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http://www.au.af.mil/au/awc/awcgate/awc-mxwl.htm

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F-15A versus F/A-22 Initial Operational Capability

A Case for Transformation

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Air War College
Maxwell Paper No. 36

Air University Press
Maxwell Air Force Base, Alabama

November 2005

This Maxwell Paper and others in the series are available electronically at the Air University Research Web site http://research.maxwell.af.mil and the AU Press Web site http://aupress.maxwell.af.mil.

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Foreword

The F/A-22 Raptor is a new weapons system replacing the F-15C Eagle. Its operational debut in 2005 comes at a time of constrained budgets, a changing global threat environment, and the ongoing global war on terrorism (GWOT). Because of the current security environment, the aircraft's more than 15 years of development, and the close scrutiny of the F/A-22's test and evaluation (T&E) program, the US Air Force needs the Raptor's initial operational capability (IOC) status to be successful. One means of achieving this is to recognize and implement the lessons learned from America's current air superiority fighter, the F-15 Eagle. And just perhaps the overall effect might be to challenge the US Air Force's approach to major weapons-system development.

The F/A-22's development, testing, and IOC declaration at Langley AFB, Virginia, in December 2005 closely parallels the F-15A's experience of 29 years ago. This paper provides background information on both aircraft, their T&E processes, and their first operational assignments to Langley AFB. Comparisons are made, differences highlighted, and recommendations offered. While it may appear that everything about the F/A-22 is new, the path to its IOC is well worn.

A fresh look at F-15A development yields valuable insights for emerging twenty-first-century USAF weapons systems. Surprisingly, the overall lessons of the F-15A in 1976 still apply to the F/A-22 of 2005.

The 1st Fighter Wing is again tasked with birthing a major weapons system, and the difficulties of 29 years ago will again be met and overcome with the proven successful combination of leadership and teamwork. However, this paper not only focuses on the 1st Fighter Wing's path to IOC but also considers the USAF's T&E process.

Comparison of the two T&E processes has identified that the F-15A and F/A-22 used the same model for T&E (developmental testing and then operational testing). The programs faced milestones that were used to keep the programs on track and aligned with the contracts. Both had to react to changing oversight direction, both needed

greater operational involvement in the early phases of testing, and both completed their initial T&E processes immediately before IOC at Langley AFB, with further T&E to follow. Both programs introduced significant changes to the T&E process, but striking similarities after nearly three decades could point to a need for major transformational change in the USAF's T&E process.

In addition, the author identifies specific recommendations that could improve the IOC of new weapons systems. Some are relatively intuitive: units declaring IOC should gather data from other units undergoing the same process, capture the experience in the form of histories, and make an effort to get the aircraft "on the road" to better introduce it to the Combat Air Forces (CAF). A suggestion to implement an IOC advisory board to keep senior leaders informed of actions and benefit from senior officer experience also may have merit.

Recommendations such as improving the handoff between testers and operators or redefining the meaning and process of IOC are far-reaching suggestions, and their implementation would have an impact on organizations, processes, and funding that could transform the way the USAF acquires new weapons systems. Finally, Colonel Mott is clearly on target when he concludes that the initial Raptor units, whether test or operational, must capture, challenge, and doctrinally address the operational mind-set for employing the F/A-22. F/A-22s should not simply use F-15 tactics; the F/A-22's transformational nature must be nurtured and exploited to provide maximum combat effect for the war fighter.

Surprisingly, 29 years have not completely changed the nature of bringing a new weapons system to IOC at Langley AFB. The repetition of similar challenges such as T&E timeliness and completion, reaction to changes directed by oversight, assumptions about sortie production rates, maintenance factors, and technology choke points all combine to call for transformation of the USAF path to weapons-systems IOC. This study calls for transformational change to be considered within either the T&E process or the buildup to IOC such that IOC declarations of future weapons systems might be improved. By doing so, future war fighters will get a better weapons system at IOC than they

have either in the past or currently. This study should encourage a critical look at the F/A-22's road to IOC, prompting thinking on changes that might be made to other new weapons systems like the Joint Strike Fighter or CV-22.

As with all Maxwell Papers, this research is provided in the spirit of academic freedom, open debate, and serious consideration of the issues. We encourage your responses.



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About the Author

Lieutenant Colonel Mott is assigned to Headquarters Air Education and Training Command, Randolph AFB, Texas. He is a command pilot with more than 3,000 hours in the F-15C. An F-15C instructor pilot, Colonel Mott is a USAF Weapons School graduate and former squadron commander. His assignment prior to Maxwell AFB, Alabama, was deputy group commander, 33d Fighter Wing, Eglin AFB, Florida. He has had operational tours at Nellis AFB, Nevada; Langley AFB, Virginia; and Bitburg Air Base, West Germany. In addition, he served as a J-3 action officer, Headquarters North American Aerospace Defense Command, Peterson AFB, Colorado. Colonel Mott is a distinguished graduate of the US Air Force Academy, Colorado. He holds master's degrees from Embry-Riddle Aeronautical University, the US Army Command and General Staff College, and the Air War College (class of 2005).

F-15A versus F/A-22 Initial Operational Capability

A Case for Transformation

You ask me a question about . . . air-to-air tactics. All I can say is that the cardinal rules of air tactics haven't changed one bit since World War I . . . formation integrity, good eyesight, aggressiveness, training, of course, a plan of action helps, integrity of flight. . . . All these things are well known to fighter pilots. Unfortunately, they are not so well understood by other members of the Air Force or by people who sometimes design airplanes and buy them.

—Col Robin Olds, Commander
8th Tactical Fighter Wing
12 July 1967

Although air-combat tactics have not changed during the last 100 years of manned flight, aircraft certainly have. The purpose of air-superiority fighters remains the same—to maximize the warrior's ability to kill the enemy in the air and achieve the critical war-fighting enabler of air dominance. However, aerospace design, testing, and engineering development have combined to make the modern jet fighter a more complex and costly machine than ever before.

In 2005 we see the dawn of a new fighter—one that is specifically designed to dominate in every air battle, to provide the United States an undeniable ability to operate over enemy territory, to exploit an enemy's airspace, and to hold his entire nation at risk. That aircraft is the Lockheed F/A-22 Raptor. At a program cost of $72 billion in fiscal year 2004 dollars, an F/A-22 costs twice what an F-15C costs in constant dollars during the later stages of its production and at a production rate half that of the F-15.[1]

The F/A-22 is a multibillion-dollar acquisition program that is the center of controversy ranging from within the Department of Defense (DOD) to the United States House and Senate. The F/A-22 has the technology to dominate in air combat but at what cost? Is the aircraft an overpriced Cold War relic? Is it worth the investment in light of ever-increasing costs associated with the current global war on terrorism (GWOT)? Even as late as December 2004 the total buy is uncertain, according to a defense consultant: "If the Pentagon's reported plan to reduce F/A-22 orders to



F/A-22 Raptor USAF Photo

about 160 planes is approved, production cuts would start taking effect after the 2007 budget year and production could end by 2010."[2] The military and political debate surrounding the F/A-22 has produced tremendous interest in its acquisition, oversight, and testing programs. Yet, how different will the first operational squadron of F/A-22s in 2005 be from the last grand opening of a squadron of air-superiority fighters at Langley AFB, Virginia?

In 1976 the 1st Tactical Fighter Wing (TFW) declared initial operational capability (IOC) in the 27th Tactical Fighter Squadron (TFS) with the McDonnell Douglas F-15A Eagle. Like the F/A-22, the F-15A was—and still is—an outstanding air-superiority fighter. It was a generational leap in technology (beyond the F-4 Phantom it replaced) and the center of a new, if not controversial, acquisition process. The similarities are too great to evade the question: has the USAF learned anything from history? Or, are the F/A-22 pilots of 2005/2006 going to relearn the same lessons of 1976?

A complete comparison of the F-15A's and the F/A-22's acquisition programs is beyond the scope of this paper. This paper's focus is first on the background events that



F-15A Eagle USAF Photo

led to the development of the F-15A air-superiority fighter. It then considers the F-15A's test and evaluation (T&E) process and buildup to IOC at Langley AFB in 1976 and repeats this evaluation for the F/A-22. Finally, it recommends adjustments to the F/A-22's path to full operational capability (FOC) and for the Joint Strike Fighter's (JSF) IOC.

The declaration of IOC for both aircraft heralded a new era in American fighter technology and capability and is a critical point for review. By distilling the development process of the F-15A to its culmination as a weapons system ready for combat and comparing it to that of the F/A-22, it is possible to assess the F/A-22's efficacy at IOC. Obviously weapons systems introduced in 1976 have matured with time in the field, and the same is true in 2005 with the F/A-22. But should not this information age we live in produce a more complete, more capable system at IOC than we had 29 years ago?

F-15A Eagle Acquisition Process

Procurement of the F-15A weapons system was a dramatic change for the USAF. Behind lay the tragedy of the Vietnam War, the abortive attempt in the F-111 to build one fighter for both the US Navy and the USAF, and the costly (and controversial) C-5A Galaxy acquisition process.[3] Ahead lay the F-16 low-cost, multirole fighter; the A-10

tank-busting attack aircraft; and the on-again, off-again B-1 strategic bomber. The lessons learned with the F-15A would serve as a guidepost as the Cold War matured in the 1980s. The F-15A's format for development, engineering, and even testing would leave its mark on the future F/A-22 program.

The first step to understanding the F-15A's acquisition process is to examine the decision to build a fighter with a single mission. What drove the USAF to write a requirement for and Congress to fund the development of an air-superiority fighter? The answer is found in the history of the USAF and its combat experiences of World War II, Korea, and Vietnam. During World War II, the Army Air Corps started with a doctrine of ground attack: "United States War Department Field Manual 31-35, 'Aviation in Support of Ground Forces,' 9 April 1942, allocated aircraft resources to ground units and placed pursuit aviation under Army control. It specifically prescribed that airpower's mission was to attack 'the most serious threat to the operations of the supported ground force.'"[4]

This apportionment of fighters to ground commanders contributed to defeat at Kasserine Pass and resulted in a change in doctrinal organization in January 1943 that was modeled after the Royal Air Force.[5] Suddenly, new doctrine ranked "the gaining of air superiority . . . the first requirement for the success of any major land operation, placing this function ahead of tactical air's interdiction and close air support missions."[6] From North Africa, the role of the fighter continued to be focused on air superiority by supporting the USAF's daylight precision-bombing campaign against Germany. The influence of the P-47 Thunderbolt and P-51 Mustang on the air war in Europe is well known and ultimately led to the establishment of air superiority and the declaration of the supreme commander, Gen Dwight D. Eisenhower, that "if you see fighter aircraft over you, they will be ours."[7]

The importance of air superiority continued in the Korean War as the advent of the MiG-15 upped the ante for technological supremacy over the Korean peninsula. A harbinger of air superiority's importance came when B-29 attacks were operationally restricted, even to the point of flying only at night due to their being shot down by MiG-15s.[8]

The air war over "MiG Alley" and the Yalu River produced fierce fighting between the F-86 Sabre and the MiG-15. The USAF's F-86 Sabre proved equal to the task, ultimately achieving a kill ratio of 10 to one.[9]

The war in Vietnam saw the critical move away from air-superiority fighters like the F-86. The 1960s saw a rise of the "bomber generals" that focused Tactical Air Command (TAC) on nuclear delivery and a gradual dulling of the skills of fighter air combat, commonly known as "dogfighting." Hanson Baldwin writes in the introduction to *Thud Ridge* that "there had been too much dependence on nuclear weapons and 'the bomber generals' in the Air Force had long down-graded the tactical air arm."[10] Worse, the procurement of aircraft resulted in weapons systems ill suited for the conventional war over North Vietnam. Col Walter Boyne, USAF, retired, observes that "out of the 833 production aircraft, some 350 F-105's were lost to combat or other operational causes."[11] Obviously, all F-105 combat losses cannot be attributed directly to its design and suitability for combat over North Vietnam, but the sheer number of F-105 losses is indicative of problems with the aircraft's operational record.

While the F-4 Phantom did achieve limited air superiority over North Vietnam, it was still not perfectly designed for air combat in that it was missing a gun, a fact that was not lost on Colonel Olds in the skies over Hanoi: "I gnash my teeth in rage to think how much better this wing could have done had we acquired a gun-carrying capability earlier."[12] Fighter pilots in Vietnam found themselves in a shooting war with a motivated foe, and they didn't have the right aircraft for the mission. That dissatisfaction with the air war in Vietnam led to a great many changes in the USAF in the 1970s and 1980s. The desire to have a superior dogfighting aircraft led to the design of the F-15A:

> Although air superiority remained the "prerequisite" for conducting any air operation, General Bruce K. Holloway, the Air Force Vice Chief, wrote in 1968 that plans to develop a new day fighter were continually sacrificed in favor of interceptor and fighter-bomber designs: "Penetration was more important than maneuverability, ordnance load-carrying capability more important than armament, alert status more important than sustained sortie rates. The tactical fighter became less and less an air superiority system and more and more what was once called an attack aircraft."[13]

By the late 1960s, the stage was set for the resurgence of single-mission aircraft, notably the F-15 and the A-10. While the debate between "not a pound for air to ground" versus a multirole fighter continues today, the USAF pursued a single-mission air-superiority fighter with the F-15A and again with the F-22. This was to last until 2002 when the F-22 Raptor was redesignated the F/A-22 by the chief of staff of the Air Force (CSAF).[14]

Armed with an understanding of *why* the F-15A was built, it is appropriate to look at *how* it was built. The birth of the F-15A came at a time when there was great concern for the ability of the government to successfully run a large aircraft-acquisition program. According to Lt Col Edgar M. Lewis, USAF, retired, "The Air Force was being severely criticized in the Research and Development/Program Management area because of the F-111 and C-5 problems. The F-111 cost over-runs, schedule delays, technical difficulties and operational introduction problems have been well documented in various Air Force and TAC . . . documents. The cost and schedule problems with the C-5 and in particular the wing fatigue problem were in the headlines in 1969."[15] In addition, the F-15 was the technological lead agent for a family of systems developed during the later decades of the Cold War. In 1973 Col Thomas G. McInerney noted that "the F-15 engine, radar, avionics (tactical electronic warfare system, internal navigation system), and gun development programs will provide a family of systems that will be available for many other defense requirements throughout the 1970's and early 1980's, but for which the F-15 program has absorbed the brunt of development costs."[16]

Concerns for the F-15A program and the technical challenges faced by the engineers can be grouped into three categories: "blueline" (or streamlined) management, system program office (SPO) and TAC relationships, and cost versus contract. Analysis within these areas not only sheds light on the F-15A's history but also provides parallels to the F/A-22. Prior to 1969, DOD systems-acquisition policy consisted of highly centralized management and total-package procurement.[17] The change in policy implemented by the DOD's senior leaders resulted in decentralized authority for programs and a use of prototyping rather than

paper studies to reduce risk.[18] This command relationship, when coupled with blueline management, meant that program monitors could rapidly gain access to senior USAF decision makers: "The F-15 was put under the 'Streamlined management' approach, wherein the System Program Director (SPD) reported directly to the Commander, Air Force Systems Command [AFSC], who in turn, reported directly to the Air Force Chief of Staff and Secretary and the Assistant Secretary of Defense (Mr. Packard)."[19]

Next the F-15A SPO (the developer) and TAC (the customer/user) established formal relationships that allowed TAC visibility into the development process. The efficacy of these relationships remains unclear. Research indicates a variety of comments. According to Colonel McInerney, in 1973 "the TAC/F-15 SPO relationship . . . [was] good," which he concluded from an interview with Brig Gen Walter Paluch, deputy chief of staff for requirements, Headquarters TAC.[20] Yet, by 1975 Headquarters TAC had initiated monthly meetings/briefings to improve F-15 SPO/TAC communication.[21] That same year Gen David C. Jones, the chief of staff, became involved in the detailed process of establishing "Super-PARs," or program assessment reviews, to assess major weapons systems.[22]

Further, the *History of the F-15 Eagle* report that Headquarters TAC generated addressed organizational hindrances to full coordination between TAC and the F-15 SPO. At Wright Patterson AFB, Ohio, "the senior managers/directors were products of the Green Door/Blackbird (secret/closed access) society. The natural tendency was to maintain the same closed society, i.e.: don't discuss progress/problems with anyone outside of a very close knit group."[23] This philosophy prevailed at Headquarters TAC as well:

> The secretiveness even pervaded the TAC Staff. Problems were known and discussed only at the Director/DCS and Command section levels. The responsible Staff Officer often found out about a problem by accident, deduction or after it was resolved. The closed loop was insisted on by the F-15 SPO, or the flow of information would stop. In this manner "bad press" was avoided, but conversely "good press" was not available to engender support for the F-15 program throughout the Air Force.[24]

Clearly, coordination was an issue in 1975–76. If this problem continues today, consequences could be significant. Aircraft are not developed in a short period of time: technology, management, congressional oversight, leadership, and even roles and missions can change from the time that the Operational Requirements Document (ORD) is signed until the aircraft's first flight. There should be a means to balance program changes versus engineering commitments during the development process. Without proper controls, costs can increase; even worse, the commitment to purchase the entire airframe can erode. Witness the 2004 US Army decision to cancel the Comanche attack helicopter and then redirect the funds to other aspects of US Army aviation requirements.[25] The F/A-22 has also been crippled by cost overruns—"cost growth has been a problem for the Raptor program. Most cost increases have been due to government decisions that changed requirements, delayed development, reduced production rates or cut the size of the planned fleet. Costs also have been increased by technological challenges that were not fully anticipated."[26]

After streamlined management and TAC-SPO relations, another important factor in ensuring the F-15A's success was in its funding and contract development. The F-15A program's contract is full of buzzwords that today are familiar to acquisition officers. At the time, they were innovative and a result of lessons learned from the F-111's and the C-5's program shortcomings. The F-15 would be a cost plus incentive fee (CPIF) for development, and critical subsystems were developed competitively and selected on the basis of performance in a "fly-off."[27] Milestones—or measures of performance—were included at significant development points to allow for decisions before further development. A Cost/Schedule Control System (C/SCS) was implemented that "provided meaningful performance measurement status by comparing an established budget baseline plan with actual resources expended."[28] The F-15 program was not free from difficulties as its F-100 engine had numerous developmental problems early in its history, yet McInerney says in his 1973 research that "this is probably one of the best contracts ever written on such a complex development program despite the cost growth on the engine."[29] It would

not be an understatement to say that the lessons learned from the F-15's acquisition form a foundation that endures today. As discussed in the next section, perhaps the biggest aspect of the F-15A's development program that affected the IOC was the requirement to "fly before you buy."

F-15A Test and Evaluation Process

Fly before you buy acquisition means to develop program milestones that demonstrate an appropriate level of technical and flight-test confidence before decisions are made to further obligate US government funds.[30] Not only does this develop a flight-test program that supports the aircraft's engineering and production, it also develops operational insight before the weapons system reaches IOC. The different T&E steps occurred at different bases, were flown by different pilots, overlapped in content and scope, and yielded a four-year process from first flight to IOC at Langley AFB (fig. 1).

Contractor Developmental Test and Evaluation

Contractor developmental test and evaluation (CDT&E) was conducted from first flight on 27 July 1972 to the end of 1974.[31] This piece of the overall development was conducted by contractor pilots (McDonnell Douglas Corporation) at Edwards AFB in California. As would be expected, this phase of testing focused on translating the F-15A's designed performance into actual aircraft-handling qualities. While not the focus of this paper, some of the findings during this period resulted in changes (called engineering change proposals [ECP]) to the raked wingtips, the dog-tooth horizontal stabilators, the enlarged speed brake, and 20 other engineering or manufacturing refinements.[32]

Air Force Developmental Test and Evaluation

Similar to the contractor tests, Air Force DT&E (AFDT&E) ran from April 1974 to mid-1975.[33] Conducted by USAF pilots at Edwards AFB, it again focused on the airframe and the basics of getting the components to work together as prescribed by the engineers. In this phase of development,

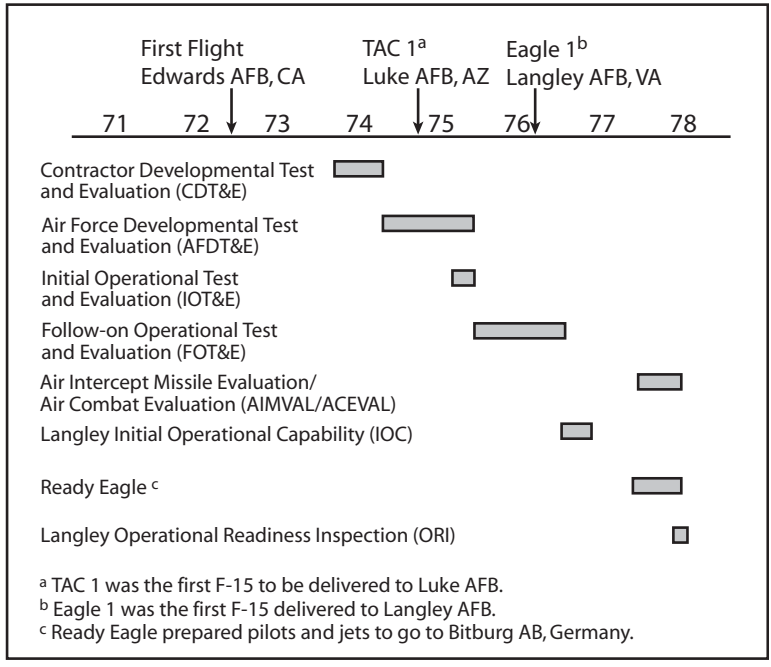

Figure 1. F-15A developmental test (DT)/operational test and evaluation (OT&E) schedule and milestones. (Data compiled from sources cited in notes 3, 4, 33, 49, and 53.)

the F-15 SPO took a step back and allowed the Air Force Test and Evaluation Center (AFTEC) to take the lead in testing the F-15A. Contractor and Air Force DT&E produced a common goal but with a different focus. The contractor focused on meeting the USAF's requirements while at the same time refining and developing production methods at the factory. Although the USAF was also concerned with qualifying the design versus contractual requirements, it was more concerned with operating the aircraft with minimum contractor support.[34]

A key point to F-15A testing is that CDT&E and AFDT&E occurred hand-in-hand. They both flew at Edwards AFB, and both had a clear arrangement for test objectives and processes. But on 11 February 1971, the deputy secretary of defense established a new test policy for the Air Force that required testing by the operator, in

addition to that performed by the contractor and developer of the airframe.[35]

Initial Operational Test and Evaluation

Initial operational T&E (IOT&E) was a critical and yet unique phase in the development of the F-15A. It was a vital complement to contractor and Air Force testing that let the operator—TAC—have a say in the evaluation process. A 1977 AFSC history explains that the "F-15 IOT&E was jointly conducted with the Air Force/contractor development, test, and evaluation. This IOT&E was Air Force directed, TAC conducted, and AFTEC monitored. The IOT&E provided estimates of system operational effectiveness and suitability and also identified the need for modifications early in the acquisition process."[36]

Now this description of IOT&E sounds great, but a "peeling of the onion skin" reveals a few unmistakable factors. A briefing by Lieutenant Colonel Robbins to the TAC/CC in 1976 summarized the key points of IOT&E: "1) No dedicated IOT&E flights, 2) Fulfill IOT&E objectives to the extent possible on Air Force Preliminary Evaluation/Contractor Test missions, [and] 3) Emphasis on basic aircraft handling qualities, flying and operational qualities."[37]

It is remarkable that the F-15A's IOT&E was an add-on to the developmental tests and that it was very limited in scope. Today we expect IOT&E pilots to fly the jet in the same fashion as operational pilots will fly the aircraft. The same was true in 1976 but in a much more limited sense. The following test events for IOT&E demonstrate the simplistic nature of this evaluation phase at that time:

1) Preflight: Start, taxi, ground operations
2) Takeoff: Flying qualities, gear retraction
3) Climb and en route: Cockpit visibility, formation
4) Maneuvering: Flying qualities, buffet, stall, tracking, performance, offensive and defensive maneuvers
5) Recovery: Approach, landing, rollout
6) Mission equipment: One-man operability[38]

The list of test items is suggestive. Did taxi and takeoff receive as much evaluation as offensive and defensive maneuvers? How complex was this phase of the testing? It

almost seems like an afterthought to the F-15's test process for two reasons. First, the USAF Historical Research Agency at Maxwell AFB, Alabama, contained no IOT&E report. Second are the comments of Lieutenant General Starbird, the deputy director for T&E, Office of the Director of Defense Research and Engineering (DDR&E), to researcher Colonel McInerney in 1973 that "he would have liked to see a 'heavier' IOT&E phase and the Tactical Electronic Warfare System was not available for testing prior to the production decision."[39] The research here implies that the F-15A's IOT&E was of limited utility because of its add-on nature, the limited focus of the testing, the possible nonavailability of the results, and the comments of leadership at the time. The scope and nature of the next phase of testing also tend to confirm this hypothesis.

Follow-On Operational Test and Evaluation

Follow-on OT&E (FOT&E) was conducted at Luke AFB, Arizona, between March 1975 and July 1976. The test report's executive summary notes that the "purpose of the evaluation was to verify the operational effectiveness and operational suitability of the production F-15A weapon system."[40] It appears that FOT&E was the major evaluation used to prepare the F-15A for operational service. During the test, live weapons were employed; maintenance was evaluated; operational deficiencies were found requiring immediate corrective action; and specific operational and planning factors were determined, such as cost of ownership.[41] The specific test objectives to measure operational effectiveness were more detailed than in IOT&E:

1) Verify the operational effectiveness of the F-15A aircraft in its primary role as an air-superiority fighter.
2) Verify the operational effectiveness of the F-15A aircraft in its secondary role as an air-to-ground weapons system.
3) Verify the operational effectiveness of the F-15A aircraft during routine phases of flight.
4) Evaluate the reliability and maintainability characteristics of the F-15A and assess system availability and logistical supportability.

5) Estimate the probability that the F-15A will successfully complete representative missions.
6) Determine manpower requirements for operation and support of the F-15A.
7) Evaluate the cost of ownership for the F-15A.[42]

As the last step in T&E for the F-15A, a number of aspects come to light. This test was completed four months before IOC at Langley and was concurrent with the pilot-training programs for the Langley IOC pilots. It also went into considerable depth of evaluation versus the IOT&E. FOT&E utilized 1,111 F-15A sorties and approximately 900 support sorties.[43] Also, over 1,000 bombs were dropped, demonstrating the secondary capability of the F-15A.[44] However, the weapons systems were not fully tested. The AIM-9L, the major weapons change from the F-4 Phantom, was not available for FOT&E. A recommendation from the report was that "incorporation of the AIM-9L missile should be expedited,"[45] and, indeed, this weapon would not be fired from the F-15A until the end of 1977.[46] While FOT&E was more detailed than IOT&E, the research conclusion here is that the F-15A weapons system was not tested in its entirety until nearly one year after IOC.

Illustrative conclusions can be drawn from this review. The F-15A's T&E process was remarkable and produced a superior flying fighter. But hindsight from 2005 yields some interesting observations. IOT&E was added onto developmental testing, and FOT&E was not completed until four months prior to IOC. Given these developments, how much information, in a completed form, was available to Langley's IOC pilots? The limited nature of operational testing and the short time from its completion to IOC must have posed difficulty in transferring lessons learned to IOC pilots. Certainly, this must have resulted in the F-15A at IOC being less of a weapons system than it would be in a matter of one or two years. The question remains—should tactics, techniques, and procedures be developed after IOC or before? With the F-15A, they seem to have been developed after IOC.

The F-15A's T&E process foreshadows the current system but without the detail and time needed for a complete and timely report. Further evidence of this lies in the execution

of an additional F-15A test called Air Intercept Missile Evaluation (AIMVAL)/Air Combat Evaluation (ACEVAL). AIMVAL/ACEVAL culminated in June–November 1977, half a year after IOC.[47] The testing was flown on the Nellis AFB, Nevada, test ranges with F-15s and F-14s fighting F-5Es in scenarios illustrative of the projected scenario of visual air combat in the 1985 time frame.[48] And the results of the AIMVAL/ACEVAL tests? Some would argue, as this author and F-15C instructor pilot (IP) does, that the tests in 1977 were the first evaluations of the F-15A's weapons system in the configuration and with the weapons that it was designed to use. However, many saw the actual results as problematic:

> The AIMVAL/ACEVAL exercises were badly flawed and very expensive. The flaws . . . had to do with an unrealistic scenario, incorrect assumptions on missile capabilities, and somewhat arbitrary rules on equipment carriage. . . . Due to the aggressive and competitive nature of fighter pilots, this quickly changed from a good-natured evaluation of hypothetical missile concepts to as close as one can get to combat without actually firing weapons.[49]

Clearly, the AIMVAL/ACEVAL test was late and imperfect, but it was the test that was perhaps needed to close F-15A development before IOC was declared. It serves to summarize the F-15A's T&E program—magnificent but incomplete and overdue. The F-15A's T&E needed earlier operational involvement (IOT&E) and integration of the AIM-9L into the aircraft. Ultimately, developmental programs must achieve a balance between testing in the IOC configuration and meeting production milestones. Unfortunately, when the developmental program fails to meet milestones, the only solution is either to slip the IOC date or to finish developmental testing after IOC (as AIMVAL/ACEVAL did). In either case, the operational unit assumes the risk and must rise to the task during preparation for IOC. The next section evaluates the 1st TFW's experience with the F-15A's IOC process.

F-15A IOC at Langley AFB, October 1976

The F-15A's IOC was the culmination of the Eagle's development process that put the weapons system in the war

fighter's hands. While testing at Nellis AFB would continue, 1976 marked a shift in focus from operational testing to combat/training operations in the field. A number of lessons are noteworthy regarding this stage of development.

The actual celebration of the F-15A's arrival at Langley AFB—Eagle Day on 9 January 1976—was attended by members of Congress, generals, and of course, the men and women of the 1st TFW.[50] Comments on record from visiting dignitaries testify to the excitement associated with the arrival of the F-15A. Virginia's First District congressman concluded by saying that "every American can breathe a little easier when he knows the Eagle is on the perch."[51] The F-15's revolutionary impact on TAC was expressed by Gen Robert J. Dixon, TAC commander, as he spoke to the 1st TFW:

> You will set the pace for all who will follow . . . you into the F-15, but, more importantly, you will set the pace for those—like you—who will be first in the AWACS [Airborne Warning and Control System], A-10 and the F-16. You have the . . . responsibility to test the validity of our research and development of our maintenance concepts and procedures, . . . our tactics and training . . . and to set . . . higher standards that . . . become the baseline for those who follow.[52]

During 1975 the 1st TFW's focus on beddown issues revolved around three areas—facilities development, wing organization, and initial training.[53] The change from the F-4 to the F-15A necessitated many facility changes, and the shift to line replaceable unit (LRU) maintenance and intermediate-level maintenance necessitated changes in hangars and work centers at Langley.[54] A critical aspect of facilities was the "need to coordinate . . . [their] development . . . with the flow of incoming aircraft, equipment, and personnel."[55] Transition in 1976 from the two-seat F-4 Phantom to the single-seat F-15A Eagle also required a change in manning, resulting in organizational changes. Such changes faced by the 1st TFW in 1976 due to the loss of the second aircrew were not duplicated in the F/A-22's IOC and are not considered in this research.

Initial training for both maintenance crews and pilots seems to have been the most critical issue for the wing in 1976. Obviously, aircraft knowledge and training were achieved via the testing process and the Replacement Training Unit at Luke AFB, Arizona; they were transferred

to the 1st TFW by means of written guidance as well as the likely transfer of experienced personnel to Langley AFB. Pilot training at Luke AFB included the following aspects:

> Conversion training, F-15, was conducted at Luke AFB by the 555th Tactical Fighter Training Squadron. The training was divided into two phases, conversion and aerial attack. IPs received a third phase. . . . Completion of the phases is concurrent with an 88 hour academic program comprising 8 classes. . . . Sorties for line pilots were lowered to 21. . . . Cockpit Procedural Trainers were used to complete 38 lessons to augment academic and flying training. . . . For simulator training . . . aircrews had to go to St. Louis, MO.[56]

But the real training issue, which resided at Langley AFB, was almost a catch-22 situation between operations and maintenance. Operations needed to fly, and fly a lot, so as to gain and maintain proficiency obtained from the Luke F-15 course. But that required jets on station and a steadily increasing sortie-production rate. Paradoxically, the first quarter of 1976 saw a limit placed on sortie production: "The training of the 1 TFW pilots prior to the wing possessing aircraft and slower than programmed aircraft delivery resulted in fewer than required sorties being available this quarter. The wing was some 78 sorties short of meeting the minimums for Mission Ready, Mission Capable, and Basic Proficiency Aircrews."[57] To mitigate the effects, the wing sent pilots to Holloman AFB, New Mexico, for T-38 sorties and also received loaner F-15s from Luke AFB.[58]

Looking at aircraft beddown would help in understanding the nature of the sortie-generation problem. The first F-15 for maintenance training arrived in October 1975,[59] the first aircraft for operational use arrived on 18 December 1975,[60] Eagle Day was 9 January 1976, and IOC was declared in October 1976. As F-15s arrived, sortie production increased from 26 in January, to 93 in February, and to 183 in March.[61]

But actual sortie production was still beneath planned production. The reasons for this shortfall—planning assumptions, maintenance, and technology—provide insight when one considers sortie generation with new aircraft. Captains Tom Lennon and Jim Wray of the 1st TFW describe the biggest misconception regarding sortie production as "overcommitment . . . result[ing] . . . from excessive optimism based on data from contractor, developer and user test programs. Consequently, operations in TAC started

with an advertised capability of 1.13 sorties per aircraft per day. . . . Initial tasking was based on what was thought to be a conservative .9 sortie production rate (SPR). However, in practice, a .61 SPR was the best achieved, and even then only with considerable difficulty."[62] If Langley AFB in 1976 experienced a sortie rate 60 percent of that planned, then many pilots and maintainers watched jets that sat on the flight line as they fell further behind on the path to IOC.

Maintenance was the reason for low sortie rates during the final push to IOC. It was further explained that "aircraft reliability in that first year measured by mean time between failures (MTBF) was less than one-half that predicted. It took considerably longer to repair each failure, and spare parts did not cover the needs."[63] In hindsight it is logical to expect that repair time would be longer with a new aircraft and that spare parts availability would limit sortie production. Like sortie rates, a greater percentage of downtime for maintenance must be allocated when dealing with new aircraft.

Finally, new technology was a contributing factor for low sortie rates. The F-15A was the lead aircraft under the maintenance concept of LRU repair at home station:

> One of the most painful lessons learned in introducing the F-15 was the avionics automated test station area. The concept included a built-in (BIT) system in the aircraft to isolate failure to any one of 99 LRU's. The failed LRU was to be removed and replaced—or if no spares were available to base supply—removed, repaired, and replaced. The faulty unit was then repaired in the base-level intermediate shop where computer-driven test stations were used to isolate the problem to a single shop replaceable unit (SRU).[64]

This was a great maintenance technological idea that continues today, but in the 1976 time frame the practical result was that while Langley could test and repair 92 of the 99 F-15 LRUs, an average of only 48 percent were actually repaired at base level—the remainder went back to the contractor for repair because test stations were down for extended periods.[65] Clearly, the LRU maintenance idea captured efficiencies to decrease maintenance downtime, but the overall system then had an unforeseen Achilles' heel—test-station failures—that negatively affected IOC.

Assumptions, maintenance, and technology combined to create challenges for sortie production and, ultimately, training limitations for IOC. In a surprising move, the 1st

TFW's leadership selected a unique method for preparing for IOC—deployments.[66] The 1st TFW's F-15As participated in four 30-day deployments during 1976.[67] Seventeen days after the first squadron had received 24 aircraft, the 27th TFS deployed to Nellis AFB for Red Flag training.[68] While assuming risk by taking a new weapons system away from home station, the decision to conduct operations on the road was crafted around three focused reasons:

> First, the F-15 represented a much larger advance in air superiority capability than had been previously experienced by those associated with the F-15 program and it was obvious that tactics to exploit these capabilities were lagging. . . . Secondly, since training sorties were the most precious resource available, it made sense to go where sorties were the most productive. The third reason is somewhat more controversial but, in the opinion of 1st TFW leaders, the F-15 support system was geared in attitudes and pace to the development and training cycle rather than to operational demands. Early deployments produced beneficial pressures to shift gears and the support system responded.[69]

The 1st TFW's deployment to Nellis AFB was the catalyst that overcame the system's early shortcomings. How deployed operations could correct problems with maintenance and training is a significant point. By replicating combat conditions in a training environment, the Red Flag deployment placed an artificial "need" for the F-15A weapons system to perform—the "beneficial pressures" that Lennon and Wray point out. This aspect of the F-15A's IOC points to the power of leadership: the 1st TFW should have been able to perform better at home station, yet morale and unit pride combined with demanding and realistic off-station training, became keys to Langley's successful IOC.

In summary, facilities, training (operations and maintenance), sortie production (assumptions and technology), and deployability seem to be focus areas for the F-15A's IOC. Training and sortie production were the limiting factors, while deployments were used as a solution. Was the F-15A's IOC a success in October 1976? The USAF had one squadron IOC with a second to follow in three months. Even more telling was the wing's ability to train and generate a squadron of jets bound for Bitburg Air Base, West Germany, by April 1977.[70] Clearly, the F-15A's development process put "iron on the ramp," with an ability to de-

ploy and train soon after delivery. The F-15A's T&E was late and incomplete, but with the exception of the AIM-9L missile, the combatant commander (COCOM) who would use the F-15A at IOC would have a significant improvement over the F-4 Phantom. That successful IOC was a result of the challenges met and overcome by the 1st TFW. Would these challenges be repeated in the F/A-22's IOC 29 years later?

F/A-22 Test and Evaluation Process

The F/A-22 Raptor is a great leap in aircraft technology. It is a Cold War–legacy weapons system that has undergone careful scrutiny and emerged as a needed paradigm shift for the air and space expeditionary force (AEF) of the twenty-first century. The Cold War's end and the review of the aircraft's need have combined to forge the F/A-22 into a complex and comprehensive developmental program:

> The overall development goal for the F/A-22 is to achieve a balance between performance, survivability, reliability, maintainability, and affordability. The F/A-22 must have proven lethality to ensure first look, first kill in all operational environments, and maneuverability and acceleration to ensure superiority over any known or predicted threat in the close-in fight. It must have the survivability to conduct its air superiority missions over enemy territory. It will do this through a balanced combination of supersonic cruise (without afterburner), reduced signatures, tailored countermeasures, and maneuverability. The F/A-22 systems must provide the pilot significantly improved beyond visual range situational awareness using its highly integrated offensive and defensive systems. The Air Force will field the F/A-22 with current generation weapons, but it must be capable of taking advantage of improved and follow-on weapons.[71]

The F/A-22's road to IOC is very similar to the F-15A's but with a few marked differences that demonstrate the refinement of the USAF's T&E process. The F/A-22's program is under careful DOD oversight but still attempts to give the war fighter a capable fighter at the outset of IOC. The milestones—decision points—of the F/A-22's production and testing phases serve several vital functions (fig. 2). First, they serve to keep the USAF, Office of the Secretary of Defense (OSD), and Congress informed as to program status. Second, they allow decision makers the means to ensure that the weapons system is meeting expectations during development. This means that the aircraft purchased not only meets the ORD but also keeps the con-

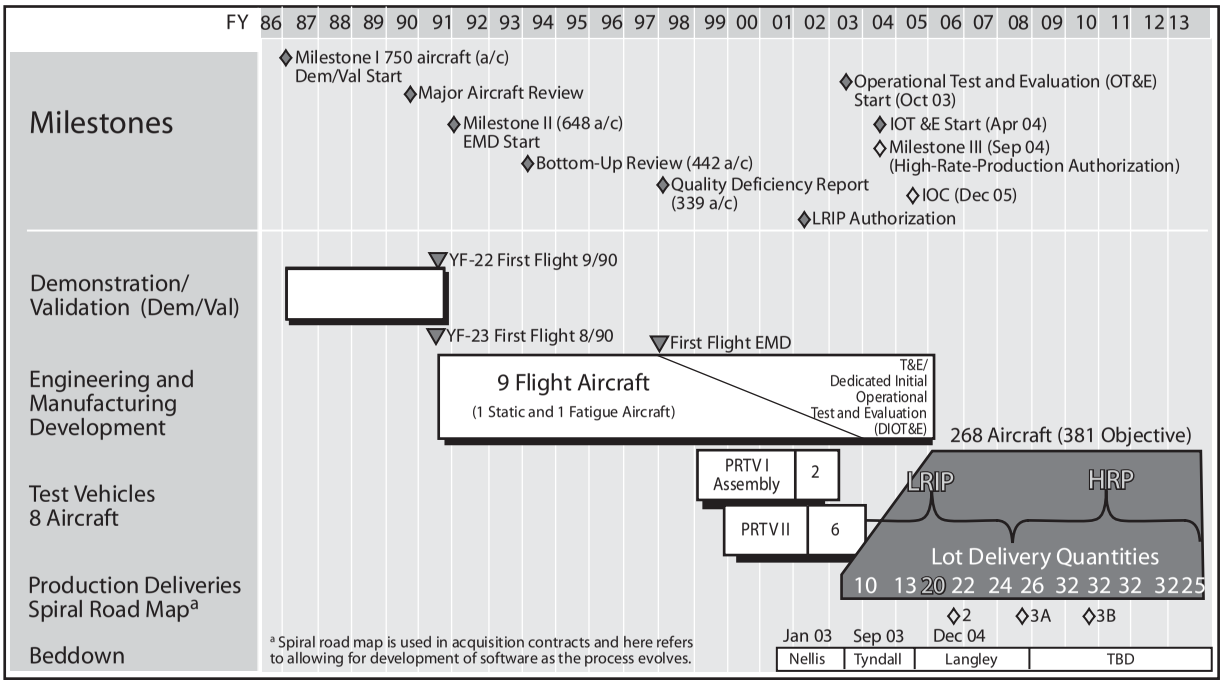

Figure 2. F/A-22 milestones. (From Lt Col Scott Ruflin, HQ ACC DR-F/A-22, Langley AFB, VA, PowerPoint briefing and notes, subject: F/A-22 Raptor, 18 June 2004.)

tractor from having to react to changes to contracts or expectations by the military. Figure 2 demonstrates how the F/A-22 proceeded from a first-flight aircraft to a prototype and then to a high-rate production aircraft off the assembly line. This process yields the following terms: *validation aircraft* (YF-22A), *engineering and manufacturing development* (EMD) *vehicles*, *production representative test vehicles* (PRTV), *low-rate initial production* (LRIP) *vehicles*, and, finally, *full-rate production* (FRP) *vehicles*. These aircraft combine to yield a T&E fleet used for developmental and operational testing.

Like the F-15A, the F/A-22's test program was divided between developmental and operational testing. Key agencies are the F/A-22 SPO (developer), Air Combat Command (ACC) (operators, replaced TAC in early 1990s), and Air Force Operational Test and Evaluation Center (AFOTEC) (evaluators, replaced the AFTEC). Interestingly, the ties between these agencies occur early in the process. The F/A-22's first flight was in 1990, AFOTEC was involved with development from 1996, and operational testing did not begin until 2003. AFOTEC's final report on the F-22 states that the "AFOTEC team has been fully integrated with the development effort from early on to ensure an in-depth understanding and comprehensive insight in preparing for the OA (operational assessment). Since 1996, AFOTEC has supported virtually all F-22 IPT (integrated process teams) and working groups."[72]

Another "F-22" test program necessity was to determine how best to evaluate the fighter and attack missions of the F/A-22: "The [F/A-22's] . . . IOT&E will focus on the 'F' or air superiority fighter capability of the F/A-22. . . . FOT&E, currently scheduled to start in June 2005, will focus on closing out unresolved and deferred IOT&E issues and on the 'A' or attack capability."[73] Just as the F-15A "morphed" into an attack version—the F-15E Strike Eagle—so did the F/A-22 shed its single-mission façade and became an air-and-space dominance vehicle.[74]

Developmental Test and Evaluation

Like the F-15A, F/A-22 DT&E remained a contractor and USAF Combined Test Center mission. The test emphasis

was on airframe certification and EMD process certification and modification. The basics of ORD validation were accomplished in this phase. The F/A-22's DT&E was a critical step in the testing of a new weapons system, but it did have limitations for the operational pilot. AFOTEC's final report on the F-22 weapons system also indicates that "it is important to note that this stage of DT&E includes virtually no mission avionics testing because those capabilities have yet to be included in the test fleet. As a result, data for Operational Assessments includes results of F-22 testing from a variety of sources including various laboratories, models and simulations, and the Flying Test Bed (FTB)."[75]

While DT&E had a distinctly contractor/test-pilot flavor, the F/A-22's DT&E did attempt to look forward to operational testing by incorporating an operational pilot. Lt Col David M. "Doc" Nelson, a graduate of the USAF Weapons School and Test Pilot School, flew the F/A-22 during DT&E to assess its Military Utility Testing (MUT),[76] designed to provide "an unprecedented degree of operational insight into developmental testing with corresponding benefits to both phases of testing."[77] Colonel Nelson's evaluation of the F/A-22's ability to be ready for operational testing reviewed such areas as signature, speed, flying qualities, air-refueling handling qualities, agility, and so forth.[78] However, "MUT was not completed until one month prior to dedicated operational test. This left no time to implement any changes based on MUT findings."[79]

This brief look at the F/A-22's DT&E yields three observations. First, as for the F-15A, DT&E remained focused on airframe and manufacturing development. Second, the need to "look ahead" to operational testing is recognized (via MUT) yet remained difficult to accomplish. Finally, the need to have cooperative and overlapping T&E (developer to operator) is a necessary part of the acquisition process.

Operational Assessment

The Defense Acquisition Board (DAB) established the requirement for an operational assessment to support the decision to proceed with F/A-22 LRIP in August 2001.[80] The F/A-22's OA ran from January 1998 to December

2000 and, using the results of the DT&E missions, ultimately supported the certification of system readiness for operational testing.[81] In supporting the LRIP decision, the OA evaluated the F/A-22 against "the user's concept of operations (CONOPS), the ORD, and joint employment concepts to define F-22 system requirements and the environment in which it is expected to operate."[82] The OA also looked at the challenges or issues with further operational testing and considered the operational environment that the F/A-22 would operate in. Specifically, the OA contains the critical operational issues (COI) and key performance parameters (KPP) (table 1):

Table 1. F/A-22 critical operational issues and key performance parameters

F-22 Critical Operational Issues

1. Is the F-22 support package required to meet sortie surge rates in a global environment deployable with the authorized airlift?
2. Can the F-22 execute the counterair mission in the intended operating environment?
3. Is the F-22 more survivable operating in the intended surface-to-air and air-to-air environment?
4. Will the F-22 meet the required sortie surge rate?
5. Can the F-22 deliver air-to-surface munitions (JDAM [Joint Direct Attack Munition] 1000) during day, night, and all weather operations?

F-22 Key Performance Parameters

Radar Cross Section
Supercruise
Maneuver
Acceleration
Radar Detection Range Data
Combat Radius
Payload
Mean Time between Maintenance
Sortie Generation Rate
Independent Airlift

Reprinted from AFOTEC Final Report 00-27, *F-22 Weapons System Operational Assessment for LRIP* (Kirtland AFB, NM: Air Force Operational Test and Evaluation Center, 2000), 5.

The COI/KPP product frames the entire OT&E process to produce meaningful results. Note that COIs one through four were tested in IOT&E, while COI five is held for

FOT&E. ("As directed by SAF/AQ in the Program Management Document, AFOTEC will defer this COI until Joint Direct Attack Munition development has been completed.")[83]

Combined Developmental Test/Operational Test

Like the F/A-22's OA for LRIP, another aspect of F/A-22 testing that is distinct from F-15A testing is the combined developmental test (DT) and operational test (OT) relationship. In the F-15A, IOT&E was an addition to the developer's/contractor's testing. With the F/A-22 the relationship is formal, fulfills a specific purpose, and meets Title 10 *US Code*: "The term 'combined testing' means testing conducted by the developmental and operational testers when, because of cost, schedule, or test item availability, they must share test facilities, data or resources. Combined DT/OT serves as a bridge between the DT&E and IOT&E test programs."[84]

The major activities of combined DT/OT testing are sensor integration, offensive-weapons integration, survivability, suitability, climatic testing, and MUT.[85] Combined DT/OT testing meets the Title 10 legal requirements to evaluate separately but still achieve economies. The beauty of the combined DT/OT testing, when matched with the OA, is that it better prepares the evaluators to provide a superior product (in the form of reports and the actual weapons system) to the operator at IOC. Formal DT/OT integration is necessary to reduce cost, minimize duplication of effort, and push operational considerations further forward into the EMD process; it also clearly defines necessary program separations demanded by Title 10: "DT and OT may share data and resources; however, OT evaluators must evaluate and report data independently."[86] Finally, it is useful to have some familiarity with the timelines for developmental and operational testing (fig. 3).

F/A-22 to F-15C Comparison Testing

An interesting aspect of US fighter development is that the T&E process is not set in stone. The DOD can inject changes to the process to meet political, budgetary, or oversight requirements. An example of this occurred in 1977 with the F-15A's program when the AIMVAL/ACEVAL

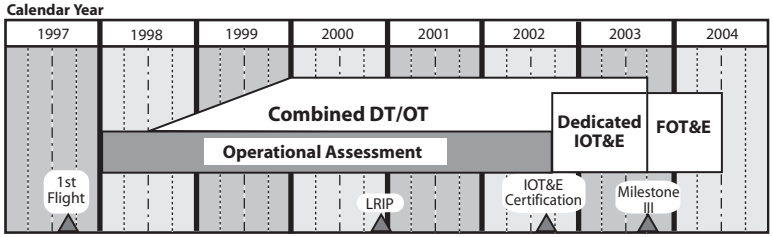

Figure 3. Timelines for developmental testing/operational testing. Air Force Operational Test and Evaluation Center, *F-22 Combined DT/OT Requirements Document* (Kirtland AFB, NM, 2000), 1–3.

test was guided by the director of defense research and engineering as a joint Navy/Air Force program with the Navy designated as executive service.[87] AIMVAL/ACEVAL looked at air combat in 1985, and "the results identified advantages and deficiencies of current air superiority aircraft in a fighter sweep scenario and suggested changes in research and development efforts, procurement, training and tactics to meet a forecast highly lethal, all-aspect threat in the visual arena."[88]

In the case of the F/A-22, a comparison between the F-15C and its replacement, the F/A-22, was directed via an acquisition decision memorandum (ADM) in 1992 to compare effectiveness as a prerequisite for passing the FRP decision.[89] AFOTEC was directed "to compare the mission effectiveness of the F/A-22 to the F-15C at the Nellis Test and Training Range (NTTR) with a criterion of 'two times better' under identical open-air conditions."[90]

To meet the ADM's requirements, F-15C and F/A-22 aircraft flew identical missions with specific methods of evaluation and performance to prove the F/A-22's two-times-better superiority. These missions are representative of current air-to-air doctrine and included force protection; high-value airborne-asset attack; and first-look, first-kill (FLFK) events.[91] This final event is unique in that it focuses on the prime reason for the F/A-22's superiority and also enables the evaluators to focus on weapons-system avionics: "ACC's top-level ORD requirement for the F/A-22 is that it achieve a first look, first shot, and first kill. Therefore, the

purpose of the FLFK is to determine the extent to which the F/A-22 and F-15C have an opportunity to detect, engage, and launch a missile that reaches endgame before the Red AI [airborne interceptor] has an opportunity to launch a missile."[92]

Phase One Operational Test and Evaluation

As with comparison testing (CT), Phase One OT&E (OT&E[1]) is an ADM-directed adjustment to the F/A-22's test program that demonstrated flexibility and a committed focus to operational evaluation. While OT&E(1) baselined the F/A-22's performance, it also incorporated open-air missions and simulator sorties at the Marietta Air Combat Simulator (ACS) facility.[93] The point to OT&E(1), however, is not the specific tests or number of missions flown, but the attitude that it demonstrates. OT&E(1) was the introduction, or warm-up, for IOT&E. As such, it demonstrated a commitment to make IOT&E as real, challenging, and "evaluate-able" as possible: "The IOT&E pilots will fly open-air OT&E(1) and IOT&E trials at the Edwards AFB Ranges and NTTR and then 'fly' 240 IOT&E trials in the ACS. It is critical that they stabilize at a high level of F/A-22 flying proficiency and also be highly proficient in F/A-22 tactical employment before starting OT&E(1) and IOT&E."[94]

As a warm-up for IOT&E, OT&E(1) emphasized that the F/A-22's IOT&E was more complex than the F-15A's (the "add-on" to DT). It was more detailed in scope—more operational and tactical measures of effectiveness than the F-15A's evaluation of offensive and defensive maneuvers—and demonstrated a desire to train the evaluators to a higher standard than the F-15's IOT&E or even its FOT&E. The F/A-22's pilot, maintenance, and test-support personnel were all trained via OT&E(1) before IOT&E.[95] OT&E(1) also established a commitment to enter testing when ready. AFOTEC calls this an active ready-to-test effort, which includes "quarterly reviews of all issues by AFOTEC/CC, Air Force Flight Test Center Commander, ACC Director of Requirements, AFOTEC Director of Operational Test and Evaluation, the F/A-22 SPO Director, and others as appropriate."[96] The mission of OA, CT, combined DT/OT, and OT&E(1) was to pave the way towards a smooth and effec-

tive initial operational test of the F/A-22. This represents a major change, even improvement, over the F-15A's T&E.

Initial Operational Test and Evaluation

IOT&E was conducted between April and August 2004.[97] The test report was not available at the time this research paper was written. Missions were similar to OT&E(1), with some as large as four F/A-22s against eight threat aircraft.[98] During the test, efforts were made to ensure that the test aircraft were configured similarly to production aircraft: "This includes efforts to eliminate all production representative differences with respect to effectiveness, such as mission planning, systems integration, employment, and interoperability, as well as with respect to suitability such as those that affect reliability, maintainability, and availability."[99]

However, the aircraft available for IOT&E were not "full-up." That is, they had limitations to their flight envelope—the program imposed aircraft operating limitations that were active through IOT&E.[100] But again, these restrictions were not expected to complicate or invalidate IOT&E results as the impact was accountable by the pilots, and the production aircraft will have improved G and airspeed capabilities over the IOT&E aircraft.[101]

Follow-on Operational Test and Evaluation

FOT&E is the final step in T&E for the F/A-22 en route to IOC at Langley AFB in December 2005. FOT&E began on 29 August 2005: "FOT&E will focus on air-to-ground attack and re-testing selected areas and capabilities found either before or during IOT&E to be deficient. Also, AFOTEC will test and evaluate those combat capabilities that are not released until FRP, yet still required for full operational capability. Deferred testing includes: JDAM, ferry mission demonstration, and pilot training system."[102]

It is notable that FOT&E begins four months before Langley declares IOC; the inferable impact is that any critical lessons learned from FOT&E could be simultaneously passed to the operators as they build up to IOC. But while lessons learned might be passed, changes to the aircraft or its avionics advised by FOT&E will not be possible. In ad-

dition, FOT&E will compete with IOC buildup for sortie generation and maintenance priorities. Unfortunately, as was the F-15A's FOT&E, the F/A-22's is late, relative to IOC. However, it will be "complete" in that the weapons and avionics in FOT&E match those of the IOC aircraft.

Summary

The various phases of T&E for the F/A-22 combine to form an interesting picture of the overall process that is easily compared to the F-15A's experience. The F-15A's T&E proceeded from contractor, to USAF, to operational testing (add-on initial and then follow-on during the buildup to IOC at Langley AFB), and finally to AIMVAL/ACEVAL testing after IOC to satisfy questions from oversight organizations. The process fielded a capable weapons system at IOC, but this researcher's overall impression of the testing was that it was incomplete and late.

By the time the F/A-22 was developed, the process had changed. The program was milestone-dominated to support production decisions, and in the case of the OA for LRIP decision, data from developmental testing was used for the OA. DT&E began the process, economies were achieved to allow combined DT/OT testing, and operational testing occurred in the familiar forms of initial and follow-on. But IOT&E(1) was added as a warm-up to initial operational testing, and oversight guidance was honored by CT of the F/A-22 versus the F-15C. As was the case with the F-15A, FOT&E will be accomplished during the final months of IOC buildup at Langley AFB.

Is the F/A-22's T&E incomplete and late, as it was with the F-15? The comparison is striking, yet the answer is not definite—clearly the F/A-22's process has yielded a weapons system that has been tested to an operational standard far exceeding that of the F-15A. The testers and evaluators have "done more" with the F/A-22 than was done with the F-15A. The current test program shows the unmistakable signs of the computer and the information age—more detail in the test plan, more organizational involvement, and a greater depth of evaluation than was possible in the 1970s. While the F/A-22's COIs/KPPs do not address every aspect

of operational employment, they certainly go beyond the scope of assessment of the F-15A's IOT&E and FOT&E.

The best conclusion regarding the F/A-22's T&E is that it used the same basic model as the F-15A, but with positive changes that attempted to push operational testing further forward in the process. However, the same challenges were met, and the same timing/delivery issues were repeated. But the USAF's experience of the past 29 years—along with the concurrent march of technology—has produced an aircraft with more capability at IOC than its predecessor. Like the F-15A, the brunt of the work for IOC still falls to the 1st Fighter Wing (FW) at Langley AFB. Perhaps the real question after comparing the F-15A with the F/A-22 is whether or not the T&E process has transformed during the last 29 years. That question will be considered after reviewing the F/A-22's IOC.

F/A-22 IOC at Langley AFB, December 2005

The first F-15s arrived at Langley AFB in December 1975, and so too the F/A-22 Raptor is destined to become IOC at Langley in December 2005. The buildup to IOC, as well as issues and concerns, is similar for both aircraft. Ironically, the comparison between IOC activities at Langley



F-15C and F/A-22 in formation over Langley AFB, Virginia **USAF Photo**

AFB for each aircraft bespeaks a 30-year technological gap; unfortunately, similarity remains at the core of both programs. The critical issues for the F/A-22's IOC in 2005 are virtually identical to those in 1976—facilities, training (operators and maintainers), sortie production (assumptions and technology), and deployability.

F/A-22 Facilities Issues

Beddown of the F/A-22 at Langley AFB is closely monitored and planned at the wing and major command (MAJCOM) levels by means of Site Activation Task Force (SATAF) analysis, program management review (PMR) coordination, and briefings to the ACC commander (COMACC). The PMR briefings codify issues as either red, yellow, or green with respect to their impact on IOC (table 2). The chart indicates that planners have addressed construction issues but that they have not identified potential limitations to IOC. However, a problem that was not experienced with the F-15A at Langley is the intense classification requirements associated with the F/A-22 and the squadrons, hangars, and other maintenance facilities needed. This problem is similar to the security issues associated with the F-117 and the B-2. While not significant, innovative solutions are part and parcel of the 1st FW's leadership at Langley AFB during the F/A-22 beddown.[103]

F/A-22 IOC Training Issues

IOC calls for an aircraft, weapons, a support system, a CONOPS for combat employment, and the people trained to operate the weapons system. This presents a problem since the aircraft has to fly in order for both pilots and maintainers to get training. Training is accomplished through academic courses, transfer of lessons learned from test and fighter training unit (FTU) operations, maintenance trainers, and simulators. All of these training methods were in place for the F-15A, but the march of time has definitely left its mark—technology has changed the means of learning and the degree of expertise required. By way of analogy, replace the F/A-22 with a 2005 Cadillac, and compare it to the technology, repair, and training needed to operate a 1976 Cadillac. The computer is the

Table 2. 1st Fighter Wing facilities status

Item	Current Status	Assessment
Low Observable and Composite Repair Facility (LO/CRF)	Configuration Review Board (CRB) has some control problems being corrected	Yellow
Flight Simulator	Boeing working electrical concerns w/their equipment. Estimated completion date (ECD)–Dec 04	Yl/Gr
Hush House Repairs	Hush House #2 ECD–30 Nov 04; Hush House #1 ECD–24 Dec 04	Green
Weapons Load Trainer (WLT) Repair	Awaiting Noise/Exhaust Data Report from SPO to begin design	Yellow
Missile Storage (Munitions Storage Area [MSA])	Preconstruction meetings complete by 1 Dec 04	Green
Aerospace Ground Equipment (AGE)/ Maintenance (MX) Storage (MSA)	Preconstruction meetings complete by 1 Dec 04	Green
Munitions Assembly Conveyor (MSA)	Preconstruction meetings complete by 1 Dec 04	Green
Munitions Storage Igloo (MSA)	Preconstruction meetings complete by 1 Dec 04	Green
Squadron Ops 2 & 3	On Track	Green

Adapted from Thomas Tinsley, commander, 1st Operations Group, Langley AFB, VA, PowerPoint briefing and notes, subject: 1st Fighter Wing F/A-22 Status of Operations, 1 Nov. 2004, slide 2.

largest single technological change, and the simulator is a good example of the differences between the F-15A's and the F/A-22's IOC.

Unlike the F-15A's pilots, who did not have a simulator to use at Langley AFB until late 1976, the F/A-22's pilots have two simulators available. The simulator at Langley AFB was open for use in May 2005, and the ACS facility at Lockheed in Marietta, Georgia, is also under contract for pilot training.[104] IOC pilots have had access to simulator training at their home station for six months prior to IOC and to the ACS facility for nearly a full year. But simulators

do not replace real flying. In terms of fighter-pilot proficiency, simulators augment sorties, and it is in this area that IOC meets its greatest challenge.

F/A-22 Sortie Production

The key to IOC from the operations perspective is to have proficient pilots at IOC, and that necessitates the need to generate sorties.[105] IOC requires a combination of aircraft, trained pilots from Tyndall AFB, Florida (the FTU), and proficient pilots. As it did for the F-15A's IOC, Langley AFB will receive loaner jets from Tyndall AFB (Luke in 1976) for maintenance training and operations flying.[106] The 1st FW built a plan that used the best data for aircraft delivery from the F/A-22 SPO, determined the proper level of flying for pilot proficiency (modeled on current fighter-training standards), and made sortie-generation assumptions based on the F/A-22's performance at Tyndall AFB.

The 1st FW made some key assumptions that show an understanding of the lessons of the F-15A. First, the sorties required for pilot proficiency are adjusted from those used by a fully operational aircraft. Headquarters ACC's Ready Aircrew Program (RAP) is designed to codify the training-sortie rates needed for proficiency and thereby create planning factors for sortie rates and the ability to justify flying budgets.[107] What Langley has done is allow for a monthly increase in RAP requirements leading to IOC. Pilots will receive increasing numbers of sorties per month approaching December 2005 (fig. 4). The second key assumption is expected sortie rate. In 2004 F/A-22s at Tyndall AFB flew on average 13 times per month—or an aircraft utilization rate (UTE) of 13 sorties per month per aircraft.[108] Currently, the 1st FW's leadership is programming for a UTE that starts at five sorties per month per aircraft and increases to 12 as IOC is approached (fig. 4).[109] This allows for maintenance limitations (training, proficiency, availability of tech-order data, etc.) and spare-parts issues (availability, priority, etc.) with the F/A-22 that are similar to those of the F-15A. The 1st FW's leadership is counting on a learning curve that will allow near parity with Tyndall's performance by IOC. Failure to reach these planned UTE rates provides significant issues for pilot proficiency at

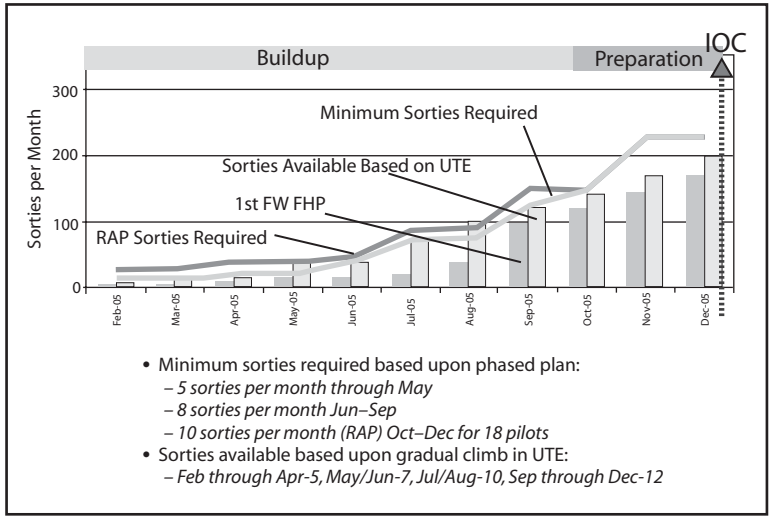

Figure 4. Langley AFB RAP sortie requirements. (From Col Thomas Tinsley, commander, 1st Operations Group, Langley AFB, VA, PowerPoint briefing and notes, subject: 1st Fighter Wing F/A-22 Status of Operations, 1 Nov. 2004, slide 6.)

IOC. If sortie-production rates are less than anticipated, then IOC will either be declared with pilots with lower flying proficiency or with fewer pilots meeting RAP-mandated levels of proficiency.

Sortie production is critical to the F/A-22's IOC. An issue for all phases of T&E, it will likely remain the frustrating aspect of IOC and the area requiring planning flexibility. Sortie production may even be a constant that cannot be overcome amongst all new major weapons systems.

Just as planning assumptions translate sortie production into pilot/maintainer proficiency at IOC, so will the F/A-22's new technology affect IOC. The F/A-22 represents a technological leap in combat performance. Its technological advances permeate the entire program and create choke points for sortie production. Two specific areas that affect IOC at Langley AFB are modifications to the aircraft after they leave the factory and a specific system called Integrated Maintenance Information System (IMIS). While these issues are not "showstoppers" to IOC, they could be-

come the source for lower sortie rates that, in turn, reduce pilot proficiency at IOC.

The F/A-22's production line is maturing as the testing proceeds. EMD aircraft serve to refine the production-line process, and LRIP aircraft allow for incorporation of modifications identified as needed during DT&E and OT&E. The actual incorporation of the needed modifications into the fleet is, however, problematic. Aircraft are of different lots or production periods and have slight differences requiring careful program management. This problem is eradicated as the aircraft move into FRP and as changes to the airframe or avionics are minimized, eliminated, or made consistent between all fielded aircraft. When modifications are needed, changes can slow aircraft production and delivery or require aircraft downtime in the field for modifications to be made.

Three such F/A-22 modifications affect the aircraft for Langley AFB: Lot three Operational Flight Program (OFP) software changes, infrared countermeasures (IRCM) shroud installation, and night air-to-air refueling (NAAR) lighting changes.[110] The details of these modifications are beyond the scope of this paper, but the solutions and impact on IOC are noteworthy.

The NAAR lighting modification is a solution offered in response to testing that identified a difficulty with nighttime refueling of the F/A-22 by the KC-135. The solution is to change the existing lighting and paint scheme around the air-refueling receptacle.[111] The installation plan is to accelerate the retrofit kit production and divide the modification work between the factory and Langley AFB.[112] This solution is common in fighter-aircraft production and modification and uses the terms *Group A* and *Group B* modifications. Group A is the work that can be done immediately during production or with parts on hand, while Group B is the portion of the modification that can be completed after retrofit kits are available from the supplier and are usually installed at the operational location. This Group A/B solution maximizes the factory's production time while minimizing the downtime that the operational site has to use for the modification. A response to flight testing, IRCM shroud modification, was also solved via a Group A/B solution with factory and operational-site in-

stallations.[113] While this method of fixing a deficiency identified in flight testing is commendable and done most efficiently, it is not without cost.

The addition of these two modifications alone requires running a modification line at Langley AFB for seven days a week, using two shifts each, and working 10 hours per shift.[114] This kind of aircraft downtime translates into lost RAP sorties contributing to IOC, greater demand on maintenance at Langley AFB, and greater potential for delays as aircraft are "cracked open" to allow internal modifications. Realistically, the assumptions graphed in figure 4 could change in real time as the modifications are made.

The final modification to the F/A-22 at Langley AFB—the avionics OFP change—is estimated to require more modification downtime and is significant. Estimated additional downtime per jet is 10 days beyond the other modifications, bringing the downtime for delivered aircraft at Langley AFB to 51 days.[115] This is a consequential issue as the sortie-production assumptions contained in the previous figures reflect "only a one month down time for the OFP mod plan of two jets per month."[116] Assuming that aircraft delivery significantly increased beginning in May 2005, a 51-day downtime on each aircraft represents 24 percent of the available time to use the aircraft for sorties before IOC. Clearly, performing aircraft modifications at the operational site could prove to be a significant hurdle to achieving IOC with the training and proficiency desired.

While aircraft modifications during IOC buildup can affect schedules, the F/A-22's technology itself can create friction. One such case is the IMIS, which

> provides the F-22 with a paperless maintenance environment and includes areas such as aircraft forms, scheduling, report generation, [and] technical order data. . . . By providing diagnostic and Interactive Electronic Technical Manual (IETM) data, F-22 IMIS reduces man-hours needed to service, troubleshoot and repair aircraft systems. IMIS performance is critical to the achievement of high sortie rates, minimized aircraft downtime, and maintenance with minimum support resources.[117]

Yet the 1st FW identifies this system as undergoing multiple software versions with incompatibility issues with different lots of aircraft.[118] Perhaps, similar to the avionics test-station failures of 1976, the IMIS (or another new technology on

the F/A-22) could be a technology choke point for the F/A-22 in 2005.

At this point, a direct comparison with the F-15A's IOC in 1976 versus the F/A-22 is instructive. Both programs faced issues with facilities, sortie production, and technology. With both aircraft the 1st FW had to overcome relatively the same issues. There are, however, some immediate differences.

For instance, the F/A-22's IOC has greater access to simulators for training but must also deal with aircraft modifications at Langley AFB that produce aircraft downtime and affect sortie rates. Another area of difference is the meaning of IOC declaration. Langley AFB expects to receive its 17th F/A-22 by 31 December 2005 and declare IOC.[119] In contrast, in 1976 Langley AFB received its 24th F-15A and 17 days later deployed to Nellis for a Red Flag exercise.[120] This was in July 1976, and IOC was not declared until October, with one squadron IOC and another IOC by December.[121] Clearly, troops in 1976 had more exposure to the F-15A prior to IOC than the men and women at Langley AFB will have with the F/A-22 in December 2005. While that may seem noteworthy, the key is the definition of IOC. According to Headquarters ACC, "IOC decision is based on providing an operationally credible capability to the combatant commanders rather than providing a specified number of aircraft."[122]

In short, the 1st TFW in 1976 had more aircraft for more time before IOC than the 1st FW will with F/A-22s in 2005. Did this translate into a "better" IOC than the F/A-22 will have? It is certainly different, but the greater detail of the T&E process coupled with the availability of the ACS should make for better F/A-22 IOC than was available for the F-15A. Perhaps the cause for concern lies in the slips to the T&E program schedule that the 1st FW must ultimately accommodate to avoid a delay of IOC declaration.

Conclusions and Recommendations

The F/A-22's IOC at Langley AFB in 2005 is a momentous time for the Combat Air Forces (CAF). It represents a paradigm shift in USAF airpower and, like the F-15A's arrival

in 1976, an opportunity for change that may not be repeated in a generation. Lessons from the F-15A's IOC can be used as a comparison and measure of merit against the current buildup for F/A-22 IOC. If developmental or IOC issues that occurred with the F-15A continue with the F/A-22, then observations can be readily made—either the issues are inherent with a new aircraft's IOC or the T&E system has not adapted—or perhaps even failed—to learn from past lessons. Langley's lessons of 1976 can either confirm or condemn the process now under way in 2005. Even beyond the direct comparison between the two aircraft, the Raptor's IOC could be used as a springboard to further needed actions. It is conceivable that this comparison might call for transformation in the entire T&E process.

Comparison of the two T&E processes reveals that both the F-15A and the F/A-22 used the same model for T&E (DT and then OT). The programs faced milestones that were used to keep them on track and aligned with the contracts. Both had to react to oversight direction (AIMVAL/ACEVAL and F-15C versus F/A-22 CT), needed greater operational involvement in the early phases of the testing (add-on IOT&E in the F-15A and a call for greater MUT in developmental testing for the F/A-22), and completed their T&E processes right before IOC at Langley AFB. Testing was more extensive and technology more prominent in facilitating proficiency at IOC for the F/A-22 than for the F-15A. But could more have been done?

An argument could be made that "better" IOC is needed—not an IOC that meets a rigid timeline but one that truly represents an initial combat capability to the COCOM. Perhaps IOC declaration needs to be adjusted to the delays that the T&E process (or the manufacturer) causes. Perhaps IOC should be a more flexible target date, one that moves as the program shifts. Instead of asking the IOC base's leadership to "do more with less," perhaps the IOC declaration date should be allowed to move. Unfortunately, it can be equally well argued that flexibility in the IOC declaration date is unrealistic because it is the key milestone that Congress uses to ensure that a program it funds is implemented as it directs and is completed on time. Ultimately, the point to debate is whether or not a hard IOC

date negatively affects organizational behavior during development or at the IOC base.

Another idea is to consider transforming the three-step T&E process to update the model that the F-15A and F/A-22 used. Surely the record of the F/A-22 does not indicate a T&E program that is beyond review. In 2002 Mr. Thomas P. Christie, the director for OT&E in the OSD said, "I took part in the DAB review in the fall of 1986 that approved its [the advanced tactical fighter] entry into Demonstration/Validation (Dem/Val). More than 15 years and $27B later, we're still at least a year away from IOT&E and several years from Full Operational Capability for the F-22."[123]

Transformation, defined by the USAF as "a process by which the Air Force achieves and maintains advantage through changes in operational concepts, organizations, and/or technologies that significantly improve its war fighting capabilities or ability to meet the demands of a changing security environment," is the watchword for the DOD in the first part of the twenty-first century.[124] Could the USAF's T&E system also be transformed? Perhaps the relationship between Air Force Materiel Command (AFMC) and ACC is antiquated and needs to be rethought. The F/A-22's combined DT/OT to achieve economies hints at a means of getting more out of T&E data. Could not the call for greater MUT in DT also be an earmark for a need of a new model or construct for T&E? Was the F/A-22's OT&E(1) a fix or a look to the future?

But just as delaying IOC declaration may be unrealistic, so too may changes to the T&E process be impractical because of the enormous bureaucracy and needed review that is associated with a modern weapons system. It could be that acquisition reform or transformation is not possible because of Title 10 legal requirements mandated by Congress. However that may be, findings of this paper indicate that ideas for improvement on a lesser scale could be made for fighter IOC that can be accomplished at the MAJCOM level—ideas that are more practical than the aforementioned grand ones:

1. *Visit the last base to declare IOC.* Wings that are expecting to transition to a new weapons system should avail themselves of the experience of the most

recent base to go through the same process. For example, the 1st FW should observe B-2 operations at Whiteman AFB, Missouri, and learn as much as it can about the B-2's IOC process. In all likelihood, certain B-2 lessons learned will be applicable to the F/A-22 at Langley AFB.

2. *Formally hand off F/A-22 from AFMC to ACC.* As the T&E process reaches milestones, decisions are made based on available information. In the case of the F/A-22, AFOTEC produced an operational assessment for LRIP with the purpose of giving decision makers every bit of information and a recommendation for the LRIP decision. A document of this flavor could be created and declared due to ACC at some time before IOC. Certainly, the current coordination between the involved commands and agencies is great. But no document could be located that said, in effect, "Langley, these are the problems, issues, and concerns that you will likely have with the F/A-22. . . . The developer and evaluator recommend the following." SATAFs, PMRs, T&E reports, and transfer of trained personnel are all great steps—however, a formal document/procedure might improve the process.
3. *Form an IOC advisory board.* Numerous organizations (e.g., the US Air Force Academy) make use of an advisory board that has the ability to look at an organization and its issues with the perspective of experience and distance. Such a board might be useful in helping the IOC wing think "outside of the box" and offer positive ideas. Granted, people don't want anyone looking over their shoulder, neither do they want close oversight of the "in my day we did it this way" variety by senior officers or extra work for an already overtasked unit trying to meet a deadline. But a positive aspect of an advisory-board model might allow issues to be rapidly elevated or provide senior officers with the information they need to remain comfortable with a project with political oversight.
4. *Conduct F/A-22 road shows.* Part of IOC needs to be a campaign to get the new weapons system into the CAF. Other weapons systems that are going to operate with it need to know what to expect, and operational

and strategic planners need to know the capabilities and differences of the new aircraft. The 1st TFW in 1976 took the F-15A on the road to Nellis AFB four times before IOC in order to affect maintenance and training. A secondary effect was to get the CAF familiar with the new aircraft. The same could be true now about the F/A-22. It represents a significant change in capability, and the tactics of the F/A-22 will likely revolutionize how the rest of the CAF fights with it. Certainly, public affairs releases can "sell the Raptor," but getting the F/A-22 visible in the field and at bases across the United States will expedite the normalization of the aircraft in the USAF.

5. *Capture the data from IOC.* Besides histories, the single source for the F-15A's IOC at Langley AFB was written by two captains, Lennon and Wray, in the 1st TFW. Without their publication, a study of the focused IOC issues would be extremely difficult and research intensive. As with Lieutenant Colonel Lewis's *History of the F-15 Eagle*, agencies connected with the F/A-22 and Langley AFB need to take the time now to create a document that records the lessons learned from development, testing, and IOC of the F/A-22. It is interesting to note that Colonel Lewis wrote his history in May of 1976 (five months before IOC), and Captains Wray and Lennon wrote their study in June 1977 (eight months after IOC). If anything, this points to the need to record the events while the memories are still recent.
6. *Change the path to IOC.* While changes to acquisition and reform for T&E may be unrealistic due to the entrenched nature of these processes, perhaps changes to IOC and its definition might be possible. From ACC's perspective, "ACC has developed tiered IOC readiness requirements to guide and monitor progress toward IOC. The requirements are divided into four main categories: Aircraft Status, Operations, Maintenance & Logistics, and Base Support."[125] The IOC definition could be tightened to create specific measures of effectiveness. If IOC dates cannot be changed once determined, then a balance must be struck between flexibility and combat capability provided to

the COCOM. The idea behind tighter IOC requirements might serve to focus energies on areas that truly matter—for example, a checklist of achievements that relates to the ability of the new weapons system to perform in combat:

a. Aircraft status: number of jets on ramp, completion of OFP changes, or hardware modifications.
b. Operations: training production from the FTU, two completed deployments (Red Flag and Weapons System Evaluation Program [WSEP]).
c. Maintenance: training production from AETC, UTE rate goals met, maintenance indicator goals met.
d. Base support: facilities construction complete, first operational readiness inspection (ORI) complete.

7. *Address transformational change.* Finally, the last step of the IOC process might be to step back from the details of replacing an old weapons system with a new one and determine if transformational change is needed. If the F/A-22 brings radical change in warfighting capabilities to the COCOM, then perhaps far-reaching change should be implemented. For example, the technology of the F/A-22 may need organizational changes in the 1st FW because of new maintenance-repair ideas. Do maintenance squadrons need to change functions, names, or relationships? Do the operational concepts of the F/A-22 call for a change to the F-15's fighter- squadron organization? Does the director of operations' scheduling shop or weapons shop need to be changed or augmented? Could the Global Strike Task Force concept that the F/A-22 is part of call for a different wing organization? Maybe air-refueling tankers need to be part of the 1st FW to allow the F/A-22 to execute its mission. Does the air-to-ground mission of the F/A-22 demand that the airspace and ranges around Langley AFB be changed to better support training for the F/A-22 mission? What about adversaries to provide training for F/A-22 pilots? If the F/A-22 is "head-and-shoulders" above other US fighters, then the current method of conducting dissimilar air combat training might be inadequate for the F/A-22. In short, if the F/A-22 is truly transformational, then

> IOC will not be complete without out-of-the-box thinking and analysis of how the USAF will use the F/A-22.

In summary, the approach of the F/A-22's IOC is not a time to lean back and smile like the parent of a newborn child. The process has been long, yet now is the time to capitalize, to push out the old ideas of the F-15C, and to lay the foundation for rapid growth of the F/A-22 as a weapons system that will mature in the next 20 or 30 years. The changes can be radical—changing the T&E model used for the F-15A and the F/A-22, for instance. Or they can be simple—perhaps merely capturing the history of the process for future fighters to use. Either way, IOC needs to go beyond "checking the squares" and determine a means of pushing for the transformation that the F/A-22 provides the CAF. If nothing else, these recommendations indicate that there are still more questions than answers for CAF leaders to consider as they plan ahead for the Raptors.

Fighter IOC is a significant event: the 29-year gap between the F-15A and the F/A-22 indicates that USAF leaders may face it only once in their careers. The cost and investment alone calls for singular emphasis and insight. Comparison of the F-15A's and the F/A-22's road to IOC reveals fascinating similarities and differences. In retrospect too much was similar, right down to the same IOC issues of training, sortie-rate assumptions, and technology choke points. In both cases the wing at Langley AFB was the final step in the process, and the leadership—separated by 29 years—had to make the difference in order for IOC to be successful. Surely this comparison calls for the USAF's vision of transformation to be applied to how a new weapons system reaches IOC.

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80. AFOTEC Det. 6 Test Report 03-001, *F/A-22 Weapons System*, 1.

81. AFOTEC Final Report 00-27, *F-22 Weapons System*, 1–2.

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83. Ibid., 17.

84. AFOTEC, *F-22 Combined DT/OT Requirements Document* (Kirtland AFB, NM: AFOTEC, 2000), viii.

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86. Ibid., viii.

87. History, Air Force Test and Evaluation Center, 1 Jan.–31 Dec. 1977, I-1.

88. Ibid., xv.

89. AFOTEC Det. 6 Test Report 03-001, *F/A-22 Weapons System*, v.

90. Ibid., F-1.

91. Ibid.

92. Ibid., F-5.

93. Ibid., 13. Note that a telephonic interview with and e-mail from Col Matthew Black, AFOTEC Det. 6/TM, 22 Feb. 2005, indicated that the 240 ACS missions were not flown as planned in IOT&E(1).

94. AFOTEC Det. 6 Test Report 03-001, *F/A-22 Weapons System*, 15.

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100. Ibid., 6.

101. Ibid.

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106. Ibid., slide 5.

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110. Ralph Andrews, Mark Parsons, and Charlie Jones, "Langley SATAF Mods," PowerPoint briefing and notes, Nov. 2004, slide 3.

111. Ibid., slide 7.

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121. Ibid., 6.

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123. Thomas P. Christie, director, Operational Test and Evaluation, "Test and Evaluation's Role in Experimentation" (speech, Southern Maryland International Test and Evaluation Association [ITEA] Chapter, 10 Apr. 2002), 4, http://www.dote.osd.mil/presentations/Christie20020410/paxspeech.html.

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