

412TW-PA-24113



HISTORY OF THE AFFTC, VOL 1 F-16 CHAPTER – PAGES 81-95

**A
F
F
T
C**

AFFTC HISTORY OFFICE

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE,
CALIFORNIA

1 JUL 74 – 30 JUN 75

RELEASED
23 APRIL 2024

DISTRIBUTION STATEMENT A – APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED.

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 23-04-2024			2. REPORT Historical Document			3. DATES COVERED (From - To) 1 Jul 74 – 30 Jun 75		
4. TITLE AND SUBTITLE Pages from - History of the AFFTC, Vol 1 (F-16 Chapter) Pgs. 81-95						5a. CONTRACT NUMBER		
						5b. GRANT NUMBER		
						5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) AFFTC History Office						5d. PROJECT NUMBER		
						5e. TASK NUMBER		
						5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES) AFTC/HO 305 East Popson Ave Edwards AFB CA 93523						8. PERFORMING ORGANIZATION REPORT NUMBER 412TW-PA-24113		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) 412th Test Wing 195 E Popson Ave Edwards AFB CA 93524						10. SPONSOR/MONITOR'S ACRONYM(S) N/A		
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION / AVAILABILITY STATEMENT								
13. SUPPLEMENTARY NOTES								
14. ABSTRACT								
15. SUBJECT TERMS AFFTC Histories, F-16								
16. SECURITY CLASSIFICATION OF: Unclassified			17. LIMITATION OF ABSTRACT None		18. NUMBER OF PAGES 17	19a. NAME OF RESPONSIBLE PERSON 412 TENG/EN (Tech Pubs)		
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified				19b. TELEPHONE NUMBER (include area code) 661-277-8615		

The Lightweight Fighter*

Summary. The lightweight fighter (LWF) program maintained a particularly crowded schedule during this fiscal year. Specific highlights were the Department of the Air Force announcement of plans for LWF full scale development, with source selection and contract awards by January 1975; the consequent acceleration of the YF-17 test and evaluation schedule to meet Source Selection Board deadlines; the growing concentration of interest in the prototype competition both on national and international levels; the January 1975 selection of the F-16 as air combat fighter (ACF), and concomitant full scale development orders; preparation for and participation of the YF-16 in the 1975 Paris International Aviation and Space Salon, and subsequent demonstration in NATO countries; and, finally, the announcement in June by a four-country European consortium of the selection of the F-16 as their air combat fighter.

During this time, the joint test force experienced continuing stress involving numerous visits of political and military dignitaries, sudden changes of schedule, and frequent unanticipated cross-country trips. By the end of the fiscal year, however, the reorganization from LWF Joint Test Force to F-16 Joint Test Force had been accomplished, and the full scale development program was under way, awaiting the imminent (early July) return of the demonstration aircraft from Europe.

* This section was written by Dr. Joseph H. Stodder.

Secretary of Defense James Schlesinger's January 1975 announcement of the selection of the F-16 as the new Air Force air combat fighter, coming as it did midway in the fiscal year, provides a convenient chronological division for a discussion of the LWF/ACF development program. The following two sections, then, on YF-16 and YF-17 testing, will cover the conclusion of the LWF prototype competition leading up to the January source selection.

YF-16 Testing. The YF-16 prototype flight test program, which had begun on 2 February 1974, was brought to a successful conclusion on 31 January 1975. The two test aircraft achieved a combined total of 347 flights and 439 flying hours. All planned test phases were completed, including not only such standard routines as aerial refueling, formation flying, and weapons launching, but also demonstration of the special YF-16 advanced technology features^{38/} Some of these features, including the fly-by-wire flight control system (without mechanical backup) with its side-stick controller, the design negative static margin, the angle of attack and structural limiters, and the fast-acting, automatically scheduled leading edge flaps, were especially noteworthy because they were state-of-the-art techniques which had been tested individually but never before been combined in a single aircraft design.^{39/}

38. Historical report, LWF/JTF, Jul-Dec 74.

39. Flying Qualities Evaluation of the YF-16 Prototype Lightweight Fighter. Final Report, July 1975, TR-75-15, Hq. AFFTC.

Fly-by-Wire System and Side-Stick Controller. One of the most unusual of the YF-16 advanced features was its fully electronic, analog, fly-by-wire flight control system with its side-stick controller. In this system, flight control surfaces were hydraulically actuated, the actuators being driven by electrically controlled signals. Impulses from pilot pressure on the side-stick controller were transmitted through a quadruplex electrical system, rather than through mechanical linkage, to the flight control surface actuators. The quadruplex system provided for fail-operative performance after two failures in each of the three control axes.^{40/}

The side-stick controller, located on the right console, resembled in size and appearance the grip portion of standard center control sticks. Its unique feature was its force-sensing capability, which enabled the pilot's control forces to be translated, through the all-electronic analog computer, into signals which activated the respective flight control surfaces in precise response to the pilot's control forces.^{41/}

Although posing an initial potential problem of adaptation for the pilot, the side-stick controller offered numerous advantages over the conventional control stick:

The hand controller was physically smaller, and when mounted on a side console allowed the lower front center cockpit area to be used for additional avionics, flight instrumentation, and other types of pilot controls. Absence of a center stick afforded the pilot an unobstructed view of, and easy

40. Ibid.

41. Ibid.

* The simultaneous transmission of four signals within the same channel.

access to, this area. Also, the ejection clearance envelope was unobstructed. Because the force stick was essentially rigid, its installation required less volume than a displacement side arm controller free to pivot about its base. A force stick was also less susceptible to the undesirable friction and deadbands associated with displacement mechanisms. The choice of a fly-by-wire flight control system without mechanical backup made it possible to choose from several stick installation locations within the cockpit; placement of the controller at the side of the cockpit offered the possibility of supporting the pilot's forearm with an armrest for improved precision controllability under high load factors. Finally, installation of a mechanically geared center stick together with a 30-degree-tiltback seat in the YF-16 would have involved a complicated stick design, would have required an unusual and unsupported arm extension for normal flight, and would possibly have hampered the pilot's ability to turn in the seat to look to his rear while maneuvering.42/

Several disadvantages were noted in the use of the system. Primary among these was its susceptibility to pilot-induced oscillations. The incorporation of fairly heavy damping pre-filters in both the longitudinal and latitudinal axes reduced this susceptibility substantially but imposed penalties on the prototype's maneuverability (degrading the rate of load factor onset and roll acceleration). The problem, however, was not regarded as a serious impediment to acceptance of the side-stick controller concept by pilots:

. . . each of the 11 pilots who evaluated it felt that it required minimum adaptation time, functioned satisfactorily in every phase of a fighter's mission, and was a sound concept suitable for further development in an air superiority fighter.

They felt that their first two YF-16 flights provided sufficient exposure and learning time to adapt to the force stick for most of the tasks normally encountered in an operational mission profile. They also felt that the methods currently used in USAF aircrew training programs would be sufficient to familiarize and qualify future pilots in side-stick-controlled aircraft.43/

42. Ibid.

43. Ibid.

In October, to explore the desirability of stick movement compared to the side-stick semirigidity, the controller was modified to provide limited longitudinal movement (a maximum of 3/4 inch aft and 3/8 inch forward). Later, in December, the controller was again modified to reduce this movement by fifty percent. The reaction of the pilots to the modifications was mixed and inconclusive, though a consensus felt that full-travel displacement was helpful in that it confirmed attainment of maximum control response.^{44/}

Design Negative Static Margin. The ability of the YF-16 prototype to accomplish most of its subsonic maneuvers in a neutral-to-negative static margin ensured maximum performance in the subsonic flight range. Basically, static margin is the difference between aircraft center of gravity and its center of pressure, or lift. The lack of stability was offset, however, by the functioning of the stabilizing loop within the fly-by-wire system, which automatically counteracted diverting aerodynamic pressures:

44. Ibid.

In the low Mach number envelope, the YF-16 flew with negative static margins as great as 11 percent MAC /mean aerodynamic chord/, although wind tunnel studies predicted only a 3 to 5 percent negative static margin in the CR /cruise/ configuration. The effective horizontal tail and active stabilizing loop in the FCS /flight control system/ pitch axis worked as designed in keeping the aircraft well balanced in pitch, except at very low dynamic pressure or during maximum rolls at high angle of attack.^{45/}

The trim drag inherent in conventionally balanced aircraft was also reduced. The YF-16 thus was able to remain in the desired negative static margin much more effortlessly than would an aircraft with conventional flight controls. Because of the instability thus created, the YF-16 possessed a degree of maneuverability previously unavailable in fighter aircraft.

Angle-of-Attack and Structural Limiters. In order to free the pilot from the ordinary concerns of remaining within aerodynamic and structural limits during high-concentration maneuvers such as occur in combat, automatic limiters have been incorporated into the YF-16 flight control system. The angle-of-attack (or "alpha") limiter was initially set 28 degrees angle of attack. During one phase of the test program the alpha limiter protection was relaxed to permit a controlled evaluation up to the angles of attack attainable with a 30.3-degree limiter. The maximum angle of attack attained in level unaccelerated flight was 29 degrees. When this test phase was finished, the limiter was again set at 25 degrees for the remainder of the prototype test program.^{46/}

45. Ibid.

46. Ibid.

The structural ("g") limiter provided structural protection in the center of the air combat maneuver envelope. Structural load factor limiting would be desirable in any high-performance aircraft, but was even more so in the YF-16:

Automatic load factor limiting was valuable because the aircraft itself provided few cues to assist the pilot to provide his own structural protection. The increased g tolerance due to the 30-degree seat tilt-back angle increased the load factors at which the traditional gray-out and black-out occurred. The pilots' subconscious reliance upon these physiological indicators was misleading in the YF-16 because the cue references were acquired in aircraft with upright seats. Further, Mach buffet intensity was reduced over the entire transonic speed range, especially at elevated load factors, and buffet was not significant as a warning device.^{47/}

The prototype g limiter was set at 6.48 g's with 80 percent internal fuel. The full scale development aircraft, however, would be less restricted, with a 7.33 g limit with full internal fuel.^{48/} The question remains, even with the more liberal g limit, as to the advisability of incorporating a limit override:

It is inevitable that there will be occasions in training and combat when pilots will inadvertantly press too close to the ground. In such situations it would appear that a pilot should have the option of overriding the g limiter and taxing the full load factor capability of the design to the extreme of the structural yield point or structural failure.^{49/}

There were, however, many complicated aspects of the question of overriding the g limiter, both from the standpoint of engineering and of pilot experience. At the end of the FY 1975 reporting period, the question of a possible g limiter override remained under study.

47. Ibid.

48. Ibid.

49. Ibid,

Fast-Acting, Automatically Scheduled Leading Edge Flaps. YF-16 maneuverability in transonic ranges was further enhanced by the incorporation of fast-acting, automatically scheduled leading edge flaps. The specific design benefits of this feature were increased directional stability and improved lift through variable wing camber. In subsonic flight, flap deflection increased, in relation to speed and angle of attack, to a maximum deflection of 32.6 degrees at Mach 0.99 and 27.2 degrees angle of attack. Combined with the vortex-generating forebody strakes, the fast-acting, automatically scheduled flaps ensured that buffet levels for the YF-16 would be considerably lower than those of current operational fighters.^{50/}

Other Advanced Technology Features. Additional distinctive features of the YF-16 which require less explanation but were no less important and innovative were:

- o a gunfire yaw compensation device which produced an automatic compensating deflection for the yaw moment caused by the firing of the M-61 20-mm cannon mounted on the left side of the fuselage.^{51/}

- o a one-piece bubble canopy, providing an extraordinarily wide visual range

- o a high-g, 30-degree-inclined seat to provide more comprehensive physical support during high g maneuvers. The inclined seat permitted increased tolerance of 1 1/2 to 2 g's.^{52/}

50. Ibid.

51. Ibid.

52. Air Force Magazine; June 1974; p. 27.

Handling Qualities During Tracking. Both the YF-16 and YF-17 prototype aircraft underwent tests to evaluate their handling qualities during tracking in this phase of the program. This tracking technique made use of stability and control testing to evaluate the overall handling qualities, control system characteristics, and precision controllability of the aircraft in the context of a "high-gain, pilot-in-the-loop, operationally oriented task."* Because tracking retained precision controllability, with its high demands on pilot performance, and because it was capable of producing quantitative data, this evaluation soon became a primary, indispensable phase of the test program.^{53/}

The following brief description may be helpful in further explaining this important technique:

A /handling qualities during tracking/ test maneuver involves approximately 40 seconds of precision tracking of an aiming point on a target aircraft during a constant-g or slow windup turn. The gun camera film is then scored and computer processed to display a qualitative and quantitative summary of the run. Pilot comments supported by analysis of the general trend of the pitch and azimuth tracking characteristics may then reveal handling qualities deficiencies which might impact on the capability of the fighter to accomplish its mission. In short, the objective of /handling qualities during tracking/ is to quickly uncover pertinent handling qualities problem areas.^{54/}

- * This refers to a task requiring a high degree of precision in the performance of the pilot. Examples are takeoff, close formation, air refueling, ordnance delivery, and landing. When these tasks were mastered by the experienced pilot, the demands of "precision controllability" were correspondingly reduced.

53. Flying Qualities Evaluation of the YF-16 Prototype Lightweight Fighter, Final Report, July 1975, TR-75-15, Hq. AFFTC
54. Ibid.

It involved three separate exercises, each designed to provide a repeatable and easily controlled maneuver that would tax the aircraft flight control system with the pilot in a high-gain task. These exercises were:

- o a slow windup turn starting at 1 g and terminating at the limiting load factor for the target aircraft
- o a slow windup turn followed by a reversal and continued tracking at elevated load factor
- o tracking during a constant load factor turn.^{55/}

Significant Events. All pertinent test elements were completed by the end of the prototype flight test program. Some of the most noteworthy achievements during this period were:

- o Six flights were accomplished on one day with one aircraft (total time: 3+35 hours; total supersonic: 45 minutes). The shortest turnaround time was 12 minutes.
- o One aircraft performed a total of 13 flights over a period of three days.
- o The longest unrefueled flight was 2+55 hours. The longest refueled flight was 4+25 hours.
- o Five AIM-9E missiles were launched to bring the total to seven. The missiles were launched from Mach 0.8 to Mach 1.6, from 15,000 feet to 50,000 feet, and up to 3 g's.
- o During the high angle of attack phase, one departure from controlled flight and fully developed spin was encountered.

55. Performance and Flying Qualities Evaluation of the YF-17 Prototype Aircraft, Final Report, July 1975, Hq. AFFTC.

The aircraft was recovered with aerodynamic controls without using the anti-spin chute that was installed for the test.

- o The two YF-16s were flown together in formation for the first time. Formation takeoffs and landings were performed.

- o An air-to-ground test element was added to the test plan. Ten MK-84 2000-pound general purpose bombs were dropped during the additional tests. Flutter, stability and control, structural, performance, separation, and delivery tests were completed, including a landing with one unexpended 2000-pound bomb on one wing.

- o The subsonic and supersonic maximum afterburner ceiling of over 60,000 feet was demonstrated from Mach 0.9 to Mach 1.4. Full pressure suits were used on all of these flights. One of the flights, lasting one hour, logged 17 minutes supersonic, 23 minutes above 50,000 feet, and 25 minutes in afterburner, all without refueling.

- o Operational factors testing of basic fighter maneuvers and air combat maneuvers was accomplished against Tactical Air Command F-4Es with leading edge slats, the other YF-16, and other aircraft. Thirty-three YF-16 sorties, 9 F-4E sorties, 26 other aircraft sorties, 24 chase sorties, and 11 tanker sorties were devoted to this test element. Over 36 YF-16 refuelings were accomplished during these tests.^{56/}

56. Historical Report, Lightweight Fighter Joint Test Force, Jul-Dec 74.

The following totals were accumulated during this period of YF-16 prototype testing:

Flight Statistics

	<u>1 July-31 December 1974</u>	<u>31 December 1974 Total</u>
YF-16 No. 1:	101 flights, 134.9 hours	179 flights, 217.7 hours
YF-16 No. 2:	127 flights, 169.6 hours	151 flights, 202 hours

The program total for both aircraft was 330 flights, 419.7 hours.

Pilot Participation

	<u>1 July-31 December 1974</u>	<u>31 December 1974 Total</u>
Contractor:	62	111
AFFTC	80	110
Tactical Air Command	81	104
Navy	5	5

The two primary YF-17 pilots in the JTF were checked out in the YF-16, while the primary YF-16 pilots were checked out in the YF-17. A U. S. Navy pilot was checked out in both aircraft and performed a five-flight preliminary evaluation, including simulated carrier landings.^{57/}

During much of this phase of the program, the joint test force was involved in the preparation of a source selection briefing that summarized the entire year-long prototype program. Briefings were conducted at Wright-Patterson AFB and in Washington, D.C. for the Source Selection Evaluation Board and the Source Selection Advisory Council.^{58/}

57. Ibid.; and interview with Lt. Col. James G. Rider, F-16 JTF Director, 5 August 1975.

58. Ibid.

Problems. One of the most significant results of the handling qualities testing was the identification, not of a problem, but rather of a potential for the problem of coupled loss of control. The "coupling" condition which could cause departure from controlled flight has been described as follows:

Lateral performance at low dynamic pressure was sufficiently high that roll and yaw rates could be generated which produced a nose-up pitching moment that could not be controlled by full trailing-edge-down (TED) stabilator.^{59/}

The potential for coupled loss of control was predicted in the progress of the high angle of attack test phase. It remained merely a potential, however, until it was inadvertently demonstrated during the air combat maneuvering demonstration. The one spin that occurred during the prototype program was also related to coupling.

The demonstrated potential for pitch and roll-coupled departures from controlled flight was the most important handling qualities deficiency discovered during the prototype test phase. A strong recommendation was issued for the elimination of this potential in the YF-16 either by modification of the flight control computer or, if necessary, by external configuration changes.^{60/}

Two other major deficiencies identified in YF-16 testing were its moderate rate of g onset (generation of load factor in response to abrupt full-aft-stick application) and the aforementioned

59. Flying Qualities Evaluation of the YF-16 Prototype Lightweight Fighter, Final Report, July 1975, TR-75-15, Hq. AFFTC.

60. Ibid.

absence of a structural (g) limiter override capability. It was recommended that consideration be given toward remedying both discrepancies.^{61/}

Another problem was experienced during landing. This was the extended landing roll caused by a combination of high residual idle thrust and low aerodynamic drag (a condition which also resulted in abnormally high taxi speeds requiring frequent braking). The problem was partly alleviated by a modification to the flight control system to allow full retraction of the leading edge flaps after touchdown.^{62/} A further modification, providing for the addition of a "reduced idle thrust" switch to eliminate the high residual thrust, was expected to substantially resolve the problem of extended landing roll.^{63/}

The performance of the F100-PW-100 engine during the prototype testing phase was generally satisfactory, but several problems (in addition to residual thrust during ground operations) were noted. The inability to obtain normal high-altitude afterburner lights constituted a serious restriction for a fighter aircraft. Compressor stalls, however, were not a problem. Though compressor stalls did occur in the process of engine

61. Ibid.

62. Ibid.

63. Interview with Lt. Col. James G. Rider, F-16 JTF Director, 5 Aug 1976.

stall susceptibility testing, no nonrecoverable stalls were experienced during the prototype test program.^{64/} Later (on 2 May 1975), during full scale development testing, an idle-off nonrecoverable stall occurred, in which the engine was shut down in flight and restarted to clear the stall. This was, however, the only such instance encountered during the entire test program.^{65/}

Other minor problems involved various YF-16 systems. Some of these were: difficulties with the operation of the air refueling receptacle; inadequate brake energy capacity; effects of gun port vibration; and lack of shock isolation for the instrument panel.^{66/} All of these minor discrepancies, once identified, were subsequently corrected.

Finally, overall reliability and maintainability were determined to be marginal or unsatisfactory for several major systems, including general access, engine and monopropellant emergency power unit access and installation, and use of a non-standard gaseous oxygen system. Recommendations have been submitted for correction of these problems for F-16 follow-on testing.^{67/}

64. Systems Evaluation of the YF-16 Prototype Aircraft, Final Report, April 1975, Hq. AFFTC.
65. Interview with Lt. Col. Robert C. Ettinger, Flight Test Director, F-16 JTF Radar Demonstration Program, 8 Sep 1976.
66. Systems Evaluation of the YF-16 Prototype Aircraft, Final Report, April 1975, Hq. AFFTC.
67. Ibid.