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# FLIGHT TESTING OF FIGHTERS DURING THE WORLD WAR II ERA

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## I. INTRODUCTION

Flight Test Engineering has always been a challenging field and during the World War II period war time demands added further challenge to a Flight Test Engineer's job. Today's Flight Test Engineers who use laser trackers, inertial measuring units and digital data recording systems may not even recognize the tools of the trade of that era.

Flight testing and aircraft design are functionally connected and hence in aircraft production organizations these two departments exchange information and work together. If politics can be considered to be the art of compromise, aircraft design can be characterized as the science of compromise. The role of flight testing is to provide the "*proof of the pudding*" for the designed aircraft. Both aircraft design and flight testing require flexibility and careful attention to detail. In [Loftin 1985] the payoff for this in design is characterized as,

> "In no other type of machine, with the possible exception of space vehicles, do the often conflicting requirements of performance, safety, reliability, and economic viability place such a high premium on detailed design optimization, based on quantitative data and analysis."

The overall combat effectiveness of a fighter depends on factors beyond aeronautical performance excellence and which cannot directly be affected by flight testing and aircraft design. Some of these are pilot training, experience and morale, the military strategic and tactical situation, and the quantity of aircraft available. Another important factor is the advantage a home territory defense fighter force has over the offensive fighter force, one's shot down pilots fly again while the other's become prisoners!

This paper will describe some features of three typical flight test programs conducted in the Allied countries during World War II. Some of the more valuable programs were those in which an enemy fighter was tested and flown against Allied fighters. In the peak period of late 1944 and early 1945 the USAAF and the RAF in Europe reached a total aircraft strength of about 28,000. By this time Nazi Germany and its allies were virtually defeated under the combined arms of the Soviet Union from the east, and the US, Canada and Britain from the west, and by the partisan and liberation forces in the countries it had invaded. By this time, except for the jet powered Me 262 fighter, Luftwaffe aircraft and most of its pilots were outclassed by allied aircraft and pilots. However, in the beginning of the war the Luftwaffe by virtue of its experienced core of pilots, well tested fighters and the shock of surprise attack (blitzkrieg) was quite dominant. Similarly, Japanese pilots and the Zero outclassed American and British fighters initially in the Asian theater. There was hence a scramble in the Allied countries to improve the combat capabilities of its fighters. Thus, when an enemy fighter fell into Allied hands undamaged, it was rushed into a flight test program to explore its capabilities and to identify maneuvers, tactics, and flight procedures required to defeat it.

Before covering some typical flight test programs the basic flight test instruments used in that era are listed. Cockpit instrumentation consisted of attitude and directional gyros that had to be caged in aerobatic maneuvers. The pressure instruments for airspeed, etc., were quite well developed except that airspeed indicator static lines were often unbalanced (see below). The radio and navigation equipment would probably be unrecognizable to many of today's pilots. Before looking at some of the flight test results that allowed North American Aviation, Republic, Lockheed, Supermarine, etc., along with research centers such as NACA and the RAE to exercise their skill and improve Allied fighters, a list of the tools of the trade is appropriate. Some of these were:

(1) For airspeed indicator calibration a reciprocal low level course was flown between two accurately located landmarks (still used today).

(2) A NACA barograph was used to measure climb performance.

(3) The instrument panel was photographed during maneuvers and this lead to the development of the photorecorder for single place fighters.

(4) Pressure rakes were used for wake flow surveys, their data record was made by photographing a cockpit manometer board!

(5) Take-off and landing performance was determined by using a movie camera that

photographed a clock along with the aircraft as it passed marks placed by the runway.

(6) Temperature was recorded by using a Brown recorder.

(7) Longitudinal dynamic stability periods were measured by a tape mark on the windshield that corresponded to the horizon line. The time it took for this mark to pass the horizon twice indicated the oscillation period.

The next sections will cover wartime flight testing of the P-51, P-38, P-47 and highlight the performance improvements made as a result of these. Wartime testing of the Japanese Zero versus American fighters and of the FW-190A against the Spitfire is then covered. In view of the brief time available for presentation, a synopsis of Soviet fighter testing and details of flight testing conducted in Germany and Japan must be left out. However, these are also very technically interesting, and will be presented on a future occasion.

## I. FLIGHT TESTING AT NACA LANGLEY

The wind tunnels and flight research facilities of NACA made valuable contributions towards nproving the performance and handling qualities of aircraft such as the P-51, P-38, P-47, etc., after they were in production. The NACA developed six series laminar flow airfoils were first used on the P-51 but probably did not give laminar flow in flight. [Cheney 1987] showed typical anomalies that arose between flight test and wind tunnel data. The main factor for this was the fact that manufacturing quality of that era could not provide the smooth contours and lack of surface waviness necessary for natural laminar flow over a large extent of the chord. With the P-51, laminar flow on the airfoil upper surface was perhaps obtained only after removing the camouflage paint, filling in surface irregularities and polishing the metal to a gloss finish, all of which were impractical for a typical wartime operational environment. However, laminar flow was possible in flight. In 1939 NACA tested a B-18 with a wooden Natural Laminar Flow glove which was carefully crafted to maintain contour and smoothness and laminar flow was obtained up to 42.5% chord at a transition Reynolds number of 11.3 million. For details the reader is directed to an excellent survey of historical and current laminar flow flight testing given in [Wagner et. al. 1988].

The NACA Langley engineers noted that most of the fighters had an unbalanced static and total ressure systems for the air speed indicator which, herefore, showed an indicated air speed that was too high (the volume of the static lines was much greater than that of the total pressure lines) [Reeder 1988]. Most of the fighters were also longitudinally unstable at all power settings except idle. At high speeds the stick force versus air speed curve became highly non-linear. Most of these fighters were designed with unbalanced control surfaces. Some of the cures initiated as a result of NACA flight testing at Langley field were:

### The P-51's roll power deficiency

In December 1941 the USAAC gave NACA a P-51 which had been built for the British, to NACA Langley for handling quality studies. These were done using the excellent guidelines defined in [Gilruth 1941]. The low rolling capability (undesirable per British requirements) of this XP-51 was cured by changing the original aileron trailing edge (TE) from a cusp to a beveled TE and increasing its deflection from 10° to 20°. This greatly improved its roll capability. Extensive testing was done on this aircraft, Figure 1 reproduced from [Reeder 1983], shows the roll parameter $\frac{pb}{2V}$ of several fighters, the improvements made with the XP-51 set later USAAF roll requirements.

The P-51 was an outstanding all round fighter design achievement in terms of Loftin's quote (see above) and demonstrated the key features of attention to design detail and good design integration. NACA flight measurements showed that the P-51D had a $C_D$ =.0163, which is exceptionally good and is hard to improve upon even today. Once the P-51 was unshackled from its Allison engine (which had a low critical altitude) and mated to a Packard built Rolls Royce Merlin engine, it became a stellar high altitude performer. The most produced Mustang was the P-51D, with a tear drop canopy, that has graced so many aviation photographs. Its Merlin put out 1505hp at its critical altitude of 19,300 ft. The maximum speed of the P-51-D was 380 knots at 25,000 ft. Its gross weight was 10,100lbs giving a wing loading of 43lb/sq. ft. and a power loading of 6.8lb/hp and a stall speed of 87 knots. It could climb to 20,000 ft. in 7 minutes, and had an aspect ratio of 5.86 and a $\frac{L}{D_{\max}}$ of 14.6. Its low drag design gave it a maximum range of 1650 miles with drop tanks, at a high altitude cruising speed. Thus, the P-51 was the only fighter to fly over all three enemy capitals--Berlin, Tokyo, and Rome.

### The compressibility "tuck under" dive problem.

The compressibility "tuck under" problems faced by fighters such as the P-38 and P-47 occurred at high altitudes when the the wing upper surface Mach Number, M, became critical and the tail became ineffective. The aircraft was hard to pull out of the dive because the controls were not aerodynamically balanced and so the dynamic pressure induced very high elevator loads. The critical Mach number for the P-47 was M=.71 as it had relatively thick (12 to 16%) NACA five digit airfoils. The shock on the wing upper surface caused a large area of separated flow, a loss of lift and so reduced the tail down-wash and hence its down load. This compressibility induced separation also caused a heavy buffet.

Before NACA's flight testing the USAAC selected a test pilot for the P-47 who was also a weight lifter. When dives were initiated at high altitudes even this pilot possibly exerting a 200lb. pull on the stick was unable to pull it out. The plane recovered itself when the denser air reduced the M. In fact the terminal M reached was .86, which was the highest reached with WWII propeller aircraft barring the Spitfire which reached M=.92 [Reeder 1988].

For the P-38 wartime constraints demanded a fast solution so Kelly Johnson and the P-38 team selected to use the dive recovery flaps jointly developed NACA and Lockheed, from among the many solutions explored. These were split flaps mounted near the 33% chord position on the wing's lower surface. When deployed in a dive they increased wing lift, changed the down wash on the tail, and allowed recovery at 3g's. (The laminar flow airfoils of the P-51, were not affected by such compressibility problems).

An unexpected but often typical incident then occurred which further delayed the adoption of these flaps by European theater P-38's. Lockheed shipped batch of dive flaps to Britain in an aircraft (probably a Lockheed Hudson) that the RAF did not recognize as friendly and so shot it down in the Irish Sea. With it was lost the entire initial production run of these flaps.

## II. FLIGHT EVALUATION OF THE ZERO

The Mitsubishi Model 21 A6M2 Zero was designed by a team headed by Jiro Horikoshi as a carrier borne fighter. It was a classic light wing loading, highly maneuverable, long ranged fighter that outclassed its Allied opponents in the beginning of the war. The opportunity to flight test one came when a Zero that had been damaged in an emergency landing in one of the Aleutian Islands was recovered and brought to San Diego to flight test against contemporary American fighters. It was repaired in two months (its damaged prop was replaced by a Hamilton Standard prop) and it flew in October 1942. Flight evaluation pilots from Eglin Field, Florida, flew the P-38F, P-39D Airacobra, P-40F, P-51A against it while Navy pilots flew the F4F-4 Wildcat and the F4U-1 The intelligence summary of the report can be found in [Mikesh 1981]. As expected the Zero's low wing loading (22lb/sq. ft.) gave it an edge climb and maneuverability while its moderate power loading (5.4lb/hp) put it at a disadvantage in top speed and acceleration.

(1) *F4F-4 Wildcat versus the Zero.*
The F4F-4 Wildcat was the principal opponent of the Zero at this stage of the war. The flight tests showed the Zero to be faster in speed and climb at altitudes above 1000 ft. As the Zero had much better turning performance the combat tactics recommended for the F4F-4 were to depend on mutual support and avoid maneuvering combat, but advantage could be taken where possible of the F4F-4's superiority in high speed rolls and pushovers.

(2) *P-51A Mustang versus the Zero.*
The P-51A was Allison powered with the radiator scoop on top of its engine cowling. In simultaneous take-offs the Zero reached its best climb speed and a 5,000 ft. altitude faster than the P-51. Level flight acceleration at 5,000 ft. from 217knots IAS was much greater for the P-51 and it pulled away from the Zero. The Zero beat the P-51 in climb rate between 5,000 ft., and 15,000 ft. Above this altitude the P-51's Allison engine operated badly and so no tests were flown above 15,000 ft.

A lot of interesting flight test and research work involving evaluating the flight characteristics of the Spitfire V and the Mosquito F-8 was done by NACA at Langley Field during the war. These are reported in several NACA war time reports. These tests showed that the Mosquito experienced vertical tail or fin stall when full aileron roll power was used.

## III. FLIGHT EVALUATION OF THE FW-190A-3 IN THE RAE, FRANBOROUGH 1942

In 1941 RAF pilots reported encountering a formidable radial engine fighter over France. Such was the superiority of the FW 190A-3 over the Spitfire V that Luftwaffe pilots were ordered to prolong engine life by limiting supercharger boost pressures to 19.8psi from 20.9psi getting 1595hp rather than 1770hp at 3,000 ft. and 1455hp at 18,000 ft. A FW-190A-3 was mistakenly landed in England by a Luftwaffe pilot in June 1942. Perhaps one of the most extensive flight test analysis made on enemy aircraft were done by the RAE on this aircraft. The details of the analysis are reported in [Green & Swanborough 1976]. The information showed that the FW-190A-3 was faster than the Spitfire Mk. V at almost all altitudes. It carried heavier impact armament and had superior engine control systems. A complicated electro-hydraulic master control mounted on the rear casing of the BMW 801D-2 engine was controlled by a single lever engine control in the cockpit. Cooling was helped by a fan that was geared to turn at 1.72 times the engine speed.

The Spitfire V was quickly modified by installing a newer mark of the Rolls Royce Merlin engine which increased the Spitfire Mk. V's 1500hp by 200hp. *However, handling qualities of this new* Spitfire Mk. IX suffered because neither the fin area nor the structure was strengthened to accommodate the more powerful engine, such was the haste forced by Kurt Tank's 'Butcher Bird'! Some Spitfires *had their wing tips clipped to improve roll inertia*, but this came at the expense of high altitude performance.

An interesting twist of events occurred when the Luftwaffe recovered a damaged Spitfire Mk. V and equipped it with the Daimler Benz engine that powered the Bf-109 (its handling characteristics were better than those of the Bf-109). This fighter was destroyed in a USAAF air raid in 1944!

## CONCLUSION

The World War II period saw rapid strides made in aircraft design, technology and operations. The flight testing and design teams could see the results of their work applied in a short time span and benefited from this feed-back. One hopes that the governments of the world have learned a lesson about the terrible cost of such a global war and flight test and design teams of the future will not have to put their products to such terrible use.

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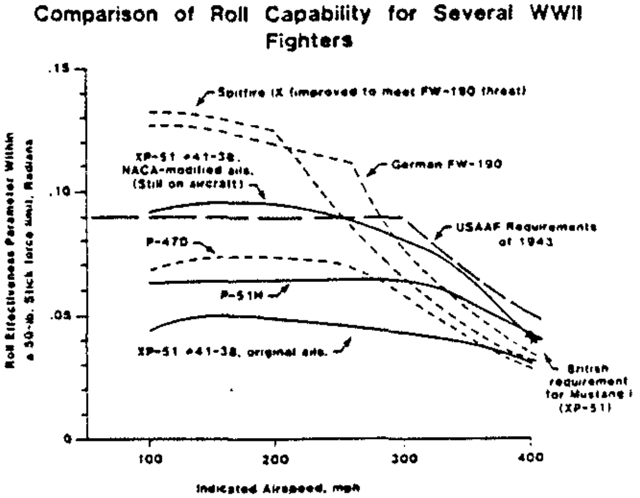
Comparison of Roll Capability for Several WWII Fighters

FIGURE 1.