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PILOTS EVALUATION OF THE DOUGLAS XF4D-1 "SKYRAY"

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3 DECEMBER 1953

FINAL REPORT

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

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PUBLICATION REVIEW

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UNITED STATES AIR FORCE
AIR RESEARCH AND DEVELOPMENT COMMAND
AIR FORCE FLIGHT TEST CENTER
California

AF Technical Report No. AFFTC 53-41

A B S T R A C T

The Pilots' Evlauation of the XF4D-1 reveals that it is an exceptionally high performance airplane. It is one of the few airplanes that combine excellent low speed handling characteristics with outstanding climb and high speed ability. The short landing and take-off characteristics are comparable to our jet trainer types. The airplane is potentially adaptable to the Air Force air superiority, interceptor, and day fighter missions.

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PILOTS' EVALUATION OF THE DOUGLAS XF4D-1

"SKYRAY"

A. PURPOSE:

1. This report presents the results of a brief preliminary evaluation of the Navy Douglas XF4D-1 airplane.

B. INTRODUCTION:

2. A flight test evaluation program was conducted on the XF4D-1 aircraft, BU No. 124587, consisting of eleven (11) flights and 5:30 hours flying time. The tests were conducted by Major General Albert Boyd, Brigadier General J. S. Holtoner, Lt. Colonel Frank J. Everest, Jr., and Captain J. S. Nash, at Edwards Air Force Base, California, 11 November through 18 November 1953.

3. Description of the Aircraft:

a. The XF4D-1 is a single-place, jet-propelled, modified delta-wing, fighter-interceptor, manufactured by the Douglas Aircraft Company, El Segundo, California. It is characterized by the modified delta wing planform, the absence of a horizontal tail surface, and by a single swept vertical tail surface. The airplane is equipped with a tricycle type landing gear and was designed to operate from a carrier deck with the aid of a catapult and from land bases. Elevons, for longitudinal and lateral control, perform the functions of both ailerons and elevators, and are operated by irreversible hydraulic systems which, in turn, are controlled by the conventional control stick movements. An artificial feel system is used to simulate this force. A mechanical advantage changer system automatically changes the ratio of stick-to-surface travel to provide a relatively constant stick travel throughout the speed range, and reduces surface sensitivity at high indicated airspeeds. Longitudinal and lateral trim is accomplished by a trimmer surface installed on each side of the aircraft inboard of the elevons. Conventional rudder pedals and an electrically operated rudder trim tab on the rudder are provided for rudder control. A yaw damper system dampens yawing motion and is coupled to lateral stick movement at low speeds to control adverse yaw. Automatic wing slats on the leading edge of the wing are provided to improve the low-speed characteristics of the airplane. The aircraft is equipped with variable control speed brakes that extend from the inboard section of each wing surface. The aircraft presently utilizes a Westinghouse Model J40-WE-8 engine, equipped with an afterburner for power. Ten flights were made at a take-off gross weight of 19,660 pounds, and a center of gravity position of 24.0% M.A.C. One flight was accomplished with four rocket launchers, each capable of carrying seven 2.75" folding fin rockets, installed externally, at a gross weight of 19,815 pounds, and center of gravity position of 24.1% M.A.C.

C. FACTUAL DATA:

4. Cockpit:

a. Cockpit accessibility is gained by the use of an external ladder. Cockpit size is adequate; the seat is very comfortable, with a back inclination of only 9 1/4 degrees. The more upright seating of the pilot is far superior to that provided in single presentation Air Force interceptors and fighters which employ 15 to 17 degree inclinations. The more upright seating of the XF4D provides improved pilot comfort and visibility on take-off and landing where high angles of attack are employed, and will provide a more natural position for the pilot when viewing the radar scope. Vertical adjustment of the seat is accomplished by actuating an electrical switch on the right-hand console. The restraining harness consists of shoulder harness belts 2 3/4 inches in width, and a 2 inch belt between the pilot's legs that fasten into the buckle of the conventional lap belt. The restraining harness is comfortable and the pilot is more secure than with the conventional Air Force restraining harness. The canopy is ejected by actuating a control on the forward left corner of the canopy. The seat is ejected by the conventional Navy pull-down curtain. A handle is provided next to the pilot's head-rest to eject the pilot through the canopy if the canopy fails to eject. Conventional Air Force ejection methods, accomplished with actuators on the arm-rests, would be much more desirable because it is conceivable that high "g" loads could prevent the pilot from actuating the ejection devices in the XF4D-1. The stick control pedestal is large and restricts the pilot's leg movement. Rudder pedal adjustment is by means of an electric motor which adjusts both pedals simultaneously. The flight instruments are located on the upper center section of the instrument panel. Contrary to the standard Air Force arrangement, the engine instruments are grouped on the left-hand side of the instrument panel. This aircraft is a test vehicle and the cockpit has a multitude of colored indicator lights to warn the pilot of such items as speed brake gap, gear door position, wing slat position, and to indicate the operation of items of instrumentation. These lights should all be removed from the production aircraft because they are distracting to the pilot and tend to confuse the monitoring of the essential indicator warning lights. The XF4D is not equipped with a low-level fuel warning light. The low-level fuel warning light is a definite requirement for this type aircraft. The fuel quantity indicator was very erratic at lower fuel levels. The radar scope in the F4D production aircraft is located below the instrument panel and on the center pedestal. It is tilted upward so that the pilot can view the scope. This installation is similar to the one employed in the F-86D. This is a very serious discrepancy because ambient light will cover the face of the radar scope during daylight operation and compromise its interpretation. The side consoles are particularly well designed. Both consoles slope toward the pilot and slope rearward from the instrument panel. This design precludes the pilot from inadvertently actuating switches or controls next to his elbows. The controls and instruments on the side consoles are easily interpreted and all the controls are actuated easily without cramping or twisting the arms. The aircraft is not equipped with an adequate canopy defrosting system. This condition should be rectified.

5. Emergency Systems:

a. The emergency systems are generally satisfactory. The landing gear is lowered in an emergency by releasing the uplocks which allow gravity plus aerodynamic load, to force the gear down and into the locked position. The flight controls are irreversible, with the exception of the rudder which operates through a conventional mechanical linkage. An electrical hydraulic pump operates from the battery to give 3 - 5 minutes control operation of the elevons if the engine-driven hydraulic pump fails. In the event of hydraulic system failure, the aircraft can be controlled laterally with the rudder and longitudinally with the pitch trimmers, or the pilot can disengage the power controls to the elevons and operate the surfaces which are mechanically connected to the control stick. The control stick may be extended and the mechanical advantage system set to provide the pilot with additional mechanical control. The mechanical system is not considered satisfactory as an emergency system because of the high forces. A dual hydraulic pump, one from each spool in the J-57 installation, similar to that of the F-100, should be incorporated. The emergency fuel system consists of a secondary engine-driven fuel pump of the same capacity as the primary engine-driven fuel pump. Emergency braking is accomplished by residual hydraulic fluid trapped in the brake lines and brake cylinders.

6. Taxiing and Ground Handling:

a. The taxiing and ground handling characteristics of the aircraft are very satisfactory. The visibility from the cockpit is excellent. Nose wheel steering is not provided in this aircraft, but nose wheel steering is not a requirement because the aircraft is easily maneuvered with brakes and there was no tendency for the nose wheel to cock. No difficulty was encountered taxiing the aircraft in a 20 knot crosswind. The brakes are adequate to hold the aircraft in military power, but the brakes will not hold the airplane when the afterburner is ignited. Brake pedal forces and response are satisfactory, however; the toe pedal throw should be reduced by about one-third.

7. Take-off and Initial Climb:

a. The take-off and initial climb performance of the aircraft are excellent. Take-off was measured by instrumentation and was determined to be 1520 feet, with clearance of a 50 foot obstacle at 2300 feet (standard day, sea level, no wind conditions). Best take-off performance is accomplished by leaving the nose wheel on the ground until the aircraft has accelerated to 100 knots, and then raising the nose wheel until the tail bumper gear touches the runway. The aircraft becomes airborne immediately thereafter, at approximately 110 knots. Nose wheel lift-off can be made at 70 knots, but this is not done in the normal take-off procedure because of the high induced drag. The tail bumper gear prevents the pilot from assuming too high an angle of attack on take-off, and a similar installation should be studied for Air Force delta-wing type aircraft. With the excellent visibility and upright seating, the pilots did not find the high angle of attack at take-off disconcerting. Low-speed stability and control is excellent during take-off and initial climb; however, stick forces, both laterally and longitudinally, are considered high. The pilot is prone to over-control slightly longitudinally during the initial climb because of the high breakout forces.

8. Climb:

a. Acceleration after take-off is very rapid. Climbs were accomplished to 40,000 feet in approximately 4 1/2 minutes from brake release.

On the climb, with four external rocket pods, the time to 40,000 feet was increased by five seconds. Afterburner blow-out was experienced at 43,000 feet. At this point, the aircraft has a very high rate of climb, and it is reasonable to assume that the production F4D, equipped with the J-57 engine, will be capable of attaining a very high combat ceiling. Stability during the climb was satisfactory, however, the best climb speed at altitude is very close to the longitudinal trim change encountered at 0.93 Mach number. When the airspeed nears 0.92 Mach number, the nosedown trim change is apparent, and at 0.93 Mach number, about 15 to 20 pounds of back stick is required to keep the aircraft from pitching down. There was a slight tendency for the pilot to over-control longitudinally during the climb. This condition was caused by the high breakout forces. Cockpit pressurization of 5.5 pounds per square inch differential pressure is provided in the aircraft, but cockpit pressurization of only 2.75 pounds per square inch was usable in the test aircraft because of a cracked windshield condition. Heating and ventilation were satisfactory. Visibility during the climb is excellent.

9. Level Flight:

a. Static longitudinal stability was considered positive up to 0.93 Mach number. At 0.93 Mach number, the longitudinal nosedown trim change is very pronounced and approximately 20 pounds of back stick is required to correct this deficiency at 40,000 feet. If the airplane is trimmed at maximum level flight speed at 40,000 feet (approximately 0.985 Mach number) 15 1/2 degrees of noseup trim on the trimmer surfaces is required. Obviously, a large amount of trim drag is encountered in this speed range. It is strongly recommended that a study be made to determine if the trim drag rise that occurs at Mach numbers above 0.93 would be lessened by using the elevons instead of the trimmers. A further study is recommended to determine if drooped leading edges and/or twisted wing tips would eliminate or reduce the pitching moment. Static directional-lateral stability was positive throughout the speed range. However, a moderate rudder buffet is apparent at 0.93 Mach number, and this condition persists in supersonic flight with diminishing intensity. The dynamic directional stability is satisfactory with the yaw dampener engaged and the longitudinal dynamic stability is satisfactory. Control forces at low and high indicated speeds are high and only in the medium speed range, below 0.93 Mach number, were the forces considered reasonably satisfactory. It was the opinion of the evaluation pilots that a "q" spring device should be employed in the XF4D in lieu of the mechanical advantage changer-bungee system presently employed to control the longitudinal force gradients. Eliminating the friction in the longitudinal control system would also contribute to improved control, by eliminating the high breakout forces and subsequent over-control about this axis. The lateral force gradients are also high at low and high speeds. Lateral control in the XF4D is characterized by poor centering of the elevons and a detent where slow response to lateral stick movement is suddenly transformed into a very rapid response, with an increased movement of the control stick. These lateral control deficiencies were particularly evident when flying formation and considerable attention was required to keep from over-controlling longitudinally in formation. Rudder forces are very high throughout the speed range. Dihedral effect enables the rudder to be used effectively as an additional means of lateral control. Ability to trim the airplane for hands-off flight is considered marginal. The XF4D has excellent level flight acceleration. The rocket package installations reduced the maximum level flight speed with afterburner by approximately .005 Mach number, but a reduction of approximately 0.02 Mach number was evident in level flight with the rocket packages installed at military power without afterburner. The maximum speed of the XF4D-1 in the clean configuration (approximately 0.985 Mach number at 40,000 feet, with afterburner and approximately 0.925 Mach number at 35,000 feet, without afterburner) appeared to be limited by both power and drag rise. However, with the installation of the production engine (J-57), greater performance is expected.

10. Stalls:

a. Complete 1.0 "g" stalls cannot be made in the clean or landing configuration; however, the airplane was flown with full up elevon, to a very high angle of attack and rapid rate of sink, with no indication of stalling except for a very mild airframe buffet below 104 knots. Lateral and directional stability and control is satisfactory. The stick forces are very high and are considered to be unsatisfactory. Recovery from the stall approach is easily made by releasing back pressure on the control stick. In the landing configuration the sink cannot be controlled by military power without afterburner below approximately 105 knots. Accelerated stalls are characterized by airframe buffet, mushing, and a rapid loss of airspeed. Recovery from the accelerated stalls is normal and is easily effected by release of back pressure on the stick.

11. Maneuvering Flight:

a. The aft shift of the aerodynamic center of pressure, which occurs on the wing of the XF4D at approximately 0.93 Mach number, is marked by the pitchdown moment discussed in Paragraph 9, and by a loss of elevon effectiveness. The airplane has excellent maneuverability below 0.93 Mach number, but above 0.93 Mach number the maneuverability is not considered to be satisfactory for future air superiority fighter aircraft. The low speed maneuverability of the airplane in the clean and landing configurations is excellent. Despite the high control forces, the stability and control of the XF4D, plus the excellent visibility, make the XF4D a particularly secure airplane in the landing pattern. The yaw damper is coupled to lateral stick movement at speeds below 183 knots so that the rudder moves to counteract adverse yaw and produce a coordinated turn. The yaw damper is efficient in this regard, but the action of the yaw damper is fed back through the rudder pedals, which should be eliminated. The excellent low-level, high speed performance of the XF4D is recognized, but three deficiencies in this speed range were readily noted. The airplane must be flown on a longitudinal out-of-trim condition above 0.93 Mach number because the trimmers are stressed for only 7 1/2 degrees of noseup trim at high "q". The rudder and airframe buffet are very pronounced at high "q", and the yawing moment cannot be trimmed. In the medium speed range below 0.93 Mach number, the control force gradients are more reasonable and the controls are very effective. The airplane has a high rate of roll and the maximum load factor, or accelerated stall, can be accomplished. The loss of airspeed in maneuvering flight, theoretically more pronounced with the delta-wing planform, was not as evident as the evaluation pilots anticipated. At 40,000 feet the XF4D can be stabilized at approximately 0.86 Mach number in a constant two "g" turn. No Air Force fighter type is capable of this sustained maneuvering factor. In the speed range below 0.93 Mach number, there appears to be no stick reversals, either position or force-wise, and the overshoot tendency associated with all swept wing aircraft was not objectionable. A loss of control effectiveness is evident at maximum level flight speed. When maneuvering the XF4D in this speed range the pilot was subjected to pitch-up at 0.93 Mach number when the airspeed was bled off with an applied load factor. The wing slats open during maneuvering flight at high lift coefficients. It was the opinion of the evaluation pilots that a study should be made to determine if the open slats increase the drag to such a degree that would warrant the incorporation of a device to lock the slats closed. No unusual de-stabilizing effect was encountered maneuvering the XF4D with the rocket pod installations. When maneuvering throughout the speed range the pilot becomes fatigued because of the high control forces and the requirement to frequently re-trim the aircraft longitudinally.

12. Supersonic Flight:

a. Supersonic flight is easily achieved in the XF4D with a slight dive, and it is reasonable to assume that the F4D production aircraft with the J-57 engine will be capable of supersonic level flight speeds. The airplane was dived to 1.1 Mach number. The XF4D is restricted to 1.1 Mach number because of the structural limitations of the trimmer devices. Control effectiveness is unsatisfactory in supersonic flight for a fighter type aircraft. The maneuverability is limited to approximately 3 1/2 "g's" and the rate of roll should be increased. Control forces are excessive and moderate rudder buffet is apparent. The XF4D is stable statically and dynamically in supersonic flight; however, it is apparent that there is a definite need for additional control effectiveness. A study should be made to determine the feasibility of using a horizontal tail to provide additional longitudinal control effectiveness and to minimize the trim drag in this speed range. The rocket pod installation did not have an adverse effect on the stability and control of the XF4D in the supersonic speed range, but a slightly steeper dive was required to obtain supersonic speeds.

13. Speed Brakes:

a. The speed brakes are variably controlled and are actuated from a switch on the throttle. Speed brake effectiveness is very poor throughout the speed range. A very slight nose-up trim change is evident when the speed brakes are actuated, but it is not of a magnitude to be considered objectionable. The effectiveness of the speed brakes should definitely be increased by at least 100% on the production F4D.

14. Approach and Landing:

a. The approach and landing characteristics of the XF4D are excellent. The visibility is extremely good throughout the final approach and landing, despite the high angle of attack. Control effectiveness is very satisfactory; however, the control force gradients are objectionably high. There is a minor tendency for the XF4D to be unstable laterally while the landing gear is being lowered. The landing gear was lowered at 160 knots. Adverse yaw encountered in the low speed turns is effectively counteracted by the yaw damper. Normal approach speed used was 125 to 135 knots, and the over-the-fence speed was 115 to 120 knots. No difficulty was experienced flaring the airplane and touchdown speeds varied from 100 to 115 knots. Initial contact with the ground is usually made on the tail bumper gear, followed by the main landing gear. Elevon power is sufficient for the pilot to hold the nose-high attitude with the associated induced drag as a means of deceleration on the initial phase of the landing roll. Brake effectiveness is satisfactory, however, the braking action could be improved by reducing the toe pedal throw by about one-third. The XF4D is not equipped with a drag chute, however, the airplane could be safely flown tactically from a 6000 foot runway in its present configuration. One landing was made in a 40° crosswind at 20 knots, with no difficulty. The rocket pod installation did not adversely effect the approach and landing characteristics.

15. Power Plant:

a. No special engine tests were flown to specifically investigate the quality of the J-40 engine, however, it was obvious from the flights conducted in the XF4D that the J-40 engine is unsuitable in its present configuration. The afterburner on the J-40 engine blows out at 43,000 feet and relights of the afterburner were restricted to altitudes below 25,000 feet. Engine compressor stalls were encountered above 25,000 feet. Numerous delays in the evaluation test program were occasioned by engine and engine control deficiencies. The specific fuel consumption on the J-40 appeared to be high. The J-57 engine should improve the performance and potential of the F4D.

D. CONCLUSIONS:

16. It is concluded that the XF4D possesses a very suitable wing planform for a superiority fighter or for an interceptor type aircraft. The control system deficiencies and the longitudinal trim change encountered at 0.93 Mach number generally compromise the capabilities of the XF4D. If these discrepancies are eliminated and the F4D is equipped with the J-57 engine and an increased internal fuel capacity, the potential of this type aircraft as an air superiority fighter, or as an air defense interceptor, is greatly increased.

E. RECOMMENDATIONS:

17. It is recommended that:

a. A low-level fuel warning light be installed.

b. The speed brake, gear door, and wing slat warning lights be eliminated.

c. The accuracy of the fuel quantity indicator be improved.

d. The radar scope in the production F4D-1 be located on the top center section of the instrument panel. (Reference scope installation in Air Force F-102.)

e. The size of the stick control pedestal be reduced.

f. The effectiveness of the control system at high speeds be improved.

g. The elevon force gradients be improved by employing a "q" spring device in lieu of the Mechanical Advantage System.

h. The handling characteristics be improved by:

(1) Eliminating the friction and high breakout forces in the longitudinal control system.

(2) Reducing the longitudinal force gradients.

(3) Improving the center and eliminating the detent on the lateral control system.

(4) Reducing the high rudder forces.

(5) Eliminating the feedback from the yaw damper to the rudder pedals.

i. The nose-down pitching moment at 0.93 Mach number be eliminated.

j. The rudder buffet and airframe buffet above 0.93 Mach number be eliminated.

k. The speed of the trimmers be increased.

l. An investigation to compare the trim drag induced by the trimming surfaces and that induced by elevon deflection be conducted.

m. The feasibility of employing drooped leading edges and wing tip twist be investigated to reduce trim drag.

n. A dual hydraulic control system be used with the J-57 installation. (Reference the control system in the F-100.)

o. A study be made to determine the merit of having the wing slats locked closed in maneuvering flight.

p. The toe pedal throw on the brakes be reduced by about one-third.

q. The effectiveness of the speed brakes be increased.

r. The AFFTC evaluate the production F4D-1 with the J-57 engine installation.

s. The Air Force revise the specifications to permit future Air Force fighters to use seats with approximately 9 to 10° tilt angles, as compared to the present day fighters equipped with 15 to 17° seats.

t. A study be made to determine the feasibility of installing the restraining harness employed in the XF4D in Air Force fighters, as it appears to be more secure and is more comfortable than those used in present Air Force fighters.

u. The Air Force study procurement of an F4D type aircraft as a high altitude air superiority fighter and if an interim air defense interceptor is required, this aircraft should seriously be considered for the role.

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