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MICHAEL S. MUTTY

A COMPARISON OF MILITARY AND COMMERCIAL AIRCRAFT DEVELOPMENT

ABSTRACT

When compared to the commercial sector, it takes the military almost four times longer to develop an aircraft. For example, Boeing Company developed the 767 jetliner in about four years whereas the Navy's next generation tactical aircraft, the AX, is expected to take 15 years to develop.

This research paper examines both commercial and military approaches to aircraft development. The paper focuses on establishing whether or not commercial practices, where more cost effective, can be incorporated into the military acquisition system.

The paper illustrates that aircraft development in the commercial and military are different for two fundamental reasons. First, military aircraft development exploits the latest untested developments in technology where the commercial sector relies only on existing technologies. Second, a commercial aircraft is developed for the single mission of ferrying passengers and cargo. Military aircraft are required to perform far more varied and different missions with each parameter driving its own unique challenge for design and testing.

This research paper concludes that without similar mission requirements, there are few commercial applications that can be applied to military aircraft development.

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A COMPARISON OF MILITARY AND COMMERCIAL AIRCRAFT DEVELOPMENT

by

Michael S. Mutty

INTRODUCTION

Current planning for the Navy's next generation attack aircraft, the AX, calls for the airplane to be designed, developed and placed in service in about 15 years. While this time span is similar to the time associated with the development of equivalent military aircraft, compare it with the Boeing 767 which took about four years. In some ways, the development process is quite similar between the commercial and military sector. In many respects however, the two acquisition systems differ radically because the technical and economic challenges are quite different between the two sectors.

In either sector, a new aircraft program is initiated when a requirement (military sector) or market void (commercial sector) is defined. In each sector, a new aircraft eventually rolls off the assembly line. What happens in between will be the primary focus of this paper.

With the end of the Cold War, Department of Defense (DOD) decisionmakers no longer have the luxury of meeting perceived threats with carte blanche solutions. Since future investment budgets in the DOD are expected to contract, DOD decisionmakers, like their commercial counterparts, will be further constrained by economic realities. Accordingly, this paper will compare and contrast the two approaches to aircraft development. The focus will be on establishing whether or not commercial practices, where more cost effective, can be incorporated into the military acquisition system. The following sections present a phase by phase comparison of commercial and military aircraft development.

THE PHASES OF AIRCRAFT DEVELOPMENT

INITIATION

As noted above, the first step in initiating an aircraft development in the commercial sector is the definition of a market void. In the mid-1960s, Jaun Trippe, then the Chief Executive Officer of Pan American Airlines, experienced an impressive 15 percent annual growth rate in passenger traffic. Altschul and Bender noted,

> "In the past, government-paid research and development for military aircraft had yielded dividends in commercial derivatives. In September 1965, the [C-5A] contract was awarded to Lockheed, with GE designated as the engine maker.

As soon as the news came out of Washington, Trippe placed a call to Courtland S. Gross, the president of Lockheed. 'Congratulations,' he said. 'Shall we talk about a commercial ship?'"[1]

Anticipating a full plate, Gross would not commit Lockheed to a commercial version of the C-5A jumbo jet. Undaunted, Gross turned to Boeing and a letter of intent for the Boeing 747, with initial deliveries to Pan Am scheduled for November 1969, was signed on December 22, 1965. In securing board approval of Trippe's decision to buy the 747, Altschul and Bender observed, "The only thing they [the Board of Directors] were unsure of as they entered the boardroom was what Trippe was going to do about it; he took none of them into his confidence. As usual, the outside directors had the sketchiest information on which to base their approval of Jaun's fait accompli."[2] Thus launched one of the most successful commercial aircraft developments in history--the Boeing 747.

The Navy's A-12 aircraft program was canceled by the Secretary of Defense on 7 January 1991. While canceling the A-12 program itself the Secretary reaffirmed the need for the Navy to develop the next generation attack aircraft to replace the aging A-6 Intruder. Further, on 9 January 1991, the Secretary of the Navy directed his Service Acquisition Executive (SAE) to immediately start work for a replacement program for the A-6.[3] The replacement program was dubbed the AX. Given this high level support from both the Secretary of Defense and the Secretary of the Navy, it is not unreasonable to conclude that the AX can be used as an example of a program that was on a "fast track" for program initiation. In the acquisition arena, the DOD's equivalent of a corporate Board of Directors is the Defense Acquisition Board (DAB). Even though the AX was considered to be on a fast track, permission to initiate the program, or in DAB terms, a Milestone 0 decision was not made until July 1991, seven months after the A-12 was terminated. It was another five months before study contracts for concept exploration and definition were signed. In comparison, Boeing and Pan Am signed the definitive contract for the 747 only four months after the initial letter of intent was executed.[4]

Many military Program Managers feel that the road to program initiation is filled with pitfalls and indeed it is. However, in both the military and commercial sectors the initiation of the program is the easy part. This is due primarily to the limited level of investment authorized by the respective approving boards. In the case of the 747, Pan Am could have canceled the deal up until the point that Boeing had secured additional customers, an event not likely until the program was better defined. In today's environment, airlines frequently "initiate" a program by expressing an interest in the next generation aircraft. The aircraft manufacturers, Boeing, McDonnell and Airbus take the professed interest as a signal to commence product definition studies with no financial commitment from potential customers. In the case of the

AX, the DAB approved an investment of about $100 million to conduct concept exploration and definition (CE&D) studies. While $100 million is a significant amount of money, it is relatively minor when compared to the total AX program investment. In either sector, difficult decisions, especially a commitment to buy a new airplane, are deferred until the program is better defined.

PROGRAM DEFINITION

The classified tentative operational requirement (TOR) for the AX consisted of numerous and varied desired capabilities. The desired capabilities are based on inputs from several communities, including Navy attack pilots, Navy fighter pilots and different Air Force aviation communities. Thus a variety of "customers" framed a wish list that would require an airplane that would exceed affordability goals. Furthermore, government engineers held that such an airplane could not meet all of the desired characteristics without defying the laws of physics. While one could conclude that the Navy is a single customer with a monolithic requirement, nothing could be further from the truth. In effect, the conflicting requirements of the many varied communities contributing to the AX TOR presented potential AX contractors not with a monopsony but with a situation similar to that faced by their commercial counterparts, a large number of customers. As in the commercial sector, the key to success was to satisfy as many customers as possible with an affordable product.

According to the AX Program Manager's pre-solicitation presentation to the potential AX offerors, CE&D work was to be focused into two areas, including trade studies and risk reduction/proof of concept. The trade studies were expected to result in design critical trade offs which would lead to a more realistic operational requirement. The contractors were also encouraged to propose risk reduction/proof of concept work unique to their design concept. Trade studies were the contract deliverables and the underlying expectation was that a preferred design fulfilling the needs of the maturing operational requirement would be developed. In short, the government was relying on airframe contractors to recommend the best approach to maximize the solution to the "shopping list" represented by the TOR and its many customers.[5]

In contrast to the Navy's structured program, the commercial sector relies on a different approach. In a sense, the government frequently assumes the active and structured role as the buyer whereas in the commercial sector, the manufacturer or seller takes the more active role. The seller's approach ranges from a relatively informal discussion with customers to setting specific parameters for program initiation which is known in the commercial aircraft industry as "launch criteria". For example, Aviation Week reported the following in an article discussing the next generation large aircraft:

"The Boeing Co., in response to a strong interest expressed by Pacific Rim airlines, is forming a customer advisory group to help define a new or derivative large aircraft capable of carrying approximately 650 passengers".[6]

Reflective of the other end of the spectrum are the formal key phases in commercial aircraft development which were presented to the Naval Air Systems Command by McDonnell Douglas Corporation (MDC) on 19 June 1991. These steps included concept development/business capture development where an iteration of designs (new or derivative) is compared with market potential. The business plan/design development phase includes the advanced design of the selected concept, iteration with prospective customers and business considerations such as estimates of development costs and purchase price. The authority to offer is that point at which the MDC Board of Directors approves proceeding to offer a design at a price to potential customers. The launch criteria or the number of firm orders required from domestic and foreign airlines prior to go ahead is set. Finally, MDC generally proceeds with long lead activity until launch criteria is met.[7]

From the discussion above, it is clear that the fundamental differences between the commercial and military sector during this phase of development are twofold. First, once the launch criteria are met, the commercial customers are committed and the airplane goes right into production, often without prototypes. Second, the commercial customer has little influence over detailed aircraft design issues. Generally, prototyping is not necessary because the selected technology is fairly well understood.

In a 1986 Defense Science Board Study, "Commercial Airplane Procurement Practices (767 Airliner Case Study)", the summary report noted that:

> "The Technical Staff at Boeing is constantly monitoring developments in various technology fields and carrying on research to extend the technology needed for more efficient airplanes. The general philosophy of new programs is to choose technology levels that are well understood but which may require considerable development for production implementation. The selection is dependent on the time of program go ahead." The report further stated, "...more advanced systems such as fly-by-wire, fly-by light, flat panel video displays, and high levels of stability augmentation were left for future airplanes. Similar decisions were made in the area of propulsion."[8]

With respect to the design involvement, commercial manufacturers and their customers usually discuss top level design requirements such as capacity, range and reliability which all contribute to seat mile costs or customer profitability. The detailed technical tradeoffs are generally done by the manufacturer without close coordination with their customers. In lieu of technical coordination, the commercial aircraft buyer relies on key performance guarantees and warranties.

DEMONSTRATION AND VALIDATION

Because military aircraft development programs do not rely on existing technologies but rather seek to test the limits of science and research, another step is built into the process. DOD Directive 5000.1 requires a phase entitled Demonstration and Validation (D&V). In a sense, the mature technologies adopted for use in a commercial aircraft have already been demonstrated and validated. Therefore, one might argue that commercial D&V, although not formally identified as such, is done in an earlier phase--prior to program initiation. In any event, the nature and magnitude of the military D&V phase merits some discussion.

The primary focus of the planned AX Demonstration and Validation program is risk reduction [prior to entering into Engineering and Manufacturing Development or (E&MD)] and proof of concept flying prototypes. In the AX pre-solicitation brief, the Program Manager stated that he expected the D&V phase to last four to five years. The contractor will be expected to perform operational capability trade offs as the perceived threat evolves. Risk reduction includes not only proving state of the art aircraft and avionic technologies but enhanced manufacturing techniques, as well. Although there is some technical disagreement over the value of flying prototypes, they are mandated by Congress and, therefore, will be built.[9]

In the D&V phase, the myriad of government specifications and other requirements will, for the most part, be used for guidance only. The contractor will be encouraged to trade off specifications in an attempt to introduce cost effective requirements.

One of the more important deliverables under the D&V contract will be the specification used to enter into the E&MD phase. Here, the divergent development paths of the military and commercial arena begin to converge again.

ENGINEERING AND MANUFACTURING DEVELOPMENT

Under DOD Directive 5000.1, the E&MD phase is the precursor to the Production and Deployment (P&D) phase. Engineering tasks are geared towards designing the aircraft to fulfill the requirements of a detailed design specification. During the course of E&MD, DOD engineers are intimately involved in detailed design decisions. Progressive reviews are contractually required including Initial Design Review (IDR), Preliminary Design Review (PDR) and finally, Critical Design Review (CDR). In theory, CDR is that point in the contractor's design of the aircraft where government engineers are satisfied to the extent that significant aircraft fabrication is undertaken. Each individual phase of the design review process may involve hundreds of engineers and may take months to complete and the level of review becomes very detailed. For example, during the A-12 CDR, seemingly mundane issues such as access door fasteners took weeks to resolve.

Commercial customers are not necessarily precluded from design decisions, however, there is no direct comparison to the military design review process. In fact, past practices actually discouraged detailed customer involvement in design decisions. "Designers used to resent it even more when customers put in their two bits. Gordon A. McKinzie, United's 777 program manager, says he spotted rolling eyes when Boeing engineers learned that United and the No. 2 customer, All Nipon Airways Co., would be snooping around."[10] If it weren't for Boeing's investment in a European developed solids-modeling program called Catia, customer involvement in detailed design decisions would probably continue to be discouraged.[11]

Programs like Catia have enabled design teams to effectively implement a new design philosophy entitled concurrent engineering (CE). Briefly, CE is a process whereby a team of representatives from different disciplines such as production, maintenance and outside suppliers are co-located with the design engineers. Before the design is frozen, the manufacturing representative can review it from a producibility perspective. This review saves costly redesign because non-producible parts can be redesigned before the mistake is discovered on the assembly floor. In a similar fashion, maintainability and other "ility" issues are accommodated earlier in the design cycle. Historically, many "ility" issues raised later in the design cycle could not be accommodated because the costs associated with a redesign were prohibitive.

Unlike earlier development programs, Boeing's new philosophy has allowed some customer input into some 777 design decisions. United's McKenzie listed the following items that were impacted by his airline's early involvement in the design process: hydraulic accumulator, trailing edge flaps, push buttons and access.[12]

Unlike the government's involvement in detailed design decisions, commercial involvement is still quite superficial. A recent article in Aviation Week treats United Airline's early involvement in early 777 design decisions as almost revolutionary. In discussing the trailing edge flap, the article noted:

> "This control surface on the 777 is 43 ft. long--longer the same device on the 747. For manufacturing reasons, Boeing wanted to build it in one piece, using its 60-ft. autoclave for applying the high temperature and pressure required for curing the honeycomb. But United lacks and autoclave large enough to accommodate the flap for repair, and it was not

worth the investment for a single piece of structure. 'Boeing fought us on this,' McKinzie said, but the result is a structure that can be disassembled to allow repair in a smaller autoclave."[13]

The foregoing account of United's experience with the trailing edge flaps highlights another fundamental difference between the military and commercial sectors. Although trade offs between specification requirements are often encouraged, military aircraft development standards anticipate almost every known design contingency with detailed specifications to guide design decisions. In the commercial sector (with the exception of Federal Aviation flight certification requirements), only top level performance characteristics are specified by the customer.

PRODUCTION AND DEPLOYMENT

In commercial aircraft development, once the corporate launch criteria are met, a commitment to both E&MD and Production and Deployment (P&D) is made. In the military sector, P&D is not authorized until another Defense Acquisition Board is convened. As in earlier phases, the military threat or the need for the system has to be revalidated. Since the design has matured, more accurate cost data is generated to support affordability decisions. From a technical perspective, the aircraft is measured against previously specified performance thresholds. In today's environment, missing thresholds could easily spell program cancellation. While the manufacturer continues to monitor cost performance and the customer monitors aircraft performance, there is no equivalent decision point in the commercial sector. In short, the P&D decision is another sequential milestone which represents another time consuming exercise not encountered in the commercial sector.

WHY IS THERE A DIFFERENCE?

Having briefly described the steps leading to the introduction of a new aircraft, a critical comparison of the two development approaches will be discussed in the following sections. In general, the fundamental differences between the two approaches are caused by the fact that a commercial aircraft is designed for only one mission, the ferry mission or "single point design" and the timing of technology insertion.

As military aircraft become more expensive with declining defense budgets, fewer aircraft will be bought. To cope with shrinking aircraft inventories, military planners envision multi-role missions for future aircraft. For example, the Navy's AX is being developed to replace the A-6 which is a carrier based medium attack aircraft. Mindful of budget realities, the airplane is being developed in close coordination with the Air Force as a replacement for the F-111, the F-117 and, possibly, the F-15E and the F-16. In the tentative operational requirement, potential missions included air to ground, air to air, air to sea surface, mining operations, electronic warfare and so on. By comparison, a commercial cargo or passenger aircraft has one mission which is the equivalent of a military ferry flight profile.

As noted earlier, technology inserted into new commercial aircraft programs generally exists. By eliminating the need to demonstrate and validate new technology, as much as five years is eliminated from the commercial development schedule. In contrast, military aircraft development programs expand the technology envelope by absorbing the cost and time associated with state of the art technology enhancements. One example of this in propulsion technology is the high-bypass jet engine. When contacted about building a new engine for the 747 program, General Electric (GE) declined. "In short, GE didn't want to take on the 747 project, until the costs of overcoming basic problems common to all high-bypass engines had been largely absorbed by the Pentagon. GE was also worried, with good reason, about the Boeing-Pan Am timetable for the 747."[14] In other words, General Electric was content to let a military development program, the C-5A, absorb the cost and time associated with enhancing high-bypass jet engine technology. Commercial development programs have always leveraged the technology developed by the military. Systems commonplace in commercial aircraft today such as radar, identification friend or foe (IFF) interrogators, and even the jet engine were first developed for military applications.

Given the general hypothesis that military and commercial aircraft development are fundamentally different because of technological maturity and single point design, the following sections will compare each phase of program development in this light.

INITIATION

The roles played by the buyer and seller in commercial and military aircraft development programs are most similar during the initiation phase. The buyer is challenged to meet and overcome a constantly changing threat. For an airline, the threat is competition from other airlines, cost/fuel efficiency, noise abatement requirements, system capacity constraints, etc. New aircraft are required to satisfy emerging regulatory and business considerations. Similarly, DOD needs new aircraft to meet emerging military threats to the nation.

In DOD, the need must be documented and approved through formal procedures which are set forth in law and regulation. The decision to recognize a need is made by the Chiefs of Staff of the services in a forum called the Joint Requirements Oversight Counsel (JROC). The JROC is chaired by the Vice Chairman of the Joint Chiefs. Generally, the Defense Acquisition Board (DAB) grants approval to conduct concept exploration studies following JROC recognition of the need. This is known as a Milestone 0 decision.

Because minor resources (dollars) are required to execute this phase, the decision is seldom contentious and the process is normally not lengthy. In the case of the AX, the Milestone 0 decision was granted within seven months of the cancellation of the A-12.

The commercial sector does not have as rigid a process to acknowledge a need. It varies widely from airline to airline and from manufacturer to manufacturer. Although many suspect programs are launched because the investment is minimal during this phase, the DOD system provides a well conceived system of checks and balances and does not significantly contribute to the overall length of aircraft development. Accordingly, I see no commercial practices that could benefit the process prior to and including a Milestone 0 decision.

CONCEPT EXPLORATION AND DEFINITION

In the military sector, the CE&D phase is the first of a series of sequential developmental building blocks. In theory, the contractors explore different concepts as means to meet the perceived threats. A new aircraft is not necessarily the correct solution. It could be an upgrade to an existing platform or even something totally unrelated to aircraft such as the use of Cruise missiles. In the commercial sector, the solution is always an aircraft. In practice, however, the solution is, generally, a new aircraft. This is not surprising because the companies that undertake the CE&D studies are aircraft manufacturers and, therefore, have a vested interest in aircraft solutions. The CE&D phase appears to be little more than an instrument under which contractors are paid to iterate their preferred aircraft designs. Further, under what normally would be strict disclosure rules in a military aircraft competition, the CE&D phase prohibits open consultation between contractors and government engineers and military operators.

In the commercial sector, the manufacturers are not constrained by government procurement laws in terms of discussing requirements with potential customers. In addition, discussions with commercial customers are more localized in that individual airlines are generally focused and know their requirements. On the other hand, the military is so large, it is difficult for the manufacturer to receive focused requirements. The fighter community wants speed whereas the attack community wants range and payload. Carrier aviators want two engines whereas Air Force pilots do not have a strong preference. In short, without a formal process to lend discipline, aircraft manufacturers would not be able to concentrate on optimizing the preferred solution.

The Concept Exploration and Definition phase adds about one to two years to the time that appears to be required for military aircraft development. However, commercial aircraft development experiences a similar time span for CE&D. The commercial CE&D phase is done in parallel rather than in series. Like program initiation, the time allotted to Concept Exploration and Definition is well spent. Any shortcuts in this phase would, once again, inhibit the technical maturity of a new aircraft.

DEMONSTRATION AND VALIDATION

The most underlying difference between commercial and military and commercial aircraft is best illustrated during the Development and Validation (D&V) phase of aircraft development. The difference revolves not around expenses and tasks but, again, in timing. In commercial development the D&V phase is conducted in parallel, if not before CE&D; whereas in the military sector, D&V follows CE&D sequentially.

The theme underlying the systemic differences is once again technological maturity. By the time the "launch" customer is secured in the commercial sector, D&V for the initial configuration of that generation of aircraft is done. In the military sector, it has just begun.

Once again, a comparison between the technical goals of the AX in the D&V phase and the Boeing 777 in a comparable time illustrate this point. The technical goals of the AX include technical state of the art issues such as stealth or low observable, advanced materials, aircraft design in a carrier environment, radar absorbent structures and materials (RAS and RAM), software maturity, reliability and maintainability issues, advanced engine technologies and weapon separation maturity.[15]

A search of commercial periodicals reveals only one technical challenge of a similar nature which is software:

> "When Boeing's new 777 airliner first takes to the skies in a few years, computers will control such crucial functions as setting flaps, and adjusting engine speed. Electrical circuits will relay a pilot's actions to these computers, where complicated programs will interpret the signals and send out the instructions necessary for carrying out the appropriate maneuvers. Pilots will no longer fly the aircraft via direct electrical and mechanical controls, except when using an emergency backup system."[16]

Because of the safety of flight issues associated with the 777 software, reliability of the coding is critical. Unlike standard commercial development programs, Boeing was faced with a significant "known unknown" as it undertook the 777 development. "The analysis also affirms that using multiple programs, which independently arrive at an answer to a given problem doesn't necessarily guarantee sufficiently high reliability".[17]

The Boeing 777 software challenge represents something of an aberration in commercial aircraft development. When the commercial sector envisions a new aircraft, a fundamental risk reduction precept is that only technologically mature subsystems are selected. Put another way, by selecting mature subsystems, commercial manufacturers ensure that demonstration and validation has been completed. Assuming the threat is such that time is available and as long as requirements for tactical military aircraft push the state of the art envelope, a D&V phase is prudent. Accordingly, a direct comparison between the D&V phase of military and commercial development is not applicable.

ENGINEERING AND MANUFACTURING DEVELOPMENT

As noted previously, the difference in technical maturity between commercial and military aircraft development programs prevents a direct comparison during the CE&D and D&V phases. With the perceived reduced threat from the former Soviet Union and with the concomitant reduction of concurrency in military development (i.e. mature systems out of D&V), the E&MD tasks in the military and commercial sector are very similar. The tasks include the detailed design engineering and development of manufacturing processes necessary to build an aircraft. The commercial sector has to complete a rigorous flight certification program to the satisfaction of the Federal Aviation Administration whereas the military sector must pass developmental operational testing to the satisfaction of an independent DOD test organization.

Because the two sectors are comparable in this phase, the comments of a former Boeing Chairman of the Board are worth repeating. In testifying before a panel of the House Armed Services Committee in September 1980, T.A. Wilson said:

> "The development of a plan under which military procurement could take advantage of commercial practice...might have a favorable on both capacity and cost."[18]

Mr. Wilson also noted that Boeing often commits hundreds of millions of dollars in training and long lead high productivity machinery two or more years before go ahead. Ironically, the two issues raised by Mr. Wilson in 1980, commercial practices and financing, are still responsible for the major differences between military and commercial aircraft development. Another point not mentioned by Mr. Wilson was the difference in complexity between military and commercial aircraft development. This factor causes a significant increase in the time required for flight test, alone.

COMMERCIAL PRACTICES

In their presentation to the President's Blue Ribbon Commission, Boeing noted a number of successful military procurement programs that utilized existing commercial products:

"The examples with which we are most familiar are those which have used modified commercial aircraft to good advantage. Such programs are Airborne Warning and Control System (AWACS), which uses the 707 airframe; the Airborne Command Post (ABNCP), which uses the 747 airframe; the Advanced Tanker Cargo Aircraft (ATCA), which uses the DC-10 as the airframe; the Medical Evacuation Aircraft, which uses the DC-9 airframe; and the T-43 Advanced Navigation Trainer, which uses the 737 airframe. This is not an exhaustive list but it makes the point."[19]

The aerodynamic mission for all the examples cited by Boeing replicates the commercial ferry mission of the airlines. The list of successful commercial product acquisitions is impressive, it predates the Navy's difficulty with E-6 aircraft. The E-6 is a Boeing 707 modified to trail a communications wire. During tests of the flight profile required for E-6's mission, parts of the vertical tail fell off. The 707 had been in service for almost four decades yet when an expanded envelope was required for the E-6's mission, nobody predicted that the tail would fail. This point illustrates that even with identical aircraft, military missions may be different than that of the airlines which results in additional flight test (time and money).

In the 767 program which was delivered to its first customer four years after go ahead, flight certification was granted by the

FAA within nine months of first flight.[20] In comparison, notional planning schedules for the AX envision a three year flight test program.[21] The difference in flight test programs is that the FAA is concerned primarily with safety of flight for the ferry profile. Their primary tests include structural strength, design margins and engine out work. The AX flight test includes over 7,000 flight test hours of which only 12% are associated with safety of flight type issues for the many missions that the AX has beyond the ferry mission. Additionally, through the designated engineering representative (DERs) and designated manufacturing inspection representatives (DMIRs)programs, the FAA allows the contractor to perform many of the engineering and manufacturing reviews itself with little government involvement. These functions are generally reserved for government representatives in military development programs. In short, military aircraft fly significantly more flight profiles with more complicated and additional suites of avionics. The philosophy of flight testing may be similar but the sheer quantity of military profiles to be tested drives a much longer military flight test program. Multi-mission profiles require similar testing in subsystems and static and fatigue test articles which add a commensurate amount of time and cost to this level of testing as well.

FUNDING

In relating Boeing's early commitment of funds to new commercial program which was noted above, Mr. Wilson was trying to send a message to the President's Blue Ribbon Panel. "The message being emphasized in these remarks was that the uncertainty of government programs constituted a major deterrent to similar anticipation of capital investment and training in support of defense production."[22] In other words, with the short one year planning cycle in the federal budget cycle, significant company investments in technology to improve the process are not encouraged. For example, without significant funding commitments, other companies may not invest in systems similar to Boeing CATIA systems described earlier. Short term budget horizons will continue to foster business as usual attitudes in military aircraft development. Advances in areas such as concurrent engineering have enhanced productivity at Boeing. Similar productivity improvements must be encouraged in the military sector with long term commitments to major aircraft development programs.

Funding commitments and designing and testing to the multi-roles of a military aircraft are what drive the length of the military E&MD phase when compared to the commercial sector. The foregoing has focused on why the systems are different. In the following section, application of ideas and practices from the commercial sector to military development programs will be discussed.

WHAT CAN THE MILITARY DO?

One underlying difference between military and commercial aircraft development appears to be a degree of trust in business and technical relationships. When compared to the commercial sector, the volume of specifications and oversight in military development programs is enormous. McDonnell Douglas likes to point out that the MD-11 detail specification is under 300 pages. In a graphic presentation, the number of pages contained in the F/A-18 detail specification is off the chart.[23] The specifications are so lengthy primarily because a prior contractor failed to perform as expected. The expected performance was codified by the affected engineer and was written into the next specification. Much of this due to personnel shortages in the government.

Much is written about the obtrusive oversight contractors suffer while performing government contracts. Ironically, however, it is lack of oversight early in the design phase of development contracts that cause contractors to make assumptions. Frequently, these assumptions are incorrect and expensive design effort has to be reworked after the government engineer's oversight at a later design review. The engineer's review of the design will probably result in added requirements in the next specification. Had the government engineer worked more closely with his industry counterpart at the outset, the correct decision would have been made and expensive rework and time would have been avoided. Clearly, what is needed is better coordination and teamwork at the start of a design.

During the AX CE&D contract, most of the prime contractors recommended collocation of the Navy and contractor program offices. The benefits included improved communication; improved efficiency with faster decision making and turn around; and decreased delegation to Defense Plant Representative Office (DPROs). Rockwell noted that on the X-30 program, significant collocation resulted in the aforementioned benefits with government employees acting as "team mates" working towards program success rather than simply providing oversight. With a strong contracting officer presence, the incidents of constructive changes could be minimized. The downside to this approach is personal disruptions caused by relocation and loosing influence with decisionmakers as a result of physical distance. These problems could be overcome if the tours were kept short and included only the formative early years of a development program. An alternative to collocation might be an on line information system as currently being demonstrated on the

Navy's F/A-18 E and F development program. Using computer packages similar to Boeing's CATIA and teleconferencing may result in similar benefits to those enjoyed on the 777 program illustrated above.

With FAA's designated engineering representative program as a model, consideration should be given to greater contractor self-certification. The Defense Contract Management Command appears to be leaning in this direction with their IQUE and CASPRO initiatives. Naysayers may believe that contractors can not be trusted but the FAA experience seems to refute this judgement. Personnel savings realized by this approach could be applied to increased staffing in the engineering community to provide early team mates to industry in the design phase. Early and aggressive communication is the key to successful development programs. Unnecessary rework and duplication of effort can be avoided thereby saving time and money.

CONCLUSION

Other than producing airplanes as end products, there are few significant similarities between commercial and military aircraft development programs. The differences are driven by the technological maturity of subsystems such as avionics, materials, etc. As military threats emerged, military requirements specified state of the art technology as a counter to the threat. As a consequence, military aircraft development programs are involved in developing and validating a whole series of advanced technologies. In comparison, commercial aircraft development programs are more concerned with packaging or building an aircraft around proven systems that already exist. In other words, commercial aircraft development is evolutionary whereas military aircraft development is revolutionary.

The flight profile of a commercial aircraft is limited to a single mission, ferrying passengers and cargo. This single point design requirement is easier to design and requires far less flight testing prior to certification. By comparison, a military tactical aircraft must be designed for several missions with flight profiles that require constant technical tradeoffs. The design is much more time consuming and requires far more flight testing. Even non-tactical military aircraft like the new Air Force C-17 air transport, while similar to a commercial airliner faces more stringent design challenges. John McDonnell, the Chief Executive Officer of the McDonnell Douglas Corporation, contrasted his company's MD-11 with the C-17. He stated that because of additional military requirements such as short field landings or battlefield operations, the MD-11 could only partially perform the mission required of the C-17. The additional military missions require additional design and tests adding significant costs to the C-17 program when compared to a commercial aircraft application.[24] When missions or flight profiles are similar, the military does take advantage of commercial development programs. For example, the C-9, the KC-10 and the C-12 had similar missions and exploited their commercial counterparts, the DC-9, the DC-10 and the Beech King Air, respectively.

Although there is little in common between the two development systems, military aircraft development can benefit from commercial practices. The most important lesson to take from the commercial arena is communication and teamwork among all parties. With careful planning and execution, aircraft development programs can avoid costly and time consuming design rework. Politics, statutes and regulations cannot be ignored, however, people are behind every successful aircraft development. Strategically training and locating the right people in the right place is the key to a successful program.

ENDNOTES

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