NACA Contributions to the N.A.A. P-51 Airplane

NACA has made many contributions to the development of the P-51 and other airplanes. An important contribution was a drag reduction program conducted on 23 actual airplanes in the NACA, Langley, 30-by-60-foot Full Scale Wind Tunnel from 1935 through 1945. This program identified sources of drag and other aerodynamic problems that could be eliminated or minimized during design or re-design. Airplane no. 23 was the P-51B and the last of the aircraft examined in these wind tunnel tests. The results are summarized in NASA TN D-8206. The P-51B aircraft had 1/3 less drag than the first aircraft tested in their respective original configurations.

Another important NACA contribution to the general development of the P-51 and most other airplanes of today was the flight research that produced the report on "Requirements for Satisfactory Flying Qualities of Airplanes," by Robert R. Gilruth in 1941 (classified at the time). This contribution is outlined by Courtland D. Perkins in his von Karman Memorial Lecture of 1969 titled "Stability and Control Technology." It was published as AIAA Paper No. 69-1137. James Hansen, in his book "Engineer in Charge," NASA SP-4305, also discusses this activity at Langley.

Perkins, of Princeton University at the time, had been chairman of AGARD following the death of von Karman. In his von Karman Lecture, Perkins selected "Flight Research-Flying Qualities" for his main emphasis.

Flight research began at NACA, Langley, in 1919 with two JN-4H's by Ed Warner and F.H. Norton with the objective of correlating MIT wind tunnel data and flight data for lift, drag, stability and control. The airplanes and pilots were borrowed from the Army at Langley. Most of the flying was done by Eddie Allen who became the most accomplished of the test pilots. Allen was later president of Boeing and was killed on a test flight in an early B-29. The NACA hired its first Civil Service pilot, Tom Carroll, in 1922.
In 1920 NACA Headquarters hired Edward P. Warner from MIT and he soon became responsible for the early flight research at Langley. He was hired as a consultant by the Douglas Aircraft Co. in about 1935 to help define desirable stability and control characteristics (handling qualities) for a large transport airplane. At this time Warner had become Chairman of the NACA Aerodynamics Committee, and he obtained research authorization for Langley, under the supervision of Hartley Soulé, to investigate a variety of airplane configurations, large and small, for the purpose of defining satisfactory stability and control characteristics commensurate with the required piloting tasks. This program required the development of flight test techniques and recording instrumentation of high accuracy, the development and use of skilled engineering test pilots, and the proper interpretation of data with the cooperation of participating pilots. The NACA and British RAE were, in effect, the first test pilot schools.

After this initial program Robert R. Gilruth then conducted a broader program of flight evaluation of military and civil aircraft, both large and small, with expert support from NACA test pilots such as W.H. McAvoy and M.N. Gough, particularly. The results of flight evaluations of sixteen different airplanes were published in a classified report, "Requirements for Satisfactory Flying Qualities of Airplanes," in 1941. The report was published as an unclassified NACA Technical Report, No. 755, in 1943. By the end of WW 2 sixty aircraft had been evaluated. Upgrading of the requirements follow periodic reviews. These original basic requirements have formed the basis for military and civil handling qualities requirements world-wide.

Soon after the N.A.A. XP-51 #1038 was acquired by the U.S.A.A.F. in 1941 from the British Purchasing Commission, it was assigned to NACA, Langley, for evaluation of its handling qualities for possible upgrading of the
"Requirements" recently published by Gilruth in 1941. The aircraft was found to have very good handling qualities overall, except for inadequate roll rate capability. The only specified British roll requirement was for a $\frac{pb}{2V}$ (wing tip helix angle while rolling) of 0.04 at 400 mph indicated airspeed within a 50-pound stick force limit. The XP-51 aircraft as received did not meet the British roll requirement. The aileron deflection provided was only 10 degrees and the aileron hinge moments were high, such that the cable stretch further reduced the aileron deflection available. At intermediate speeds the roll rate was less than half that of the Spitfire and the FW 190. At the request of the A.F. for an increased roll rate, Gilruth's group doubled the aileron deflection to 20 degrees and added bevelled trailing edges (25 degrees included angle) to the ailerons to reduce the hinge moments and stick forces to meet the roll requirements with 50 pounds of stick force. With these modifications the XP-51 demonstrated rolling velocity capability which essentially established the U.S.A.A.F. requirement for roll rate published in 1943 and is essentially that of the current requirement, except that maximum stick forces in roll are limited to 20-30 pounds currently. The P-51H had an increased deflection of 15 degrees, thus providing only 50% increase in effectiveness over the original XP-51, and only 70% of the A.F. requirement of 1943, and only half of that for the Spitfire and FW 190 at intermediate speeds.

Other NACA Contributions

Russell G. Robinson of NACA Headquarters helped N.A.A. select the specific parameters for the most suitable laminar-flow airfoil shape for the XP-51 A, B, and D models. Operational environments prevented laminar flow. The laminar flow airfoil's primary advantage proved to be the increase in its critical Mach number, thus postponing drag rise, severe buffeting, large trim changes, etc., due to shock stall.
Violent cooling duct "rumble" occurred early in the P-51B at high speeds. The aircraft was put into the 40 x 80 foot wind tunnel at the Ames Center and the cause was found to be flow separation in the duct ahead of the radiator. The cure was to move the inlet forward and downward to clear the fuselage boundary layer and provide air by-pass gutters. The inlet was sliced back at the bottom to be perpendicular to the inlet flow at high speed.

In high speed dives the P-51D directional stability became weaker at high speed allowing inadvertent sideslip or wandering. Also, in maneuvering flight excessive sideslip could be introduced with imperfect use of rudder, or by out-of-trim due to large speed or power changes. Langley had designed a taller fin during its wing-flow model research to obtain steadier flight. The Air Force also liked the larger fin and made it a retro-fit on late model P-51's, and some P-51B's.

Early tests of the P-51H showed low directional stability at high speeds, and to speed up delivery of the aircraft to the Pacific Theater the Air Force adapted the NACA P-51D fin to the P-51H.

NACA Langley designed and conducted evaluation tests of dive recovery flaps on an XP-51 #1039 to be used for recovery from severe "tuck" and shock stall if encountered at high speeds. I don't know why the A.F. installed such flaps on production P-51's. The effects of shock stall on the P-51's was much milder than for aircraft with older airfoils, and I have not heard of serious difficulties at high speed with P-51's.

John P. Reeder 1-27-'50
Contributions to NACA Aerodynamic Research
by use of the P-51 Mustang Airplane

In turn, the North American P-51 Mustangs, namely the XP-51, P-51B and several P-51D’s, proved to be very useful to the NACA in its research role in addition to establishing handling qualities standards. The high speed wind tunnels of the pre-war II era could not attain sonic (Mach = 1) air velocities in the test sections because of "choking" of the flow due to existence of strong shock waves in the test sections. In 1944 Robert Gilruth of the Flight Research Division heard his pilots describe the shadow of the normal shock on the wing of the Mustang, somewhat aft of mid-chord and extending toward the wing tip (caused by refraction of sunlight by the shock surface when the sun is high). The shock responded to elevator input and gusts by moving forward under higher load factors, and vice versa. Gilruth reasoned from this that the laminar flow airfoil (64 series), with some local tailoring, had a useful run of practically uniform supersonic flow ahead of the shock in which small, half-span aircraft models could be mounted endwise on recording force balances within the wing contour and with provisions for rotating the model through an appropriate angle of attack range. Several P-51’s were so equipped, and each carried two unique models, one on each wing.

By diving the P-51’s to about 0.81 Mach number (true) the models being carried were experiencing Mach numbers of about 1.4. For consistency in the dive angle flown, 25 degrees, the pilots used directional gyro’s with axes oriented horizontally for this purpose. This wing flow technique proved to be an important aerodynamic bridge to the transonic/supersonic research aircraft and fighters to come.

Slotted-throat wind tunnels capable of supersonic speeds emerged between 1947-1950, and were again to become a prime tool for high speed aircraft development.

A P-51B was used by NACA to further develop high speed laminar-flow airfoils by overlaying the original airfoil with gloves of desired contours and surface conditions for study. Extensive surface measurements of boundary layer and separation characteristics on the airfoils were made as well as momentum surveys in the wake to determine overall drag of the glove section. Note in the photo of the P-51B with the test wing section that the aircraft fin, as compared with the P-51B without the rake, has been extended vertically for improved directional stability and steadiness for data.
The XP-51 #1039 also was used for study of shock locations and regions of flow separation as it affected flight loads. Also, specialized instrumentation was used, including movie photography of shock shadows on the aircraft surfaces in steady flight and in maneuvers.

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