." (McNutt, 1998) Finally, Lt Col McNutt suggests that the limited funding available for defense procurement is being spread too thin over too many projects at the same time. Unfortunately, he points out, there is no effective screening process to limit the number of projects entering development. (McNutt, 1998)

Funding instabilities can be crippling to defense contractors. Ben Rich, former director of the Lockheed "Skunk Works," suggests that the government's dysfunctional funding methodology can lead to big losses for the aerospace industry. In his book, *Skunk Works*, Rich points out that the development effort for the F/A-22 was so expensive that Lockheed had to partner with General Dynamics and Boeing. These companies put up nearly $690 million to match the development funding offered by the government. The contractors were willing to do this because the government had indicated a desire to purchase as many as 700 aircraft. However, funding instabilities have caused that number to shrink to 177. In 1994, Rich thought it unlikely that the companies involved would ever recoup their investment in development. He wrote, "The sad truth is that our stockholders would have done better financially if they had invested that $690 million in CDs." (Rich, 1998)

By funding programs one year at a time, we are building tremendous inefficiencies into the system. For example, when Lockheed was asked to reopen the U-2 production line in the early 1970s, Ben Rich knew that he was going to need to produce 5 aircraft a year for 7 years. However, because procurement funding came in one year increments, he was unable to prepare for the production in years 2 through 7. In fact, to do so would have been illegal. Rich points out, however, that, "...by doing so, I could probably reduce my production costs if I were allowed to purchase in volume tooling and materials for say, three years at a time, rather than doing so annually and incrementally." (Rich, 1998)

4.1.5 Research and Development Funding

Research and Development (R&D) is a pillar of the acquisition community and only recently has been receiving annual increases (versus decreases) in budgetary commitments with the exception of the 1986-90 short term spike during the Reagan Administration. Figure 8 below pictorially displays the U.S. R&D budgetary funding trends.

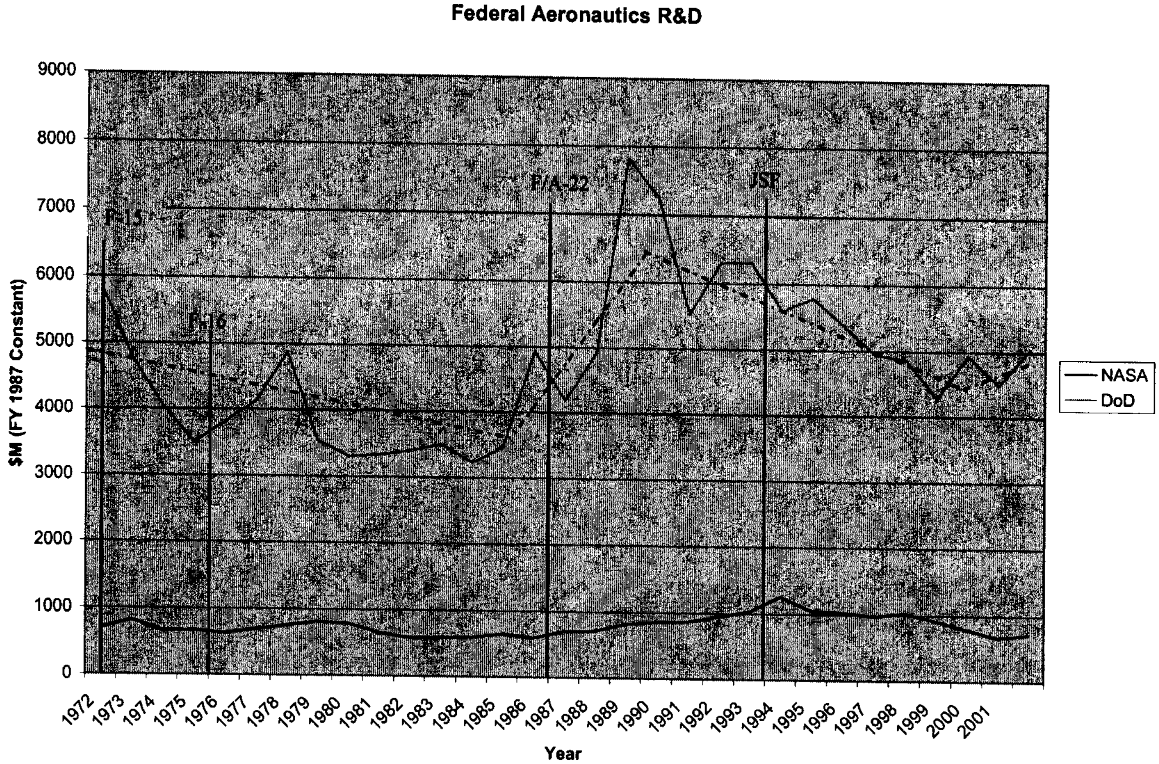

Figure 8: Federal Aeronautics R&D (Aerospace Industries Association)

Over the past 50 years, dedicated military R&D conducted or directly funded by the U.S. Government has been critical in the development of new higher-performance aircraft. Major new technology breakthroughs have come more often from government labs or by government sponsored R&D than from the commercial sector. Much of the basic research done by the Air Force and NASA in aerodynamics and propulsion post World War II and in the 1950's permitted supersonic flight. Much of the technology that allowed for stealth combat aircraft was generated by sustained research in government and industry labs in the 1950's and 1960's. Further reliance on commercial sector research may create risks for future military aircraft development. For example, the commercial sector would not have developed stealth, super-maneuverability and thrust vectoring. (Lorell, 1998) Care must be utilized in reading this R&D chart. Funds spent in any particular year will not affect the fighter aircraft acquisition process for at least 5 to 10 years if at all (research is characterized by trial and error so not all funds expended produce favorable technologies). This chart shows low R&D expenditures during the time period when the F-15 and F-16 were acquired. What benefited these aircraft were the R&D expenditures of the late 60's which were particularly high due to the war. Contrast that with the F/A-22. The program began about the time R&D spending had just began an upward climb but notice that the R&D budget had been dropping for a period of over 15 years prior to this. There was a short surge in spending during the Reagan cold war attack against the USSR which did have a positive, yet limited affect, on R&D. One challenge noted by Ben Rich about this time in acquisition history was the fact that the available manpower at the time was so limited that in some cases, qualified new hires were impossible to find "at any cost." (Rich, 1994) Inconsistent budgetary spending makes for an unhealthy research industry. Highly trained technicians can't be hired and fired like union construction workers. We have an obligation to maintain at least a minimum base of scientists to ensure technology advancements are available for future acquisition programs 10 or even 5 years down the road.

4.1.6 Budgetary Competition

Figure 9 displays a small snapshot of which programs within DoD are competing for the RDT&E funding at any particular time.

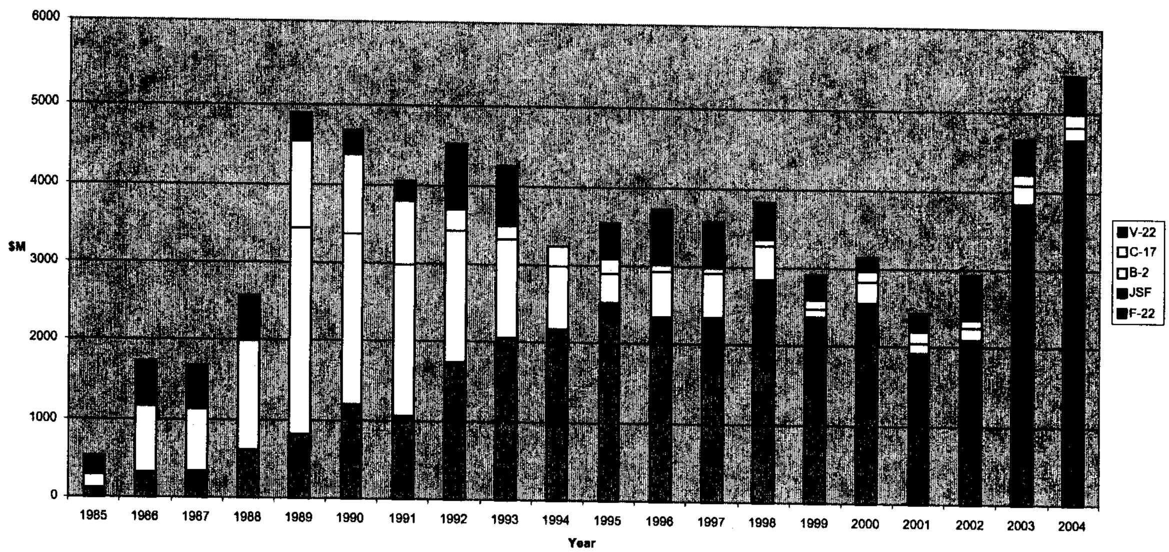

Figure 9: RDT&E by Aircraft (1996 Constant), (Aerospace Industries Association)

The competition is not limited to within the DoD for funds though. In a March 25, 2004 report, GAO's Director of Acquisition and Sourcing Management, Allen Li, reported on the funding difficulties within the Federal Government, which impact the DoD and the F/A-22 and the JSF. At the Federal level, the government is facing large expenditures with the stand-up to the Department of Homeland Security. This organization costs $40 billion and employs 170,000 people. Medicare is an issue for the government, which has a projected cost of $500 billion over the next 10 years. Within the DoD the F/A-22 and F-35 have to compete with missile defense, the Army's Future Combat System, and larger investments in space systems.

4.1.7 Budget Conclusions

Funding can be tied to almost every facet of the acquisition process, and a lack of which will seriously affect the amount of time it takes to acquire a new fighter aircraft. The combination of low levels of funding, inconsistent funding, and a system based on annual budgets makes for an inefficient acquisition environment at best. Extremely low annual aircraft production rates have resulted in a sickly aircraft industry made up of a very few lone surviving companies that are comprised of old, battered, merged and bought out companies of the past. Low annual aircraft production rates increase the "per unit" costs of today's aircraft simply due to economies of scale. In order to afford more expensive programs, the military tends to spread programs out over several budgetary cycles due to a misunderstanding of the costs of delaying programs. Finally, tight research and development budgets combined with a varying array of programs in heated competition for those funds directly affect the amount of mature technology available for today's new acquisition programs. All of these various factors have the potential for negatively affecting a programs cycle time.

4.2 Technology

Fighter aircraft are among the most demanding and technologically challenging items to design. "Historically, the performance requirements generated for new fighter designs have often pushed the outer limits of design and engineering knowledge during any given period." (Fox, 2004) However, it is very difficult to compare the capabilities of the aircraft development contractors of the 1960's and 1970's to the contractors of today. Without question, technology challenges and issues surfaced during the development of the F-15, F-16, F/A-22 and F-35. The question is whether the requirements for the current fighter programs are too advanced for current technical capabilities causing delays. This section looks at the technology challenges of the F-15, F-16, F/A-22 and F-35.

4.2.1 F-15

The biggest technology challenges during the development of the F-15 were the engine and the radar. The F-15 was designed to be an air superiority fighter requiring more thrust than aircraft weight. This necessitated advancements in engine technology. Each engine was required to develop 40% more thrust and weigh 25% less than the TF-30, the engine used in the F-111. The F-15 also required an advanced radar, able to detect and track small objects, at long-range and high speed, from high altitude down to tree top level. The F-15 was designed from the beginning to maximize air-to-air capabilities, without hampering it with other duties. The prime contractor was McDonnell Douglas, which had recent fighter aircraft development experience with the F-4. It was decided not to require a prototype competition, saving development time. However, the government did conduct prototype competitions for the engine, radar and armaments subsystems. Figure 10 summarizes the technical performance characteristics of the F-15 as put on contract and the then estimate at completion dated 31 March 1970. As the figure shows, all of the technical characteristics were met.

Technical Characteristic And Unit of Measure	Contract Definition	March 1970
1. Max Speed @ Sea Level	1.2 Mach	1.2
2. Max Speed @ Altitude	2.5 Mach	2.5
3.Mission Range – Cruise	200 NM	200 NM
4. Mission Range – Dash	60 NM	60 NM
5. Thrust/Weight Ratio TO	1.1	1.17
6. Thrust/Engine lbs	22,800	23,470
7. Landing Distance ft	3840	3840
8. Take-off Distance ft	2500	2500

Figure 10: F-15 Requirements versus Capabilities (F-15 Selected Acquisition Report 23 Apr 1970 Hoover – Copy from ASC History Office)

4.2.2 F-16

The F-16 was designed from the beginning to be a lightweight fighter to complement the more expensive F-15. It had many first time technology applications. It used "fly by wire" primary flight controls without mechanical backup (although this was tested by NASA on an F-4). It had relaxed static stability for trim drag reduction and enhanced lift characteristics (wing leading edge extensions & variable camber) for increased maneuverability. It utilized a composite primary structure on the horizontal tail. The pilot sits in a semi-reclining seat, increasing pilot "g" tolerance. The F-16 is designed for a 9 "g" maneuver envelope.

4.2.3 F/A-22

Fast-forward a generation to the F/A-22, it has several technology challenges. The first is the low observable materials. Although used on the F-117 and the B-2, this is the first supersonic application. The F/A-22 is required to cruise at supersonic speeds in stable flight without using afterburners. Its maneuverability is enhanced by the first use of thrust vectoring. Another first is the use of an integrated maintenance information system. The F/A-22 also has deployability as a key performance parameter; it is to deploy with a much smaller footprint of support equipment and personnel than the F-15. The biggest technology challenge to the F/A-22 is the integrated avionics suite, which fuses radar, electronic warfare, communications, navigation, and identification sensor outputs. The avionics suite is much more advanced than previous fighter aircraft. It uses a common computer instead of several computers to receive, process, and display information to the pilot. This is supposed to greatly reduce pilot workload and increase situational awareness (GAO, 1999). This was a problematic area during development. It wasn't until 9 years into development that the avionics met an acceptable level to begin production development. The cost of the F/A-22's avionics has increased by over $980M. (Walker, 2003)

The F/A-22 program office did assume a high level of risk by utilizing technologies that were no fully developed. Did technology cause the development of the F/A-22 to take longer? According to this 2003 GAO study, "The effects of immature technologies cascaded into the F/A-22 development program, making it more difficult to achieve a stable design at the right time. The standard measure of design stability is 90 percent of design drawings releasable by the critical design review. The F/A-22 achieved only 26 percent by this review, taking an additional 43 months to achieve the standard."

The F/A-22 regularly reports the status of 10 performance parameters. The GAO developed figure 11 to show these parameters. To keep the document unclassified, they assigned a value of 100 percent to represent the acquisition program baseline. Time has proven the estimate for reliability far short of the goal. As of October 2003, the mean time between maintenance is demonstrated at just 0.5 hours. (Li, 2004)

Key Performance Parameter	Acquisition Program Baseline	Estimated Performance (December 1998)
Supercruise	100%	115%
Acceleration	100%	115%
Maneuverability	100%	104%
Airlift Support	8 C-141 equivalents	7.7
Sortie Generation Rate	100%	100%
Radar Cross Section	100%	Favorable
Mean Time Between Maintenance	3.0 hours	3.1
Payload (missiles)	4 Medium range 2 Short range	6 Medium range 2 Short range
Combat Radius	100%	124%
Radar Detection Range	100%	117%

Figure 11: F/A-22 Performance Parameters, (Li, GAO-03-645T)

4.2.4 F-35

The goal of the F-35 program is to affordably provide a family of aircraft. A large challenge is commonality, which is not new. The F-111 was to have 89 percent commonality between Navy and Air Force versions. That ended up being zero after the Navy version was canceled. The F/A-18E/F Super Hornet was to have 60 to 70 percent commonality with the F/A-18C/D; it ended up with very little airframe commonality. The T-45A was expected to maintain 64 percent commonality with the British Aerospace Hawk, this dropped to 8 to 10 percent. (Grantham, 1997) Concerning the F-35, the Navy requires a survivable carrier-based strike fighter. The Air Force wants a multi-role fighter to replace the A-10 and F-16. The Marine Corps desires a Short Take-Off Vertical Landing (STOVL) fighter to replace the AV-8 and the F/A-18. Finally the Royal Navy requires a STOVL fighter to replace the Sea Harrier. *(A quest for commonality)* Other goals for the JSF include: greater sortie generation rates than current aircraft, reduced deployment footprints compared to the F-16 and AV-8, reduced IR/RF signature, and speed and maneuverability comparable to the F-16. Design challenges to date include weight growth, and software development and integration.

Like the F/A-22, the F-35 assumed a high level of risk by using technologies that weren't fully developed. According to the GAO, one problem in the F-35's development is that the F-35 continued with system development before the technology was fully ready. "Many of the technologies needed for the product's full capabilities were demonstrated only in a lab environment or ground testing and not in the form, fit and function of or functionality needed for the intended product design. Also, while the program had a proposed technical solution to meet the warfighter's requirements, it did not deliver a preliminary design based on sound systems engineering principles." (GAO, 2005) The report also states the aircraft is suffering from weigh problems and software development and integration challenges. These issues contributed to the decision to delay critical design reviews and the first flight of developmental aircraft. This resulted in delaying IOC.

4.2.5 Technology Long Pole

Technology advancements in engineering have made some disciplines of aircraft design easier over time. According to Jack Abercrombie, aerodynamicist for McDonnell Douglas on the F-15, "Certainly the F-22 and JSF represent a higher state of technology, but at the same time, the tools available to the engineer to develop and apply that technology have advanced greatly from what we had to work with on the F-15. (We were still using slide rules for some calculations!) Tools, in general, have advanced faster than their application to real-world aircraft design." In 1990, Dr. Hallion, in his article, *A Troubling Past: Air Force Fighter Acquisition since 1945*, described a method to show the change in fighter aircraft over time using component cost as a percentage of aircraft costs. For example since 1945, airframe costs have decreased from 66 to 47 percent. Engine costs have held steady at approximately 25 percent. The area with the largest change has been in avionics. Figure 12, from Dr. Hallion's article shows the percent of functions performed by software.

Aircraft	Year	Percent functions Performed by software
F-4	1960	8
A-7	1964	10
F-111	1970	20
F-15	1975	35
F-16	1982	45
B-2	1990	65
F/A-22	2000*	80

*Projected in 1990

Figure 12: Software Function Percentage, (Hallion, 1990)

There has been a dramatic increase in the amount of software incorporated into aircraft design since the development of the F-15. The F-15A had 60,000 lines of code. The F/A-22 was originally planned to have 1.4 million lines of code written in Ada, the DoD's common computer language, which was written by 600 programmers in 6 different states. By 2004, the lines of code increased to 2.1 million. The F-35 will have 17 million. Both the F/A-22 and F-35 have had issues with avionics and software. In a 2004 study RAND points out how software intensive systems also require more testing. "The cost of testing software intensive systems will continue to grow. This is proven correct when comparing the F-15 avionics test to the F/A-22. The F/A-22 has twice the number of test aircraft dedicated to avionics testing than the F-15 did (6 to 3). It has flown almost twice the avionics flight test hours (1574 to 819). The JSF is planned to have a 7 year, 10,000 hour flight test program.

Avionics development has been an issue on the F/A-22 for a while. The GAO reported difficulties in this area back in 1998 (GAO, 1999). That report also highlighted software integration difficulties. The F/A-22 is planned to have a more robust air-to-ground capacity and enhanced intelligence, surveillance, and reconnaissance in later models. These upgrades will require the current computer architecture and processor to be replaced because they are "old and obsolete." (GAO, 2004) Certainly this will cost more in time and money.

Not surprisingly, the F-35 is currently experiencing software and other avionics issues. According to the latest GAO review of the aircraft, only about 40 percent of the 17 million lines of code needed for the system's software have been released. In addition, the software required for mission systems integration will not be ready until 2010; 3 years after F-35 is scheduled to enter production. Any additional problems discovered in testing will undoubtedly add more time to the program. "The JSF, like many past DoD weapons programs, is very susceptible to discovering costly problems late in development when the more complex software and advanced capabilities are tested." (GAO, April 2005)

Software development is still a relatively new science compared to aerodynamics or mechanics. It is often still considered an art instead of a well-understood engineering process. Back in 1982, Norman Augustine, CEO of Lockheed Martin described software, "Software is like entropy, it is difficult to grasp, weighs nothing, and obeys the second law of thermodynamics, i.e., it always increases."

Within systems engineering, software development is our most significant challenge. "Software development is difficult because of complexity. A complete software system is impossible for one person to get there hands around. Plus, software is invisible and intangible. It's hard to visualize the structure." (Graham, 2004) "Many of the performance, schedule or costs are traceable to deficiencies in software processes." (Eisner, 2002)

Another difference between the aircraft developed in the 1970's and today is their mission requirements. Historically aircraft have accomplished different mission than they were originally designed. The F-4 is a good example. It was designed for fleet defense. It ended up accomplishing multiple missions. Both the F-15 and F-16 we developed with as single mission in mind; air superiority. They both have evolved into multi-role missions, but the original development was for single missions. Today, the F/A-22 and F-35 are being developed as multi-role. The F-35 is expected to eventually replace several different aircraft. Clearly the additional complexity needed to perform multiple missions takes time to develop.

4.2.6 Aerospace Industry

The U.S. Aerospace Industry has changed since 1970. There are fewer aerospace contractors with the expertise to develop a complicated fighter aircraft. In 1965 the original Request For Proposal (RFP) for the F-X, which became the F-15, went out to 13 companies. Eight companies submitted proposals. (Neufeld, 1974) Today, there are only 2 corporations that have the ability to build a modern fighter aircraft. A RAND study, *The Cutting Edge: A Half Century of Fighter Aircraft R&D*, suggests historically, the climate of competition in the aerospace industry encourages creative ideas and solutions. They see the reduction in aerospace corporations a risk for future aircraft development. Both of the "big" corporations are now acting more as integrators bringing in and assembling the aircraft with parts being made elsewhere. The F/A-22 is being produced in 42 states.

We can make two other quantifiable statements about the aerospace industry. First, the U.S. military is purchasing far fewer aircraft overall since 1970. Second, there are far fewer scientists and engineers (S&Es) working in the aerospace industry (See figure 13.)

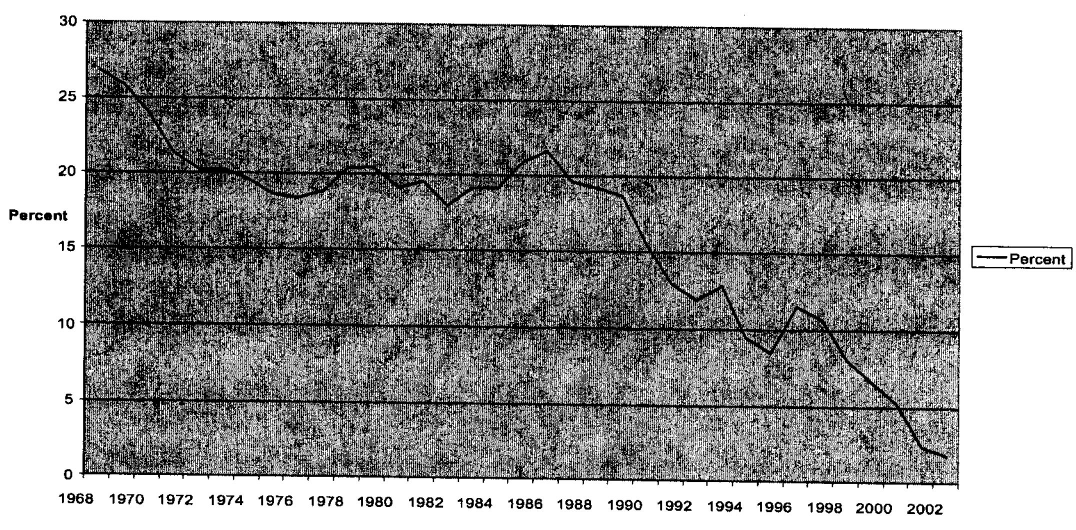

Figure 13: Employment of R&D Scientists and Engineers in Aerospace, (Aerospace Industries Association)

It is impossible to equate the quality of the S&Es in 1970 to today. We do know the S&Es of today have more computing power and ability to conduct computer simulations than earlier generations It isn't only the number of S&Es that has gone down. The overall employment in the aerospace industry has declined from the peak in 1968 of 1,502,000 workers to 714,000 workers today. The number in just the aircraft industry has reduced from 852,000 in 1968 to 410,000 now (Aerospace Industries Association, 2003).

Ben Rich laments the loss of these workers and suggests that the new aerospace workforce will take years to gain the experience of their predecessors. Writing in 1994, Rich observed, "The old guard is retiring or being let go, while the younger generation of new workers lucky enough to hold aerospace jobs has too little to do to overcome a steep learning curve any time soon." (Rich, 1998) Former Secretary of Defense Caspar Weinberger echoed Rich's concern in the epilogue to Rich's book. Secretary Weinberger wrote, "...I am frankly concerned that Lockheed and other companies are looking to new civilian areas because there is no future in defense...That means we will have an incredibly hard time trying to hold on to our best and most skilled aerospace engineers and shop workers." (Rich, 1998)

4.2.7 Air Force Acquisition Professionals

The Air Force breaks up its acquisition officers into 3 areas: scientists, engineers and acquisitions. The Air Force has a hard time manning these positions. Currently, captain level scientists are manned at 40%, captain engineers are at 50%, and field grade officers are at 75%. Acquisition field grade offices are at 70%. Figure 14 shows the numbers of officers in these career fields.

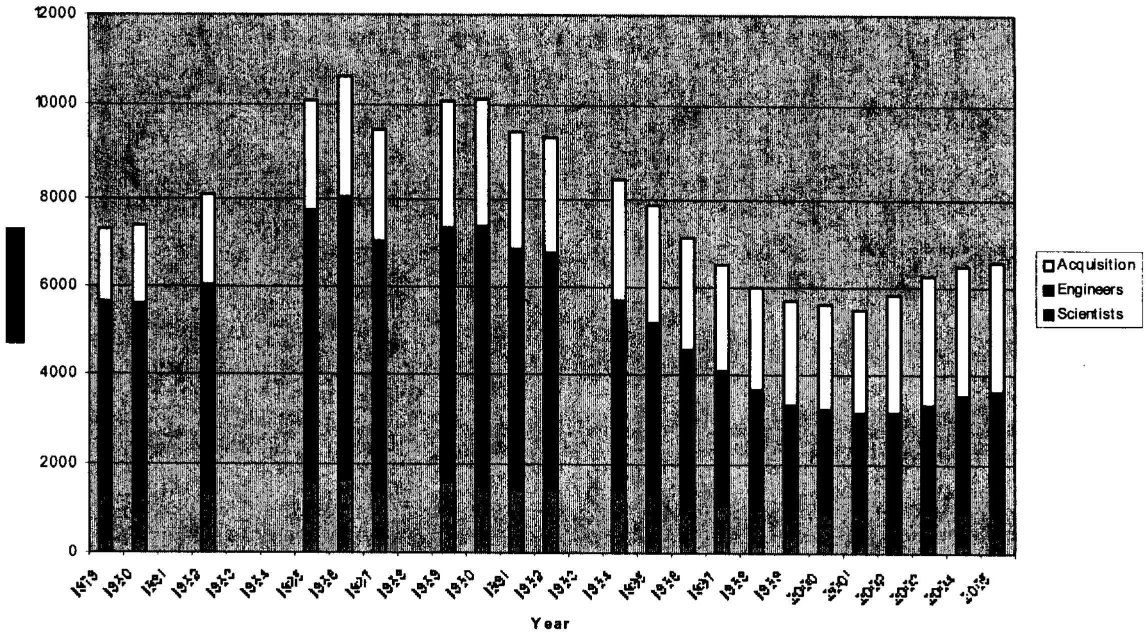

Figure 14: Air Force Acquisition Officers (Air Force Association AF Almanacs 1979-2005)

The Air Force Association explains the importance of having qualified people in these positions. "Of equally critical importance is the need to educate and nurture a skilled cadre of Air Force officers in the R&D and the Science and Technology (S&T) community. The evolution of Air Force leaders, from their entry into the service through graduation from the Air Force Institute of Technology, and then on to increasing S&T and R&D experience, including program management, is the crucial factor in rebuilding and maintaining Air Force R&D. The slowly diminishing number of highly qualified acquisition officers is of great concern." Don Nash, former flight test engineer on the F-15 and engineering consultant to Lockheed on the F/A-22 program mentioned his frustration with Air Force managers. When asked what he felt were problem areas during F/A-22 development he said, "Micromanagement by inexperienced officers who have no experience in aircraft development." It is impossible to come up with a fair comparison of the acquisition officers that help develop the F-15 and F-16 to the current officers. We can objectively state we have fewer of them now than we did then.

4.2.8 Technology Conclusions

Is the reason aircraft development programs are taking longer today due to technology? This is a very subjective question. We can say fighter aircraft typically push the technology envelope. The F-15, F-16, F/A-22 and F-35 all had or currently have technical challenges. The newer aircraft will have more capabilities than their predecessors. The F/A-22 and F-35 will have additional capabilities over the F-15, F-16 and A-10, the aircraft they will replace. Both newer aircraft offer improvements in stealth, maintainability, supportability, and deployability. One common problem area on both the F/A-22 and F-35 is the avionics systems which are much more software dependent. Software development hasn't caught-up with mechanical or electrical systems development yet. There are fewer standards and less of an infrastructure to rely upon (Eisner, 2000). Overall, it is hard to determine if the requirements are pushing the technology bounds too much, but it is safe to say the technology requirements are a contributing factor in the increased fielding times.

4.3 Climate

Proper systems engineering approach dictates we look at all external systems. This is very true concerning an expensive undertaking such as a fighter weapon system. We collected the external system of a fighter aircraft acquisition process in this "climate" category. The topics we investigated are: threat, Air Force Organization, Additional Oversight, Commercial Practices, and the Available Labor Force.

4.3.1 The Threat

During the late 1960's, the Vietnam War showed the U.S. could not always assume we would keep air supremacy. Before the F-15, the last aircraft designed from the on-set as an air superiority fighter was the F-86 Saber. The Century series fighters (which includes the F-100 thru F-111, the F-4's original designation was the F-110) were mostly designed for use in nuclear war instead of tactical combat. The air-to-air kill ratio of the U.S. vs. North Vietnam was 2.5 to 1, much less than the 10-1 ratio during the Korean War. Then in July 1967, at an air show near Moscow, the Soviet air force revealed two new fighters: the MiG-25 Foxbat and the MiG-23 Flogger. Many officials in the Defense Department believed that these new fighters, particularly the MiG-25, would be difficult for the F-4 or other existing U.S. tactical fighters to counter. (Lorell 2003) The Air Force needed a true air-superiority fighter to deal with this new threat. It was easy to for the Air Force to convince the Congress on the requirement. Plus, according to the May 1970 issue of Air Force Almanac, the F-15 was the Air Force's "Number one priority." Also, during the 1960's the failed quest for a universal fighter in the F-111 helped justify the development of single mission aircraft. The Navy developed a fleet defense fighter in the F-14. The Air Force developed the air superiority F-15, the low cost, lightweight F-16 and the close air support A-10. Clearly, during the early 1970's an environment conducive to aircraft development existed.

Look ahead 25 years to the F-15. Although it is aging it is undefeated in aerial combat. The Cold War is over. The U.S. was supposed to enjoy a "piece dividend" for winning the Cold War. To one not familiar with the threat of the SA-10 surface to air missile or any of the new generation Russia fighters such as the Su-27 it would seem we do not need a replacement for the F-15. The same argument can be made for the F-16; it has been a very successful aircraft. The F-35 is going to replace the F-16 and the A-10, two very different weapon systems. Obviously, the more missions an aircraft is to perform increases the complexity. Plus the A-10 is very cheap - $9.8M each. (Air Force Link) Why replace it with such an expensive aircraft?

From the U.S. Constitution, it is the job of Congress is to raise, support and fund the military. Anyone that has had an assignment to Washington D.C. will attest the Congress takes this very seriously. As mentioned earlier, the military does not receive the percentage of the Gross National Product as it did in the past. It is harder to convince the Congress and the American taxpayer of the need for a new fighter aircraft. Especially since the face of Congress has changed dramatically in the last 20 years. Since 1985, the number of senators with military experience has dropped from 75% percent to 31 percent. And the number of house has dropped from 53 percent to 25 percent.

4.3.2 Air Force Organization

The Air Force has gone through organizational changes since the 1960's. Back then, the Air Force had a Deputy Chief of Staff for Research and Development. This position no longer exists. It has been replaced with the Under Secretary of the Air Force for Acquisitions. This position is responsible for all acquisitions, including test, production and modernization, in addition to research and development. Also, in the late 1960's, the Air Force Systems Command was responsible for all technology R&D. In 1992, AFSC merged with Air Force Logistic Command to form Air Force Material Command. AFMC does not only support R&D but also ensures sustainment of all weapon systems. It cannot be proven analytically these organizational changes had any impact on the acquisition process, but it is a question to ask.

The F-15 development team was organized to reduce bureaucracy. The F-15 SPO director reported directly to the Deputy Chief of Staff for R&D who reported to the AF Chief of Staff and SecAF. Today, the F-35 is a Joint Program, with stakeholders in the Air Force, Navy and Marines, plus overseas partners. The management chain currently runs from the Navy PM through the Office of the Secretary of Defense for Acquisition, Technology and Logistics, (OSD/AT&L) down to SAF/AQ. (Stathopoulos, 2005) In addition, the F-35 faces challenges of dealing with foreign partners. Clearly this is daunting task. Obviously, any additional layers of management or bureaucratic issues a bound to slow down a project. Kelly Johnson, the chief engineer of Lockheed's Skunk Works would not have liked the F-35's arrangement. His first 3 rules for a successful project were: Single Manager, small program office, and limited access. (Schneider) That hardly seems possible in today's environment.

4.3.3 Additional Oversight

There is more oversight on programs now than in the early 1970's. Currently, Americans are inundated with news from multiple sources. We have multiple 24-hour news stations on television, plus 24-hour access on the Internet. These did not exist in the early 1970's. The news media loves to report on Government fraud and waste. Thanks to the $400 hammer and $500 toilet seats of the mid 1980's, the DoD is constantly forced to justify all expenditures to a much better informed American taxpayer. This takes time and effort. Mr. Nash mentioned how contractors are forced to spend too much time on congressional and Air Force level reviews on the F/A-22. One example is the Government Accounting Office (GAO). The National Defense Act for FY 1998 requires the GAO to review the F/A-22 program and assess whether the program is meeting key performance, schedule and cost goals. They've done 45 studies on the F/A-22 so far. The GAO also by law has to investigate the JSF yearly. They've already accomplished 16 reports. Back in the 1970's, the GAO did only 4 studies during the F-15 development. They didn't investigate the F-16 development at all.

Another example is the congress. General Larry Welch, former CSAF, said, "If I wanted an airplane and the secretary of the Air Force agreed, we had four key congressional committee chairman to deal with and that was that. The same was true of the stealth fighter project --

except we had eight people to deal with on the Hill instead of four. But by the time we were dealing with the B-2 project, we had to jump through all the bureaucratic hoops at the Pentagon and on the Hill." (Rich, 1994) It is easy to see the F/A-22 can garner congressional input – it is produced in 42 states. Gen Scofield, in is report, *Delivering Combat Capability at Home and Abroad*, described how congressional support was greater during the aircraft developments of the 1970's. Congress did not make any funding changes in the F-15 and F-16 development programs.

4.3.4 The fallacy of Commercial Practices

It is difficult to compare complex military systems such as fighter aircraft with simpler commercial systems. Yet, there is a common perception that the commercial world does acquisition much better than the DoD. We often hear terms like "commercial business practices." During the 1990's, Air Force Material Command was instructed to run much more like a business. The GAO even compared the F/A-22 acquisition process to more successful commercial firms. This is not a fair comparison. For example, consider the challenges in developing a computer system for a modern day weapon system. Put together a team that designs the computer system hardware for your aircraft and then call a company like Dell to buy these computers. You tell them that it has to handle sustained flight loads in excess of 9 Gs and loads due to vibrations that exceed 25Gs. All of the wiring has to be specially designed to protect against electromagnetic interference, electromagnetic pulses, and has to work off of three-phase power. You would like them to deliver the computers no earlier than one day prior to the need for the computer and you only need 5 delivered per month. By the way, if Dell accepts this contract, they also have to fill out weekly reports to be sent to the SPO and monthly, the top engineer has to travel to WPAFB to present the SPO with a status report. When outside agencies review your acquisition program, they will bring up charges against the SPO director for allowing Dell to overcharge the Air Force for these computers. Dell is being paid $50,000 per computer when their website has a special on PCs for $496.00. There must be corruption in the system, they will say. What the FOX and CNN reporters normally overlook is the fact that the mass production line concepts only work for mass production. A company that makes thousands of computers a day has the ability to make money even while charging incredibly low prices. These companies also don't have to send their top engineers to visit the customer on a regular basis to supply a status report on their progress nor do they have to meet specialized regulations and procedures specified by each individual customer.

4.3.5 Available Labor Force

Who is doing the "Lions Share" of the technical work and the managerial work today? How does that compare to the early 70s when the acquisition system seemed to be operating at what we consider to be its most efficient? If you go back to World War II, you see the military active duty manpower numbers drop by over 85%. The Air Force alone went from a total of 2,282,259 in 1945 to 455,515 in 1946. At its most extreme, we went from 2,372,292 in 1944 down to a low point of 305,827 in 1947. (Air Force Almanacs) Where did all of this manpower go? Under the GI Bill, from 1944 to 1949, nearly 9 million veterans received close to $4 billion from the G.I. bill's unemployment compensation program. The education and training provisions existed until 1956, providing benefits to nearly 10 million veterans. The Veterans' Administration offered insured loans until 1962, and they totaled more than $50 billion. The economic assistance provided by the G.I. bill and the Veterans' Administration accelerated the postwar demand for goods and services. (Houghton Mufflin web site). To analyze the implications of this information, let's say the average age of veterans entering college at the end of the war under the

GI bill was 25 yrs old. The average age of these veterans would be 30, in 1950. At this point, they would be settling into their first jobs having already received their diploma. These are the new hires at most of the DoD contractors across the nation. From their first day at work, they would not surprisingly be disciplined, mature, war veterans who are mostly married and starting to have children, a lot of children (more on this in a moment). These employees were serious about their work and needed very little motivation, very little supervision, and very little training with respect to how the military operates or what its general requirements were. The aerospace industry and its relationship to the military can almost be described with those very same words. As can be observed through the Hollywood movies of the era, the war put aviation on a very tall pedestal. The entire nation considered aviation to be the future so everyone wanted to be a part of it. College recruiting needed no help getting freshmen to sign up for engineering and the GIs were no different. The aviation industry had an ample supply of engineers and they were all motivated by the gallantry of aviation, not just money. The results can be seen by the historic events that occurred during the 50s in the aviation world. Maximum airspeeds increased from 957 mph in 1949 to 2,094 by 1959. Maximum altitudes increased from 71,920ft in 1949 to 125, 907 by 1959 (www.skytamer.com/Aviation-History-Famous-Historical-Flights) And there are limitless other examples. The 1950's saw more different kinds of aircraft manufactured than any other time in our history.

There was another phenomenon occurring at the same time as the explosion of the aviation industry, the "baby boom." Our 30-year-old GIs began families at the same time as their new careers in industry. This fact leads to the following analysis. Between 1950 and 1970, our veterans were making a name for themselves as revolutionaries in the aviation world and their children were growing up and going to college to be like their parents. Again, their children saw taking engineering in college as a great career option and going into the defense industry to help fight against the all powerful and evil communists as a logical choice (at least for those entering college by the mid 60s). Most workers in this generation were loyal to only one company and usually worked there their entire career. By the end of the 60s, the manpower structure was built using the 50-year-old veterans as the upper management and their historically large number of children acting as an ample supply of engineers starting careers to take their place. The new hires had a few differences than their bosses. This younger generation was not made up of war veterans for the most part and hence required a little more training. In the early 70s we had an event occur (the end of the Vietnam War) that had manpower affects similar to the 1945-1946 military drawdown but not nearly of the same magnitude.

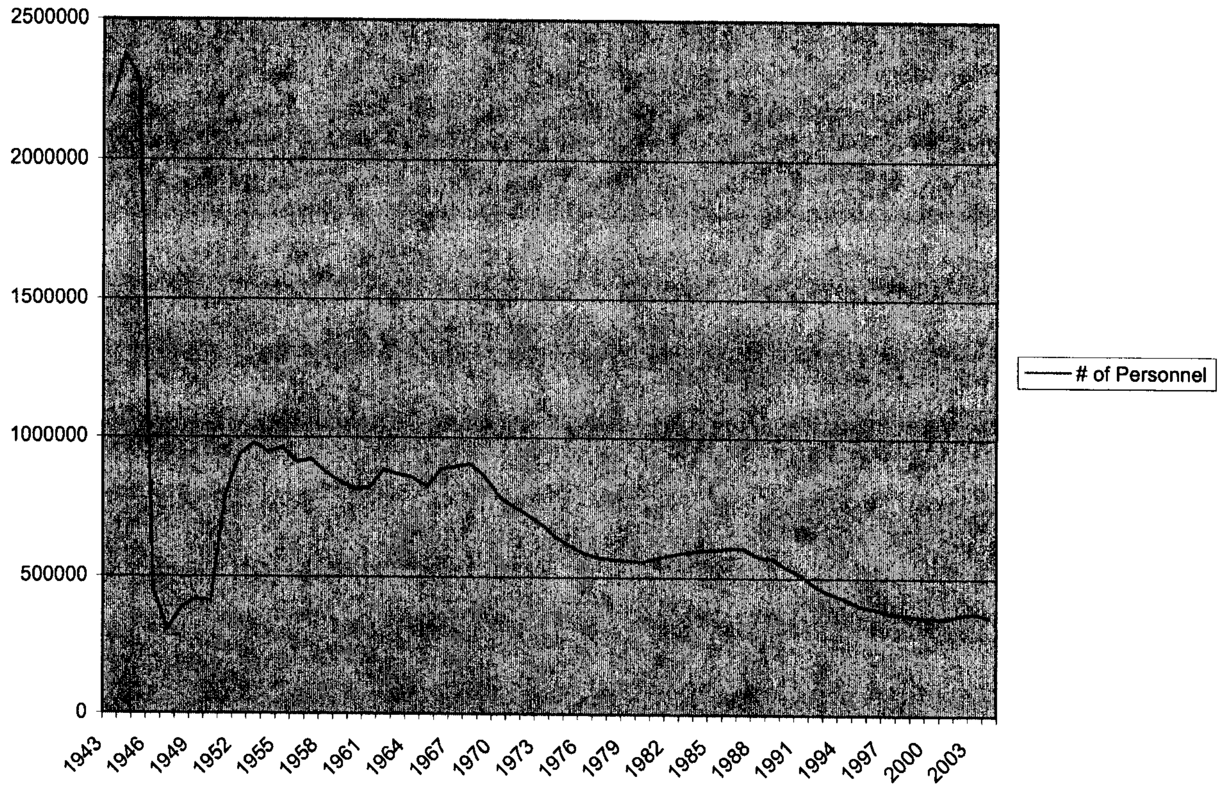

Figure 15: Air Force Total Personnel Strength Numbers (Air Force Almanacs)

The Air Force reduced it's manpower by over 35% between 1968 and 1976. (AF Almanacs) This represented over 300,000 veterans being released into the job market but the enthusiasm for the aerospace industry was reduced significantly. The GI bill still was available for these veterans but the anti-war sentiment took its toll. A snapshot of the DoD contractors reveals a fairly healthy industry due to the very experienced and motivated management tied in with a motivated engineering workforce from the end of the 60s. This is the work force considered responsible for several extremely successful acquisition programs. Those programs include the development of the "world's greatest air superiority fighter", the F-15 Eagle, the "safest single engine fighter produced in Texas", the F-16 Fighting Falcon, and the elegantly simplistic and devastatingly effective A-10 Warthog. This group of veteran managers continued to be productive during the Reagan administration of the 1980s. In fact, these workers would ultimately be joined by throngs of new recruits as President Reagan pushed military spending through the roof and the aerospace industry enjoyed record sales across the board. In *Skunk Works*, Ben Rich recalls actually having difficulty hiring at this time. Rich remembers, "...defense industry sales increased 60 percent in real terms and the aerospace workforce expanded 15 percent in only three years – from 1983 to 1986." (Rich, 1998) However, over time, this aerospace boom began to decline and the veteran aerospace workers, along with the regular graduating classes of the 1970s began shifting their enthusiasm over to a new field. This field of study began to steal the glamour away from aviation and space; computers. From the mid seventies to the present day, you can not talk about your technological work force without starting with your computer experts. That is the field with the most exciting advancements occurring which draws not only money but the future majority of the college students. The late seventies and early eighties is hence the beginning of a hard to see, insidious reduction in the available new hires that are technically competent and highly motivated by their jobs (not just the money). This generation has been labeled "Generation X." As the eighties and nineties rolled on, the computer industry along with the "dot com" industry seriously competed with the aerospace industries contractors, NASA, government laboratories, and the military acquisition community for quality engineers. The WWII veterans began retiring at a rapid rate in the late eighties and early nineties, a new government culture of increased supervision and micromanagement took hold of the industry and if that were not enough, the end of the cold war fired up anti-acquisition political rhetoric resulting in reduced defense spending and the well documented "procurement holiday" of the 1990s. There are many more factors and externalities affecting today's acquisition community but, any discussion without an analysis of the composition and supply of manpower is incomplete.

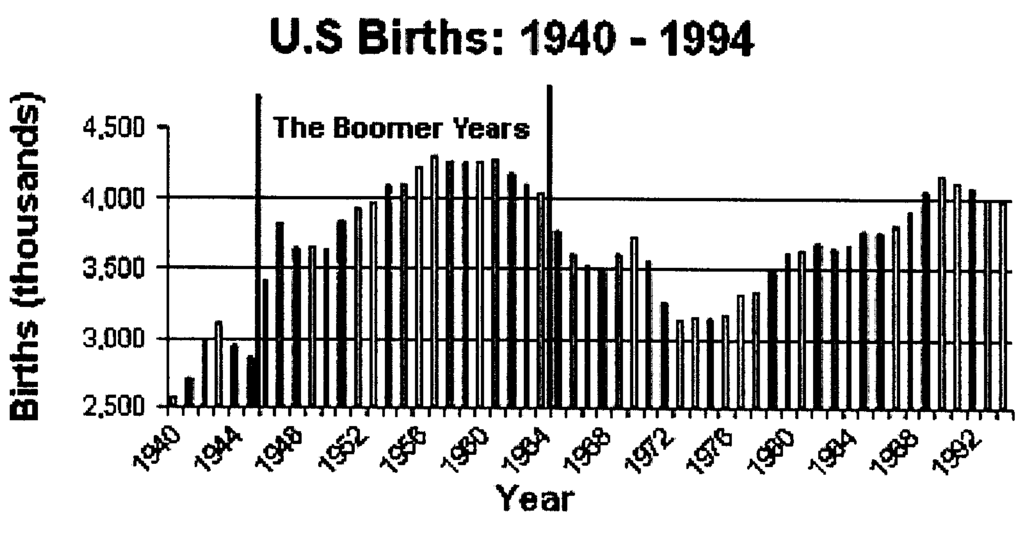

Figure 16: U.S. Birth Rates

Using the years 1946 through 1964 as boundaries, boomers are now (in 2005) between 41 and 59 years old. As of 1996, when the boomers were between 32 and 50, the Census Bureau reported the age of Americans as follows. Again, the number for each age group is in thousands.

21-25	18,197	**36-40**	**22,001**	51-55	13,052	66-70	9,045
26-30	19,339	**41-45**	**19,617**	56-60	10,884	71-75	8,460
31-35	**22,251**	**46-50**	**16,598**	61-65	10,003	76-80	6,246

4.3.6 Climate Conclusions

An aircraft acquisition is a dynamic process with many external actors exerting pressure. There were many external changes to the threat, work force, and as mentioned in previous sections, budget and technology. Although very hard to quantify, these changes are bound to have an effect on the outcome of any weapon systems.

4.4 Acquisition

Another obvious area to look to for longer acquisition times is the acquisition system itself. Could the process used by the Defense Department be part of the reason for the extension in time to acquire new systems? The system in use has changed several times over the last few decades, there is a lot of 'red tape' in the entire acquisition process, and at times the services ask for too much.

4.4.1 Acquisition Reforms

To start, today's system is vastly different from systems past. From the Revolutionary War to 1996, the Congress passed over 4000 acquisition related statutes, the General Accounting

1971	DODD 5000.1 (Major Systems Acquisitions)
1972	Commission on Government Procurement
1973	DODD 5000.4 (Cost Analysis Improvement Group)
	DODD 5000.3 (Test and Evaluation)
1975	DODI 5000.2 (Major Systems Acquisitions)
	DODD 5000.28 (Design to Cost)
1976	OMB Circular A-109
1978	Defense Science Board Acquisition Cycle Task Force
1979	Defense Resource Management Study
1981	Carlucci Initiatives; Defense Acquisition Improvement Program
1982	Nunn-McCurdy (Thresholds)
1983	Office of Federal Procurement Policy Act
	Grace Commission
1984	DOD Authorization Act (Public Law 98-94)
	Competition in Contracting Act (CICA)
1985	DOD Procurement Reform Act
	DOD 5000.43 (Streamlining)
1986	Packard Commission
	Goldwater-Nichols Department of Defense Reorganization Act
	Defense Procurement Improvement Act
	Defense Acquisition Improvement Act
1987	DODD 5134.1 (Undersecretary of Defense, Acquisition)
	DODD 5000.49 (Defense Acquisition Board)
1989	Defense Management Review
	Ethics Reform Act
1990	Defense Acquisition Workforce Improvement Act
1991	Revised DODI 5000.2 (Major Systems Acquisitions)
	Section 800 Panel created by 1991 National Defense Authorization Act
1994	Defense Acquisition Reform
	Federal Acquisition Streamlining Act (FASA)
1995	Federal Acquisition Improvement Act (FASA II)
	Air Force Lightning Bolts 1
1996	Federal Acquisition Reform Act
	Clinger-Cohen Act
	Rewrite DOD 5000 series
1999	Air Force Lightning Bolts 2
2000	Revised DOD 5000 series
2002	Agile Acquisition Initiatives (Air Force Lightning Bolts 3)
2003	Rewrite DOD 5000 Series

Figure 18: Acquisition Initiatives and Legislation (Scofield, 2004)

Office has issued more than 900 reports, and since World War II 12 major commissions (see figures 17 and 18) have made acquisition reform recommendations. (Reeves, 1996) In a climate such as this, it is impossible to efficiently acquire a major weapon system when the rules are in constant change.

1949	Hoover I
1953	Rockefeller Committee
1953	Hoover II
1961	McNamara Initiative
1970	Fitzhugh Commission
1972	Commission on Government Procurement
1983	Grace Commission
1985	Packard Commission
1989	Defense Management Review
1993	Section 800 Panel Report
1993	National Performance Review
1994	Federal Acquisition Streamlining Act

Figure 17: Major Defense Acquisition Reform Studies, Commissions, and Panels (Reeves, 1996)

4.4.2 Acquisition Process

One of the consequences of our heavy bureaucratic systems is a vast amount of briefings, road shows, justifications, etc. that must be given during any acquisition. All of these items take time away from the 'real work' and add to the time required to complete a project. According to Ben Rich, "...the most obvious place to start in achieving greater efficiency is to ferociously attack unnecessary bureaucratic red tape and paperwork." (Rich, 1994) He came by this opinion after leading the Skunk Works while the F-117 program was shrouded in secrecy and then after the program became more "white" and, hence, subject to greater scrutiny and reporting requirements. Near the end of the program, Rich was saddled with a team of government auditors. In his book, Rich quotes one of these auditors inadvertently summing up the problem with excessive oversight. The auditor is alleged to have said, "Mr. Rich, let's get something straight: I don't give a damn if you turn out scrap. It's far more important that you turn out the forms we require." (Rich, 1994)

4.4.3 Air Force Acquisition Professionals

As mentioned in section 4.2.6, there are fewer Air Force officers in the acquisition profession (see section 4.2.6). Another aspect of this manning issue is high turnover rates, especially in the all important area of program management. The GAO noted, "Since the JSF program began, a little over 8 years ago, the program has had five program managers—a new program manager assigned about very 2 years. The development program is estimated to last another 9 years, and it is likely that the program manager currently involved in decisions about key program elements such as design, cost, and schedule will not be responsible for seeing JSF through its completion. In other words, plans accepted now will likely become the responsibility of future program managers." (GAO, 2005)

Lt Col McNutt's research also addressed the problem of high turnover rates. He pointed out that for a program taking 11 years to complete (not at all unreasonable), management turnover would be as depicted in figure 19 (McNutt, pgs. 48-49).

Position	Number
Program Director	4
Program Executive Officer	5
Service Acquisition Executive	8
Defense Acquisition Executive	8
Chairman of Joint Chiefs	5
Secretary of Defense	7
President	3
Budget Cycles	11

Figure 19: Management Turnover for 11-year Acquisition Programs

This high turnover may lead to instances of not implementing the best solution since by the time a problem arises, the current program manager will be gone. In other words, it will be someone else's problem to deal with later. Shorter acquisition times would lend itself to a single program manager who is responsible for the entire program; start to finish.

4.4.4 Spiral Development

Recent acquisition programs have had the tendency to ask to the 'whole enchilada' up front, versus fielding a baseline product with planned upgrades; commonly referred to as spiral development. Using the F-15 as an example, the first Eagle was delivered as an F-15A. Shortly thereafter, the F-15C was introduced which brought with it a host of upgrades and modifications making the F-15 even more lethal. The Multi-Stage Improvement Program followed with even more upgrades and increased combat capability. The final step was a new aircraft; the F-15E.

This platform had a completely different mission (air-to-ground versus air-to-air), yet was based on the F-15 platform.

By contrast, the plan for the F/A-22 was to deliver an aircraft that had all of the pieces in place from the start. The F/A-22's acquisition approach was to deliver the 'whole enchilada' from the first production article, instead of delivering a portion of the projects capabilities then upgrading at a later time. In addition, according to the GAO, the F/A-22's acquisition approach was not knowledge based or evolutionary. It attempted to develop revolutionary capability in a single step. This caused technology and design uncertainty, which led to cost overruns and schedule delays. (Sullivan, 2005)

4.4.5 Contractor Teaming

The acquisition climate of today's military causes competing contractors to join forces in an effort to pool resources and win contracts. This has a variety of repercussions throughout the industry and the government. First, it reduces the number of eligible companies competing for contracts. This, in turn, reduces the number of ideas and designs submitted for a typical RFP. Obviously the number of proposals for a government to choose from is less, which may lead to inferior designs.

Second, this contractor teaming increases the amount of time required for a project to be completed. With more than one company working on a project, the communication required increases, the coordination required increases, etc. The net result in a process that takes longer and is subjected to more oversight and red tape than an equivalent single company project would be subjected.

4.4.6 Acquisition Conclusions

The process used by the DoD to acquire new systems is in need of repair. The risk we run is one of obsolescence; the amount of time it takes to develop and field a new system is too long compared to the rapid change in technology. Lt Col Vollmecke says it best, "The pace at which we develop weapon systems is too slow to keep up with the pace of technological change. Because of this mismatch, the acquisition process produces 'yesterday's capabilities for tomorrow.'"

The changes implemented in May 2003 in the form of two directives (DoD Directive 5000.1, The Defense Acquisition System, and DoD Directive 5000.2, The Operation of the Defense Acquisition System) may have the desired effect of streamlining the process of acquiring new weapon systems. Only time will tell, but we have traveled this road before.

4.5 Schedule

Lt Col Ross McNutt's work is particularly revealing in the area of schedule. His dissertation presents a compelling argument that we in the government do not appropriately value time and, as a result, we fail to place a priority on reducing schedules. However, in reviewing Lt Col McNutt's work, we found that although the implementation of his recommendations would almost certainly result in reduced cycle time, there is no evidence to suggest that the problems he has identified are causing the growth in cycle times. That is, the lack of appreciation for the value of time, lack of schedule related information, unstable funding, and other factors Lt Col McNutt points out were most likely present at least to some degree when the F-15, F-16, and A-10 were developed, just as they are today. That said, his work is still highly instructive and anyone seeking to reduce acquisition cycle time would be wise to read it. The following are some of the more applicable observations from Lt Col McNutt's dissertation.

4.5.1 Schedule Proposals

Among Lt Col McNutt's observations is the fact that government contractors tend to base their proposed schedules on the program office's expected schedule. These contractors do not have any incentive to bid anything different. Moreover, this attitude is reinforced by government personnel. In the course of his surveys of government program managers, Lt Col McNutt found that, "...project managers stated that different schedules [than the one calculated by the program office] are presumed to carry higher risk or be non-responsive." (McNutt, 1998) This analysis is borne out in figure 20. Lt Col McNutt asked contractors to rank five factors in schedule determination from "no impact" to "sole determinant." One of those factors was the customer's desired schedule. It would seem that the responses regarding that factor indicate that contractors base their schedules on what the government asks for rather than what is achievable or reasonable.

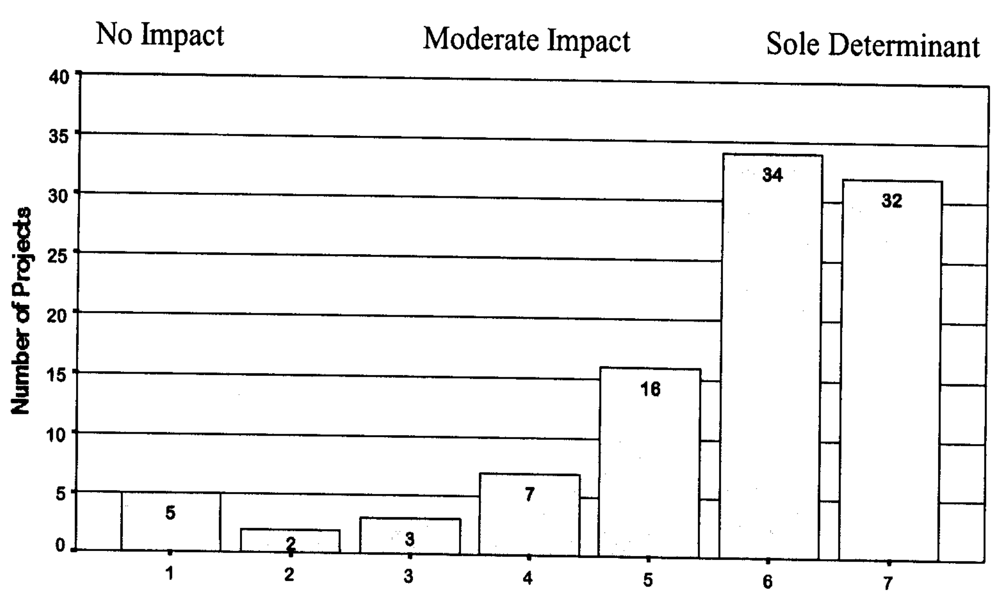

Figure 20: Customer's Desired Schedule (McNutt, pgs. 225-226)

The fact that contractors base their schedules almost exclusively on the government's predicted schedule is only a problem if the government schedule is inaccurate. If the government personnel charged with creating project schedules undertake a serious engineering analysis to determine minimum time to completion, there is no problem with contractors adhering to that estimate. After all, in some cases technology concerns, testing, and other factors may dictate that a drawn out schedule is appropriate. However, according to Lt Col McNutt's research, government schedules are often created with more regard for funding availability than the engineering to be done. He surveyed program offices regarding 130 projects to determine the impact various potential sources of schedule information had on their estimation. His findings in this area are reflected in figure 21 below.

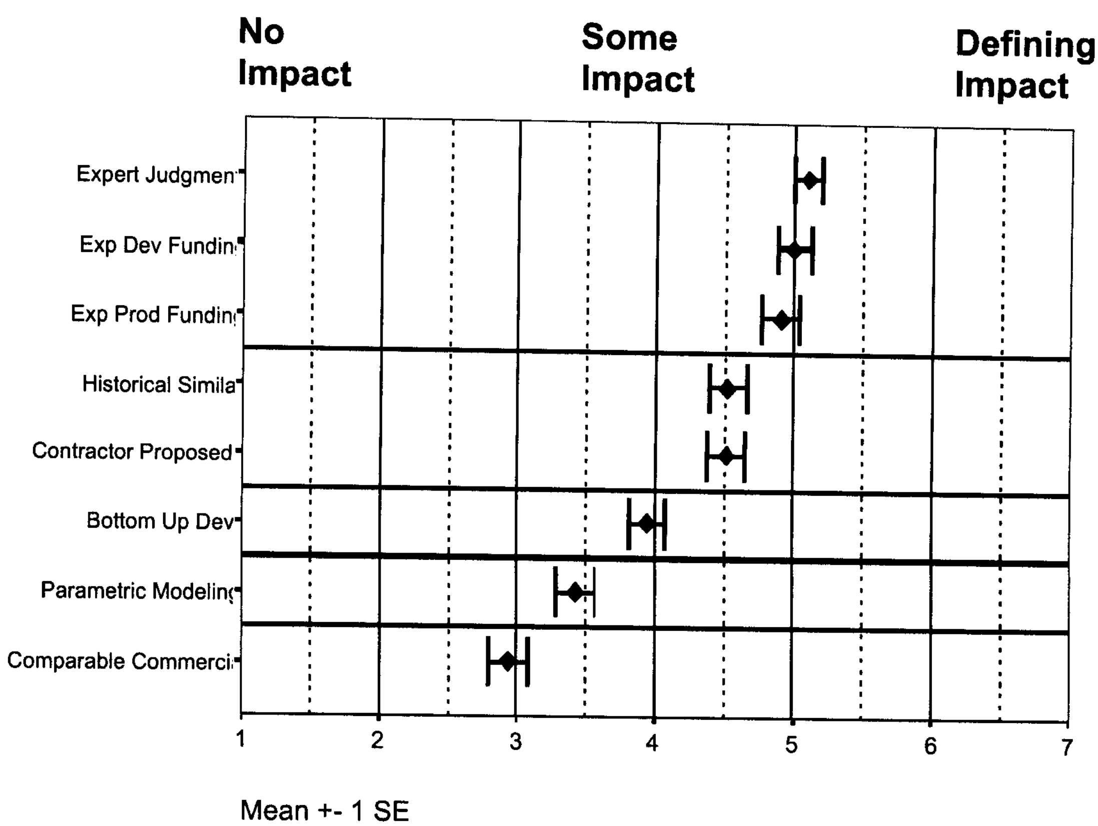

Figure 21: Impact of Potential Sources of Schedule (McNutt, pg. 214)

According to Lt Col McNutt, this attitude among government acquisition professionals is reflected in the perceptions of contractors. His research revealed that, "Some 73 percent of contractor project managers indicated that the Program Office did not provide any incentives, or in some cases provided negative incentives, to shorten schedule." (McNutt, 1998) Overall, Lt Col McNutt's survey of contractors working some 102 projects revealed that this feeling is common throughout industry. These results are summarized below in figure 23.

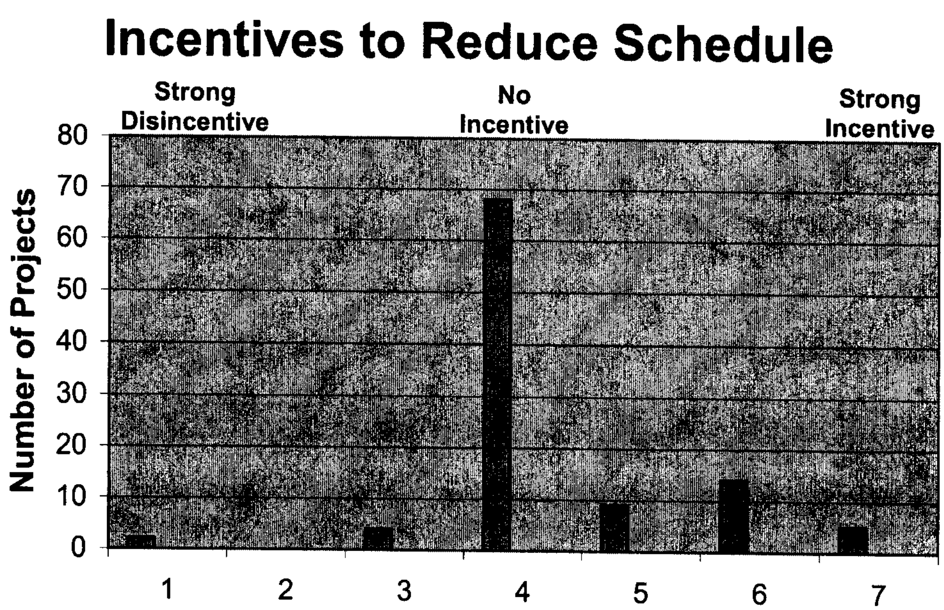

Figure 23: Incentives to Reduce Schedule
(Chart Adapted from McNutt, pg. 260)

4.5.3 Schedule Conclusions

The preceding discussion is only a snapshot of the work Lt Col McNutt did. His dissertation is 344 pages long and cannot possibly be fully summarized within this report. However, we felt that the concepts summarized herein were the most applicable to our project.

As mentioned at the beginning of this section, it is entirely possible, even likely, that the attitudes uncovered by Lt Col McNutt's research were also present at the time of the development of the F-15, F-16, and A-10. For that reason, we feel it is unlikely that these factors are causing the growth in cycle times themselves. Moreover, we are not suggesting that by simply appreciating the value of time we can overcome the very real barriers to expediency that exist. Just knowing that faster is better does not make more funding appear, nor does it reduce technological uncertainty. However, if we can address the areas he highlights in his work, we may be able to improve the cycle times.

5 Conclusions

5.1 Conclusion

Daniel Aronson, in his paper "Overview of Systems Thinking," states that, "So many important problems that plague us today are complex, involve multiple actors, and are at least partly the result of past actions that were taken to alleviate them." (Aronson, 1998) We feel that this sentence perfectly describes the problem we were asked to study.

In studying the acquisition of fighter aircraft, we have chosen to view it as a system and therefore to apply systems thinking. For this reason, we do not feel it is justified or wise to look for a single "silver bullet" that could be implemented to reduce the acquisition cycle time. To do this would be to attempt to break the system down and analyze it in a piece meal fashion. Rather, we see the growth in acquisition cycle times as the product of a general trend within each part of the system toward slower response to operational need. In the preceding pages we have identified facets of the acquisition system which we feel play a role in creating the problem at hand. What we do not do, however, is rank order those causal factors or attempt to identify the "one" that is the real problem. Each factor contributes to the delay and each must be addressed if the delay is to be reversed.

Our analysis focused on the budget, schedule, technology, climate, and acquisition policy. We have demonstrated that there has been a decline in the amount of money spent on military aircraft over the past several decades. Moreover, the fact that our budget comes to us annually creates instability and inefficiencies within the system. Also, our review of Lt Col McNutt's work revealed that the general attitude among acquisition professionals and contractors alike is that schedule is an outcome rather than a goal. Adding to the problem, the technological complexity of the aircraft we buy continues to increase. This, of course, drives the need for more development time and additional testing and leads to further delays in fielding new systems. All of these problems attack a system which exists within a climate characterized by a lack of a peer competitor and the sense of urgency one would engender. Furthermore, the workforce building these systems has changed dramatically since the days of the F-15 and F-16. Finally, possibly fueled by frustration with the lethargic pace of our acquisition system, managers within the Pentagon and Congress continue to levy additional rules and increased oversight. If we address any of these areas individually, we are likely to see short term improvements. However, only by addressing them all can we hope to reverse the current trend toward outrageous cycle times.

For example, suppose we decided to dump money into the F/A-22 program in the hope that an infusion of cash would speed the program up. Most likely, this would have some positive impact on the program. However, if Lt Col McNutt is correct, the people working the Raptor program would still view schedule as an outcome, seeking only to stay on schedule without any incentive to get ahead. In the same way, the addition of funds into the program would not erase the impact of immature technologies cited in the 2003 GAO study referenced in section 4.2.3. The F/A-22 program would still exist in a culture that sees it as having no immediate threat to face. It would also still rely on a reduced pool of aerospace workers to build it. Finally, if we add more money to the program, it will still be saddled with the reporting requirements and scrutiny that slows down any modern acquisition effort. Indeed, an increased bottom line would probably result in even more oversight! The point is that the acquisition system is precisely that – a system. To improve that system's performance we must apply systems thinking.

In short, yes, it is taking longer to develop new aircraft than in the past. The reason for the slowdown boils down to a general trend within the system toward a slower pace. Basically, the development of a new weapon system requires certain things and can be hindered by others. One needs money, government acquisition professionals, a dedicated aerospace workforce, and a sense of urgency if one intends to develop a fighter aircraft. We have demonstrated that the acquisition system of today has less of all four of these things. In contrast, we have plenty of oversight, reporting requirements, and convoluted organizational charts. Unfortunately, these are the things we could live without.

5.2 Areas Requiring Further Study

5.2.1 A helpful study would be to investigate the development time for different families of aircraft from the beginning of the Air Force in 1947 to today. The goal would be to see if there is indeed a statistically justified trend or if the F/A-22 and F-35 are just outliers.

5.2.2 Complete case studies of the aircraft acquisitions of the 1980's and 1990's would provide lessons learned. Candidates could be the B-1, B-2, C-17 and F/A-22.

5.2.3 Each section of our study, budget, technology, climate, acquisition and schedule could be studies in further depth.

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