
Figure 1 - Republic P-47D-40 Thunderbolt

Philip Makanna

Flight Test Comparison . . .

Ending the Argument

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Photos Courtesy Kalamazoo Aviation History Museum and Harry Tope

During World War II, the United States introduced four new fighter designs produced by four separate manufacturers: the Republic P-47 Thunderbolt, the Vought F4U/FG-1D Corsair, the Grumman F6F Hellcat, and the North American P-51 Mustang.

These fighter designs introduced in the early 1940s have become legendary. Many Army Air Corps, Navy and Marine pilots became aces at their controls. Much has been written, and even more said, concerning the exploits of these famous aircraft. Today, more than 45 years since these aircraft entered combat squadrons, the facts and myths of their capabilities are blurred together as memories fade and the few remaining examples of these former warriors are preserved by museums and aviation enthusiasts. Flight time on these aircraft is usually limited to public air show exhibitions and, in deference to the aging airframes and scarcity of engines and parts (not to mention their cost), they are normally operated well within their original design limits.

"Ending the Argument" documents the results of a limited flight test program which was designed to compare, as far as possible on equal footing, the performance and flying qualities of these four historic World War II fighter aircraft. Unfortunately, the title we chose for the paper turned out to be rather ambitious as the test program actually raised more questions than it answered.

The P-47D Thunderbolt, FG-1D Corsair and the F6F-5 Hellcat used in the program were borrowed from the Kalamazoo Aviation History Museum, the "Air Zoo", of Kalamazoo, Michigan. The P-51D Mustang was on loan from Harry Tope of Mt. Pleasant, Michigan.

TEST AIRCRAFT

Republic P-47D-40 Thunderbolt

The aircraft is shown in Figure 1. Serial number 45-49181. Powered by Pratt & Whitney R-2800-59 engine with Curtiss Electric four-bladed, constant speed propeller. The aircraft and induction system had been modified by removal of the exhaust-driven turbocharger with engine exhaust being routed through the former wastegate. The 100 gallon auxiliary fuel tank had been disconnected and only the main fuel tank, 270 gallons, was usable. The test aircraft was equipped with one stores pylon mounted under each wing. It is one of five P-47s believed to be in flyable condition in the United States.

Goodyear FG-1D Corsair

The aircraft is shown in Figure 2. Bureau number 92509. Powered by Pratt & Whitney R-2800-8 engine with Hamilton Standard Hydromatic three-bladed, constant speed propeller. With the exception of modern communication and navigation equipment, the aircraft is unmodified from its original manufactured condition. The Corsair also had one stores pylon under each wing. It is one of approximately 25 Corsairs of different models which exist in flyable condition in the United States.

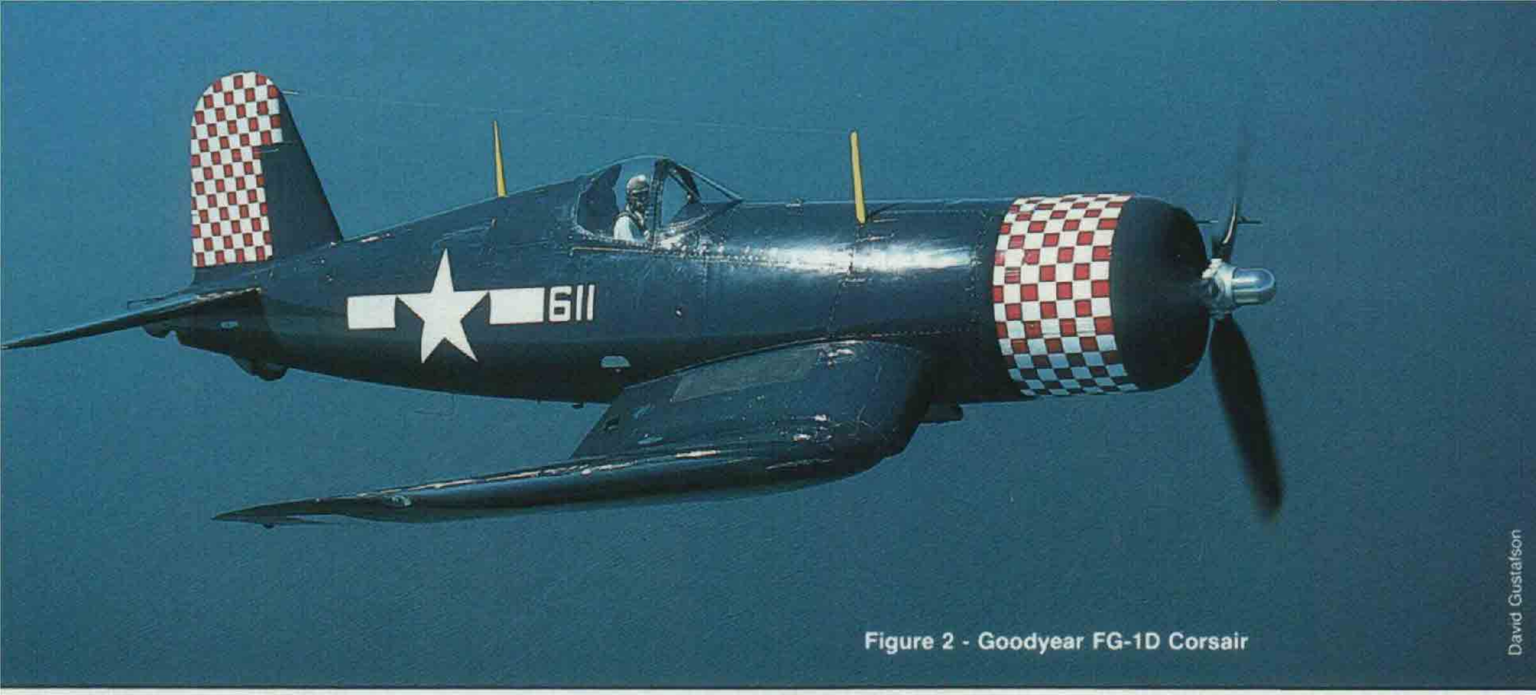


Figure 2 - Goodyear FG-1D Corsair

David Gustafson

Grumman F6F-5 Hellcat

The aircraft is shown in Figure 3. Bureau number 79683. Powered by Pratt & Whitney R-2800-10 engine with Hamilton Standard Hydromatic three-bladed, constant speed propeller. With the exception of modern communication and navigation equipment, the aircraft is unmodified from its original manufactured condition. It is one of five Hellcats in flyable condition known to exist.

North American P-51D Mustang

The aircraft is shown in Figure 4. Serial number 45-11586. Powered by Rolls Royce V-1650-9 Merlin engine with Hamilton Standard Hydromatic four-bladed, constant speed propeller. Major modifications include the removal of a 65 gallon fuel tank located behind the cockpit and installation of a passenger jumpseat. Modern communication and navigation equipment had been fitted as with the other aircraft in the test program. Approximately 125 flyable P-51 aircraft are believed to exist.

ENGINE PERFORMANCE

The R-1800 engines in the test aircraft were virtually identical and all rated at approximately 2,000 BHP. The varied dash numbers refer to minor differences such as accessory position and carburetor type. The Merlin engine in the P-51 was rated 1490 BHP.

MISSION BACKGROUND

Although all designed as fighters, there were in fact considerable differences in the ways the four aircraft were employed in combat. In addition, following a trend which has persisted to this day, they were all sooner or later used in the air-to-ground role, though to greatly different extents.

The two Army Air Corps fighters, the

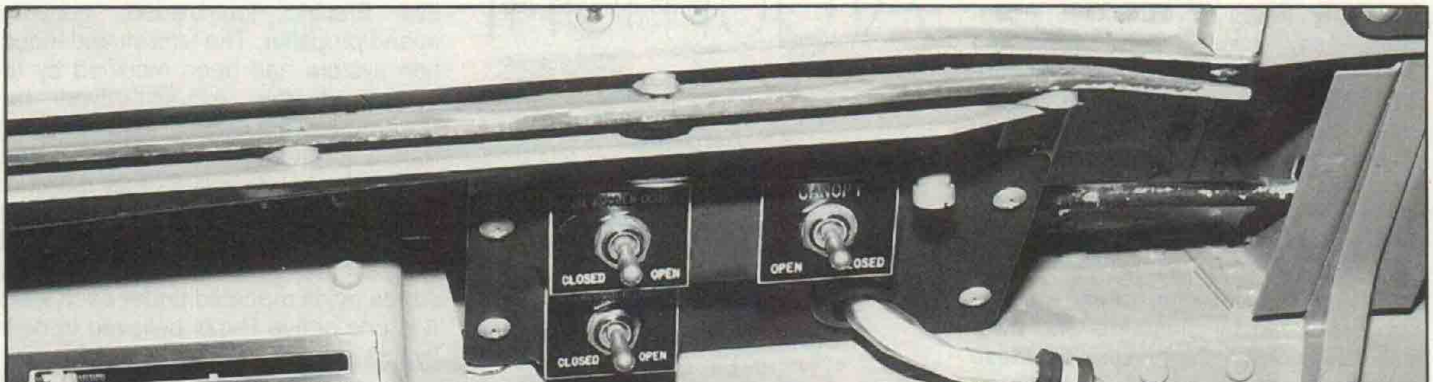


Figure 5 - Engine Cooling Switches

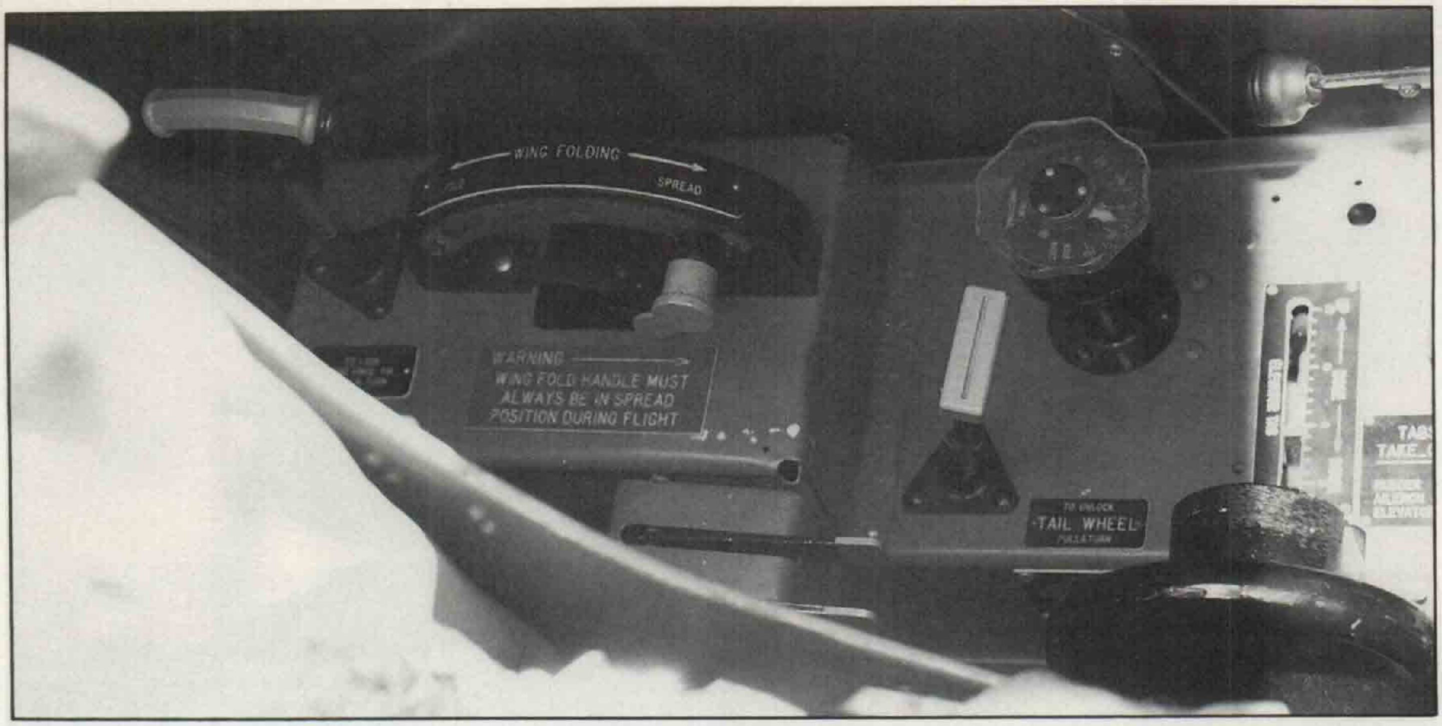


Figure 6 - FG-1D Wing Lock

P-47 and P-51, are best known as long range bomber escorts. While their final combat scenarios would have been practically indistinguishable from those of the F6F and FG-1D (apart from the opposition being Me. 109s and FW 190s rather than Kates and Zeroes), an important distinction lies in the fact that by the time battle was joined, the Thunderbolt and Mustang pilots had already been in the air for several hours. Thus the levels of noise, vibration and comfort in the cockpit environment, while never unimportant, assumed particular significance in ensuring that the pilot arrived comparatively fresh and ready for the fight. A tired and cramped pilot whose head is buzzing from a noisy engine is not likely to fight as effectively as one who has spent the previous three hours or so in a comfortable seat in a quiet cockpit. These considerations must be put in the context of the primitive radios and indifferent sound attenuation qualities of 1940s helmets.

TEST ENVELOPE AND LIMITATION

Recognizing the age of the aircraft in the test program, it was agreed that structural loads would not exceed 6g. Military power was permitted for takeoff and climb to 10,000 ft. MSL consistent with manifold pressure limitations appropriate for operating on 100LL fuel. The non-availability of higher octane fuel reduced the maximum allowable manifold pressure by approximately four inches for the three aircraft powered by Pratt & Whitney R-2800 engines. The Rolls Royce Merlin 1650 in the P-51D was unaffected. For all other tests, power was limited to maximum continuous settings. Superchargers were limited to "low blower" ranges which restricted the investigation to altitudes between the surface and 10,000 ft. MSL. Unfortunately, this limitation precluded an evaluation of the aircraft at typical "bomber escort" altitudes. All of the aircraft had permissible CG ranges of five and one half to eight inches. The P-47 was tested at a CG range very close to the forward limit, the F6F at one third aft, the P-51 at exactly mid CG and the FG-1D at three quarters aft.

COCKPIT EVALUATION

The cockpits were all essentially typical of 1940's vintage tailwheel aircraft, which is to say they had some major ergonomic shortcomings. Important controls were often positioned with little regard to whether the pilot could see, reach or operate them without considerable effort. Each of the aircraft possessed fields of view which on the ground were limited chiefly by the precise extent of the area ahead blocked by the engine and forward fuselage. The need for constant S-turns to avoid hitting things while taxiing was part of the charm of flying these aircraft. In all cases the field of view improved considerably from the moment the tail was raised during the takeoff roll; but even in flight the forward fuselage and engine continued to present a serious obstruction to forward and downward vision and must have caused considerable difficulties in shooting at large deflection angles or in air-to-ground aiming with a depressed sight-line when the target would tend to disappear under the nose. In addition, sitting above or behind a large straight wing creates a further blind area in a direction which could well be critical in combat with the opposition coming up to meet you from below. Rather than describe every fault in detail, we shall pick out some of the best and worst features.

P-47 - The massive size of the P-47 is misleading. In fact, it had the most cramped and uncomfortable cockpit of all four aircraft. The rudder pedals were adjustable for reach and the seat for height (as were all the aircraft), but the maximum available seat back to pedal distance was only 41 inches which corresponds to a 20th percentile leg length. Longer legged pilots were condemned to suffer without thigh support, which was uncomfortable enough during these short duration test flights and would certainly have been hard to endure on a long range bomber escort mission. The tops of the pedals could be folded down to allow the pilot to put his feet on them but even that brought scant relief.

The control switches for the oil cooler flaps, intercooler flaps and canopy were clustered under the canopy rail at the pilot's left shoulder (Figure 5), almost impossible to see and very hard to identify.The cooler control switches in particular were arranged one on top of the other, operated in the same sense, and were difficult to tell apart by feel. Inadvertently operating the canopy switch in flight would be immediately obvious but operating the wrong cooler switch would not and, if followed by a hectic period at high power, could lead to engine damage before being detected.

The tailwheel lock control was on the

Figure 3 - Grumman F6F-5 Hellcat

cockpit floor outboard of the seat attachment point and required an awkward stretch to reach; but on the positive side, the incorporation of an automatic tailwheel lock which operates whenever the landing gear is lowered is an enhancing feature and one which could well have been copied in other designs.

FG-1D - Anyone familiar with the cockpit of the SNJ/AT-6 family would feel instantly at home in the bottomless pit of the Corsair. Anything dropped and not secured to the pilot's person is probably gone for good, or at least until after the flight, given the natural tendency of inanimate objects to wedge themselves into corners from which they cannot be dislodged even by determined applications of negative Gs.

All cockpit controls are in the pilot's normal view and within easy reach except for the wing fold lock control at the rear of the left cockpit shelf (Figure 6). It was difficult to reach and very stiff in operation requiring more strength than the pilot could exert while seated and necessitating his unstrapping or getting help from a plane captain to manually lock the wings in the spread position. Doing so would delay a mission or perhaps induce the launch of an aircraft with the wing hydraulically but not mechanically locked. Other Corsair owners indicated that the wing locking mechanism on this aircraft was not untypical which suggests that the several documented cases of Corsair wings folding in flight could have been caused by this problem.

F6F - Largest and roomiest cockpit of all. Adjustable seat and rudder pedals gave a maximum seatback to pedal distance of 47 inches, enough to accommodate a 98th percentile leg reach. The only control difficult to reach was the emergency landing gear extension lever which required the pilot to unlock his harness to operate it.

P-51 - The most comfortable cockpit of all. Seat and rudder pedal adjustments were of a range to fit practically any size pilot. The seat was inclined aft and the pedals were installed higher than in the other aircraft which gave the feeling of sitting in a high class sports car. An enhancing feature was the fully automatic operation of the coolant door and oil cooler shutters which required no attention in flight other than monitoring the appropriate temperatures.

Overall, the four aircraft were ranked approximately the same for each of the three categories of pilot comfort, ease of operation of cockpit controls, and field of view in the air and on the ground: P-51, F6F, FG-1D and P-47.

TABLE I

TAKEOFF AND MILITARY POWER CLIMB

	P-47D	FG-1D	F6F-5	P-51D
Takeoff Weight	11,535	11,055	10,681	8,900
Runway Temperature	54°F	77°F	62°F	62°F
Liftoff Speed	110 mph/96 kts	85 kts	90 kts	115 mph/100 kts
Takeoff Distance	1500 ft	1200 ft	1400 ft	1500 ft
Climb Speed	155/mph/135 kts	135 kts	130 kts	175 mph/152 kts

TAXI

The P-47, F6F and FG-1D all had tailwheels which were locked for takeoff and landing or free castering for taxiing. Directional wheel control was by differential braking. The P-51 had a tailwheel linked to the rudder pedals which was steerable through 6 degrees either side of neutral. The steering mechanism could be disengaged by pushing the stick full forward which allowed the tailwheel to become fully castering for tight turns or maneuvering in confined spaces. All aircraft were easy to taxi but taxiing in a crosswind with the three fully castering tailwheels required riding the downwind brake, increasing wear and possibly leading to brake overheating. Once again the P-51 came out on top.

TAKEOFF HANDLING

Takeoff for all four aircraft was made

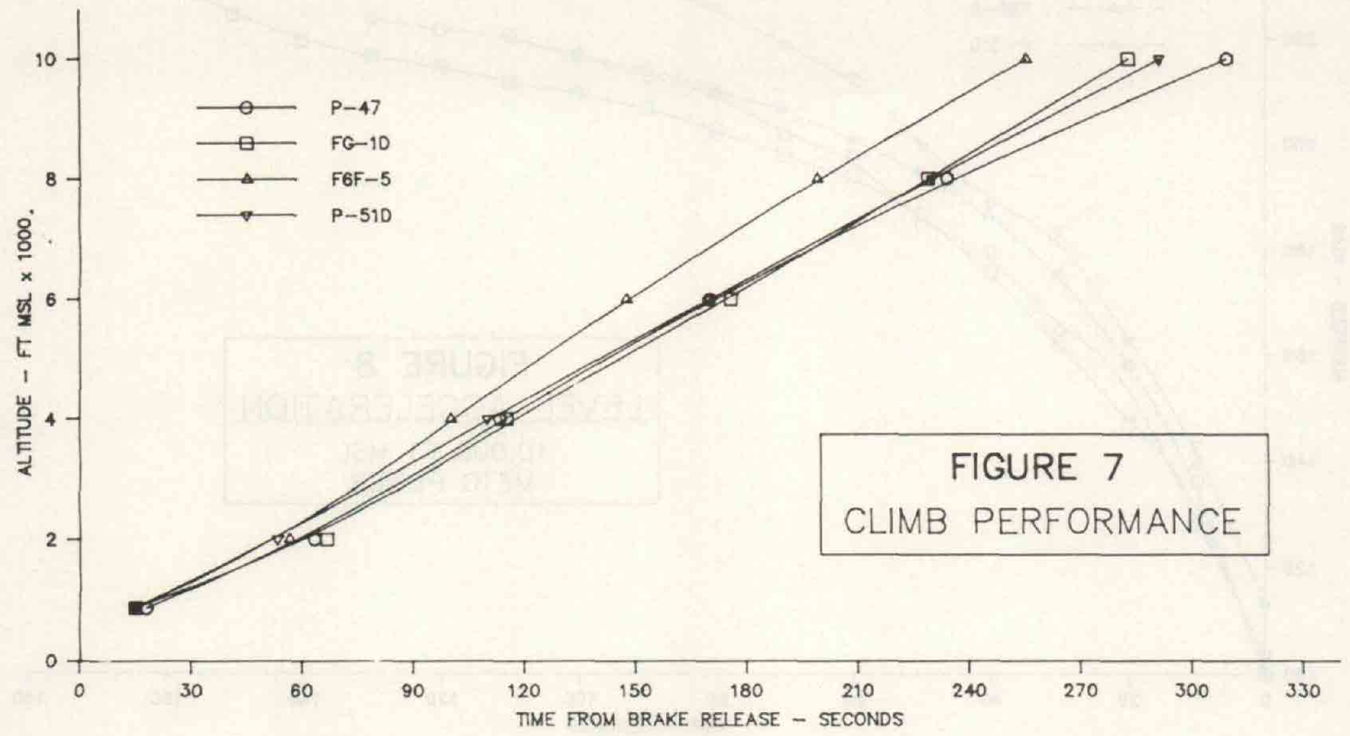


FIGURE 7
CLIMB PERFORMANCE

with the flaps up, setting field barometric manifold pressure while holding the brakes and increasing to military power immediately after brake release. The tail was raised to the takeoff attitude as soon as elevator control was available. A positive rotation was made for liftoff and the gear was retracted as soon as a positive rate of climb was established. Takeoff conditions are listed in Table I.

All the aircraft required some preset right rudder trim for takeoff. The P-47 called for 5 degrees and the P-51 and FG-1D required 6 degrees while the F6F needed full rudder trim. For all but the Hellcat, the preset takeoff trims provided good control of the initial swing with application of military power and yet enabled the foot forces to be completely trimmed out during the climb. The Hellcat, however, required additional right rudder during the takeoff roll and climbout when the foot forces were light and easy to apply.

In all other respects the aircraft were easy to fly and trim, with minimal trim changes from gear retraction and initial acceleration.

CLIMB PERFORMANCE AND HANDLING

The results of test day military power climbs to 10,000 ft. MSL for the four aircraft are presented in Figure 7. The data for the Mustang is not truly representative because rough running at 4,000 ft. required the power to be reduced to METO which smoothed out the engine operation but naturally reduced the rate of climb somewhat. The Hellcat came out on top with a time of four minutes fifteen seconds from brake release to 10,000 ft. but there was less than thirty seconds between it and the FG-1D, while the Mustang would clearly have benefited from the missing few inches of manifold pressure. The handling of all the test aircraft in the climb was good and all control forces could be trimmed out with the exception of the rudder forces in the F6F Hellcat which needed continuous right rudder for this and all other high power operations at fairly low speed. The forces were estimated at 80 to 100 pounds and were high enough to be tiring even during the few minutes in the climb to 10,000 ft. A prolonged climb to higher altitude would have been very tiring and the probability of a pilot relaxing the right rudder force and incurring a loss of climb performance would be high.

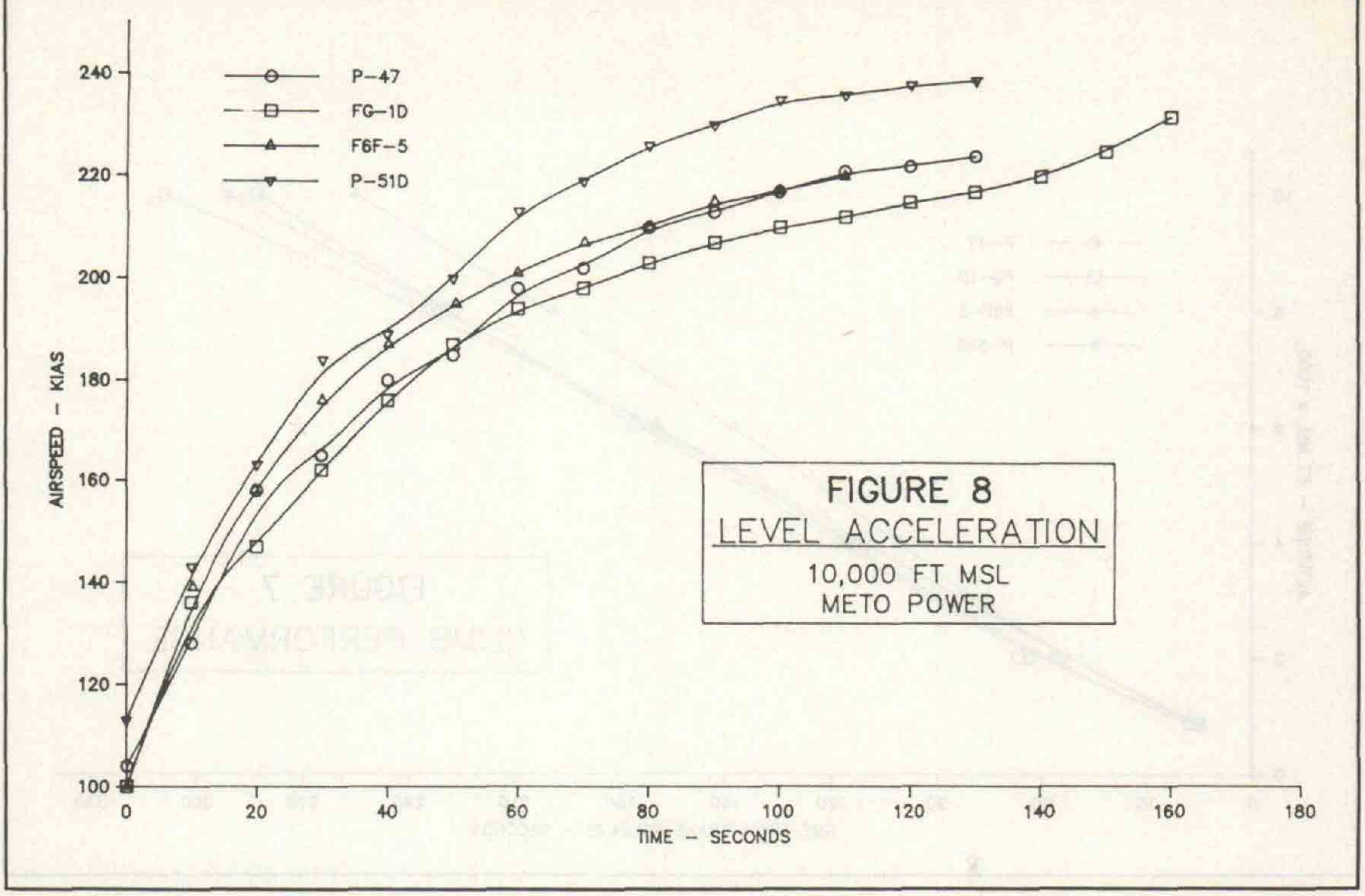
LEVEL ACCELERATIONS

The level acceleration tests were conducted at 10,000 ft. MSL using METO power. For all tests the OAT was 50 degrees F. The results are presented in Figure 8. It can be seen that, while there was not a great deal of difference between the R-2800 powered airplanes, the P-51 had a decided advantage both in acceleration and top speed. Both the P-47 and the FG-1D were handicapped by underwing pylons but it is doubtful if the results were significantly affected.

STALL CHARACTERISTICS

Normal and accelerated stall characteristics were evaluated for all the aircraft in the cruise and landing configurations with power at idle, cruise and METO at 10,000 ft. MSL. Normal stalls, power on or power off, were conducted in straight flight using a slow deceleration (less than one kt./sec.). Accelerated stalls were conducted in a constant 3g turn allowing the airspeed to decay at less than one kt./sec. The results are presented in Table II.

Aerodynamic warning of the normal stalls in both configurations ranged from scant to nonexistent. The P-47 was the best with some light airframe buffet occurring about five kts. above the stall. The P-51 had virtually no warning, the Corsair and Hellcat a couple of knots apiece. Secondary cues such as decreasing aileron effectiveness and increasing longitudinal stick forces were noticeable in all except the FG-1D in which the stick forces tended to lighten before the stall. Normal stalls for all aircraft in all configurations, power on or



power off, were defined by an uncommanded nose down pitch accompanied in most cases by a wing drop, the direction and severity of which were strongly influenced by any departure from balanced flight conditions. In all normal stalls except those in the Corsair with power on, it was possible to control the wing drop by coarse use of the rudder.

The behavior during accelerated stalls is of more interest from the combat pilot's point of view and it was here that the most significant differences were found. The most predictable and controllable were the Hellcat and the P-47. Both could be flown at will into the pre-stall buffet, which at no time was heavy enough to present problems with tracking and held at maximum usable lift coefficient with ease. Any significant sideslip became noticeable as a progressive wing heaviness which was the pilot's cue to make a rudder correction, but in the absence of gross mishandling there was little tendency to depart.

The Corsair generated considerable airframe buffet five knots prior to stall in a constant 3g turn but at the stall there was a pronounced g-break and a rapid right wing drop regardless of the direction of the turn. With care, the wing drop could be prevented with some anticipatory left rudder but the aircraft then became very unpredictable at the stall with moderate to severe bucking and porpoising motions and the ever present likelihood of departure.

The P-51 provided virtually no warning whatsoever of the accelerated stall other than a very slight trembling felt through the stick immediately before departure which was not obvious to an alert pilot with nothing else to concern him and would have been almost certain to be missed during the heat of combat. At the stall, the aircraft invariably departed with complete loss of control, on occasion achieving 270 degrees of roll before recovery could be effected. The departure was accompanied by a violent aileron snatch which was strong enough to take the stick out of the hand of an unprepared pilot. However, the two-handed pull necessitated by the high maneuvering stick forces would probably have reduced the chances of that actually happening in combat. Altitude lost in the departure and recovery was about 500 ft.

From these results, it can easily be seen that the P-47 and Hellcat were the most "user-friendly" of the four, with the Corsair next and perhaps more suited to experienced pilots. The P-51's lack of stall warning and consistent departure constituted what these days would be classified as a Part I deficiency. Indeed, as we discovered, there are plentiful accounts of Mustangs spinning out of combat engagements.

TURN PERFORMANCE

Sustained turn performance was evaluated at 10,000 ft. MSL at METO power. While again not reflecting the true performance to be achieved at combat power settings, we believe that the playing field was level enough to allow reasonably valid comparisons between aircraft. Instantaneous turn performance was evaluated in wind-up turns from 10,000 ft. The results are presented in Figures 9 and 10.

The results are interesting in that, below about 130 kts., the sustained and instantaneous turn performances for each aircraft were virtually the same, though separated by about 1g between the best and the worst. As expected, the Hellcat out turned the other three by a fairly conclusive margin. There was too much scatter in the results to make a confident distinction among the rest, but it looks as though the P-47 came off worst with the P-51 and FG-1D ahead but not by much.

Another interesting feature is that for all the aircraft the corner speeds were remarkably close to the maximum level flight speed, implying a very rapid energy loss when turning at the structural limit. The Hellcat was in light airframe buffet at 6g at Vmax, while the P-47 exhibited light buffet at 4.8g and moderate at 5.2g. The FG-1D and the

TABLE II

STALL CHARACTERISTICS

	P-47D	FG-1D	F6F-5	P-51D
C P[1] Vwarn	107 kts	90 kts	75 kts	89 kts
C P[1] Vstall	97 kts	85 kts	68 kts	87 kts
C P[1] Height Loss	200 ft	250 ft	200 ft	250 ft
C P[2] Vwarn	90 kts	78 kts	68 kts	85 kts
C P[2] Vstall	87 kts	76 kts	62 kts	83 kts
C P[2] Height Loss	50 ft	100 ft	50 ft	100 ft
L P[1] Vwarn	91 kts	73 kts	65 kts	76 kts
L P[1] Vstall	87 kts	69 kts	60 kts	74 kts
L P[1] Height Loss	200 ft	150 ft	100 ft	150 ft
L P[2] Vwarn	74 kts	57 kts	58 kts	72 kts
L P[2] Vstall	70 kts	55 kts	52 kts	70 kts
L P[2] Height Loss	50 ft	50 ft	50 ft	50 ft
Accel Vwarn	126 kts	103 kts	100 kts	122 kts
Accel Vstall	109 kts	98 kts	95 kts	122 kts
Accel Height Loss	100 ft	150 ft	150 ft	500 ft

NOTES: C - Cruise Configuration; L - Landing Configuration; P[1] - Power Off; P[2] - Power On; Accel - 3g Turn, Decaying Airspeed

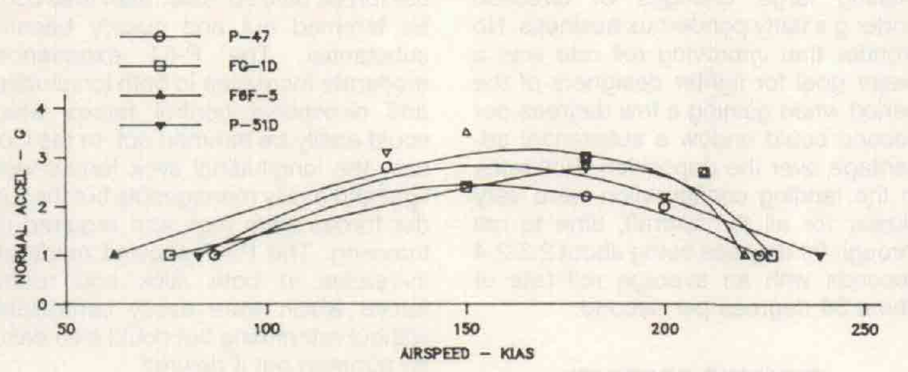


FIGURE 9

SUSTAINED TURN PERFORMANCE

10,000 FT MSL METO POWER

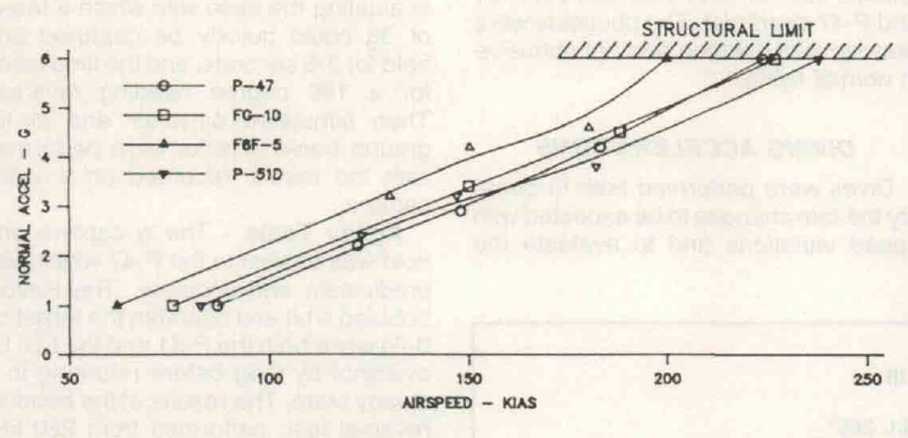


FIGURE 10

INSTANTANEOUS TURN PERFORMANCE

10,000 FT MSL METO POWER

P-51D were buffet free up to 6g at their maximum level flight speeds. Of course, the maximum level flight speeds would have been higher at combat power settings but so would the structural limits: the Corsair, for example, had an operational limit of 7.5g.

MANEUVERING STABILITY

The maneuvering stability as indicated by the stick force per g in wind-up turns at Vmax is presented in Figure 11. Probably the most conspicuous feature is the very high stick forces displayed by the Mustang, averaging over 20 lbs. per g. In fact, the force gauge only read to 60 lbs. so that the forces for 4 and 5g were estimated. But throughout the test program, there was no doubt at all that the Mustang was a two-handed airplane in which prolonged hard maneuvering was extremely tiring. By contrast, the FG-1D with an average of only 5 lbs. per g, and a local gradient between 4 and 5g (a great deal less) was almost too light. The P-47's 7.5 lbs. per g was just about ideal while the Hellcat's 12.5 lbs. per g was barely acceptable and verging on excessive.

STATIC LATERAL-DIRECTIONAL STABILITY

The aircraft all exhibited positive static directional stability and positive dihedral effect. Steady heading sideslips in cruise and land configurations revealed nothing out of the ordinary beyond the fact that the rudder forces in both the Hellcat and Corsair were extremely high. Full rudder sideslips generally required 50-60% of available aileron deflection in cruise at 180-190 kts. and 20-50% aileron in the landing configuration. Sideforces were highest for the P-47 which required 45 degrees of bank to the left at 190 kts. and 20 degrees at 120 kts. Rather surprising in view of its deep fuselage and large keel area, the Hellcat did not require particularly large bank angles, but this may well have resulted more from limited rudder control power and strong directional stability restricting the amount of sideslip that could be generated.

All the aircraft showed marked asymmetries between left and right sideslips, especially with regard to the bank angles which were as a rule substantially less for slips to the right than to the left. Unfortunately, steady heading sideslip data was incomplete for the FG-1D and the P-51. This precluded further investigation of a peculiarity which came to light during rudder-only turns. The Corsair's only response to left rudder in either configuration was to drop its nose, suggesting weak or non-existent dihedral effect with right sideslip.

All the aircraft except the P-47 pos-

TABLE V

DIVING ACCELERATION
(30° DIVE, 10,000' - 5,000' PULL UP - LEVEL @ 4,000')

	P-47D	FG-1D	F6F-5	P-51D
START SPEED	110 kts	100 kts	100 kts	120 kts
MAX SPEED	350 kts	348 kts	315 kts	350 kts
TIME	23 sec	32 sec	28 sec	25 sec

TABLE VI

LEVEL 180° HEADING CHANGE (METO)
(START 220 kts @ 10,000' MSL)

P-47D	FG-1D	F6F-5	P-51D
9.7 sec	8.5 sec	9.9 sec	10.0 sec

sessed at least moderate degrees of adverse aileron yaw, the worst being the Hellcat in which the yaw was quite marked. Countering it during aggressive maneuvering was hard work and quite tiring in the Hellcat and the Corsair because of their very high rudder forces. The P-51 also required continuous rudder coordination but the forces were low enough for it not to be a problem. Aileron yaw was negligible in the P-47 which made accurate tracking considerably easier than in the other aircraft.

ROLL PERFORMANCE

Roll performance was evaluated using full aileron deflection in rolls to the right and left at 10,000 ft. MSL at 200 kts. for 1g rolls through 360 degrees and 220 kts. for rolls at 3g through 180 degrees. The results are presented in Tables III and IV.

While the 1g roll rates are not particularly impressive by modern standards, they were nonetheless quite respectable for their day. It is significant that all the aircraft, with the exception once again of the P-47, showed substantial reductions in roll performance when rolling under g. Eventually the P-47 lost 11% of its roll performance in loaded rolls to the right (though nothing to the left), but this was negligible compared to 25-27% for the Mustang, 28-33% for the Corsair, and 26-38% for the Hellcat, making large changes of direction under g a fairly ponderous business. No wonder that improving roll rate was a major goal for fighter designers of the period when gaining a few degrees per second could endow a substantial advantage over the opposition. Roll rates in the landing configuration were very similar for all the aircraft, time to roll through 90 degrees being about 2.3-2.4 seconds with an average roll rate of about 38 degrees per second.

TABLE III

TIME TO ROLL 360°
(10,000 ft MSL, 200 KIAS)

	P-47D	FG-1D	F6F-5	P-51D
RIGHT	4.9 sec (74°/sec)	4.5 sec (81°/sec)	4.6 sec (78°/sec)	4.8 sec (75°/sec)
LEFT	5.9 sec (61°/sec)	4.9 sec (73°/sec)	5.9 sec (61°/sec)	5.1 sec (71°/sec)

DYNAMIC STABILITY

As expected, the dynamic modes were typically well behaved. Damping ratios were high resulting in short period oscillation which were either deadbeat (P-47 and FG-1D) or nearly so (F6F and P-51 and a single overshoot). Dutch roll modes were also well damped, the Corsair being the worst with three overshoots, the F6F with one, and the P-51 and P-47 deadbeat. The phugoids were likewise well damped and not obtrusive in normal flying.

DIVING ACCELERATIONS

Dives were performed both to quantify the trim changes to be expected with speed variations and to evaluate the ability of the aircraft to run out of a losing fight. Starting in level flight at 10,000 ft. MSL with METO power from typical pattern speeds, the dives were entered via a minus 1g pushover to a 30 degree angle. Recovery was initiated at 5,000 ft. The results are presented in Table V.

From the performance aspect, the results are slightly confused by the fact that the starting speeds were not the same for all aircraft. The 10 and 20 kt. starting advantages that the P-47 and P-51 had over the Corsair and Hellcat probably influenced the results, though it is nonetheless significant that the P-47 still outran the P-51 despite being 10 kts. down on it at the beginning. The F6F apparently being four seconds quicker than the Corsair, despite starting from the same speed and ending 33 kts. slower, suggests that there may be some scatter in the results.

The flying qualities encountered during the dives were of more interest. In the Hellcat, the out-of-trim stick and rudder forces built up faster than they could be trimmed out and quickly became substantial. The P-51 experienced moderate increases in both longitudinal and directional control forces which could easily be trimmed out. In the Corsair, the longitudinal stick forces were light and easily manageable but the rudder forces were high and required retrimming. The P-47 showed moderate increases in both stick and rudder forces which were easily controllable without retrimming but could also easily be trimmed out if desired.

SIMULATED MISSION TASKS AND AGILITY TESTING

This was, so to speak, the "proof of the pudding" part of the test program. The aircraft were subjected to a couple of basic agility tests (suggested by the reports on agility testing conducted at Edwards recently) consisting of evaluating the ease with which a target of 3g could quickly be captured and held for 3-5 seconds, and the time taken for a 180 degree heading reversal. Then simulated air-to-air and air-to-ground tracking tasks were performed with the results recorded on a video camera.

Agility Tests - The g capture and hold was easiest in the P-47 which was predictable and accurate. The Hellcat bobbled a bit and overshot the target by 0.2g while both the P-51 and the FG-1D overshot by 0.5g before returning to a steady state. The results of the heading reversal test, performed from 220 kts. straight and level at 10,000 ft. with METO power, are presented in Table VI and are somewhat inconclusive, though apparently showing the FG-1D as the winner with 8.5 seconds for the 180 degrees. With 0.3 seconds cover-

Figure 4 - North American P-51D Mustang

ing the other three aircraft, no clear conclusions can be drawn.

Air-to-Air Tracking - The starting conditions for the air-to-air tracking task were 210 kts. at 10,000 ft. MSL, straight and level. The target profile consisted of a 3g turn to the left building to 4gs followed by a hard reversal into a 4g right turn. The video recorder was mounted on the glare shield in each aircraft in approximately the same position as a gunsight. The video tape shows, among other things, just how limited the field of view was from these aircraft.

Accurate tracking was easiest in the Corsair, at least partly because the light longitudinal stick forces did not interfere with lateral aiming corrections. The P-47 and Hellcat were next with the order dictated by the increasing longitudinal stick forces and difficulty of coordinating aileron inputs with rudder. Finally, the Mustang. The very high longitudinal stick forces required both hands on the stick and made delicate lateral corrections difficult. Also, the complete absence of any stall warning resulted in a totally unpredictable departure at about 4.5g during a longitudinal tracking correction. The characteristics encountered during this test strongly supported the conclusions reached in the stall evaluation. Tracking accuracy was not

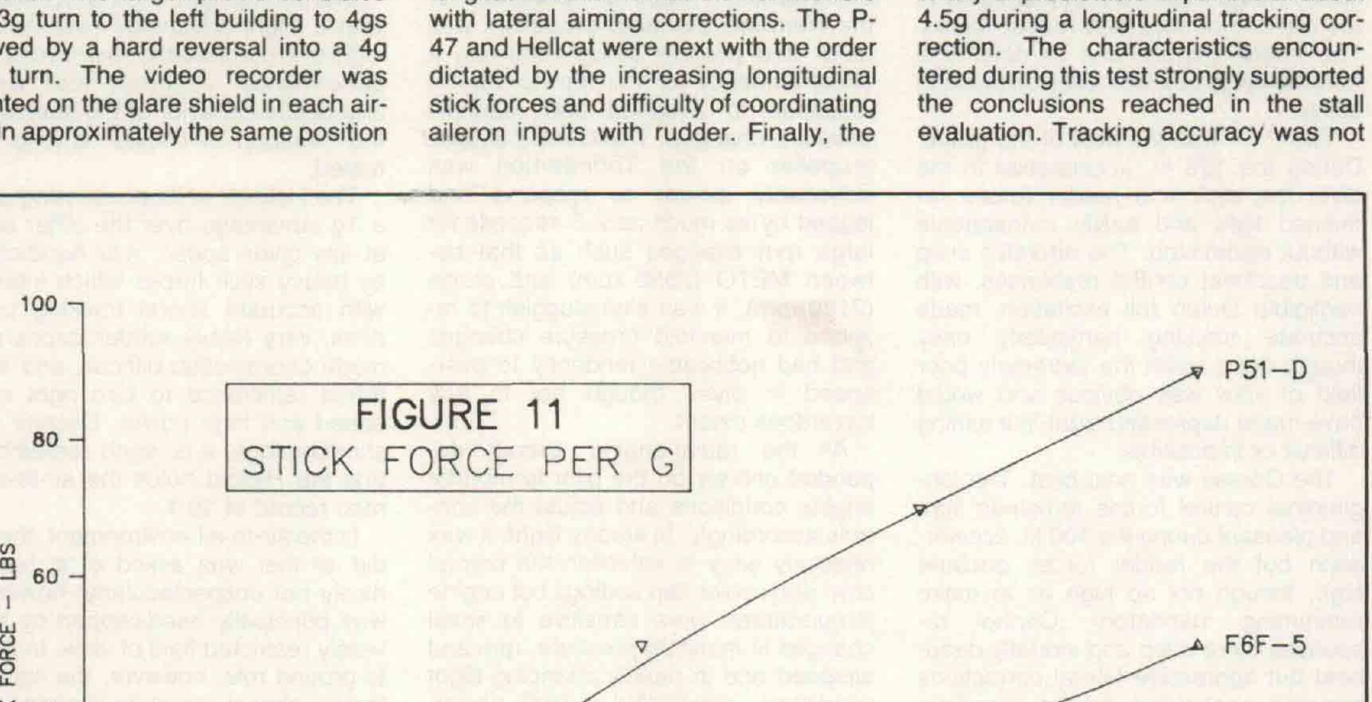


TABLE IV

TIME TO ROLL 180°
(10,000 ft MSL, 220 KIAS, 3g)

	P-47D	FG-1D	F6F-5	P-51D
LEFT	2.7 sec (66°/sec)	3.1 sec (58°/sec)	3.7 sec (48°/sec)	3.3 sec (55°/sec)
	-11%	-28%	-38%	-27%
RIGHT	3.0 sec (61°/sec)	3.7 sec (49°/sec)	4.0 sec (45°/sec)	3.4 sec (53°/sec)
	No Change	-33%	-26%	-25%

the whole story however. The forward field of view, while not good in any of the aircraft, was particularly bad in the Thunderbolt because, as well as being long, the nose was so wide. The Corsair scored well in this respect because its forward fuselage was narrow but still accommodated the R-2800.

Air-to-Ground Tracking - The air-to-ground tracking task consisted of a 90 degree roll into a 30 degree dive starting from 200 kts. at 5,000 ft. MSL allowing the aircraft to accelerate in the dive. Recovery was a 3.5g right rolling pullout to a 90 degree heading change initiated at 2,500 ft.

The flying qualitites were essentially unchanged from those seen in the diving acceleration though the smaller speed range reduced the magnitude of the out-of-trim stick and rudder forces. The major interest was to determine how the flying qualities affected tracking ability.

The P-47 was the best of the group. During the 125 kt. acceleration in the dive, the stick and rudder forces remained light and easily manageable without retrimming. The aircraft's crisp and deadbeat control responses, with negligible Dutch roll excitation, made accurate tracking particularly easy though once again the extremely poor field of view was obvious and would have made depressed sight-line aiming difficult or impossible.

The Corsair was next best. The longitudinal control forces remained light and pleasant during the 100 kt. acceleration but the rudder forces became high, though not so high as to make retrimming mandatory. Control responses were crisp and virtually deadbeat but aggressive lateral corrections required continuous rudder coordination which was hampered by the high pedal forces.

The Mustang was similar to the Corsair in roll but the longitudinal stick forces were noticeably heavier though rudder forces were lower and coordinated lateral corrections were slightly easier.

The longitudinal stick forces in the Hellcat increased approximately 20 lbs. during the 100 kt. acceleration and the rudder forces became high enough to be a considerable hindrance to accurate tracking.

POWER MANAGEMENT

The primary power management controls consisting of throttle, mixture and propeller controls were located in quadrants to the pilot's lower left side. The Hellcat and Corsair used identical hardware but the P-47 and P-51 were different from them and from each other. Secondary controls such as cowl flaps, oil cooler and intercooler controls varied substantially among the four aircraft.

Throttle and Propeller Response - Manifold pressure response to throttle movement was instantaneous in all aircraft, though no automatic manifold pressure limiters were fitted and it was entirely the pilot's responsiblity to avoid overboosting. Propeller response for the Hamilton Standard propellers was quick and positive though showing a small tendency for the rpm to vary in response to airspeed and manifold pressure changes. The Curtiss electric propeller on the Thunderbolt was noticeably slower to respond and lagged by as much as 2-3 seconds for large rpm changes such as that between METO (2550 rpm) and cruise (2100 rpm). It was also sluggish to respond to manifold pressure changes and had noticeable tendency to overspeed in dives though not to any hazardous extent.

All the radial-engine aircraft depended entirely on the pilot to monitor engine conditions and adjust the controls accordingly. In steady flight, it was relatively easy to establish the correct cowl and cooler flap settings but engine temperatures were sensitive to small changes in manifold pressure, rpm and airspeed and in rapidly changing flight conditions, especially at high power. Management of the secondary controls was a demanding task, especially when coupled with confusing or awkwardly placed control switches. The general consensus would generally be to overcool an engine rather than overheat it and that the best thing to do would be to worry about the engine until after the fight. Unfortunately, cowl and cooler flaps are quite serious drag producers and have significant adverse effects on performance. Getting the answer wrong either way could have serious consequences.

The automatic control of the oil and coolant radiator flaps in the P-51 relieved the pilot of a great deal of fussy, secondary workload and enabled him to direct more of his attention to matters of major importance. It is surprising that more effort was not given to developing similar systems for other aircraft of the time.

CONCLUSIONS

The objective of the test program as stated, albeit rather tongue-in-cheek, was to decide which of these four aircraft was the "best" U. S. fighter in World War II. The answer is, "it depends." For general, all-around comfort, field of view and ease of operation, the Mustang was a hands down winner. It also scored high in performance, was well suited to long range escort missions and would do well intercepting and defending against non-maneuvering targets. However, its extraordinarily high maneuvering stick forces, totally inadequate stall warning and vicious departure characteristics make it quite unsuited to the ACM environment. It is a tribute to the adaptability of the pilots who flew them that Mustangs scored so many kills against the opposition.

In a turning fight, the FG-1D emerged with a slight advantage over its rivals. Light and comfortable stick forces, good performance, adequate stall warning and docile behavior at the stall made it the "weapon of choice" among those tested.

The Hellcat, while possessing almost a 1g advantage over the other aircraft at any given speed, was handicapped by heavy stick forces which interfered with accurate lateral tracking corrections, very heavy rudder forces which made coordination difficult, and an extreme reluctance to turn right at low speed and high power. Despite these shortcomings, it is worth remembering that the Hellcat holds the air-to-air kill ratio record of 19:1.

In the air-to-air environment, the P-47 did all that was asked of it, handling nicely but unspectacularly; however, it was principally handicapped by its severely restricted field of view. In the air-to-ground role, however, the light stick forces, almost complete absence of adverse yaw, and crisp, deadbeat tracking responses overcame that drawback and made it particularly suitable for the mission. The other major weakness of the Thunderbolt was the poorly designed and extremely uncomfortable cockpit which would undoubtedly degrade pilot performance on a long mission.

In closing, we would like to express our sincere thanks to Harry Tope and the Kalamazoo Aviation History Museum for making available the aircraft used for this test program.