One of the awards presented at Oshkosh '76 was a Special Recognition trophy for Darrell Skurich of Ft. Collins, Colorado — for his work in restoring the EAA Air Museum Foundation's XP-51. Flown directly from Charlie Day's San Angelo, Texas paint shop to Oshkosh, the aircraft as it was viewed by the tens of thousands of convention goers was ample justification for the award ... but, as usual, there is much more to the story than could be discerned during a quick walk around inspection.

The XP-51 is a very unique airplane ... and it took a very unique, dedicated person to restore it to flying condition. The fortuitous crossing of paths of this man and this machine is our story.

Warbird buffs everywhere are familiar with the story of the Mustang ... how it was conceived as an export fighter by North American's president, Dutch Kindelberger, for sale to the beleaguered British in those dark early days of World War II when the Luftwaffe's star was still in its ascendancy ... how in order to get the contract, Kindelberger had to agree to design, build and fly a prototype in 120 days ... how the prototype, NA-73X (NX19998), was so impressive that production of Mustang Is for the RAF was immediately begun ... how the U.S. government had agreed to the contract with the proviso that two early examples of the new fighter be turned over to them (free of charge) for evaluation ... and how the mighty Mustang went on to become the finest all-round fighter aircraft of the war.

But that's getting 'way ahead of the story.
The Machine

In 1940 North American's small engineering department headed by Raymond H. Rice was resourceful and had some brilliant designers — particularly Edgar Schmued, the person who actually laid out the P-51 as we know it today. Their experimental shop was staffed with some clever, ingenious people who could — and did — whip out a flyable prototype in a wink and a blink of the eye . . . but they were not magicians who could create something out of nothing. The prototype was, as most prototypes are wont to be, handmade.

To meet their all important deadline, as much off-the-shelf materials and components as possible were utilized — meaning a lot of T-6 stuff. When a stock part was not available, a chunk of metal was slapped in a lathe and the suitable shape was carved out on the spot. Since the second Mustang built was also the first "production model", this cut-and-try process apparently went on quite a way into the initial batch of Mustangs before the design of each and every component was frozen and production tooling was built. With this, you begin to see the monumental problems faced by Darrell Skurich when he began tearing into the XP-51.

Those two Mustangs promised the USAAC that the 4th rather than the 5th aircraft was turned over to the USAAC. Since it was the 5th Mustang to be built, including the prototype, some confusion has obviously crept into the history books in the intervening years. At any rate, the two aircraft, Serial Numbers 41-38 and 41-39, went to Dayton, languished for a time, finally came to the attention of the powers that be as superior to anything in Uncle Sam's arsenal . . . and then were flown down to Langley Field near Norfolk, Virginia to spend the remainder of the war serving in the crucial roles of test beds for various NACA experiments — experiments that would improve the breed of fighter aircraft, allowing them to safely nudge a little closer to the then not very well understood sound barrier.

At the end of the war the first of these two, 41-38, was flown to Orchard Airport in Park Ridge, Illinois (now Chicago's O'Hare Field) where the Air Force was collecting significant military types for a future museum. On January 3, 1949 the collection was turned over to the Smithsonian's National Air and Space Museum and the XP-51 eventually was dismantled, crated and shipped to the NASM's storage facility at Silver Hill, Maryland.

In 1975 the U.S. government's very first P-51 Mustang was traded to the EAA Air Museum Foundation for a Northrop Alpha in a rather complex deal also involving TWA. The XP-51 was trucked to Hales Corners and, finally, in August of 1975 was shipped to Ft. Collins, Colorado . . . to the shop of warbird specialist, Darrell Skurich.

The Man

What elements go into the making of a man whose destiny it is to one day have the task of poking into the innards of an airplane handbuilt 35 years earlier — an airplane for which no drawings, blueprints or manuals exist today — and attempt to restore it to a like-new condition?

Darrell was born in Grand Rapids, Minnesota but grew up in Greeley, Colorado where his family moved when he was five years old. Like most EAAers, Darrell seemingly was born with a genetic proclivity for airplanes and flying, so that when he was first exposed to them at around age 5 or 6, a subliminal spark was ignited that worked itself into his conscious mind and has since remained the principal motivating force in his life.

When he was in the 5th grade, Darrell started riding his bicycle to his hometown airport and shortly wormed his way into favor with the FBO — thereby stepping into the role of the most hallowed of American aeronautical institutions, The Airport Kid. Initiation rites included all the usual things, sweeping out hangars, washing airplanes, serving as everyone's "go-fer", etc. . . . at first for rides but as soon as he could reach the rudder pedals, dual instruction. At 12 he was already an accomplished stick and rudder man, and, at 14, a person who shall remain anonymous for obvious reasons, took Darrell to an outlying duster strip in a J-3 and kicked him out of the nest.

After high school, as all young men must, Darrell

SPORT AVIATION 59
An old NACA photo of the XP-51 taken sometime during World War II when the aircraft was being used as a test bed at Langley Field. Photos like this told how the plane should be finished.

Darrell Skurich and Jimmy Leeward relax on the wing of the XP-51, shortly after their arrival in Oshkosh from Texas.
Darrell regarding the restoration of the XP-51 (Photo by Darrell Skurich)

The XP-51 nearing completion in Darrell Skurich's shop in Ft. Collins.

"Worse than normal. By that I mean worse than I usually get in my shop for restoration. Corrosion appeared to be the biggest problem, but after a thorough clean-up, I found it was just on the surface rather than intergranular. And it was banged up a little... one flap was destroyed and the other was damaged, the leading edge on the left wing had a good crunch in it and both tips were in bad shape. Some other minor storage damage was also evident."

Once you got into dismantling the airframe, what did you find... what are the differences between the XP-51 and the P-51Ds you usually work on?

"Everything! The whole airplane is different."

For example.

"There are a lot of T-6 components... the main gear retract cylinders are T-6, the hand hydraulic pump is T-6 and even the stick is T-6.

"None of the hydraulic cylinders and components were production parts. You could see that they went to work with a mill and drill press and made each one. There was not a single standard size O-ring in the entire hydraulic system. Ail goofball stuff. I had to make all new pistons for the hydraulic systems and groove them to take standard O-rings."
At the Interview Circle Paul Poberezny, left, interviews Jimmy Leeward and Darrell Skurich, seated, as Roscoe Morton, right, looks on.

"Also, a lot of the plumbing to the engine was non-standard stuff. The electrical system was stock for that day but "antique" by today's standard. The generator was junk and it had a reverse current relay and voltage regulator of the old vibrator type. I put all of it back in original, but overhauled condition... and the first time I fired up the engine the generator went out. I replaced it with a late model and it worked so good that it ate up the voltage regulator!

"The old reverse current relay and voltage regulator were small units mounted ahead of the panel - they were replaced with modern units mounted behind the seat. The original wiring was pretty good - after all it was almost new.

"What else? The radiator. There just aren't any like it... one of a kind. The military must have been flying with water in the radiator and failed to drain it when the airplane was placed in storage. It froze and damaged everything. When I pressure checked it, if it had one it had ten thousand leaks! Even the case was cracked. Young Radiator of Racine, Wisconsin rebuilt it - did a terrific job."

Any other special problems?

"The two fuel cells could not be reused - and they were completely different from those in later P-51s so I couldn't substitute."

How did you get around that?

"Had an outfit in California, Fuel Safe, Inc., make new ones. They make foam filled fuel cells for race cars and have a very interesting manufacturing process. You provide them with your old tank (or a set of dimensions) and they make a cardboard form using the original as a pattern. This is covered with ballistic nylon, the stuff used to make bullet proof vests, and is coated with a polyurethane rubber. Then it's put in an oven and baked. Afterwards, the filler holes are cut out and the cardboard is ripped up and pulled out through them. The tank is then filled with foam, so that you don't need any baffles, ribs, stiffeners, etc. A rigid tank is what you get - one that's explosion proof. The foam displaces about 2% of the potential fuel load but the bladder walls are so thin as compared to the original tank that you gain it all back. Each tank, incidentally, has a capacity of 85 gallons - 170 total."
With what did you cover the control surfaces?

"Grade A ... is there anything else?"

"The XP has goofy ailerons ... beveled trailing edges that were a part of a NACA experiment to get better aileron response."

How about the engine?

"The Allison was overhauled by Jack Sandberg's METMA of Minneapolis. He did a beautiful job of converting this early Dush Number to a late model -- heavier crank, late style rods and pistons, etc. I sent the prop out for overhaul and found the electric prop motor to be a ball of rust. It was a real stroke of luck when Morton Lester, one of our EAA Air Museum Trustees, told us he had a Curtiss Electric, still in cosmol ine, in his propeller collection. It was the right model and the motor is flying on the airplane today. Morton really saved the day when he donated that item."

What's the story on the paint job?

"After the XP was finished and test flown. I flew it down to San Angelo, Texas to Charlie Day's paint shop. He had already offered to donate an Alumigrip paint job. I had the airframe stripped, of course, and had painted the interior, the wheel wells, landing gear legs, etc. as I rebuilt them. Charlie would do the exterior. Before leaving Ft. Collins, I had thoroughly researched the airplane and, after talking to Paul, knew what I wanted. The XP was to be painted silver and have the numbers and markings it had when new. Fortunately, NACA, test pilot Jack Reeder and others had sent EAA lots of pictures, so we knew just how it looked. I also cut all the stencils before I left home and had them ready to use at San Angelo.

"The paint job took about 10 days. The XP was washed down with MEK, etched, alodyned, primed with yellow primer and, finally, shot with Alumigrip. In all there are 5 colors, including the silver, so we had to wait a day between each color. We-painted the aircraft silver to simulate the original bare metal because there were just too many nicks and scrapes on the skin to try to polish it out and come up to the standard we had hoped to meet for the XP."

Since you are the only person presently current in both the XP-51 and the P-51D, how do you compare the two?

"It's like comparing a race car and a Rolls Royce."

Please elaborate.

"The XP is just like a little race car -- it's fast, noisy, uncomfortable, and hot; the D has room, you can see out
of it - just like being in the lap of luxury after flying the XP. It (The XP-51) is a lot lighter on the controls, especially the rudder and elevator, than the D. Ailerons are about the same. The rudder is really light."

Does this super light rudder affect ground handling?"

"This is a weird airplane - it has virtually no torque on take-off. I think mainly because of the 3-blade prop ... less P-factor than with the 4-blade on the D."

How fast is it?

"It's a lot faster than the D. At the same power settings it is about 45 mph faster. I flew along side Jim Leeward's D from Ft. Collins to San Angelo and from there to Oshkosh and had ample opportunity to compare the two."

"The XP changes speed instantly. Put the nose up or down or change power settings and it reacts instantly. It's like an electric motor as compared to a gas motor."

You mentioned that the XP was uncomfortable ... "It's uncomfortable to fly... you can't see out of it, it's hot, awfully crowded, everything is operated manually - coolant doors, you are continually monitoring coolant and oil temperatures and have to control them by hand. On the D everything is automatic.

"You sit low, have all those squares in the canopy frame to look through. Can't see ahead, can't roll back the canopy like you can on a D and lean out to look around the nose. You have just a hinged side panel to lean through and with a headset on and shoulder harness, you just can't move far."

"It's uncomfortable... but it sure is fun!"

Are those real 50 caliber guns? "The XP had two 50 calibers in the nose and six wing guns. I cut off the barrels and used only them. I wanted to save the weight of the heavy breeches - the guns weigh about 100 pounds each - and save room for a suitcase in the gun bays."

Any final words?

"Yes, I want to thank Jimmy Leeward. He gave me more help than anyone on this project. He flew to Ft. Collins from his home in Florida a number of times while I was rebuilding the airplane and took time off to escort me down to San Angelo when it was ready to go. He stayed with me all the way to Oshkosh. We had some teething problems with the airplane just as you always do with a 'new' airplane and it would really have been impossible to get the XP to Oshkosh for everyone to see had it not been for Jimmy's help."

What's ahead for Darrell Skurich? "More of the same. I've got a Bearcat, and several 51s to do. That takes me a number of years down the road... but that's what I do..." 

... and you love it!

Epilogue

A lot of people helped somewhere along the way to get the XP-51 on the line at Oshkosh '76. Sam Huntington helped organize a work party to load the aircraft on a truck at Silver Hill for the trip to Hales Corners. Tom Austin of Greeneville, Tennessee donated the use of the truck and provided the driver, Paul Johnson, who took special care to deliver his precious cargo safe and sound. Bob Hoover raised restoration funds on several occasions by taking persons for rides in exchange for donations to the XP-51 fund. Champion donated several sets of spark plugs. EAA's own Warbirds of America and the Rockwell Corporation made substantial donations to the restoration fund... and there were others. All were sincerely interested in seeing that this historic aircraft be preserved. All of us owe these people a debt of gratitude.

And to Darrell Skurich a special salute. He was the right man for the job. available at the right time and, most of all, one who could look on the task as a labor of love.

Just look at the aircraft... it shows.

What a slick airplane!

(Photoby Jimmy Leeward)
P–51 Mustang, Cavalier, Enforcer

One of the few truly great aeroplanes of World War II, the North American Mustang owed its inception to British rather than American requirements, and achieved its greatest success when fitted with a British engine. The product of a still-young design team, headed by Raymond H. Rice and Edgar Schmued, with unfettered ideas about the design of a combat aeroplane, the Mustang was also notable for the speed with which it was designed, built and put into operation. By the time the war ended in 1945 (bringing cancellation of contracts then in hand for 5,973 Mustangs) 15,586 aircraft of this type had been built in North American’s factory—yet design work did not begin until 1940.

In the early months of that year, the British Air Purchasing Commission was seeking to purchase large quantities of aircraft in America to strengthen the hard-pressed RAF. None of the fighters then available from US manufacturers was considered to be ideal for European combat conditions—although many stop-gap orders were placed—and the possibility of having an entirely new type developed specifically for the RAF was discussed with J. H. Kindelberger, NAA’s president, in April 1940. With enthusiastic support from the

Top left: The NA–73X, prototype of the Mustang family.

Left: The first Mustang (NA–73) built on British contract, AG345.
company and an approving nod from the US government, which stipulated that two early production models should be made available for USAAC testing at no cost, the project got under way in April 1940 with a 120-day target for completion of the prototype.

The prototype was identified as the NA-73X and it was designed around a 1,100hp Allison V-1710-39 engine. Noticiable features of the design were its angular lines, chosen for ease of production, location of the radiator 'bulb' well aft below the cockpit to preserve clean lines for the front fuselage, and a laminar-flow wing section for low drag at high speed. Provision was made for four wing guns and two in the lower nose cowling. First flown by Vanc Breeze on October 26th, 1940, the NA-73X carried civil registration NX19998 as a company-financed prototype. It eventually crashed and was destroyed, but not before it had demonstrated excellent low-level performance and outstanding handling characteristics.

The British Air Purchasing Commission was well satisfied with the NA-73X and confirmed an order for 320 NA-73s, for which the name Apache was briefly considered before Mustang was adopted. A second order for 300 followed soon after.

Top right: The tenth production Mustang airframe, completed as an XP-51 (NA-72) and shown here while on test by NACA at Langley Field.

Right: An experimental installation of 40mm Vickers 'S' cannon on Mustang I (NA-83) AM105.
these being built as NA-82s, but all were Mustang Is in RAF service, having an armament of four 0.50in and four 0.30in machine guns—two of the former in the nose below the engine and the remainder in the wings. The Allison F3R engine was rated only for low altitudes and the Mustang Is were therefore assigned to tactical reconnaissance duties, carrying an oblique camera in the cockpit behind the pilot. The first production aircraft flew at Inglewood on May 1st, 1941 and the type entered service with No 2 Squadron, RAF, in July 1942.

Fulfilling its obligation to the USAAF, North American built two additional NA-73s (actually the 4th and 10th production aircraft) which went to Wright Field as XP-51s. Successful trials, and the high speed of 382mph then demonstrated, led the USAAF to include the Mustang in its procurement plans—still primarily in a low-altitude tactical rôle. Orders were placed for 310 P-51As, with armament of four 0.50in wing guns and the 1,200hp Allison V-1710-81 engine, and 500 A-36As, which had six 0.50in guns including two in the nose, wing racks for two 500lb bombs, dive brakes and the 1,325hp V-1710-87 engine. The latter were the first USAAF Mustangs to go into operation, in Sicily and Italy during 1943.

Using Defence Aid Funds, the USAAF also ordered 150 P-51s for supply to the RAF as Mustang 1As. These had a wing armament of four 20mm cannon but were
otherwise similar to the Mustang Is. Of this total 57 were retained for service with the USAAF, but under subsequent lend-lease arrangements, fifty of the P-51As referred to above were supplied to Britain as Mustang IIs, plus a single example of the A-36A for evaluation.

The idea of installing the Rolls-Royce Merlin in the Mustang, to improve its performance at higher altitudes, was conceived in the Spring of 1942 after one of the early Mustang Is had been flown at the AFDU by a R-R test pilot. Theoretical calculation showed that a Mustang with Merlin XX engine would achieve 393mph at 18,600ft while use of the Merlin 61 would bestow a speed of 432mph at 25,500ft. A programme to convert several Mustang Is was put in hand at the R-R test establishment at Hucknall, and the USAAF instructed North American to proceed with a similar programme to fit the 1,380hp Packard-built V-1650-3 version of the Merlin.

The first flight with a Merlin-Mustang was made at Hucknall on October 13th, 1942, the aircraft being Mustang I AL975/G and the engine being a Merlin 65. Four more aircraft were converted by Rolls-Royce, and Merlin 70 and 71 versions were

Top left: Canon-armed P-51 (NA-91) in North American test markings, 1942.

Left: USAAF P-51-I (NA-91) reconnaissance version in experimental black and white splinter finish; oblique camera is mounted in blister at rear of cockpit.

Right: P-51A (NA-99) Mustangs of the USAAF with smoke curtain installation beneath the wings.
also flown. All five aircraft were officially designated Mustang X when fitted with Merlin engine, and were distinguished by the air intake for the intercooler radiator located immediately behind the spinner. Speeds as high as 433mph were achieved, vindicating the original estimates, and conversion of 500 Mustang Is to Mustang X standard was projected. However, the latter step became unnecessary because the success of the parallel North American programme led to a switch to the Merlin engine for all subsequent Mustang production.

The two NAA prototypes were initially designated XP-78s but were completed as XP-51Bs, being converted P-51 airframes. They had a small air intake behind the spinner, strengthened airframe and wing pylons for up to 1,000lb each side. A maximum speed of 441mph was demonstrated. Production had already been put in hand at Inglewood, which built 1,988 P-51Bs with armament of four 0.50in wing guns; a second production line established by NAA at Dallas produced 1,750 of the similar P-51C. Included in these totals were 910 to be supplied to the RAF as Mustang IIs—274 from Inglewood and 636 from Dallas.

A major improvement in all-round visibility was achieved in the next production variant, the P-51D, which had a cut-

Top right: An A-36 (NA-97) supplied to the RAF for evaluation, showing the bomb racks and dive brakes on the wings.

Right: Experimental installation of a Merlin 65 by Rolls-Royce in Mustang X A48208.
down rear fuselage and a 'tear-drop' canopy. Also standardised in this model were features that had been introduced progressively on later P-51Bs and P-51Cs, such as a six-gun wing armament, 1,695hp V-1650-7 engine and a small dorsal fin. Inglewood built 6,502 P-51Ds and Dallas built 1,454, with 271 of this total assigned to the RAF as Mustang IVs. The Dallas plant also built 1,337 P-51Ks, which differed from the 'D' only in having an Aeroproducts propeller; the RAF received 594 of these, also as Mustang IVs.

The final production version, and the fastest of all the Mustangs, was the P-51H. This was evolved through a series of experimental lightweight versions and was more than 1,000lb lighter than the P-51D, despite having increased fuel and the 2,218hp V-1650-9 engine driving a four-blade Aeroproducts propeller. A taller fin and shorter canopy were fitted, and the top speed was 487mph. Production totalled 555, with another 1,845 cancelled, together with 1,700 similar P-51Ls to have been built at Dallas. One example was supplied to the RAF.

In addition to the production models of the Mustang described above, the following versions were also designated:

TP-51D: Originally, ten P-51Ds were converted to two seaters by NAA with this
designations, having full dual control in a second cockpit behind and higher than the regular pilot's position. Some P-51B and C models were converted to two-seaters at field bases and, post-war, more conversions to similar TP-51D standard were made by Temco and Cavalier.

*XP-51F:* Three lightweight prototypes with bubble canopies and V-1650-3 engines; one to the RAF.

*XP-51G:* Two prototypes, similar to XP-51F with Merlin RM-145M engines; one to the RAF.

*XP-51J:* Two prototypes similar to XP-51F with Allison V-1710-119 engines.

*P-51M:* The last production P-51D from Dallas was fitted with a V-1650-9A engine and redesignated.

*P-51-1:* See F-6 below.

*F-6:* An armed tactical reconnaissance version of the Mustang for the USAAF. The first batch of aircraft were the 57 P-51s retained from the British Defence Aid contract. They had four-cannon armament and two K-24 cameras in the fuselage. Tentatively designated F-6As, they were finally called P-51-1s.

*F-6B:* Thirty-five P-51As converted as above, with machine gun armament.

*F-6C:* Ninety-one P-51B/C conversions
with two K-24 or one K-17 plus one K-22 camera installation.

**F-6D:** Camera-equipped conversion of P-51D; 136 produced.

**F-6K:** Camera-equipped conversion of P-51K; 163 produced.

**F-51D:** Surviving P-51Ds redesignated in 1951.

**F-51K:** Surviving P-51Ks redesignated in 1951.

**RF-51D:** Surviving F-6Ds redesignated in 1951.

**RF-51K:** Surviving F-6Ks redesignated in 1951.

**TRF-51D:** Two-seat variant of RF-51D.

To meet an urgent need for a new fighter to serve with the RAAF, the Australian government acquired a license to build the Mustang in its P-51D version in 1943. One hundred sets of components were purchased from North American (included in the Inglewood production total quoted above and built as NA-110) plus one pattern aircraft tested in Australia as A68-109. Production of the Mustang was entrusted to Commonwealth Aircraft Corporation, which used the NAA components to assemble 80 CA-17 Mustang XXs with V-1650-3 engines. The first of these flew on April 29th, 1945. Production continued with the CA-18 variant powered by the V-1650-7 engine, CAC delivering

Top right: An early production P-51D (NA-106) with tear-drop canopy and no dorsal fin.

Right: Late-production P-51D (NA-109) with dorsal fin and drop tanks.
40 as Mustang 21, 14 as Mustang 22 with oblique F24 camera in the fuselage and finally 66 Mustang 23 with Merlin 66 or 70 engines from the UK. Fourteen Mk 21s were later converted to Mk 22s. Production of 50 more CA-18s and 250 CA-21 Mustangs was cancelled, and the RAAF acquired instead 214 P-51Ds and 84 P-51Ks from the USAAF. Too late to serve in the War, the RAAF Mustangs were assigned to occupation duties in Japan and one squadron, No 77, was operational in the Korean War until April 1951, when some of these Mustangs were transferred to the Korean Air Force.

No other original production of the Mustang was undertaken, but both during and following World War II the type saw widespread service. Fifty P-51Ds were supplied to China before the war ended and forty were accepted by the RAAF for use by the Netherlands East Indies Air Force (serialled N3-601 to N3-640), while ten Mustang 1s are reported to have been shipped to Russia from Britain. Post-war, major users of surplus USAAF Mustangs included the Swedish Air Force, which bought 140 in 1945/46, the Swiss Air Force, which acquired about 140, and the RCAF, which obtained thirty in 1947 and 100 more in 1950/51. Another Commonwealth Air Force, that of New Zealand, used thirty Mustangs and for its contribution to
United Nations forces in Korea, the South African Air Force bought 95 P-51Ds in 1950/51—losing a total of 73 of these in the course of the conflict.

Under the terms of the Rio Pact of Mutual Defence signed in 1947, the USA supplied surplus Mustangs to several South American nations, including Bolivia, Brazil, Cuba, Guatemala, Haiti, Honduras, Nicaragua and Uruguay. Italy acquired about fifty from USAAF sources soon after the end of the war, and Indonesia inherited some of the P-51Ds and P-51Ks operated by the NEI Air Force when the country became independent. Disposal of the Mustangs operated by the Swedish Air Force allowed Dominica to acquire 32 in 1952 and Israel obtained 25 from the same source. Other user nations included Somalia and the Philippines.

A number of ‘civilianised’ Mustangs appeared in US air races immediately following World War II and these sported a variety of modifications designed to enhance their performance. Continuing interest in the aircraft among civil pilots led in the mid ‘fifties to the marketing of a two-seat executive Mustang by Trans-Florida Aviation Inc. This model was named Cavalier 2000 and subsequently the name of the company marketing it was changed to Cavalier Aircraft Corp. Basically an F-51D, the Cavalier 2000 had new

Top right: A tail-finned P-51H (NA-126).
Right: A P-51K (NA-111) over the Great Sand Desert near Karachi.
Instrumentation and avionics, a passenger seat in tandem behind the pilot, a modified bubble canopy and 110-US gal wing-tip tanks stressed for aerobatics. With a maximum permissible speed of 505mph at sea level, the Cavalier 2000 was marketed at $32,500 in 1961.

Further variants of the type were evolved subsequently, as follows:

**Cavalier 750**: No extra tanks.

**Cavalier 1200**: As 750 with two additional 48-US gal internal wing tanks.

**Cavalier 1500**: As 750 with two additional 63-US gal internal wing tanks.

**Cavalier 2500**: As 200 with two additional 60-US gal internal wing tanks.

In addition to the executive Mustang, Cavalier Aircraft received a contract from the USAF in 1967 to supply a small batch of remanufactured F-51D's for MAP delivery to South American nations. These aircraft had V-1650-7 engines, the taller P-51H-type fins, strengthened wings with six 0.50in guns and eight hardpoints. All

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Top left: An F-6D conversion of a P-51D, with camera port in rear fuselage.

Left: Two-seat TP-51D conversion of the Mustang by Temco.

Top right: A Mustang in use as a test-bed for ram-jet engines at the wing tips.

Right: The Mustang 'Beguine' used by Bill Odom in the 1949 Thompson Trophy Race, with the ventral radiator replaced by wing tip radiators, reduced wing span, a boosted Merlin engine and other modifications.
had a second seat behind the pilot, and one was a TF-51D with full dual control. In 1968, the US Army purchased two Cavalier conversions for use as chase aircraft; these two-seaters were unarmed and had wing-tip tanks.

As a private venture, Cavalier developed two counter-insurgency patrol and attack aircraft from the F-51D. The first, known as the Cavalier Mustang II had a 1,760hp Rolls-Royce Merlin 620 engine and strengthened airframe to carry a wide variety of weapons beneath the wings. Fixed wing-tip tanks of 110-US gal capacity each were fitted, giving an unre fuelled duration of 7½ hours. The Mustang II first flew in December 1967.

Flown in late 1968, the Turbo Mustang II had an airframe similar to that of the Mustang II, but was powered by a 1,740hp Rolls-Royce Dart 510 turboprop and additional structural and aerodynamic modification to permit higher speeds to be achieved. Based on flight testing of this aircraft, Cavalier put in hand two additional prototypes—one a single-seater and the other a two-seater—to be powered by the 2,535hp Lycoming T55-L-9 turboprop. Before completion, these aircraft were taken over by Piper for development with the name Enforcer. The first prototype flew on April 29th, 1971 but crashed on July 12th. The second prototype was completed and was one of three types chosen for evaluation in the USAF Pave Coin project in 1971, intended to select an 'off-the-shelf' specialised tactical aircraft for Forward Air Control and light strike missions. The inclusion in this evaluation of an aircraft the basic design of which was more than thirty years old was clearly a
Great tribute to the soundness of North American's work on the original NA-73X.

### Specification

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<tr>
<th>Specification</th>
<th>Measurements</th>
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<tbody>
<tr>
<td><strong>SPAN</strong></td>
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<tr>
<td>(No tip tanks)</td>
<td>37` ft</td>
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<tr>
<td>(Cavalier 2000)</td>
<td>40<code> 1</code> in</td>
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<tr>
<td>(P-51B)</td>
<td>32<code> 3</code> in</td>
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<tr>
<td>(P-51H)</td>
<td>32<code> 6</code> in</td>
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<tr>
<td><strong>LENGTH</strong></td>
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<tr>
<td>(Cavalier 2000)</td>
<td>40<code> 1</code> in</td>
</tr>
<tr>
<td>(P-51B)</td>
<td>32<code> 3</code> in</td>
</tr>
<tr>
<td>(P-51H)</td>
<td>32<code> 6</code> in</td>
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<tr>
<td><strong>HEIGHT</strong></td>
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<tr>
<td>(Cavalier 2000)</td>
<td>32<code> 2</code> in</td>
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<tr>
<td>(P-51B)</td>
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<td>(P-51H)</td>
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<tr>
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<tr>
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<tr>
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<td>(P-51H)</td>
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<tr>
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<td><strong>MAX SPEED</strong></td>
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<td>(P-51H)</td>
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<tr>
<td>(Turbo Mustang III)</td>
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<td>(Cavalier Mustang II)</td>
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<tr>
<td>(Turbo Mustang III)</td>
<td>2,300 miles</td>
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Top left: Cavalier 2000 two-seat conversion of the Mustang for private use.

Left: A two-seat Cavalier-built F-51D built for the USAF in 1947.

Right: The Cavalier Mustang II prototype.
Production

NA-73X: NX19998
Mustang I: AG345 to AG664, AL958 to AL999, AM100 to AM257, AP164 to AP263.
XP-51: 41-038 to 41-039.
P-51A: 41-37320 to 41-37469, (13418 to 13567).
A-36A: 42-83663 to 42-84162.
P-51A: 43-6003 to 43-6312.
XP-51B: (41-37352 and 41-37421).
P-51B: 42-106429 to 42-106538, 42-106541 to 42-106978, 43-6313 to 42-7202, 43-12093 to 42-12492, 43-24752 to 43-24901.
P-51C: 42-102979 to 42-103978, 43-24902 to 43-25251, 44-10753 to 44-11152.
P-51D-NA: 42-106539 to 42-106540, 44-13253 to 44-15752, 44-63160 to 44-64159, 44-72027 to 44-75026.
P-51D-NT: 44-11153 to 44-11352, 44-12853 to 44-13252, 44-84390 to 44-84989, 45-11343 to 45-11742.
XP-51F: 43-43332 to 43-43334.
XP-51G: 43-43335 to 43-43336.
P-51H: 44-64160 to 44-64714.
XP-51J: 44-76027 to 44-76028.
P-51K: 44-11353 to 44-12852.
P-51M: 45-11743.
CA-17 Mustang XX: A68-1 to A68-80.
CA-18 Mustang 21: A68-81 to A68-120.
CA-18 Mustang 23: A68-121 to A68-186.

Top right: With a Dart turboprop engine, the Cavalier Turbo Mustang III.

Right: Still basically a Mustang—the heavily armed, turboprop-engined Piper Enforcer of 1971.

62
F-82 Twin Mustang

One of the most unusual products of the North American company to reach production, the Twin Mustang was a highly ingenious solution to the problem of providing a very long range escort fighter. Operations by the USAAF in the Pacific area during 1943 showed that the pilots of single-seat fighters were being subjected to very severe strains by the lengths of typical missions. To provide a two-seat fighter whilst retaining the desirable features of the P-51 Mustang and also minimising development time, North American adopted the simple expedient of joining two Mustang fuselages and outer wing panels together by a new centre section and tailplane.

The first of two NA-120 prototypes designated XP-82 flew on April 15th, 1945, some sixteen months after the start of work on the project. These aircraft had two Packard V-1650-23/25 Merlin engines with opposite rotation to eliminate engine torque while a third prototype, the XP-82A, had Allison V-1710-119 engines both rotating in the same direction. Before the first flight, the USAAF ordered 500 P-82Bs with Merlin engines but only twenty of these were built before the wholesale cancellation of production contracts after VJ-Day. Of these, two were later converted to night fighters, carrying radar in a large pod beneath the centre section and with one cockpit equipped for a radar operator instead of pilot. These two aircraft had two different types of radar—SCR 720 in the P-82C and APS-4 in the P-82D.

To replace the Northrop P-61 Black Widow mid-air refuelling fighter, the XP-82C designated NA-130 was constructed. It was powered by four Packard V-1650-21 Merlin engines in a tandem arrangement with the intake on the left side and the exhaust on the right. The XP-82C was equipped with a Westinghouse WZS-1 radar in a large pod beneath the centre section. However, the production order for 750 aircraft was cancelled after the 82s had only been flown twice.

The second prototype XP-82 (NA-130) Twin Mustang.
Widow, the USAF ordered 100 P-82Fs with SCR 720 and fifty P-82Gs with APS-4 in 1946, together with 100 P-82Es without radar for service in the escort fighter role. They went into service with Air Defense Command during 1947 and were available for deployment in support of United Nations forces in Korea. An F-82G flying with the 68th Fighter (All-Weather) Squadron of the 8th F-B Wing is credited with the first air-to-air victory of that war in a combat which was also the first in which a pilot serving with the USAF (rather than the USAAF) scored a 'kill'. By this time the Twin Mustangs had taken the F-82 designation in place of P-82.

North American completed fourteen of the night fighters as F-82Hs for service in Alaska, with special features to permit cold-weather operations, this action reducing the F-82F contract to 91 and the F-82G deliveries to 45. The Twin Mustang was the last piston-engined fighter ordered in quantity by the USAF.

**Specification (F-82F)**

- **Span**: 51ft 3in
- **Length**: 39ft 1in
- **Height**: 13ft 10in
- **Wing Area**: 408sq ft
- **Gross Weight**: 24,864lb
- **Max Speed**: 465mph at 21,000ft
- **Cruising Speed**: 304mph
- **Range**: 2,500 miles

**Production**

- **XP-82**: 44-83886 to 44-83887
- **XP-82A**: 44-83888
- **P-82C**: 44-65160 to 44-65179
- **P-82C**: 44-65169
- **P-82D**: 44-65170
- **P-82E**: 46-255 to 46-354
- **P-82F**: 46-405 to 46-504
- **P-82G**: 46-355 to 46-404
- **F-82H**: 46-384 to 46-388, 46-496 to 46-504

**Production of Other Types**

In addition to the design and construction of aircraft of its own design, the North American company has undertaken the production of certain other types. Primarily this occurred during World War II, although one of the company's very earliest contracts involved the production of 161 sets of floats (one main and two wing-tip) for Curtiss SOC-1 floatplane for the US Navy. These were built at the
original Dundalk, Maryland, plant under the NA-17 designation but a second batch of 48 sets for SOC-2s were built (as NA-24) at Inglewood.

Making a significant contribution to US four-engined bomber production, despite the large quantities of P-51s and B-25s it was also turning out, North American established a Consolidated Liberator assembly line at the Dallas plant in 1942, and began deliveries in 1943. Two versions were built, both under the designation NA-95, production comprising 430 B-24Gs—a version similar to the Consolidated-built B-24D—and 536 B-24Js. Another 734 B-24s on order from North American were cancelled at the end of the war, together with a plan to build 1,000 Lockheed Shooting Stars as P-80Ns (NA-137) at Kansas.

Also at Dallas, a production line was set up in 1943 for Fairchild Packet transports, and North American received a contract to build 792 of a version designated C-82N (NA-135). Only three of these were completed before VJ-Day cancellation of the programme. Plans for North American to participate in B-29 production were abandoned.

Production
B-24G: 42-78045 to 42-78474.
C-82N: 45-25436 to 45-25438.

North American B-45A (NA-147), the USAF's first jet bomber.

**B-45 Tornado**

America's first four-jet bomber to fly, and to enter service, was born on the drawing boards of the North American company during 1944/45. With the war in Europe nearing its end but the results of German research into swept-back wings not yet available to American designers, the NA-130 was laid out along conventional lines, its only really radical feature being the use of four General Electric J35-A-4 jet engines, paired in nacelles one under each wing. Like the Mitchell, the new North American aircraft had a shoulder wing, two pilots, a bombardier in the nose and a gunner in the tail, without pressurisation.

Three prototypes were ordered as XB-45s in 1945 and the first of these flew at Edwards Air Force Base on March 17th, 1947. The USAF bought a production batch of 96 (plus one 'flying static' test vehicle) with deliveries starting in 1948, the first aircraft going to the 47th Bomberment Group at Barksdale AFB, which then became the USAF's first jet-equipped bomber unit. The first 22 B-45As were delivered with J35-A-11 engines, but the J47-GE-9 was then adopted as the standard power plant.

The B-45B, with changed radar and fire control equipment, being cancelled before production, the next variant of the Tornado to appear was the B-45C. Only ten were built, differing from the B-45A in having uprated, water-injection J47-GE-13/15 engines, single point refuelling, higher gross weight, strengthened airframe and wing-tip fuel tanks containing 1,200 US gal of fuel each. These same new features were incorporated in the 33 RB-45Cs that were delivered between June 1950 and October 1951, but these aircraft also had twelve cameras mounted in four groups in the nose and centre fuselage. Contracts for
Nervous Energy V is modified into dual control configuration.

PENSACOLA'S MARLIN

History of the last surviving Martin P-5 Marlin flying boat

THOSE NACA MUSTANGS

Overview of P-51 Mustangs operated by the National Advisory Committee on Aeronautics along with a listing of survivors
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COVER: Wallace Sanders and Matt Jackson flying P-51D Nervous Energy V over the California coastline. Photograph by Michael O'Leary
those NACA Mustangs

BY MICHAEL O'LEARY

COLOR PHOTOGRAPHY BY MICHAEL O'LEARY

Special thanks to Cam Martin of NASA for helping make this article possible

During the last 1944 in and over X-1 and NACA 148 at Edward WACOB IN TWC

4 WARBIRODS INTERNATIONAL
NEARLY FORGOTTEN BY THE PASSAGE OF TIME, THE NORTH AMERICAN MUSTANGS OPERATED BY NATIONAL ADVISORY COMMITTEE ON AERONAUTICS ARE CURRENTLY UNDERGOING A BIT OF A RESURGENCE WITH TWO FLYING AND ANOTHER EXAMPLE UNDER RESTORATION.

During World War Two, the National Advisory Committee on Aeronautics (NACA, and now today's NASA) performed invaluable work on helping American military aircraft manufacturers gain the final victory over Axis forces. Through NACA’s research and pioneering utilization of wind tunnels, American aircraft builders were able to greatly improve the capabilities of a wide variety of high-performance military aircraft. The American military was most willing to assign front-line aircraft to NACA for continued testing in the spectrum of high-speed flight.

As the war progressed, reports were received concerning the compressibility effects on the North American P-51, Republic P-47, and Lockheed P-38. These reports revealed a definite need for flight measured transonic data and individuals at NACA, USAAF, and Navy were generating interest in obtaining rocket-powered aircraft to gather this then esoteric data. Congress appropriated funds for research aircraft projects in 1944 in order to provide formation on performance and lift which NACA’s conventional wind tunnels and available aircraft could not supply. These funds would directly lead to the production of the Bell X-1 and Douglas D-558-II (see Air Classics Volume 33, Number 11, November 1997).

NACA 148 P-51D Mustang USAAF s/n 44-84958 on the line at Edwards AFB on 18 May 1958. This may have been the last Mustang in NACA service and we would be interested in comments on its eventual fate.
Another view of NACA 148. Note the stock condition, except for modified tail of the aircraft. When the High-Speed Flight Test Unit was established at Muroc, some NACA aircraft were transferred from Langley, including this Mustang which was delivered on 25 August 1950. The aircraft had originally been transferred from the USAAF to Langley during July 1945. (Milo Pettzer)

Certainly one of the most interesting of NACA Mustangs, USAAF s/n 44-14817 was used, during its military career, to test the aircraft's carrier compatibility. Note the vapor trails swirling off the propeller as the Mustang begins its takeoff run from the wooden carrier deck. The aircraft was flown from the USS Shangri-La by Lt. Cmdr. R. M. Elder of VF-5. This aircraft would go on to become NACA 102.

The Mustang's hook catches a wire for an abrupt landing on the carrier deck. The aircraft was one of several Mustangs used for carrier compatibility.

After its NACA career, the P-51B being taken on charge on 4 September 1945, as NACA 127 (during which time, the craft acquired a tall vertical tail), the Mustang was apparently passed onto the Pennsylvania Air National Guard. The craft was designated ETP-51D-25-NT and is seen in bare metal finish with the coding 01-Z in front of the windshield. This aircraft has also been reported to having been utilized for carrier testing but this is not confirmed.

To acquire this data before the X-1 was built, the NACA selected the P-S1D to measure transonic data over its laminar flow wing. The Mustang, Thunderbolt, and Lightning had all been evaluated but the P-S1D was selected because of its good stability when exposed to compressibility effects at high airspeeds. To increase the stability at high velocities, the NACA had North American Aviation (NAA) modify a P-S1D to increase the size of the horizontal and vertical stabilizers. It appears that these modifications were done at the NAA factory under the supervision of Langley Research Center personnel and to NACA specifications but this is not confirmed.

It was in 1938 that British aerodynamicist W. F. Hilton first used...
the phrase "sound barrier" in remarks made to a reporter, Hilton said that an airplane wing's "resistance" to high speeds "shoots up like a barrier" the closer to the speed of sound an airplane travels (high flight speeds are often expressed in Mach number multiples, as a tribute to Austrian physicist Ernst Mach, famed for his exploration into the physics of sound. Mach 2, for example, is twice the speed of sound, or 1320 mph at 36,000 feet or higher). But to fly at "super" sonic speeds would present vexing challenges, ones that worried designers and engineers alike. Could aircraft be controlled at such high speeds? Would structures survive higher stresses and temperatures? Was supersonic flight at all practical?

"A lot of people thought for years that it was impossible to fly through this sound barrier," observed former Director of Aeronautics Laurence Loflin. "The thought was, if you bump into this invisible wall in the sky your aircraft would go to pieces. Indeed, there was some experimental evidence that this was the case. A number of pilots were killed trying."

The NACA tail tail on N4223A.

N4223A at Fresno Air Terminal during the 1960s. (Boardman C. Reed)

The chief difficulty was that of compressibility effects. The nearer to sonic speeds became, the more aircraft were subject to a sharp increase in drag and a dramatic decrease in lift. In such extreme circumstances — extreme, that is, compared with "average" subsonic flight — control surfaces of traditional propeller-driven planes didn't respond well, if at all. Some pilots during WWII, finding themselves in near-supersonic total dives, literally bent their control sticks in vain attempt to pull up in level flight. Others — the majority — managed to pull their planes up at lower altitudes.

In 1945, NACA Langley staffer Robert T. Jones was the first American aerodynamicist to realize that the angle at which airplane wings were placed in relation to oncoming air — their "sweep" — would make a critical difference in achieving and maintaining supersonic flight. Jones' calculations indicated that, at faster-than-sound speeds, the air flowing over a thin sweptback wing would actually be subsonic, thereby delaying or
preventing compressibility effects. Swept wings were a significant aeronautical advance and eventually wound up on nearly every high-performance military airplane.

For all the desire to get aircraft safely through the figurative barrier of sound, the obstacles were formidable. Particularly vexing for wind tunnel researchers was their inability to precisely measure the transonic transformation from pure subsonic to pure supersonic flow.

To better understand the nature of the transition, in the mid-1940s researchers employed several methods to collect accurate data. One of the most productive involved the dropping from high flying aircraft bomb-like devices containing electronic gear. These "drop bodies" were then tracked by radar. Information on airspeed, readings of atmospheric pressure, temperatures and the like was relayed via a small radio transmitter placed inside the drop body. Many NACA engineers considered these data reliable enough to estimate the drag and power requirements of a future transonic airplane; indeed, test results were incorporated into the design of the sound barrier-breaking X-1.

Another earlier method was termed "wing flow technique" and entailed the mounting of a small model wing perpendicular to the wing of a P-51D Mustang. The Mustang took off, flew to attitude and initiated a series of steep dives. For brief periods during the dives, the air would flow supersonically over the model. A small balance mechanism fitted within the P-51D's gun compartment and tiny instruments built into the mount of the model recorded the resulting forces and airflow angles.

The wing of the P-51D was modified to include a test section over the left and right wing gun bays. In the right wing test section, a model mount was constructed to attach various model configurations. Provisions were made to measure and record aerodynamic data such as lift, drag, and pitching moment of the model. The left wing section was instrumented to measure all the airspeed data.

NACA P-51 MUSTANGS

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FLIGHT TESTS

- Stability and control tests
- Tuffed wing studies and compressibility tests
- Wing flow pressure distribution and compressibility studies. Earlier used for carrier compatibility testing aboard USS Shangri-La. Over stressed on test dive and, after repairs, used as a NACA nuck
- This aircraft was the fifth production P-51D. To N4222A
- Correct serial may actually be 44-84683. To N4223A
- Wing flow pressure distribution tests
- Wing flow model tests
- Horned balanced rudder tests. It is thought that a Langley NACA pilot had to bail out of this aircraft
- Tests not indicated. Was known to have flown to NAS Norfolk for a display on Navy Day
- Stability and control tests

While assigned to Flight Research Center, this P-51 was used for pilot proficiency flights. It was converted to have a second seat. Several well-known test pilots are known to have flown this plane including Joe Walker, Jack McKay, Scott Crossfield, Ivan Kincheloe (USAF), Pete Petersen

NACA 127 was eventually utilized as a gate guard by the PA ANG and redesignated EF-51D. However, we have not been able to find definite proof if the Mustang actually flew with the PA ANG and would appreciate reader input on the matter. After decades of exposure, the aircraft was obtained by David Tallichet and the aircraft is currently being restored to mint condition by Pacific Fighters with the registration N51YZ.

During a typical test flight, the P-51D was flown to 27,000 feet and dove to a Mach number of 0.75 to 0.78 in order to achieve Mach numbers of 0.8 to 1.2 over the test section of the Mustang wing. The dive was recovered at 5000 feet. At these velocities, the P-51D started to develop a lateral instability, followed by a longitudinal instability.

The onset of the instability was
gradual with some fish-tailing, but nothing dangerous in comparison to the characteristics of the Thunderbolt and Lightning. The increased size of the vertical and horizontal stabilizers resulted in better stability at high velocities and gave a margin of safety to the pilots — at least to some degree. This flight test procedure resulted in the first reliable transonic aerodynamic data in the United States.

North American Aviation was also interested in improving the Mustang's stability during high-speed flight and this was one of several modifications carried out on factory test aircraft: USAF s/n 44-13253 sports the all-metal rudder and fin cap modification similar if not identical to the mods on the NACA aircraft. NACA and NAA engineers worked closely on these projects. Note the stripe paint scheme on the elevator.

The only production variant of the Mustang to receive the taller vertical fin was the P-51H, 555 of which were built. F-51H-10-NA USAF s/n 44-64630 was assigned to Bolling Field.

During the early part of the program, operations were conducted under top security. Gloves were placed over each wing and an armed MP escort followed the P-51D to the initial runway. At the end of the runway, the gloves were removed from the wings and the Mustang took off. Armed escort fighters made a flying pickup, they were instructed to chase off any aircraft that came over to observe the test.

A variety of model configurations were tested on the wing test section. A photo of NACA 102 has a model of the X-1 attached to the test section. A photo of P-51D USAF s/n 46-164 NACA 130 at NAS Moffett Field, California, on 17 May 1958.
NACA Mustangs

(Continued from page 11)

44-48861 has a model of a different type mount on the test section. Delta wing configurations were also tested.

During one flight test of P-51D NACA 102, test pilot Bill Gray had a very close call. The airspeed system that was indicated to the pilot had been accidentally switched during the installation of a new test section. As a result, the Mustang was flying 20 knots faster than was indicated on the instrument.

When Gray approached the test condition, the Mustang tucked under and pulled -2.5 G. Later, the instruments indicated that the pilot recovered at 400 feet and had pulled +7 Gs. During the tuck under, Gray could see he was not going to recover in time unless he could make a strong recovery.

Gray pulled strongly back on the stick and blacked out, recovering consciousness going back up through 10,000 feet. Gray landed the plane and walked back to the office to write his flight report.

Two views of P-51D-5-NA USAAF s/n 44-13257/N4222A ex-NACA 108 in the Miami, Florida, area during June 1959. The aircraft was assigned to NACA on 22 December 1944 and was retired on 12 July 1957. The aircraft was sold surplus from NAS Norfolk, Virginia, during 1957 and apparently purchased by David Lindsay for his Trans Florida Aviation Corp. at Sarasota (later to become Cavalier Aircraft Corp.). As can be seen, little had been done to the aircraft at the time the photos were taken except to strip off the NACA insignia and add huge registration numbers on the sides of the fuselage. The aircraft was later converted to Cavalier Mk. II standards with a first flight during December 1967. This aircraft was powered by a Rolls-Royce Merlin 620 engine of 1760 hp and had a strengthened airframe to carry a wide variety of weapons under the wings from an array of pylons. Fixed wing tip tanks each carried an additional 110 gallons of fuel, giving a range of 7 1/2 hours. The Mk. II was demonstrated to various foreign governments and then went into a lengthy period of storage. The aircraft is currently active and registered as N51DL. Beside the increased vertical fin modification, a large strengthening stiffener was added down the side of the fuselage and is clearly visible.

N4222A after a test flight at Cavalier. In its four-tone camouflage scheme, the aircraft appeared quite formidable. Fuel in the massive tip tanks could be jettisoned in 30 seconds in case of an emergency.
In-flight view of N4222A showing six LAU-3s being carried on the underwing pylons. After years of storage, the aircraft is once again flying as N51DL, originally in an all-red scheme but now camouflaged in a similar manner as illustrated in the photograph.

Sometimes later, the crew chief stuck his head in the office and asked the pilot how he was feeling. Bill said he was fine. The crew chief then asked him what had happened to the P-51D.

Bill said that, as far as he knew, the plane was fine. The crew chief then asked the pilot to come out and look at the aircraft. When he approached the Mustang he noticed the wings did not have the normal dihedral and seemed, in fact, to be drooping!

Looking closer, Bill could see that the metal skins on the bottom of the wing were stretched. Closer examination found the bottom fuselage skins, aft of the radiator back to the horizontal stabilizer, were also stretched. The bottom skins of the horizontal stabilizer were in a similar condition. The bottom skins of the horizontal stabilizer were also stretched. NACA 102 was never used for testing after that flight. The mechanics reskinned the damaged sections and the Mustang was used as a parts chaser and proficiency (the last known test dive of NACA 120 was on 20 August 1946).

With the testing of the early rocket planes completed, the NACA Mustangs were removed from the

For Project Peace Condor, Cavalier reworked a number of Mustang airframes for the USAF — which were then distributed to foreign nations. The aircraft were all assigned 1967/68 serial numbers (the original identities often disappearing) and several of the aircraft are seen in front of the Cavalier Aircraft Corp. in Sarasota. Some of the work carried out on the aircraft included strengthening the spar and incorporating the fuselage strengthening strap added by NACA to N4222A. Also, the NACA tail tail was standard equipment.
NACA 127

Also thought to have been used for carrier compatibility testing by the USAAF, this aircraft eventually went to the Pennsylvania Air National Guard although we are not completely sure that the plane flew operationally with that unit. The Mustang did wind up as a gate guard and sat exposed to the Pennsylvania weather for decades before being obtained by David Messer, Sr. in 1965.

Photographed on 9 June 1959, P-51D-25-NT N4223A displays a two-tone paint scheme. This aircraft was retired by NACA on 12 July 1957 and sold surplus at NAS Norfolk, Virginia.

Interesting view of N4223A (note the incorrectly sprayed registration N223A on the vertical stabilizer) at Sacramento, California, on 5 February 1965. (W.T. Larkins)

Hazards of dive tests. However, several NACA Mustangs soldiered on until 1958 when the last examples were finally sold as surplus.

THE SURVIVORS

It is rather amazing that three of the NACA "tall tail" Mustangs survive today and that two of these aircraft are in flying condition while the third is well on its way to a complete restoration.

NACA 108

This fifth production P-51D, the oldest surviving D model, enjoyed a fruitful career at NACA and was sold surplus to David Lindsay, the creator of Trans Florida Aviation (later Cavalier). Lindsay, an artillery officer during WWII, realized that the Mustang could be easily converted into a two-seat aircraft as an ultimate 1950s' executive transport. Single-handedly one of the most important individuals for making sure that the Mustang survives today in some numbers, Lindsay's company supplied Mustangs to civil and military sources. NACA 108 became N4222A which eventually became the prototype for a single-seat ground attack variant of the Mustang. After years in storage, this aircraft currently flies as N51DL.

NACA 126

Surplus as N4223A, this aircraft was eventually obtained by Mike Cotches — another leading light in Mustang preservation. The aircraft was displayed in a small museum for many years but Mike decided to break the aircraft down and restore it back to flying status and we had the privilege of flying with Steve Cotches, Mike’s son, during the 1997 Salinas International Airshow where we took the color photographs that illustrate this article. As can be seen, the plane now looks beautiful in its post-WWII markings and should remain flying for many years to come.

Tollichet who then sold the aircraft to W. C. Allmon who is having the aircraft completely restored back to flying shape by Pacific Fighters in Idaho. When completed, the aircraft will be in full NACA markings and will feature a "bump model" mounted on the wing.

This article, although awaiting further data in some aspects, could not have been done without the help of Carl Martin, Bill Gray, and R. Joe Wilson. We welcome comments and additions from readers.

A well-polished N4223A on the ramp at Sacramento Municipal Airport on 23 August 1965.

Photographed on 9 June 1959, P-51D-25-NT N4223A displays a two-tone paint scheme. This aircraft was retired by NACA on 12 July 1957 and sold surplus at NAS Norfolk, Virginia.

Interesting view of N4223A (note the incorrectly sprayed registration N223A on the vertical stabilizer) at Sacramento, California, on 5 February 1965. (W.T. Larkins)
August 20, 1996

Mr. George C. Larson, Editor
AIR & SPACE/Smithsonian
901 D Street, SW - 10th Floor
Washington, D. C. 20024-2518

Dear George:

Thanks for your note regarding my letter to The Editor. I never intended to get so involved in the argument about the Mustang and was content to let Ed Schmued take credit for the design work, which he supervised very well. I had mentioned the Meredith Effect in print a couple of times, but it never seemed to register.

I knew Ed quite well and thought I had reasonable relations with him. After Ray Rice sent him to England during the war for liaison work for a short time, he was never quite the same. The British and our attaché, Tom Hitchcock, lionized him and he ate it up.

He was an under-age conscript in the Kaiser's Army and in poor health when mustered out. He never finished school and started a bicycle shop in Germany. He was always enterprising and got a job with General Motors Holden in Brazil and somehow got a transfer to the United States. Since General Motors had picked up an interest in U. S. Fokker, an antecedent of North American, he got a job there on a drawing board. He was one of about twenty in the Engineering Department, and I first met him in 1934 when I came to Baltimore from Douglas as Chief Engineer with Dutch Kindelberger.

The remnants of Fokker, General Aviation, and Berliner Joyce combined to form a nucleus for the restructured North American Aviation which Dutch headed and of which I became Chief Engineer. Incidentally, General Motors held some 30% of North American stock and effectively controlled the company until 1948.
Mr. George C. Larson  
August 20, 1996
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Schmued was a good draftsman with a good mechanical sense and also a bit of an artistic flair. However, he knew nothing of aviation technology and was never near Messerschmitt in Germany.

When I realized that the true reason for the Mustang's speed advantage would never come out, I wrote the "Origin and Evolution of the Mustang" for two reasons. First, to make the point on the critical importance of the cooling drag and its ramifications, and second, to record the rather remarkable contribution of Dutch Kindelberger to the war effort.

Since he had been bringing me more and more into general management, in fairness to Raymond Rice and all concerned, my title was changed about the end of 1939 from Vice President and Chief Engineer to First Vice President. The Mustang initiative was my last technical leadership function during that period, and all the details of design and analysis were under Ray Rice's supervision and, as I have said, very conscientious and able leadership.

I hope this clarifies some of the rather baffling history bytes you are bound to hear.

Sincerely,

JLAtwood/ph
by Peter Garrison

Early in 1930, a German-born engineer of Austrian extraction arrived in the United States from Brazil, where he had lived since 1925. Short, with craggy features and a shock of black hair, the ambitious émigré from post-Versailles Europe would keep a thick German accent all his life. By the account of those who knew him, it gave a professorial impressiveness to his speech.

His name was Edgar Schmued. Born one day before the turn of the century, he had grown up under the tutelage of a devoted father to become a mechanical engineer of considerable ingenuity. By the age of 23 he already held several German patents for gadgets related to automobile engines. In Brazil he had worked for General Motors as a field service manager in São Paulo, but America lured him with an opportunity that he had craved ever since, at the age of eight, he had seen a Wright flying machine pass overhead. America meant a chance to design airplanes.

"I decided, right then and there," Schmued later wrote of the glimpse of the Wright, "that this was for me. This was going to be my life." It was a precocious decision for an eight-year-old, but his intuition was right. Aviation would be his life, and it would also give him a small share of immortality.

In the late 1920s General Motors had created a holding company, North American Aviation, which initially existed only to acquire stock in aviation-related companies. NAA acquired the Fokker Aircraft Corporation in 1929, and it was there that Schmued went to work. Hardly had he arrived when GM dissolved Fokker and reorganized it as the General Aviation Corporation, all of whose shares were held by North American Aviation. Schmued prospered at General Aviation; by 1933 he was project engineer on a large twin-engine observation plane, the YO-27.

Then came a turning point. The Air Mail Act of 1934 forced airmail carriers to divest themselves of airframe-manufacturing holdings. This landmark piece of pro-competitive leg-
islation had historic consequences. For one, it opened the way to Donald Douglas’ eventual and long-lasting domination of airline manufacture; for another, it obliged General Motors to relinquish control of North American Aviation, which ceased to be a mere holding company and took over the entire manufacturing operation of the General Aviation Corporation.

The president of the reincarnated NAA was James H. Kindelberger, known, for no logical reason, as “Dutch.” He had come to GAC from Douglas the previous year. Kindelberger now hired away another Douglas man, John Leland Atwood, as his vice president and chief engineer.

Lee Atwood was a tall, slim, refined-looking man with chiseled features, a lofty, intellectual forehead, and a bent for mathematics. Trained as a civil engineer, he had been hired by the Okay Airplane Company of Oklahoma in 1929 to design a two-seat monoplane. The Depression had swept Okay away, and Atwood had gone to Douglas in Los Angeles as a mathematical analyst and component designer.

He was still there when Kindelberger invited him to North American, where he played a principal role in the design of the new company’s first product, the NA-16 trainer. Initially an open-cockpit two-holer, the NA-16—whose wing reveals the Douglas connections of its creators—would soon acquire a greenhouse canopy and retractable landing gear. Eventually it became the ubiquitous AT-6, the main Army Air Forces trainer of World War II.

In 1935 Kindelberger moved NAA to California, setting the company up on a 20-acre, $600-a-year site where Los Angeles International Airport simmers today.

For Atwood, it was an easy return to turf familiar from his days at Douglas. For Schmued the move was more difficult. His wife Luisa did not want to go to California, so Schmued left NAA for Bellanca, based at New Castle, Delaware. He soon regretted the decision, and since Kindelberger still wanted him, Schmued, his wife, and their 14-year-old son Rolf set out by car for California late in 1935.

Perhaps Luisa Schmued had had a premonition about Los Angeles. A hundred miles east of the city there was a collision on the highway; Luisa was killed. Seriously injured, Schmued did not return to work at North American until February 1936.

Significantly for the future of the company, the British began ordering AT-6s in 1938, christening them Harvards. The British also ordered P-40 Warhawk fighters from Curtiss. The demand for war materiel was rapidly rising, and the manufacturing potential of the United States was unsurpassed. Great Britain set up an office, the British Purchasing Commission, in Manhattan. Because of the success of the Harvard, Kindelberger and Atwood developed a close relationship with the British. Atwood was then in the process of moving out of engineering and into management as Kindelberger’s right-hand man, but he still took an active interest in the engineering department, which was now headed by Raymond Rice.

In 1939 North American designed what was to be the B-25 Mitchell bomber, famous particularly for its part in the 1941 Doolittle raid on Tokyo. The airplane won an order from the U.S. Army Air Corps. Edgar Schmued, still a junior figure at North American, played a minor part in the design of its bomb racks; later that year, however, he was project engineer on a handsome but abortive two-seat tandem primary trainer, the NA-35. By 1940 he had become NAA’s chief designer.

Schmued longed to design a fighter. He was in the habit of designing “ideal” portions of hypothetical airplanes, and had sketched a light fighter that in general appearance lay somewhere between the sleek primary trainer of 1939 and the Curtiss P-40, at the time still the best American fighter in series production. The British, meanwhile, were ordering...
more P-40s than Curtiss could build. Early in 1940, the British Purchasing Commission floated the idea that North American might set up a supplemental P-40 production line.

Lee Atwood was making frequent trips to New York to meet with the British, sometimes accompanied by Kindelberger and Schmued. North American would have preferred to design a new fighter, or at least modify the P-40, rather than try to set up production for another firm's aging design. But the notion of selling the British a completely new fighter design "seemed somewhat fanciful," Atwood recently wrote, "since I had never seen any government buy a production plane without a set of requirements in detail, some kind of competition and/or flight test approval and a formal appropriation of money."

Nevertheless, early in 1940 the shape of a new fighter was on many minds at North American. The starting assumption was that the new airplane would be a P-40 replacement, using the same engine and having approximately the same size and armament but achieving superior performance. The P-40, which could reach about 350 mph with its weakly supercharged 1,000-horsepower Allison engine, was already obsolescent; the prototype, which had been ordered in 1937, had actually been a re-engined version of an even older, radial-powered design.

Inline and narrow-V liquid-cooled engines had an obvious advantage for airplanes: They allowed for a far more streamlined nose. But air still had to flow over some kind of heat exchanger in sufficient quantity to cool the engine, and the drag reduction won from a more streamlined cowling would be lost if cooling airflow were not properly controlled. The treatment of the cooling radiator was the crux of the design of liquid-cooled fighters. None of the early liquid-cooled fighters—the P-40, Spitfire, Bf 109, Hurricane—had dealt very elegantly with this problem. A lot was at stake; fully 10 percent of the total drag of an airplane could typically be blamed on engine cooling.

The problem was that in order to reduce drag, which increases with the square of speed, and also keep the air in contact with the radiator long enough to allow heat transfer,

"Dutch" Kindelberger (opposite, top) led North American Aviation on the power of charm and charisma.

The Royal Air Force, the Mustang's first customer, provided a final touch: the Rolls-Royce Merlin engine (opposite).

Edgar Schmued (above), a German born Austrian, brought a classic approach to design when he joined NAA in 1936.

it was necessary to slow the air passing through the radiator. The lower the velocity of the air for a given mass flow, however, the larger the cross-section of the radiator and its associated ducting had to be. The ideal radiator was so large that it would barely fit in the airplane—certainly not in the small underwing ducts used on the Spitfire and Bf 109.

Every possible location for radiators was tried. Indeed, the prototype XP-40 of 1938 carried its radiator in almost the same place as the P-51 would, as did the Curtiss XP-46, a proposed—but discarded—P-40 replacement built in 1940. No position had yet displayed a convincing superiority to any other. But Lee Atwood believed that pay dirt would be found there somehow, and he was mulling over this and other fighter design problems early in 1940, as were other engineers at North American who knew that a fighter project might be in the offing.

Today this rather esoteric question of radiator placement is the fulcrum of a controversy over the genesis of the Mus-
In a 1993 article in the historical journal *Air Power History*, Lee Atwood asserted that the idea of placing the Mustang's radiator behind the pilot—a decision that in many ways defined the rest of the design—was his. He relates that he had seen papers from the Royal Aircraft Establishment at Farnborough reporting on experiments with radiator ducting. A scientist named Frederick W. Meredith had provided a theoretical basis for a drastic reduction in cooling drag. The principle was similar to that of the jet engine: Heat imparted to the incoming air would make it expand, requiring that the outlet be larger than the inlet. The result, assuming roughly constant total pressure in the duct, would be a modest thrust. A long duct, gradually expanding ahead of the radiator and gradually converging behind it, was essential—the ideal duct, in fact, would have been as long as the entire airplane. While it might be utopian to expect a net thrust, Atwood hoped that what he came to call "the Meredith effect" would offset some or even most of the cooling drag.

Atwood's article brought a rebuttal from aerodynamicist Ed Horkey, who had come to North American from the California Institute of Technology in 1938 to work under Schmued. The aft location, he said, was an obvious choice; there was no room for a suitable radiator anywhere else. Neither he nor Irv Ashkenas, another Caltech-trained aerodynamicist who worked on the Mustang, remembers Lee Atwood having had a role in that decision. Horkey dismisses the algebra that Atwood used to explain the Meredith Effect to the lay reader with the words, "We used calculus." The British Purchasing Commission, Horkey thinks, was impressed less by the Meredith effect than by Dutch Kindelberger's magnetic personality and Ed Schmued's German accent.

This disagreement, surfacing more than half a century after the fact, is emblematic of the personal politics of NAA at the time. The engineering department was divided, with Atwood and chief engineer Raymond Rice on one side and Schmued and the rest of the aerodynamics staff on the other. Edgar Schmued's son Rolf says his father actively disliked Raymond Rice, while Atwood, who seemed haughty and reserved alongside the charismatic Kindelberger, was merely "not his favorite person." Schmued's persistent animus toward Rice is evident in his 1985 memoir of the Mustang design days, prepared for historian Ray Wagner. In this account, Rice emerges as either remote from Mustang development or skeptical of Schmued's design decisions and choice of collaborators.

Horkey today depicts Schmued as a brilliant designer entirely capable of creating the Mustang, both because of his natural talents and because of his exceptional willingness to solicit input from other specialists, particularly aerodynam-
Lee Atwood (above) recalls that in the 1940s, development of a new fighter in 102 days was not considered exceptional.

Ed Horkey (below) recounts events and roles differently from Atwood, but there may be elements of truth in both versions.

Irv Ashkenas (right) moved the air scoop’s intake away from the roiling boundary layer, and his “gutter” is still in use.

Atwood paints a less charitable picture of his abilities. Schmued, Atwood says, was not a full-fledged aeronautical engineer but rather a self-taught draftsman with “a real talent for shapes and arrangements.” This condescending characterization, though somewhat implausible in light of Schmued’s long and illustrious career, leaves room for Atwood’s claim of responsibility for the Mustang’s basic technical feature. Schmued was, Atwood asserts, “out of his depth” when he left NAA in 1952 to head the T-38 program at Northrop.

Atwood repeatedly discussed his fighter ideas with the senior technical man at the British Purchasing Commission and also, whatever his estimate of the chief designer’s abilities may have been at the time, with Schmued himself. Not a person given to idleness, Schmued took the hint, and when Atwood returned from New York in April of 1940 with the news that the British had accepted his proposal for a new fighter and had ordered 320 aircraft, the designer was ready. Kindelberger, whose estimation of Schmued’s abilities was evidently higher than Atwood’s, put him in charge of the project.

In order to provide at least an appearance of continuity between this and previous fighter acquisitions, the British stipulated that NAA was to purchase from Curtiss the flight test and wind tunnel reports on the XP-46. NAA acquired these for $56,000; Atwood, who made the trip to Buffalo to collect the box of papers, found Curtiss general manager Burdette Wright “reasonable enough, considering the competitive aspects.” Horkey, then chief aerodynamicist, looked the materials over. He found them “obsolete and very amateurish” and promptly filed them. Schmued supposedly never saw them and designed the P-51 on a clean slate. Nevertheless, the P-40 must have served as a basic pattern for the Mustang; the similarity in overall dimensions, areas, and general arrangement between the two airplanes is too close to be coincidental.

The cockpit layout was Schmued’s work; he had defined the “ideal” fighter cockpit long before the Mustang project—NA-73—was born, and a mockup was completed within a couple of weeks of the contract’s being let. The original Mustang had a high upper fuselage aft of the cockpit, like the P-40’s; it was not until the D model of 1943 that the more familiar bubble canopy appeared. Thanks to the narrow engine, the fuselage could be less bulky than that of the radial-descended P-40, and the wing was slightly modified at the root to accommodate a fully enclosed inward-retracting landing gear in place of the P-40’s partially exposed aft-retracting system. The radiator inlet was under the wing center section—where it was always aligned with the airflow, regardless of the attitude of the airplane—and the outlet was halfway back along the tail cone.

The Mustang had several other novel characteristics. The tips of its flying surfaces were squared off at a time when rounded tips were believed—in incorrectly—to provide lower drag. This idea for simplifying production of the P-51 came from Schmued and Horkey but was based on pre-war German work; that the design in fact incurred no drag penalty was validated by wind tunnel tests, as was the general performance of the laminar flow wing.

The laminar flow airfoil (see “Go With the Flow,” June/July 1995) used on the Mustang’s wing—the first time one was employed on a military airplane—was based on reports from Russell Robinson, an aerodynamicist with the National Advisory Com-
The Mustang's cooling system employed a large scoop with a fixed inlet leading to a chamber that allowed the cold air (blue) to expand rapidly and reduce its velocity before passing through the hot radiator. Slowing the air's passage helped to provide an efficient transfer of heat, which added energy just as a turbojet's combustor does. Aft of the radiator, the duct narrowed, and a movable flap controlled the exit pressure. As the heated air (red) converged and exited, its velocity contributed enough thrust to offset approximately 90 percent of the cooling system drag.

Committee for Aeronautics, about successful wind tunnel experiments on a new family of low-drag airfoil shapes. These profiles were back-calculated from a desired pressure distribution intended to delay the onset of turbulence; a crew of mathematicians with electrical-mechanical calculators, led by Ed Horkey, spent weeks on the job, one which can now be done by any home computer in a few seconds. (Interestingly, it was subsequently noticed that laminar airfoils bore a strong resemblance to the cross-section of a trout; natural selection had beaten the NACA to it.)

Another characteristic feature of the Mustang was the boundary layer gutter that separated the cooling air intake from the fuselage. Schmued had originally designed the airplane without the gutter, and with a variable-area entry and exit on the cooling duct. Flight testing revealed an explosive hammering noise emanating from the duct. The noise was caused by the duct's intermittently ingesting the boundary layer—the sheet of turbulent air close to the skin of the airplane—along with the smoother, faster air farther from the skin.

Aerodynamicist Irv Ashkenas came up with the idea of moving the entire duct away from the belly skin so that its inlet was in an undisturbed stream of high-speed air. A "gutter" about an inch and a half deep carried the turbulent, low-energy surface boundary layer air clear of the inlet. This arrangement became classic; the F-16's underbelly scoop is reminiscent of the Mustang's. Once the entry design was perfected, the variable-area inlet feature was dispensed with; an adjustable chute at the aft end of the duct controlled the volume of air flowing through it.

The matter of the boundary layer gutter provides an interesting illustration of a phenomenon that historians must constantly encounter: contrary yet plausible versions of an event from equally authoritative sources. Schmued reported that it was suggested to him by Rolls-Royce aerodynamicist D. B. Shenstone, who visited NAA early in 1941, while Ed Horkey insists that it was Irv Ashkenas who came up with the idea. In fact, both versions may be true, just as both the Atwood and the Horkey-Schmued versions of the radiator placement decision may be true. Ideas move about among people like air, often unnoticed; the parenthood of an idea is sometimes very hard to establish, and it is common to adopt a foundling and later to believe it one's own.

An important element in the Mustang's superior performance—late models could top 490 mph in level flight and had a cruising range of up to 2,400 miles—was overall surface cleanliness. The importance of a smooth skin was becoming clear from NACA work; any hope of attaining laminar flow, particularly, required exceptionally precise workmanship. It was Schmued's idea that every rivet in the airplane be set flush with the skin. North American had good metal fabricators, and Dutch Kindelberger was a production man at heart. Mustangs started clean and became
cleaner—if one ignores the bulbous underwing ferry tanks they were forced to carry in their role as long-range fighter escorts. In contrast, the prototype Curtiss XP-46 was a mass of bumps, seams, vents, and intakes, and it lagged behind similarly powered early Mustangs by 30 mph.

The creation of a complex machine like the P-51 is always the work of a group. Aerodynamics, structures, weights, tooling, production—they all play parts, often imposing conflicting demands on the chief designer. North American was exceptional those days in the degree of cooperation between departments, a state of affairs that was due in part to the personality of Ed Schmued and in part to the presence of a first-rate technical man, Atwood, in top management. Personal animosities, which would lead to Schmued’s resignation many years later, were submerged then in the drive to get the airplane done. And done it was, in 102 days—a period that seems miraculous today, but that was not, according to Atwood, unusual at the time. (Irv Ashkenas remembers the tempo during the development of the Mustang prototype as “relaxed.”) In any case, it was done sooner than the engine supplier expected; the finished airframe had to wait 18 days for the delivery of an engine.

But if the airplane was a team effort, its character was the work of a single man. No one disputes that that man was Edgar Schmued.

Schmued defined the form of the Mustang with the boatbuilder’s classical method of second-degree conics. He used a geometric construction originated by the 17th century French philosopher Blaise Pascal to generate curves belonging to a handsome family that includes the ellipse, the parabola, and the hyperbola. Schmued believed, with a Pythagorean faith in the underlying kinship of Number and Nature, that these fundamental geometric curves were “friendly” to moving air in special ways. “This is the kind of shape the air likes to touch,” he said. He used them to lay out a form of purity, simplicity, and elegant proportion. Later, Roy Liming, an NAA mathematician and loftsmen—lofting is the creation of full-scale drawings from which production tools are made—would translate the graphic conic-lofting procedure into mathematical terms so that all approximation evap-
orated from the definition of a compound-curved aerodynamic surface. Lugin would boast, with pardonable hyperbole, that the Britain-based Mustangs could fly to Berlin and back because their surface contours did not deviate from the mathematical ideal.

It was actually not North American but the British who in 1942 put the final stamp on the Mustang by replacing its asthmatic 1,150-hp Allison engine with a 1,650-hp Rolls-Royce Merlin. The Merlin’s two-stage blower gave the Mustang the power at altitude that it needed to become the fastest fighter of its time; it also allowed the removal of the unsightly carburetor air intake from the top of the long cowling. The technicians at Rolls-Royce came up with a series of horrible-looking cowlings for the experimental airplane on which they mounted the first Merlin; it wasn’t until North American began installing Packard-built Merlins in Mustangs at Los Angeles that Schmued’s conics restored to the airplane the patrician profile whose grace and elegance surpassed every other fighter’s.

The early years of World War II were a golden age for airplane manufacturers. Beneath the battlefields and the struggle for victory flowed a river of money. The weapons manufacturers were like prototype shops or the studios of artists, where individual genius mingled freely with cooperative enthusiasm. Lee Atwood, using the terminology of a business executive, would later write of that time, “I doubt that I shall ever see again such a degree of product improvement, employee participation, relative product value, economic production, and generally superior results as I experienced in Dutch Kindelberger’s airplane production complex during the period 1939 to 1945.”

North American’s heyday began with the AT-6 and continued beyond the Mustang: The next great American fighter was another NAA product, the F-86 Sabre. Ed Schmued remained with the company until 1952, when the personal politics had developed into a maze of rifts that still appear in recollections of the Mustang years today. After a brief period as a private consultant he went to Northrop, where he headed the T-38 development program before returning to private consultancy in 1957.

Lee Atwood became chief executive of North American after Kindelberger retired in failing health; he remained at the helm as the company entered the era of computers, cruise missiles, earth satellites, and moon rockets, retiring after its 1967 acquisition by Rockwell International. Now 91 years old and still healthy and active, he lives in Pacific Palisades, California. An indefatigable writer with an admirable prose style, he keeps up a prolific and eloquent correspondence with aviation enthusiasts and historians.

Ed Schmued died in 1985 in Oceanside, California. Two weeks later, after an airport memorial service, a flight of Mustangs, their drone mingling with the antiphonal blare of a single F-86, carried his ashes above the site of the old North American plant where the Mustang was born. They then turned westward, and scattered them over the Pacific.
THE MUSTANG'S MARGIN

AVIATION HISTORY: A CLARIFICATION

By J. Leland Atwood

The Normandy invasion of German-held France in 1944 would probably not have been attempted at that time if control of the air over the beachhead could have been seriously contested. Ships, landing craft, and beach positions were vulnerable to aerial bombs and machine gun strafing with essentially no chance for defensive trenches or protective fortifications. So, as difficult and costly as the invasion turned out to be, Eisenhower could say to his soldiers: "Any aircraft you see will be ours."

This air supremacy was earned at a great cost also, involving in U. S. forces alone the loss of some 4,500 four-engine bombers and probably a similar number of fighter planes, but the suppression of the Luftwaffe was sufficient to justify General Eisenhower's assurances. This contest did not necessarily resolve the question of whether or not unescorted, self-protecting bombers with conventional high explosive bombs could be decisive in war, but the Douhet doctrine predicting progressive collapse of the enemy under such attack certainly did not develop in Germany. The defeat of the German air force was more direct, in aerial combat and destruction of air fields and bases.
In the August 1995 issue of *Air Force* magazine, General T. Ross Milton (USAF-Retired), published an article, “Fifty Years Ago, Looking Back.” As a combat participant and later a professional officer of the highest rank, his views are significant. This paragraph is quoted: “We did a good job of bombing that day, those of us who got there, but the Eighth took a terrible beating: sixty B-17's lost, almost a fourth of those that had actually crossed the Channel. Because no military force could long sustain that kind of loss, the concept of precision bombing, which required daylight in those days, and thus, the concept of strategic airpower, both were in jeopardy. The P-51, arguably the most important weapon of the European war, arrived at the eleventh hour to save the day.”

Beginning in late 1943 the P-51D with the Rolls-Royce engine was made available in quantity. It was 20 to 30 miles per hour faster than its contemporary propeller-powered fighter planes—and just as importantly, had fuel capacity for seven hours endurance. These two characteristics were strongly interconnected in that this heavy load of fuel would have been an impossible handicap if the Mustangs could have been regularly overtaken by enemy planes when far from home. This airplane model was credited with the destruction of some 4,900 enemy planes in aerial combat and about 4,000 on airfields.
The Mustang has received much recognition and is still a favorite in air shows and races of comparable planes. It is a credit to the engineers and production personnel of North American Aviation, but that is not the reason for writing this article. Being retired and with a well-developed interest in aerospace history, I have seen many articles on the characteristics and capabilities of the P-51, but the basic reason for its speed margin, in my opinion, has never been adequately described.

While there are many complex factors in the performance of airplanes, one of the most discrete and significant in the 1930's was the drag of the engine cooling system. The Mustang had an exceptionally low cooling drag, as noted below, only some 3% of the total drag of the airplane, and the result was the rather large speed increment.

Propeller-driving reciprocating engines can use only 25 to 30 percent of the fuel heat content to develop the useful shaft power, and the remaining heat is rejected primarily in two forms--exhaust gas heat and engine operating heat. The latter is transferred either directly to air as in air-cooled cylinders or to a liquid coolant and to the well-known radiator, or heat exchanger, and thence to the outside air. The heat removed from the radiator generally depends on the
volume and temperature of the air passing through it, the volume depending, within limits, on the difference in pressure between the front and rear faces of the radiator, or the pressure drop.

Since an airplane may use full power in a climb, the radiator must have enough air forced through it to cool the engine at best climbing speed, which, in the fighter planes involved, was about half the maximum speed in level flight. Thus, if a radiator were provided in the free air stream that was adequate to cool the engine in a climb, it follows that in level flight maximum speed the cooling air forced through the radiator would be excessive. In fact, since the drag and pressure on the forward facing surface increases as the square of the speed, the pressure and volume of air passing through the radiator at high speed would be four times as much as needed for the same cooling effect gained in the climb mode at half the speed. Even worse, since power required for cooling is radiator drag times speed, the power used in such an exposed radiator at high speed would be eight times that used in a maximum rate of climb. (This neglects a small compressibility correction at these subsonic speeds and a minor temperature rise in the cooling air caused by this compression, and also variations in radiator permeability at different pressures.)
These facts led designers and engineers in the 1930's to try various methods of ducting, concealing, retracting, and shuttering radiators—all with very little systematic theory or testing. Parallel with this, cowling of air-cooled engines such as the Townend ring and the NACA cowling with cylinder baffles to equalize cooling air distribution were developed with some benefit, but did nothing to differentiate between the cooling needs in a climb compared to those at high speed. Later use of cowl flaps partially compensated for this deficiency. The most significant contribution to the problem came from Report No. 1683 by F. W. Meredith of the Royal Aircraft Establishment in Farnborough, England, in 1935. This was followed by Report No. 1702 by R. S. Capon, also of the R.A.E., in 1936, who elaborated on Meredith's rather taut analysis. Both these investigators assumed ducted radiators—that is, free stream ram air ducted to the radiator face—but contributed little to the ducting problem itself, which proved to be a major difficulty in implementing the drag alleviating method they proposed. Since their analysis and calculations were intended to apply generally, their examples showed radiators directly facing the airstream with appropriate outlet cowling, but the inlet ducting problems were bypassed and left to the airplane designer (and quite properly so).
Quite simply, the Meredith Effect involved preventing excessive cooling air from flowing through the radiator at high speed by partly closing the outlet and developing a pressure behind the radiator, which, while less than on the forward face, created a jet of exhaust air. As with any pressure jet, this put a forward reaction force on the airplane which partly offset the drag of the radiator. The temperature increase in the exhaust air expanded its volume and augmented this force appreciably because the size of the exit opening could be somewhat larger with the same internal pressure. This is summarized rather elegantly in Meredith's conclusion on page 711 of his 1935 report as follows: "The employment of the principle of low velocity cooling avoids the necessity for an increasing expenditure of power with increasing speed provided the exit conditions are adjusted to suit the speed." Contrary to some rather capricious reports, he never suggested that cooling could be effected with a net increase in propulsive power.

The most notable and probably the first application of the Meredith Effect was incorporated in the Supermarine Spitfire, one of the world's most successful airplanes. (Jeffrey Quill, chief test pilot and author of "Spitfire, A Test Pilot's Story," page 27) Over 20,000 were built in various models, but the Mark IX, with the Merlin -61 engine,
was typical of the later wartime production, and a sketch of this model with detail of the radiator installation is shown. Two aspects of this design are significant: the radiator outlet has two positions—i.e., fully open and partly closed—and cannot be progressively "adjusted to suit the speed," and secondly, the inlet upper wall is a continuation of the lower surface of the wing and expands the duct cross section by rapidly curving upward.

The first, the non-adjustable exit, is, of course, a deviation from Meredith's dictum and precludes the progressive build-up of pressure behind the radiator with increasing speed, but the second can only be judged in hindsight, from an airplane design point of view. The inlet seemed to be configured properly to recover the ram air pressure, and the first Mustang design had a similar entry opening. It was later apparent that the thin boundary layer of air flowing along the lower surface of the wing was progressively thickening ahead of the duct opening, and that the flow would break away at a point on the upward curve of the duct wall. While the resulting turbulent, unsteady flow apparently did not create a serious vibration, it certainly reduced the efficiency of the radiator and prevented a more complete closure of the exit opening which is necessary to develop the jet thrust. Very interestingly, the R.A.E.
Subcommittee on Aerodynamics in 1936—in commenting on the Meredith and Capon reports—rather accurately predicted this problem: “Experiments upon air-cooled engines in the 24-foot tunnel have shown that it is necessary to pay particular attention to the design of the entrance to cowlings and of cooling ducts in order to avoid loss of energy by the formation of eddies.” (Somewhat easier said than done at that time.)

In the case of the Mustang, the duct volume was larger and the flow instability more violent, creating an unacceptable vibration and rumble. Resourceful engineers at North American, working with wind tunnel models, overcame the problem by lowering the intake upper lip below the wing surface boundary layer, thus beginning a new upper duct surface. In this design, the flow expanded gradually as the duct velocity decreased, and the pressure at the radiator face was reasonably uniform. This permitted the appropriate closure of the exit with a temperature controlled power actuator, and a minimum pressure drop across the radiator consistent with efficient radiator function and cooling demand.

As a result, the cooling drag was estimated at only 3% of the total and used only something like 40 horsepower for cooling purposes. (Lednicer and Gilchrist, 9th AIAA Applied

While the comparable power used for cooling by the Spitfire is not available to me, the measurements made by Rolls-Royce ("Rolls-Royce and the Mustang," Rolls-Royce Heritage Trust, Derby, England, page 15), show a total power required for the same speed (400 mph) as 200 horsepower more for the Spitfire than for the Mustang.

Records show ("Combat Aircraft of World War II," Weal, Bracken Press, London, 1977, page 206, and other reliable books of record) that with the same engine and at critical altitude (25,000 feet), the P-51D speed was 437 miles per hour. The Spitfire Mk IX speed was 405 miles per hour according to Jeffrey Quill in his Appendix 5. While the Spitfire had an exposed tail wheel and other small differences from the Mustang, most of the speed difference was in the cooling drag. (The Mark VIII with retracted tail wheel is rated at 414 miles per hour at a somewhat higher altitude.)

Advanced models of both airplanes with higher performance were produced late in the war, but were not available in significant numbers before VE Day, 1945.

It seems that most other contemporary airplanes attempting to take advantage of the Meredith Effect failed
for one reason or another to combine an efficient duct system with a properly designed and regulated exit-closing mechanism and did not develop the energy recovery inherent in the Meredith method. They generally used some 10% or more of their power available at high speed to overcome cooling drag. A notable exception was the DeHavilland Mosquito multipurpose plane with the same Rolls-Royce engines and which used a wing leading edge radiator mounting with a short and direct inlet duct. The controllable exit opening had a minimum area little more that half that of the Spitfire, and while it was a larger two-engine airplane, it had a speed of 425 miles per hour.

Since jet engines do not require cooling systems of the type described here, the subject has become moot and of little current importance. There was a time, however, when this rather insignificant subject made a critical difference.
MUSTANG P-51D
RADIATORS

SPITFIRE MK IX

CARB. INTAKE

RADIATORS (2)
THE SPITFIRE AND THE MUSTANG
(The Meredith Mystery)
By J. Leland Atwood

Since 1940 perhaps 1,000 billion dollars have been spent on military aviation and possibly much more than that, and the technology is highly developed and broadly based. Such was hardly the case when the Spitfire took on the Luftwaffe over England and lived to a standoff and ultimate victory. The same year the British Purchasing Commission ordered the Mustang from North American Aviation on a rather unusual gamble that it might do as well or better than the Spitfire. This order was based, at least in part, on my representation that the design would incorporate the British "Meredith Effect" of drag reduction.\(^1\)

Today, air combat engagements can begin at long range, with guided and controlled missile ordnance at distances in the scores of miles. In 1940 nearly all effective air-to-air armament was in the 20 mm. and 30 or 50 caliber machine gun category aimed by the pilot pointing the airplane. The effective range was measured in hundreds of feet. Today, electronic offensive and defensive measures are the means of success in combat. Speed is an important tactical factor, but rarely a competitive element in a missile exchange type of engagement.

In World War II, in the words of a veteran pilot successful in combat (a friend who flew in the defense of Malta in 1942), ten miles an hour advantage permitted a pilot
to enforce the terms of the engagement and 20 miles per hour margin enabled him to dominate a plane-to-plane duel. This is not to say that other characteristics, such as maneuverability and rate of climb, are not essential in air-to-air combat because, of course, they are. But speed is the key factor in the basic elements of overtaking and evasion, and in the World War II air war, it was considered critical.

Although both the Spitfire and the Mustang were developed into higher performance models at about the end of the war, the principal production of 1943-1944 was of the Mark IX Spitfire and the P-51D Mustang. Both used the Rolls-Royce Merlin V-1650-61 engine rated at about 1360 horsepower (5) at 25,000 feet. While the P-51B was capable of over 440 miles per hour at 25,000 feet, the P-51D with the bubble canopy is universally rated at 437 miles per hour. (2) (3) The best engineering reference I can find on the Mark IX is in the Appendix of Sir Stanley Hooker's book, "Not Much of an Engineer," page 247. (5) His chart shows 405 miles per hour for the Mark IX at 25,000 feet. It is interesting to note that the Mark VIII, apparently not produced in quantity, is rated 414 miles per hour. I do not know how the Mark VIII was configured or why it was not produced instead of the Mark IX. These numbers are in almost exact agreement with those shown in Appendix V of Jeffrey Quill's book showing Boscombe Down Test Center figures, Reference (6), although the altitude varies slightly.
The difference in speed between the two airplanes is shown in a somewhat different way in the book "Rolls-Royce and the Mustang," published in 1987 by David Birch of the Rolls-Royce Heritage Trust, Box 31, Derby, England. This is depicted in a chart on page 15 which shows that the Mustang required 200 horsepower less than the Spitfire to fly at 400 miles per hour at 20,000 feet.

The two airplanes are approximately the same size in dimensions and wing area, have the same power and propeller efficiency, and the Spitfire is somewhat lighter in construction and fuel load. The Mustang speed advantage—the equivalent of at least 200 horsepower—has been the subject of speculation, involving such things as wing profile, fuselage lines, surface smoothness, and finally, radiator drag.

While most United States military airplanes used air-cooled engines in the 1930's, liquid-cooled engines were predominant in England, and the subject of the cooling drag of radiators had been under study by the Royal Aircraft Establishment in Farnborough in 1935 or earlier. The F. W. Meredith report, No. 1683 of August 1935, and the R. S. Capon report, No. 1702 of March 1936, rather well defined the radiator drag problem in a mathematical way and developed a method of ducting cooling air to the radiator which, if adequate in a low-speed climb, even with some variations in intake efficiency, would be much more than enough for cooling at high speed. Their method used the excess cooling air
passing through the radiator to pressurize the duct behind it by partly closing the outlet, exhausting the heated air under pressure, providing a propulsive thrust (see diagram).

The Mustang used this method, which had become known as the "Meredith Effect," and used a power actuator, automatically controlled by thermostats--Reference (10), P-51 manual--to close the rear outlet all that the cooling balance would permit. This developed a considerable pressure and thrust which was probably the equivalent of at least 200 horsepower at high speed. (At 440 miles per hour or 650 feet per second, 200 horsepower is generated by only 170 pounds of thrust.)

The Spitfire radiators, one under each wing, were also ducted--but for some reason, the duct outlets were not equipped with closure flaps to develop any pressure behind the radiator at high speed and to gain the available thrust as described by Meredith and Capon in 1935 and 1936. This can be noted in any well maintained example of the Mark IX in any of a number of aviation museums. An extremely interesting question is: Why did the Spitfire, described by various responsible writers as incorporating the Meredith Effect, not have the means and mechanization to automatically constrict the radiator outlet and gain the thrust and speed increment? Of course, I cannot answer that question with any confidence or certainty, but can at least discuss some interesting possibilities. My principal source of information comes from the files of the Rolls-Royce Heritage Trust and copies of
some documents which have been graciously provided quite recently by David Birch. Others are referenced to the best of my knowledge.

The aerodynamics of radiator cooling is extremely well organized and presented in R.A.E. Report No. Aero. 2290 of May 1947.\(^{(11)}\) Chapters 1 and 2 by Dr. J. Seddon develop the mathematics and offer some discrete examples. The variable outlet requirements for different heat fluxes and speeds are well developed—although the design requirements are implied rather than described.

A table on page 27 of Chapter 2 shows an interesting comparison of the power required to overcome the drag of various cooling systems listed as percentages of rejected heat in horsepower (one horsepower being 43 British thermal units per minute). The two-engine Mosquito, the British high-speed bomber and reconnaissance plane—with a wing nose inlet and a minimum outlet area just over half that of the Spitfire—used the equivalent of 4.6% of the rejected heat to overcome cooling drag, compared to 17.3% for the latter. Also, the tabulated examples on page 19 of Chapter 1 are an absolutely elegant demonstration of the drag and heat rejection effects of different sized discharge openings aft of the radiator.\(^{(11)}\)

Reginald Mitchell's life was cut short by disease in 1937 during a brilliant career. His Supermarine float plane racers were outstanding in the 1920's and early 1930's, eventually retiring the Schneider Trophy. The Spitfire
fighter plane was a derivative and had an exceptionally thin low drag wing. Early engines of some 1,000 horsepower gave it speed of over 350 miles per hour at moderate altitudes. (6) There is some literature in existence that indicates that Meredith influenced the design of the Spitfire as early as 1935 and that he made some detailed suggestions regarding the radiator cooling, air intake and venting louvers. Writers, including Alfred Price (12), Jeffrey Quill (6), Morgan and Shacklady (17), and others, have made the point that the Spitfire performance was augmented by the radiator cooling treatment known as the Meredith Effect.

The actual airplane (Mark IX is typical) fielded during the war used a rather interesting compromise shown in the accompanying sketch. The radiator outlet had a downward hinging flap, which was opened for ground operation and other slow speed conditions, but was automatically closed for all faster flight conditions. The minimum closure area can be seen to be only slightly smaller than the size of the inlet, and it seems apparent that it was too large to allow a significant pressure to build up behind the radiator at high speed with the amount of air that could be forced through the radiator matrix. Both the Mustang and the Mosquito, which used the same engines, had outlets that were little more than half as large proportionally and had the speed advantage of the resulting energy recovery. The first page of a Rolls-Royce Experimental Department report dated August 10, 1942 (reproduced) clearly shows that the Spitfire speed could have
been increased by a calculated 13 miles per hour by controlling and further closing a movable exit flap. (13) Additionally, it is estimated some 5 or 6 miles per hour could have been added by retracting the tail wheel, and the remainder of the speed difference between the two airplanes could probably have been accounted for by a boundary layer scavenging slot or bypass between the wing and the air intake (see below).

It might be further noted that the exit closure on the Mustang involved an electrically powered jack screw capable of considerable force to overcome internal duct pressures of up to 200 pounds per square foot or more, depending on speed and altitude. (10) Such a control mechanism was not used on the Spitfire.

The Journal of the Royal Aeronautical Society, August 1944 issue (14), has an interesting article by Messrs. Morgan and Smelt on aerodynamic features of German aircraft. The Messerschmitt Me.109E and the Me.110 had rather ingenious mechanisms for closing the exits of their under-wing radiators, but had poor inlets—involving the ingestion of much turbulent air from the boundary layer of the wing surface. The Me.109F inlet was redesigned to incorporate a double upper duct wall to divert this turbulence over the radiator to a rear discharge slot.

The Spitfire design would also have benefitted from such boundary layer removal, but the radiator was rather wide (2 feet approximately) for an ordinary gutter as used between
the wing and the radiator inlet on the Mustang, and the double-duct wall was apparently not attempted in that design. Consequently, the inlet ingests turbulent boundary layer air, particularly in the upper portion—and as a result, the flow tends to break away from the upper duct wall. This reduces the functional effectiveness of the upper part of the radiator. As noted above, the first Mustang had this problem (1) before lowering the duct upper intake lip well below the wing lower surface.

From an overall design aspect, it should be pointed out that the optimization of the Meredith Effect was much easier to accomplish in a fuselage submerged radiator than with an under-wing mounting such as that on the Spitfire and Me.109. This fuselage mounting was also used efficiently on the post-war MB-5 Martin-Baker fighter with the Griffon engine.

Speculation on this matter must include the unfortunate loss of Reginald Mitchell, wartime priorities and urgencies, and possibly a partial misunderstanding of the Meredith papers. After testing the Mustang, the Rolls-Royce organization seemed to have had a clear view of the possibilities. The letter of 28 June 1942 from Rolls-Royce CEO Ernest Hives to the R.A.F. Chief Marshall, published in “Rolls-Royce and the Mustang,” page 20 (7), makes this clear. Quoted in part: “We feel very depressed about the fighter position, both in this country and the U.S.A. and this has not improved since one of our own pilots examined the F.W.190....The aircraft manufacturer, however, has got to
make some contribution. So far, since the war started the entire improvements to the fighter performance have been due to engines and airscrews. We are sold completely on the Mustang. The Merlin 61 goes into it with no alteration to the engine cowling or to the radiator cowling...

Meredith's report, No.1683 (8), contains quite a bit of algebra but makes no effort to quantify the performance improvement to be gained by his method. However, the conclusion on page 711 is quite definite: "The employment of the principle of low velocity cooling avoids the necessity for an increasing expenditure of power with increasing speed provided the exit conditions are adjusted to suit the speed." Quite apparently the Spitfire design configuration did not employ the means to adjust or modulate the exit condition as the speed increased.

August 15, 1994
Revised July 14, 1995

References:


(7) "Rolls-Royce and the Mustang," Historical Series No. 9, David Birch, Rolls-Royce Heritage Trust, © 1987, P. O. Box 31, Derby, England.

(8) "Note on the Cooling of Aircraft Engines with special reference to Ethylene Glycol Radiators enclosed in Ducts," by F. W. Meredith, B.A., Reports and Memoranda No. 1683, 14 August 1935, communicated by the Director of Scientific Research, Air Ministry, page 699 to 711 inclusive.


(10) Pages 1, 13, 25 from October 31, 1944 P-51D Pilots' Flight Operating Instruction Manual (automatic radiator aft outlet closing mechanism).


(13) Rolls-Royce Experimental Department Report: "Estimation of the Increase in Performance Obtainable by Fitting a Continuously Variable
Radiator Flap," Reference Dor/Gtx.1/MNH.dated 10-8-42 (as printed).


(15) Rolls-Royce Dor/JCC.1/MNH. dated 5-11-42, "Methods of Control for an Automatic Continuously Variable Radiator Flap."

(16) "Rolls-Royce-From the Wings-Military Aviation, 1925-71," Ronald W. Harker (1976), page 46 et.seq. See also Reference (1).

SPITFIRE MK IX

CARB. INTAKE

RADIATORS (2)
Experimental Department Report

Reference: Dor/9tx.1/WMH. 10.8.42.

Subject of Report: Estimation of the increase in performance obtainable by fitting a continuously variable radiator flap.

General Conclusion:

The airflow through a tropically suitable radiator is greater than is necessary at any lower air temperatures. The airflow would be reduced to the required amount and a substantial increase in performance obtained, at these lower temperatures, by the use of a continuously variable radiator flap.

Figures of the maximum increases in performance to be expected under I.C.A.N. conditions on a Merlin 61 Spitfire are as follows:

- Level Speed, 13 m.p.h. at 21,000 ft. (M.S.).
- Rate of Olimb. 240 ft/min. at 19,000 ft. (M.S.).
- Ceiling. 600 ft.
- Range at 20,000 ft. 800 A.S.I. 7%.

Copies of Report Circulated to:
- F. C. (Sg.)
- Lp. F. (Lov.) (Lov/Sch).

Report to be noted for further action by:
- (Dor/EWS)
- Dor/Hks.

Test carried out on:

By: Test No. Date: --
The Effect of the North American P-51 Mustang On the Air War in Europe

by

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March 27, 1995

Harry R. Ankeny, Jr., the author's grandfather, with his P-51, "Betsy," (named for the author's grandmother) at the end of his combat tour on August 16, 1944.

For more on Harry Ankeny's World War II experiences, including excerpts from his combat diary, follow this link or click on the photo above. (The diary excerpts are image files, so the page may take a while to load.)

Abstract

This paper deals with the contributions of the P-51 Mustang to the eventual victory of the Allies in Europe during World War II. It describes the war scene in Europe before the P-51 was introduced, traces the development of the fighter, its advantages, and the abilities it was able to contribute to the Allies' arsenal. It concludes with the effect that the P-51 had on German air superiority, and how it led the destruction of the Luftwaffe. The thesis is that: it was not until the advent of the North American P-51 Mustang fighter, and all of the improvements, benefits, and side effects that it brought with it, that the Allies were able to achieve air superiority over the Germans.
The Effect of the North American P-51 Mustang on the Air War in Europe

achieve air superiority over the Germans.

This paper was inspired largely by my grandfather, who flew the P-51 out of Leiston, England, during WW II and contributed to the eventual Allied success that is traced in this paper. He flew over seventy missions between February and August 1944, and scored three kills against German fighters.

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Introduction

On September 1, 1939, the German military forces invaded Poland to begin World War II. This invasion was very successful because of its use of a new military strategic theory -- blitzkrieg. Blitzkrieg, literally "lightning war," involved the fast and deadly coordination of two distinct forces, the Wermacht and the Luftwaffe. The Wermacht advanced on the ground, while the Luftwaffe destroyed the enemy air force, attacked enemy ground forces, and disrupted enemy communication and transportation systems. This setup was responsible for the successful invasions of Poland, Norway, Western Europe, the Balkans and the initial success of the Russian invasion. For many years after the first of September, the air war in Europe was dominated by the Luftwaffe. No other nation involved in the war had the experience, technology, or numbers to challenge the Luftwaffe's superiority. It was not until the United States joined the war effort that any great harm was done to Germany and even then, German air superiority remained unscathed. It was not until the advent of the North American P-51 Mustang fighter, and all of the improvements, benefits, and side effects that it brought with it, that the Allies were able to achieve air superiority over the Germans.

Reasons for the Pre-P-51 Air Situation

The continued domination of the European skies by the Luftwaffe was caused by two factors, the first of which was the difference in military theory between the Luftwaffe and the Royal Air Force. The theories concerning the purpose and function of the Luftwaffe and RAF were exactly opposite and were a result of their experiences in World War I. During WW I, Germany attempted a strategic bombing effort directed against England using Gothas (biplane bombers) and Zeppelins (slow-moving hot-air balloons) which did not give much of a result. This, plus the fact that German military theory at the beginning of WW II was based much more on fast quick results (Blitzkrieg), meant that Germany decided not to develop a strategic air force. The Luftwaffe had experienced great success when they used tactical ground-attack aircraft in Spain (i.e. at Guernica), and so they figured that their air force should mainly consist of this kind of planes. So Germany made the Luftwaffe a ground support force that was essentially an extension of the army and functioned as a long-range, aerial artillery. The RAF, on the other hand, had experimented with
functioned as a long-range, aerial artillery. The RAF, on the other hand, had experimented with ground-attack fighters during WW I, and had suffered grievous casualty rates. This, combined with the fact that the British had been deeply enraged and offended by the German Gotha and Zeppelin attacks on their home soil, made them determined to develop a strategic air force that would be capable of bombing German soil in the next war. Thus, at the beginning of WW II, the RAF was mostly a strategic force that consisted of heavy bombers and backup fighters, and lacked any tactical dive-bombers or ground-attack fighters. (Boyne 21)

The Pre-P-51 Situation

Because of these fundamental differences, the situation that resulted after the air war began was: bombers in enemy territory vs. attack planes. The "in enemy territory" was the second reason for the domination of the Luftwaffe. At the beginning of WW II, and for many years afterward, the Allies had no long-range escort fighters, which meant that the bombers were forced to fly most of their long journeys alone. (Perret 104) Before the P-51 was brought into combat, the main Allied fighters were the American P-47 Thunderbolt and the British Spitfire, neither of which had a very long range. The rule-of-thumb for fighter ranges was that they could go as far as Aachen, which was about 250 miles from the Allied fighters' home bases in England, before they had to turn around. Unfortunately, most of the bombers' targets were between 400 and 700 miles from England. (Bailey 2-3) This meant that bombers could only be escorted into the Benelux countries, northern France, and the very western fringe of Germany. When these unescorted, ungainly, slow, unmaneuverable bombers flew over Germany, they were practically sitting ducks for the fast German fighters. On the other hand, the bombers were equipped with several machine guns and were able to consistently shoot down some of their attackers. Because of this, "U.S. strategists were not yet convinced of the need for long-range fighters; they continued to cling to the belief that their big bomber formations could defend themselves over Germany." (Bailey 153)

The Allied Purpose in the Air War

The Allies knew that they had to drive German industry into the ground in order to win the war. Since the factories, refineries, assembly-lines, and other industry-related structures were all inland, the only way to destroy them was by sending in bombers. The only way that the bombers could achieve real success was by gaining air superiority, which meant that nearly all of the bombers would be able to drop their bombs without being harassed by fighters, and return home to fight another day. The problem with this sequence was that the Allies did not have this superiority, (Bailey 28) because their bombers were consistently getting shot down in fairly large numbers, by the German fighters that kept coming. The Allies soon realized that in order to gain this superiority, they would have to destroy more German fighters. In order to destroy the fighters, they would have to be forced into the air in greater numbers. In order to get more German fighters into the air, the more sensitive German industries would have to be attacked with more aggression. Following this logic, the Allies began a intensified bombing effort that resulted in the famous bombings of Hamburg (July 24-28, 1943) and Ploesti (August 1, 1943), among others. And, indeed, this did cause more fighters to come up to meet and engage the bombers. Unfortunately, the bombers were overwhelmed by the German opposition, and their losses soon began to increase. (Copp 359) The Allied air forces had, in effect, pushed a stick into a hornets' nest, hoping to kill the hornets when they came out, and been stung by the ferocity of their response.

The Battle at Schweinfurt

The culminating point of this backfiring plan was the second bombing raid on Schweinfurt, which occurred on October 14, 1943. Schweinfurt was the location of huge ball-bearing factories that supplied most of the ball-bearings for the entire German military. The U.S. Eighth Air Force had staged a fairly successful raid on the same city two months earlier, but the second time around, the Germans were ready.
successful raid on the same city two months earlier, but the second time around, the Germans were ready for them. The official report afterwards said that the Luftwaffe "turned in a performance unprecedented in its magnitude, in the cleverness with which it was planned, and in the severity with which it was executed." Of the 229 bombers that actually made it all the way to Schweinfurt, 60 were shot down, and 17 more made it home, but were damaged beyond repair. This was a 26.5% battle loss rate for the Americans, while the Germans only lost 38 airplanes the whole day, from all causes. (Boyne 327) This battle was one of the key battles of the war, and undeniably proved to the Allies that the bomber offensive could not continue without a long-range fighter escort. (Copp 444) Even before October of '43, some had begun to realize the need for this kind of fighter. In June, the Commanding General of the Army Air Forces, General Hap Arnold, wrote a memo to his Chief of Staff, Major General Barney Giles, which said:

This brings to my mind the absolute necessity for building a fighter airplane that can go in and out with the bombers. Moreover, this fighter has got to go into Germany. . . . Whether you use an existing type or have to start from scratch is your problem. Get to work on this right away because by January '44, I want a fighter escort for all our bombers from the U.K. into Germany. (Copp 413-414)

The Development of the P-51

In April of 1940, "Dutch" Kindleberger, president of North American Aviation, visited Sir Henry Self, the head of the aircraft division of the British Purchasing Commission, asking if Britain would like to buy some of his B-25 bombers. Self was not interested in buying any more bombers, but was interested in buying a good fighter. He directed Kindleberger to the Curtiss company, who had a new fighter design, but were too busy building P-40's to do anything with it. Kindleberger went to Curtiss and bought their design for $56,000. He promised Self to have the planes ready by September of 1941. The prototype of the NA-73, as it was called, was ready to fly in October of 1940 and proved to have an excellent design. The NA-73 had a revolutionary wing design that allowed it to fly safely at much higher speeds. Another revolutionary idea in the plane was the way heated air from the radiator was dealt with. The NA-73's engineers designed it to expel this air and boost the planes speed by 15 or 25 mph. The engineers also worked especially hard on making the plane as aerodynamic as possible, and so they positioned the radiator in a new place, made the fuselage as narrow as possible, and set the cockpit low in the fuselage. (Perret 118-119) It was at this point that an error was made that made the Mustang useless as a long-range offensive fighter. When the NA-73 was mass produced as the P-51, it was powered by a 1550 horsepower air-cooled Allison engine, which did not have a supercharger and lost performance above 11,800 ft. At high altitudes air pressure goes down, and so there is less oxygen in a given amount of air, which means that engines do not burn as cleanly, and so lose power. Superchargers compress air before it is pumped into the engine cylinders so that there is enough oxygen for the engine to function well. The early Allison-engined planes did not have the supercharger, and so were limited to low-altitude operations. Even without a high-altitude capability, the Mustang was an impressive plane and was bought in quantity by the RAF. It flew its first mission on May 10, 1942, against Berck-sur-Mer on the French coast. (Grant 17-18)

The Installation of the Merlin Engines

So, for the next eighteen months, the P-51A's continued to fly with the RAF, doing their unexceptional jobs well. After the plane began to go into combat, some people began looking into the idea of fitting the Mustang with a more powerful engine. As the RAF said, it was "a bloody good airplane, only it needs a bit more poke." (Grant 22) One day, an RAF test pilot was flying a P-51A and the thought occurred to
him that the plane could be fitted with a Rolls-Royce Merlin engine, which had about 300 more horsepower and included a supercharger. He suggested it to Rolls-Royce's Chief Aerodynamic Engineer and "both men realized that the combination of this sort of performance with the aerodynamically efficient airframe of the Mustang would revolutionize its potential." (Grant 22) This plan was duly carried out and in November 1943, the first group of P-51B's arrived in England.

**Features, Advantages, and Benefits of the P-51**

This final Mustang design was superior to anything else that flew at the time. The P-51B had a huge internal gasoline tank capacity (around 425 gallons) and its engine was very economical, using about half the gasoline of other American fighters. This meant its range was 1080 miles and could be extended to 2600 miles when extra drop-tanks were attached to the wings. This made its range far more than any Allied or German fighter's. As far as performance went, it was superior to all others as well. Neither of the other two main American fighters could compete; the P-47 was too heavy and the P-38 had too many technical problems. The British fighters, the Spitfire and the Hurricane did not have the range, speed, or power. But most important was its superiority over the German fighters, the most important of which were the FW-190 and the Me-109. The Mustang was 50 mph faster than the Germans up to 28,000 ft beyond which it was much faster than the FW-190 and still substantially faster than the Me-109. The Mustang had between 3000 and 4000 lbs more weight, and so was able to outdive either German plane. The tightness of its turns was much better than the Me-109 and slightly better than the FW-190. (Grant 31, Boyne 389-390, Bailey 153) The result of all of this was that the Allies now had a plane that could go with the bombers all the way to and from their targets, fight and defeat the bombers' German attackers, and not run out of fuel.

**The P-51's Battle Performance**

So, at the end of 1943 and the beginning of 1944, the new American P-51B's began arriving in England in force. (Dupuy 34) For the first few months of the year, the Mustangs were settling in and having their systems perfected. But by March, the Mustangs had decisively taken control. The arrival and subsequent heavy use of the P-51's had several effects.

The first effect that the Mustangs had was in the running air battles over Europe. Before the beginning of 1944, the bombers had been alone as they approached their faraway targets. But the P-51 changed this, and quickly made an impression on all concerned, enemy and ally alike. For example, on January 11, 1944, the Eighth Air Force launched its first deep penetration of Germany with P-51 coverage. The bombers' targets were the cities of Oschersleben and Halberstadt, where many German planes were being constructed. When they arrived, there were 49 Mustangs covering a force of around 220 bombers. Even though the bombers suffered heavy casualties, they were able to inflict substantial damage on their target factories. But the most significant thing about the battle was the shining performance of the P-51's. Since the bombers were attacking two different cities, the Mustang force had to divide into two groups, to support the different attacks. Because of the sensitive nature of the bombers' targets, the Luftwaffe came out in force to defend their factories. During the ensuing melee, the 49 P-51's shot down 15 enemy planes without suffering a single loss. Major Howard, the group's leader, was credited with four kills within minutes. (Bailey 155) In the grand scheme of things, this battle was insignificant, but it goes to show how much of advantage the P-51's had over their German counterparts. Considering that these were essentially first-time pilots in the Mustangs' first big battle, this is very impressive.

**The Change in Policy on Escort Fighter Function**

Another thing happened at the same time as the arrival of the P-51 that greatly aided the Allies and fully
utilized the great capabilities of the Mustang. Before the beginning of 1944, the bomber escort's primary function was to fly alongside the bombers, repel any attacks made on the bombers, and generally make sure the bombers stayed safe. Indeed, the motto of the Eighth Air Force Fighter Command was "Our Mission is to Bring the Bombers Back Alive." One day at the beginning of the year, Jimmy Doolittle, who was the commander of the Eighth Air Force, saw a plaque on the wall with this motto on it and said, "That's not so. Your mission is to destroy the German Air Force... Take that damned thing down." (Copp 456) And just days before, in his New Year's Day address to the Eighth Air Force command, General Arnold had said, "My personal message to you—this is a MUST—is to destroy the enemy air force wherever you find them, in the air, on the ground and in the factories." (Copp 456) What this meant was that the escort fighters were not tied to the bombers anymore, and were free to roam over the countryside and through the towns and cities, destroying at will. The sweeping Mustangs were released to ravage German convoys, trains, antiaircraft gun emplacements, warehouses, airfields, factories, radar installations, and other important things that would be impractical to be attacked by bombers. The fighters were also able to attack German fighters when they were least prepared for it, like when they were taking off or forming up in the air. What made this possible was the increase in the number of American planes present in Europe. This increase in the number of Allied planes compared to the number of German planes continued to the point that, on D-Day, the Allies used 12,873 aircraft while the Germans were only able to muster a mere 300. (Overy 77) By using this overwhelming numerical advantage, the Allied fighters were able to swamp their opponents in an unstoppable flood of planes.

**P-51's Disrupt Luftwaffe Fighter Tactics**

This increase in the number of fighters plus the change in fighter philosophy allowed the escorts to cover the bombers while simultaneously ranging far from the bomber stream and destroying all that they could find. This caused the disruption of several effective German fighter tactics that had been used successfully in the past. One of these tactics was the deployment of slow, ungainly German planes that would fly around the bomber formations, out of gun range, and report back on where the bombers were and where their weak spots were. The free-ranging P-51's soon wiped out these planes. Another popular tactic was to mount rocket launchers on the wings of some of these slower craft, have them linger just out of range of the bombers' guns, and send rockets flying into the bomber formations. These rocket attacks were terrifying to the bomber crews, and often broke up formations, sending some planes to the ground. Obviously, these attacks also came to a halt. Most importantly, the fast German fighters had to change their attack tactics. Beforehand, they would fly alongside the formations and wait for the right moment to swoop in and attack a bomber. Now, they were forced to group together several miles away from the bombers, and then turn and make a mad rush at the bombers, hoping to inflict sufficient damage on one pass to shoot down some number of enemy bombers. They could not afford to stay with the bombers for very long for fear of being attacked by the Mustangs. (Perret 293) Indeed, soon after the P-51's entered onto the scene, Hermann Goering, the commander of the Luftwaffe, recommended that the German defensive fighters avoid combat with the P-51, and only attack bomber formations when there were no fighters around. The result of all of this is that the American fighters, led by the P-51's, soon began to gain air superiority. Not long after Goering's recommendation, a sarcastic Luftwaffe officer commented that the safest flying in the world was to be an American fighter over Germany. (Dupuy 35-36) It is obvious that the P-51, once it was supplied to the Eighth Air Force in great quantities, and unleashed by Doolittle and Arnold's new fighter policies, soon took a heavy toll on German air superiority.

**P-51's Give Bombers Better Support**

Another profound effect that the increased fighter coverage had was on the most important people, the bombers. After the entrance of the P-51, and the virtual elimination of the German fighter threat, the bombers were in much less danger from German fighters. The result of the decreased danger to the
bombers is subtle, but obvious when thought about. Imagine a bomber crew sitting in their cramped plane, unable to move around or evade attack during their bombing run while numerous German fighters speed past their plane firing at them. Second lieutenant William Brick, the bombardier of a B-17 bomber, tells about the day he flew to Linz, Austria on a bombing run:

... The remainder of the run must be perfectly straight and level, without the slightest deviation, or our five-thousand-pound bomb load will fall wide of the target. No evasive action is possible... Then comes the sickening rattle of machine-gun bullets and cannon fire hitting our ship; ignoring the flak from the antiaircraft batteries, German fighter planes zoom in so close that it seems they will ram us... Even at the sub-zero temperatures of this altitude, salty sweat pours down my face and burns my eyeballs. Cursing and praying, I am gripped by the same brand of helpless fear that fliers experience during every bomb run. I feel the terror in my hands, in my stomach, even in my feet. Long after returning from the mission, its effects will remain etched indelibly on my face... (Brick 61)

This kind of terror experienced by the entire crew of the bombers was sure to affect their concentration and their carefulness. Indeed, "it is an undeniable, if unquantifiable, fact that it is easier to bomb precisely when you know you will probably not be shot out of the sky." (Boyne 341)

Conclusion

In the end, the way that the Allied air forces gained air superiority was by destroying its opposition. The ways in which the fighters were able to destroy German fighters were diverse. The fighters utilized their high speed and maneuverability to fly low-level strafing missions that ranged over large expanses of territory and destroyed many Luftwaffe craft on the ground. This tactic was responsible for the destruction of many dozens of fighters that were unable to go on and fight in the air. Another way that the Allied fighters destroyed their opposition, and the most important way, was by luring them into the air. Going back to the hornets' nest analogy, the Allies stopped pushing the stick and decided to bide their time until the moment was right. When they did start pushing the stick into the nest again, they were armed with a metaphoric insecticide. In real life, this "insecticide" was the P-51. Beforehand, the Allies had nothing that could stop the "hornets" and so were helpless to stop their attack. But after they had developed an "insecticide" capable of killing the "hornets," they proceeded to lure the hornets into the open where they could be destroyed. In real life, the bombers were the lure that brought the Luftwaffe into the air. Using the long-range Mustangs, the Allies were able to make their bombing raids more effective and more deadly to Germany. The approaching end of the Third Reich was enough to get the German fighters into the air to try to stop the bombers from wrecking their war effort. "Air superiority had been won not by bombing the enemy's factories into oblivion; instead, it was won by the long-range fighter, using the bomber formations as bait to entice the Luftwaffe to fight." (Boyne 338) With the advent of great numbers of the highly superior P-51 Mustang, the German fighters that came up to attack the bombers quickly met their match and were easily repelled by the Mustangs.

Works Cited


Brick, William. "Bombardier." *American History*, April 1995, pp. 60-65. A short magazine article following the story of how a U.S. airman was shot down over Austria, and his subsequent imprisonment by the Nazis.

Copp, DeWitt S. *Forged in Fire: Strategy and Decisions in the Air war over Europe, 1940-1945*. Garden City, New York: Doubleday & Company, 1982. A book dealing mostly with the U.S. involvement in the War, with particular emphasis on the politics of the military officials, and how the major strategic decisions were made.


Send e-mail to the author, David Buckingham, stu950495@gcc.edu.

Return to David's page.

You are visitor **002381** since December 8, 1996.
Steven T. Corneliussen, 08:05 AM 1/6/97 -, Those two messages that were

X-Sender: corneliussen@micro4.cebaf.gov
Date: Mon, 6 Jan 1997 08:05:00 -0500
To: R.T.Layman@larc.nasa.gov
From: corneliussen@cebaf.gov (Steven T. Corneliussen)
Subject: Those two messages that were spit back to me from the LaRC server

Date: Fri, 03 Jan 1997 14:34:26 -0500
From: Postmaster@micro3.cebaf.gov
Subject: Undeliverable Mail
To: corneliussen@CEBAF.GOV

Bad address -- <R.T.Layman@LaRC.NASA.gov>
Error -- Nameserver error: Unknown host

Start of returned message

Received: from [129.57.33.169] by 129.57.33.169 with SMTP;
 Fri, 3 Jan 1997 14:34:25 -0500
 X-Sender: corneliussen@micro4.cebaf.gov
 Message-Id: <v01540b35ae4f30f463680@[129.57.33.169]>
 Mime-Version: 1.0
 Content-Type: text/plain; charset="us-ascii"
 Date: Fri, 3 Jan 1997 14:34:27 -0500
 To: R.T.Layman@LaRC.NASA.gov
 From: corneliussen@cebaf.gov (Steven T. Corneliussen)
 Subject: That letter I said I sent

Dick, this might be interesting. Al Braslow wrote a letter too. But since
mine was short and journalistic, they took mine. I think it's in
Dec/Jan.

I ended up writing again, as you'll see in the next message, but I
know
they won't print it. I just want the editors to think about it.
You'll see
what I mean.

> Date: Sat, 30 Nov 1996 15:14:08 -0500
> From: <CORNELIUSSEN@MICRO4.CEBAF.GOV>
> Subject: air-sp-sept96.edt
> To: corneliu@pinn.net, CORNELIUSSEN@MICRO4.CEBAF.GOV
> 
> Letter to the editor, _Air and Space Smithsonian_
> September 11, 1996
> (Please see also the note to the editor at the bottom of this
message.)
>
>"Who Made the Mustang?" (August/September 1996) interestingly

Printed for "Richard T. Layman" <r.t.layman@larc.nasa.gov> 1
engages its
title's question, but unfortunately omits a key name from the
answer: Eastman
>Jacobs, the government research engineer -- some say genius --
responsible for
>the P-51's remarkable wings.
>
>From the 1920s, National Advisory Committee for Aeronautics
researchers had
>sought to transform the wing-design art into an effective
engineering
science.
>In the late 1930s, a turning point came at the NACA's Langley
Memorial
>Aeronautical Laboratory in Virginia, now a NASA center. Jacobs --
even then
>a bearded local legend -- inverted a colleague's theoretical
approach and
>established a powerful new computational tool. Airfoils could now
be designed
>to have specific pressure distributions.
>
>Next Jacobs needed a low-turbulence wind tunnel for tests involving
the
>thin boundary layer of air next to the new shapes' surfaces. Here
his genius
>extended to technopolitics: though the terms "low turbulence" and
"boundary
>layer" aroused no interest, "wing icing" did. So Jacobs asserted an
>icing-research purpose. A low-turbulence tunnel got funded,
followed
>shortly by another that had test-accuracy-enhancing pressure
capability.
>
>The practical result: wings with superior high-speed
characteristics, and
>capable also of sustaining drag-reducing laminar flow under ideal,
>nonoperational conditions. Historians say that Jacobs's work, still
>used today, helped define the modern science of airfoil design --
and that
>in World War II it contributed mightily to the successes of the
P-51 Mustang.
>
>Steven T. Cornelius, Jr.
>Poquoson, Virginia
>
>NOTE TO THE EDITOR
>
Printed for "Richard T. Layman" <r.t.layman@larc.nasa.gov>
I have three main sources for the letter above:

1. Laminar-flow expert Albert Braslow of the NACA and NASA, who worked in Jacobs's group conducting low-turbulence pressure-tunnel development tests of the new airfoils starting in 1942. Mr. Braslow has also written to you about this. He has seen my letter and will be cc'ed with this message. I once wrote a white paper historical report on laminar flow for NASA Langley, and I found that if you do that, you use the work of Al Braslow extensively.

2. Aerospace historian Jim Hansen, of Auburn University and your editorial board. I edited Jim's NACA Langley history _Engineer in Charge_ in the mid-1980s. He has seen my letter and will be cc'ed with this message.

3. Aeronautics historian and scholar of engineering epistemology Walter G. Vincenti, who conducted NACA research in the 1940s and later was a Stanford professor of aeronautical engineering. In my opinion his essay "The Davis Wing and the Problem of Airfoil Design" is the key companion to Jim Hansen's book for understanding the historical context of the work Al Braslow wrote to you about. Professor Vincenti does not know me, but I am sending him a copy of this message.

I hope you print at least one letter about this. Vincenti says that the effort by Jacobs was historically a substantially important step, advancing the engineering science of aeronautics considerably. Al Braslow has been saying similar things for some time. As you can see, I think they are right.

I would be grateful if you would acknowledge receipt by return e-mail. Thanks very much in any case. (I'm sending this from work; my home e-mail is temporarily out because of Hurricane Fran.)

Steven T. Cornelius, Jr.
>202 Beach Road  
>Poquoson, VA 23662  
>  
>Work: 757 269-7582; corneliussen@cebaf.gov  
>Home: 757 868-9658; corneliu@pinn.net (but Fran got my modem)  
>  
  
End of returned message

Date: Fri, 03 Jan 1997 14:35:24 -0500  
From: Postmaster@micro3.cebaf.gov  
Subject: Undeliverable Mail  
To: corneliussen@CEBAF.GOV

Bad address -- <R.T.Layman@LaRC.NASA.gov>  
Error -- Nameserver error: Unknown host

Start of returned message

Received: from [129.57.33.169] by 129.57.33.169 with SMTP;  
Fri, 3 Jan 1997 14:35:23 -0500  
X-Sender: corneliussen@micro4.cebaf.gov  
Message-Id: <v01540b36aef30fd15751@[129.57.33.169]>  
Mime-Version: 1.0  
Content-Type: text/plain; charset="us-ascii"  
Date: Fri, 3 Jan 1997 14:35:26 -0500  
To: R.T.Layman@LaRC.NASA.gov  
From: corneliussen@cebaf.gov (Steven T. Corneliussen)  
Subject: Follow-up to that earlier letter  

>Date: Tue, 17 Dec 1996 08:46:04 -0500  
>From: corneliussen@CEBAF.GOV (Steven T. Corneliussen)  
>Subject: P-51 parentage, yet again  
>X-Sender: corneliussen@micro4.cebaf.gov  
>To: airspacedt@aol.com  
>Cc: abraslow@visi.net, hansejr@mail.auburn.edu,  
sts@Leland.stanford.edu  
>MIME-version: 1.0  
>  
>[cc's are to A. Braslow, J. Hansen, and W. Vincenti]  
>  
>December 17, 1996  
>  
>Letters to the Editor  
>  
>Air and Space Smithsonian_  
>  
>Dear Editor:  
>  
>     In my letter (December/January) about how the P-51 Mustang

Printed for "Richard T. Layman" <r.t.layman@larc.nasa.gov>
Those two messages that were got its remarkable wings, your editing transformed some ambiguous wording into a technology-history error. After National Advisory Committee for Aeronautics research engineer Eastman Jacobs innovated a mathematical airfoil-design method in the late 1930s, he needed a new kind of wind tunnel for developing the approach. Through politicking as shrewd as his engineering was original, he first obtained funding for an innovative low-turbulence tunnel, and then for a low-turbulence pressure tunnel. The latter combined low turbulence with test-accuracy-enhancing pressure capability. Your editing made me appear to cite a sequence of single-capability tunnels.

Wind tunnel historian Donald B. Baals divides growing midcentury tunnel technology into one new and two older branches. Besides the new low-turbulence tunnels, there were already high-speed tunnels and the pressure and full-scale tunnels that engaged the disparity between small-scale testing and full-scale flying. From the 1920s on, the versatile Jacobs had also helped nurture the two older branches.

Distinctions about these vital research tools are important if you believe, as I do, that it was not only skilled pilots and strong-willed industrialists who engineered the ascent of American aeronautics, but resourceful research engineers as well.

Steven T. Cornelius, Jr.
Poquoson, Virginia

202 Beach Road
Poquoson, VA 23662
Work: Cornelius@JLab.org; 757 269-7582
Home: Cornelius@pinn.net; 757 868-9658

cc:
Albert B. Braslow
James R. Hansen
Walter Vincenti
End of returned message
Absence of Malice

In his editorial "Double Whammy" (Viewport, Aug./Sept. 1996), George Larson says that critics of the Federal Aviation Administration envision smoke-filled back rooms in which FAA regulators and airline executives plot ways to undermine safety. You do not have to envision such collusion in order to believe that something is wrong with the current system of airline safety checks and balances. Malicious motives are not the concern. Deregulation produces competition, and competition results in risk, subtly introduced and accepted.

Larson says that businessmen don't want engine fires and smoking holes in the ground, that "if you manufacture airplanes or operate an airline in such a way that you crash a lot, you will soon be out of business." That's of little comfort to the families who have to attend closed-casket ceremonies.

The aviation industry has worked hard and long to engineer and regulate itself to an enviable level of safety, while costs to the consumer have continued to fall. What a shame it is that this progress is undermined by the FAA sitting idly by while substandard parts and procedures are introduced into the system.

The FAA should not be promoting competition at the same time that it is managing risk. The marketplace determines what kinds of financial pressures are placed on businessmen. Let the businessmen make business decisions. Let the FAA make safety decisions.

I am already making my own decisions, both in the travel agent's office and at the polls.

—Jim Herries
Redlands, California

Anyone Out There Against Safety?

Why should fees for air traffic control service be levied only against users (Viewport, Aug./Sept. 1996)? Everyone who has a vested interest in air safety should pay, including the non-air traveler who'd prefer not to have an airliner crash into his home.

—Alexis Victor Franco
Alamogordo, New Mexico

Mustang Memories

The Mustang certainly did have more than one contributor ("Who Made the Mustang?" Aug./Sept. 1996). Another one was then-Colonel Mark E. Bradley, who almost single-handedly added the extra internal tankage so important to the aircraft's range capability.

I have recently written some papers (the writer of your article, Peter Garrison, has copies) with two objectives. The first is to explain and quantify the Meredith

Strategic Air Command: 50th Anniversary

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Well-Adjusted Military Types Need Not Apply

For long-distance missions, the ideal astronaut may not be the toned, well-adjusted military type we usually associate with space travel ("The Loneliness of the Long-Duration Astronaut," June/July 1996). Better adapted might be a dreamy loner who is happiest with his nose stuck in a book. Or one of the millions who has years of experience living with one or two other people in a space no larger than a bathroom, far from home and family, experiencing mostly boredom or fear: penitentiary inmates.

—Robert Howard Berkeley, California

Aviation—It's a Small World

During World War II and the Korean police action, I served with the Navy and had the opportunity to fly from aircraft carriers and do aerial photography. I also did aerial photography as a civilian, producing work for real estate developers as well as in-flight portraits.

In your 10th anniversary issue, Chad Slattery's aerial photograph of airplanes arranged in an "X" (Sightings, Apr./May 1996) inspired me to attempt a similar photo. I have some airplane models that are in various stages of construction, and I set them out on some black plastic that would simulate a blacktop airfield. Not able to acquire the use of a helicopter, I shot from the balcony above our patio. I enclose the result [below].

—Stephen E. Kanyusik Sterling Heights, Michigan

Chad Slattery replies: I can relate. At age 12, I would put models of Russian airplanes atop a large glass patio table, crawl underneath, and shoot upwards to make the airplanes seem to be flying across the sky.

Dollars and Sensors

It's time the public knew what the "cheap" Clementine mission really cost. In "The New Millennium" (Aug./Sept. 1996) William Burrows acknowledges that the spacecraft's sensors had been developed through the taxpayer-funded Strategic Defense Initiative and Ballistic Missile Defense Organizations, but what he does not say is that this cost was $1 billion to $2 billion; amortized, some $300 million to $400 million of it was spent on Clementine.

—Saunders Kramer Gaithersburg, Maryland

Warning: Humor Ahead

In the last issue's Letters column, Mary Proko was irked by the sexual overtones in "Gossamer Wings" (Flights & Fancy, June/July 1996). I suggest she try reading with her eyes open. The article was an amusing parody of a bad romance novel. I of course had the benefit of enough intelligence to read the introduction, which made that clear.

Ms. Proko said that she "recently had to cancel subscriptions to Flying and Private Pilot because of articles and a drawing that featured sex." Does Ms. Proko have some rare allergy that will make her head explode if she sees mention of such activity?

—Lylah E. A. Hill Montclair, California

Correction

Aug./Sept. 1996 "Who Made the Mustang?" (1) The Doolittle raid on Tokyo was made in 1942, not 1941. (2) The first Merlin engine installed in the Mustang III, P-51B and C models, was rated at 1,670 horsepower; 1,650 was its displacement in cubic inches.

Address letters to: Letters, Air & Space/Smithsonian, 901 D St. SW, 10th Floor, Washington, DC 20024. Please type or print clearly. You must include your full address and daytime phone number.

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August 20, 1996

Mr. George C. Larson, Editor
AIR & SPACE/Smithsonian
901 D Street, SW - 10th Floor
Washington, D. C. 20024-2518

Dear George:

Thanks for your note regarding my letter to The Editor. I never intended to get so involved in the argument about the Mustang and was content to let Ed Schmued take credit for the design work, which he supervised very well. I had mentioned the Meredith Effect in print a couple of times, but it never seemed to register.

I knew Ed quite well and thought I had reasonable relations with him. After Ray Rice sent him to England during the war for liaison work for a short time, he was never quite the same. The British and our attaché, Tom Hitchcock, lionized him and he ate it up.

He was an under-age conscript in the Kaiser's Army and in poor health when mustered out. He never finished school and started a bicycle shop in Germany. He was always enterprising and got a job with General Motors Holden in Brazil and somehow got a transfer to the United States. Since General Motors had picked up an interest in U. S. Fokker, an antecedent of North American, he got a job there on a drawing board. He was one of about twenty in the Engineering Department, and I first met him in 1934 when I came to Baltimore from Douglas as Chief Engineer with Dutch Kindelberger.

The remnants of Fokker, General Aviation, and Berliner Joyce combined to form a nucleus for the restructured North American Aviation which Dutch headed and of which I became Chief Engineer. Incidentally, General Motors held some 30% of North American stock and effectively controlled the company until 1948.
Mr. George C. Larson  
August 20, 1996  
Page 2

Schmued was a good draftsman with a good mechanical sense and also a bit of an artistic flair. However, he knew nothing of aviation technology and was never near Messerschmitt in Germany.

When I realized that the true reason for the Mustang's speed advantage would never come out, I wrote the "Origin and Evolution of the Mustang" for two reasons. First, to make the point on the critical importance of the cooling drag and its ramifications, and second, to record the rather remarkable contribution of Dutch Kindalberger to the war effort.

Since he had been bringing me more and more into general management, in fairness to Raymond Rice and all concerned, my title was changed about the end of 1939 from Vice President and Chief Engineer to First Vice President. The Mustang initiative was my last technical leadership function during that period, and all the details of design and analysis were under Ray Rice's supervision and, as I have said, very conscientious and able leadership.

I hope this clarifies some of the rather baffling history bytes you are bound to hear.

Sincerely,

J.L. Atwood/ph
Thanks for the offer, but I already have the Dryden center history by Hallion; it's the supersonic flight book that I've kept out so long. At least, I think _On the Frontier_ is the title of the Dryden center history. But if I'm wrong, I'd LOVE to have a copy of the one I've got borrowed now in your name.

Your library books are full of yellow post-its with my notes on them. A project this week is to go to Stephens to xerox those pages, remove the post-its, and return the books maybe on Monday.

Thanks again for all of that.

Steve Corneliusen
269-7582 (note new exchange)
868-9658
home e-mail: corneliu@pinn.net
work e-mail: corneliussen@cebaf.gov

P.S.: You might be interested in a draft item I've sent to Jim Hansen and Al Braslow in advance of sending it to _Air and Space Smithsonian_: 

"Who Made the Mustang?" (August/September 1996) interestingly engages its title's question, but unfortunately omits a key name from the answer: Eastman Jacobs, the government research engineer -- some say genius -- responsible for the P-51's remarkable wings.

>From the 1920s, National Advisory Committee for Aeronautics researchers had sought to transform the wing design art into an effective engineering science. In the late 1930s, a turning point came at the NACA's Langley Memorial Aeronautical Laboratory, now a NASA center. Jacobs inverted a then-recent
theoretical approach to establish a powerful new computational tool. Airfoils could now be designed to have specific pressure distributions.

Next Jacobs needed a low-turbulence wind tunnel for tests involving the thin boundary layer of air next to the new shapes' surfaces. Here his genius extended to technopolitics: the terms "low turbulence" and "boundary layer" aroused no interest, but "wing icing" did. So Jacobs asserted an icing-research purpose, and the tunnel got funded.

The practical result: wings with superior high-speed characteristics, and capable also -- though only under ideal, nonoperational conditions -- of sustaining drag-reducing laminar flow. Jacobs's work is still used today. And in World War II, it contributed mightily to the success of the P-51 Mustang.
Figure 5. - Views of total head mounted in slipstream. North American XP-51 airplane.
Figure 5. - Views of total head mounted in slipstream. North American XP-51 airplane.
Figure 2. - Survey rake mounted behind test section of airplane wing. Original aileron shown. North American XP-51 airplane.
FIGURE 1. - FRONT VIEW OF NORTH AMERICAN XP-51 AIRPLANE.
FIGURE I. - FRONT VIEW OF NORTH AMERICAN XP-51 AIRPLANE.
Figure 2. - Three-Quarter Front View of North American XP-51 Airplane.
Figure 2. - Three-quarter front view of North American XP-51 Airplane.
FIGURE 3. - THREE-QUARTER REAR VIEW OF NORTH AMERICAN XP-51 AIRPLANE.
Figure 40. - Photograph of gun ports on leading edge of right wing of XP-51 airplane covered with doped fabric (clean wing).

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.
Figure 40. - Photograph of gun ports on leading edge of right wing of XP-51 airplane covered with doped fabric (clean wing).

Photograph by 27971

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA
**Figure 41 (A).** - Two 20-millimeter gun mock-ups installed on leading edge of right wing of XP-51 airplane.

**Figure 41 (B).** - Two modified 20-millimeter gun mockups installed on leading edge of right wing of XP-51 airplane.
Figure 41 (a). - Two 20-millimeter gun mock-ups installed on leading edge of right wing of XF-51 airplane.

Figure 41 (b). - Two modified 20-millimeter gun mockups installed on leading edge of right wing of XP-51 airplane.
petitive bidding basis. The prior system was dominated by the airlines of the holding companies who held 24 of the 27 routes available. In May of 1934, the air routes were open again to competing airlines under a new ruling which required that the airlines break all connections with the aircraft manufacturing business. At this time North American Aviation was reorganized as an aircraft manufacturing firm with the disposal of TWA and Western Airlines. Eastern Airlines was made a division of the company and was retained as such until 1938 when Eddie Rickenbacker and associates bought the airline from NAA.

The NAA company, reorganized in 1934 solely for the purpose of aircraft manufacture, was headed by James H. “Dutch” Kindelberger, former Vice President of Engineering for Douglas. Kindelberger was invited by Breech to lead the reorganized company. The plant leased at Dundalk, Maryland, was abandoned when Kindelberger moved 85 of the employees, bag and baggage, to Inglewood, California.

Kindelberger stopped all efforts at production of the transport type aircraft. He believed military contracts were the market potential for this new firm and that the military procurement system needed finished aircraft rather than paper proposals. Company money was expended on this theory rather than waiting for the circular proposals distributed from Wright Field. This idea sold many of the early production aircraft of NAA which would have been lost in the outmoded procurement system of the era. The vision, foresight and ability of the design team led by Kindelberger narrowed the odds in a gamble which established NAA as the largest aircraft manufacturer during the next decade with a production of more than 42,000 aircraft.

The first design which was sold in quantity after Kindelberger became head of NAA was a basic training airplane known as the BT-9. The first U.S. Army Air Corps contract for 42 aircraft provided the means to build a new modern plant in California. More than 250 of the BT-9 series were delivered during 1936, 1937 and 1938.

A refined development of this aircraft featuring retractable landing gear and a Wasp engine was presented as a follow-on of the BT-9. Air Corps budget limitations prevented procurement of the new aircraft as a basic trainer. The superior performance of the design prompted Kindelberger to promote its use as a basic combat trainer. This suggestion was acceptable to the Air Corps buyers and 275 examples were procured as the BC-1. The BC-1 would be developed into the famous Harvard and the AT-6 advanced training series aircraft. By 1940, increased orders for training aircraft inspired the BT-14 which was basically an uprated BT-9. RAF orders for these aircraft provided the NAA plant with a heavy production backlog. During this period the first NAA production bomber emerged as the B-25.

The development of the BC-1 type airplane led the way to a fighter design, designated as project NA-50, the 50th design by the NAA company. Components used in the airframe structure of the BC-1 were used to assemble the airframe of the new design. A Wright R-1820, nine cylinder radial engine was adapted to the firewall and an armament system of two machine guns of 30 caliber was fitted to the trainer airframe. Seven of these fighters were bought by the air force of Peru in the spring of 1939. The Wright engine and light airframe weight gave this aircraft a formidable performance.

A modification of this airplane with heavier armament capabilities was ordered by the air force of Siam in the summer of 1940 as the NA-68. Six aircraft of this type were built and shipped to that country in 1941. Commencement of World War II caused impoundment of these fighters before they could be delivered and they were used in Army Air Corps training schools as a fighter-trainer. For this role they were given the military designation of P-64. The NA-50 had been the only venture by the North American Company to produce a fighter type airplane and this had actually been an adaptation of an existing design for export.

The aircraft which would be developed from the British Air Purchasing Commission request of April, 1940, was established as project number NA-73. The first airplane was designated NA-73X and assigned a factory serial number 73-3097. The three view drawings and preliminary weight estimates which were used to secure the confidence of the British were presented by Kindelberger’s right hand man and Vice President of NAA, John Leland Atwood. Atwood spent three weeks in New York City in the converted hotel space utilized by the commission for its office. It was largely through his efforts that the agreement was reached to produce a new fighter in preference to the P-40. Air Purchasing Commission officials, Sir Henry Self, Air Vice Marshal G.B.A. Baker and Mr. H.C.B. Thomas approved the preliminary design May 4th of 1940.

In view of the fact that the North American Company had not produced a fighter airplane at this time, one stipulation was made at the time of the British contract. This required North American officials to secure all current data from the Curtiss design team on the latest P-40 developments. A unit price of 50,000 dollars was agreed upon and on May 29, 1940, the British placed an order for 320 NA-73 aircraft of the type depicted in the data submitted to the commission by Atwood. The name Mustang was then assigned to the fighter proposal, a procedure common with the British,
using a name rather than number designation for RAF aircraft. The name had been adopted from the drawings and performance estimates provided by the design team in the contract for the NA–73 fighter and no one could anticipate how appropriate this namesake would be. It was a name which would endure through all the versions and missions assigned to the sleek design which had been offered and still existed only on paper.

The original drawings had been prepared by a team led by Raymond H. Rice, chief engineer for North American since 1939. Rice had joined the company, established in Maryland, in 1935 and was among the group that Kindelberger moved to California in 1936. Prior to his appointment as Chief Engineer, Rice had worked as the Chief Structures Engineer and his ability and judgment were influential in all NAA designs of the period.

The chief design engineer assigned to the NA–73 project was Edgar Schmued. Schmued was born in Hornbach, Bavaria, and received his aeronautical and engineering training in Germany prior to 1925 when he left Germany to work for General Motors Aviation branch in Brazil. In 1930, Schmued arrived in the United States where he was employed by General Aviation and was absorbed with the force that became NAA in 1934.

Schmued was the designer who provided the first drawing of the aircraft which would become the Mustang. A profile and general arrangement with dimensions was established in these original drawings which was not changed until the power plant and canopy modifications of 1942 were evolved. Schmued worked closely with a new engineer assigned to aerodynamics, Edward Horkey. The Mustang was Horkey's first project and his staff pursued the mathematical "second degree curve development" that had not been used in aircraft design prior to this time. The position of project engineer was assigned to Herbert W. Baldwin, a draftsman who had worked with Keystone Aircraft, General Aviation and the Douglas Company.

The aircraft specifications had been established in the original drawings. The British added the armament requirements and the design team started the task of transforming the paper Mustang into a prototype aircraft, ready for flight in the allotted 120 days. The task at first seemed insurmountable but as the days merged with the nights and the weeks into the weekends, the team assumed an enthusiasm which knew no boundaries. From the outset the prime idea in the development of the prototype was to adapt all phases of construction to mass production. The assembly lines were organized and planned as each aircraft section was detail designed. The plant assembly areas were arranged in a manner similar to an automobile production line with the aircraft sub-assemblies moving through various stations for installation of respective systems and components.

Full scale templates were used by cabinet makers to construct a mockup which could be utilized to supply data for systems installations and dimensions for the engineers who were concerned with the plumbing of fluid systems and flight controls. The clean mold lines of the Mustang resulted in a fuselage of small dimensions and the mockup was an invaluable aid in locating the required equipment into the cubage available. Twenty-eight hundred drawings representing more than 60,000 man hours of effort by the design team were prepared for the construction of the prototype.

The ability of the design team to coordinate their plans with the shop people provided a system that was free of the problems usually associated with the development of a new airplane. The group was trying to accomplish in four months a feat which required as much as three years on other aircraft developed during the same period.

The basic design had made use of the V–12 inline power plant to provide a smooth nose and a frontal area of minimum drag. The calculations of the aerodynamicists required all foils and the fuselage to be blended into one smooth shape and a total drag factor was used in these calculations. To provide a faster airplane with improved performance, it was necessary to design the airframe with the least airflow resistance possible. The only known design factor during this phase was the horsepower available from the Allison engine which had been chosen.

Two basic but critical items were included in the second degree curve layout to provide a minimum of drag. These items were the placement and shape of the coolant radiator for the liquid cooled engine and the foil of the wing section. The location of the coolant radiator had been established in the lower fuselage area aft of the cockpit. Such a system was in use on the Hawker Hurricane fighter and had been tried on the Curtiss designs which led to the P–40. A development of the P–40, built as the XP–46, also used a rear radiator installation. The object of this feature was to establish this drag factor as far aft as possible on the fuselage and behind the wing foil.

Schmued and Horkey calculated that an aerodynamic duct formed at the entry and exit of the radiator could provide up to 300 pounds of thrust by utilizing ram air to eject the warmed airflow and thus overcome the drag offered to the fuselage by the duct itself. Several approaches had been made to "zero drag" cooling systems on European designs. Surface evaporation cooling systems used both on racing airplanes and military prototypes had proven impractical...
for combat airplanes. The radiator installation had to provide a minimum drag area but still be of sufficient size to cool the power plant. The location of the unit in the fuselage provided an airflow from the propeller slipstream during ground operation and taxi periods. Experience gained from the Spitfire and Messerschmitt fighters had shown that the wing mounted units were not of sufficient size and required ram airflow in flight to provide proper cooling. The location and duct design were approved for production, however. This part of the Mustang would not be so readily adapted and continual modifications were made in this area on later designs.

The wing section used on the prototype was suggested by Mr. A.C. Robinson of the N.A.C.A. and was known as a laminar flow airfoil. Robinson provided NAA with unpublished research data and a wing design was laid out conforming to the radical shape. The laminar flow theory had been known and studied for some time. An experimental racing plane of the thirties had used such an airfoil and gave tremendous performance.

The Laminar flow theory dealt with the development of a symmetrical airfoil section which had the same curvature on both the upper and lower surface. The design was relatively thin at the leading edge and progressively widened to a point of greatest thickness as far aft as possible. The theory in using an airfoil of this design was to maintain the adhesion of the boundary layers of airflow which are present in flight as far aft of the leading edge as possible. On normal airfoils the boundary layer would be interrupted at high speeds and the resultant break would cause a turbulent flow over the remainder of the foil. This turbulence would be realized as drag up the point of maximum speed at which time the control surfaces and aircraft flying characteristics would be affected. The formation of the boundary layer is a process of layers of air formed one next to the other, ie; the term laminar is derived from the lamination principle involved.

The use of this airfoil on the Mustang would greatly add to the drag reducing concept that was paramount in all design phases of the airplane. The few applications of this foil, prior to this time, had been hand-built structures which were finished to exacting tolerances. An absolutely smooth surface was necessary due to the fact that any surface break or rough protrusion would interrupt the airflow and detract from the laminar flow theory. Because of the exactness required, the foil had been shelved by other manufacturers due to the clearances and tolerances which are used in mass production. The engineers at NAA approached this problem with a plan to fill and paint the wing surface to provide the necessary smoothness. The foil which was used for the Mustang had a thickness ratio of 15.1 percent at the wing root at 39 percent of the chord. The tip ratio was 11.4 percent at the 50 percent chord line. These figures provided the maximum thickness area at 40 percent from the leading edge of the wing and resulted in a small negative pressure gradient over the leading 50–60 percent of the wing surface.

The Mustang was a mathematically designed airplane and the wing foil that was to be classified as a "semi-empirical venture" by the British was cleared for adoption on the new design. The wing section would be the only part of the fighter which would be tested in a wind tunnel prior to the first test flight. Due to the speculation of the success of the radical foil, the engineering department was committed to adopt a more conventional airfoil within thirty days of the tests in the event the wing did not come up to specifications. A one quarter scale model of the wing was designed and constructed for tests in the wing tunnel at the California Institute of Technology.

While the aerodynamics team proceeded with the wing design, work progressed with the fuselage section. The performance demanded of the NA–73 project made the adoption of the inline liquid cooled engine inevitable. The power plant available was the Allison V–1710 model known as the F3R which had been scheduled for current P–40D production. The F3R made first use of the spur reduction gearing feature by Allison. The choice of the inline provided the most power with least frontal area and resultant drag that was available from American manufacturers. The use of a liquid cooled engine in a combat aircraft had prompted criticism from the military due to the vulnerability of the airplane. In the event the slightest damage occurred to the coolant system, the plane and pilot could be lost as a result of engine overheating and eventual failure. The logic of producers using the inline engine was manifested in the performance of the clean airplane and the ability to out-maneuver the enemy in combat. An additional influencing factor was the success of the British and the German designers with the liquid cooled engine.

One of the design features of the first Mustang was the use of a cantilever engine mount of aluminum construction. The complete mount weighed less than 200 pounds and provided an attachment point for cowling, ducting and the two fifty caliber machine guns which would be synchronized to fire through the propeller arc. The factor which prompted the use of the new mount design was a result of the mass production concept. The complete engine assembly with accessories could be built-up for installation onto the fuselage frame at the appropriate assembly station.
The new mount provided considerable rigidity over the contemporary steel tubing type mounts used during the period.

The cockpit area and aft fuselage sections were developed from the cabinet makers' wooden mockups. All equipment required for the basic airframe systems in addition to British radio equipment, was fitted into the confined area. The resulting fuselage was a compact, well designed unit. The assembly consisted of three major fuselage sections; the engine mount, forward section and aft section. The sections separated at the firewall and the station behind the radiator air scoop fairing. The forward section was attached to the complete wing assembly at four points and the horizontal and vertical tail surfaces were fitted to the aft section.

The complete airplane was designed with plumbing and cable disconnects to facilitate assembly. The Mustang had to be built, test flown, disassembled and crated for shipment to England. The cockpit fairing consisted of a racing type windshield formed in one piece and a built-up frame work with glass panels adjacent to the pilot. A rear view panel was provided on each side of the fuselage aft of the cockpit, faired into the aft fuselage which was contoured into the vertical fin.

A mockup of the wing section was used to install and test the landing gear system. A novel design was fitted with fairing doors which would only be extended into the airstream during a cycle of the landing gear struts. A timing and sequence linkage was required to operate the fairing door enclosures on the main landing gear and was adapted with a cable and actuating rod system. The doors provided a smooth fairing over the retracted gear in flight and closed again after gear extension to allow a smooth airflow through the radiator scoop.

The landing gear handle featured three positions; up, down and emergency. The latter position could be used to force the down lock pins in place in the event of emergency extension. The aircraft hydraulic system used an engine driven pump, emergency hand pump and a time lag power control valve. The latter device could be selected to allow a pressure buildup for approximately 1.5 minutes to provide pressure for the actuation of hydraulically powered components. Sliding mechanical indicators were provided on the left forward side of the cockpit to follow the movement of the landing gear, wing flaps and coolant shutter.

The complete wing section was comprised of six sub-assemblies to facilitate production and provisions were designed into the left and right panels for two integral fuel cells of 85 gallons capacity each. The left hand tank was divided into two sections, the smaller of which held 32 gallons and was selective as a reserve tank. Outboard of the fuel tanks, a gun and ammunition storage bay was provided with space for three machine guns. The inboard mount was designed for a fifty caliber gun and the outboard positions were adapted for two 30 caliber guns. A large compartment between the two wing spars was used for ammunition storage and routing through feed-chutes from the removable trays to the respective weapons.

The integral fuel tanks were plumbed through a 4 position selector which functioned as a shut-off valve. This valve allowed selection of the right and left wing tanks and the reserve tank to route fuel to the firewall mounted electric booster pump. The wing sections were designed to be assembled into a right and left panel and assembled together with the left hand panel butt rib forming a center junction for the completed wing.

The stabilizer, fin and wing tips of the Mustang were to be squared off, primarily to facilitate mass production. The mathematical calculations used in design and previous aircraft tests indicated that the use of the laminar foil adapted to the square tip planform with a lesser degree of turbulence being present than with a curved profile. An unknown factor existed in the wing tip area in regard to the stalling characteristics. When the first wing test was completed in the wind tunnel the results caused elation among the exhausted crew. The wing had been tested up to the transonic speed range and had indicated a drag factor of less than 50 percent of any previously tested. A subsequent test with silk tufts secured to the surface revealed a violent stall tendency in the tip area and the disheartened designers went back to the drawing boards. After a week of calculations and minor modifications, the model was again tried in the tunnel. The same result caused an investigation of the tunnel characteristics and the possibility was considered that the tunnel might be too small for the airflows needed for accurate testing. Arrangements were made to airlift the wing model to a laboratory at Seattle, Washington, where a larger facility was available. This time the wing performed according to calculation and the production order was issued for a flight model.

The timing of the tests and the efforts of the mock-up engineers blended into a coordinated schedule that allowed the completed assembly of the airframe to be finalized in just nine weeks. Large castings for the landing gear attach points had to be contracted to another manufacturer and a member of the team was assigned to follow up and bring the units to the plant while they were still warm from the molds. The multiple disc wheel brake assemblies had been ordered from a brake manufacturer and were still not available.
Aircraft Dimensions and Statistics

The Mustang aircraft maintained a continuity of dimension throughout its progressive development until the appearance of the P-51H. The major dimensional change occurred in the earlier models with the installation of the bubble canopy and the dorsal fin. The most noticeable difference between models was the increase in total weight when loaded for combat as the Mustang progressed through development.

The semimonocoque fuselage was constructed entirely of aluminum alloy. Four main longerons, two upper and two lower, comprised the basic structure of the main section. Formers were placed to maintain fuselage shape and covered with 24ST aluminum alloy sheet stock which was flush riveted in place. The rear section of the fuselage was built on two longerons, a flat shelf and bulkhead. The formers were covered with flush riveted skin similar to the main section. Forward and aft radiator air scoop housings were fitted under the main section and the aluminum alloy engine mount was fastened to the firewall on the main section by four bolts. Formers were fitted to the engine mount to maintain shape and provide attachment for the removable cowling assemblies.

The full-cantilever wing assembly was constructed around a main and aft spar. Forty-two pressed ribs were fitted to maintain the laminar flow shape and a center rib was used to join the two main panels. Extruded stringers were fastened to the ribs and covered with flush riveted aluminum sheet stock. Box sections were formed between the spars by using rib form to provide space for the armament installation, retracting landing gear and fuel tank compartments. Removable wing tips, metal covered ailerons and plain trailing flaps completed the wing assembly.

The one piece horizontal stabilizer was constructed of a forward and aft spar, flanged ribs and extruded stringers covered with alclad sheet stock. D stringers were fitted to the lower surface to re compression. Removable tips were attached by screws and fabric covered elevators were secured with five hinge bearings. The elevator assemblies were interchangeable and featured static and dynamic balancing through cast lead weights fastened to leading edge of the surface. The horizontal stabilizer was attached to the fuselage aft section by four bolts.

The vertical stabilizer used a forward and aft spar, flanged ribs and an alclad sheet stock covering. Aft spar contained mounting provisions for a lead last weight which varied in size with different Mustang models. The fin tip was not detachable and the fabric covered rudder was attached to three hinge bearings and was dynamically balanced with two lead weights on the leading edge. Grade A mercerized cotton fabric was hand stitched to the metal leading edge.
the rudder and elevator assemblies. Phenol fiber tabs were fitted to all movable control surfaces and attached with three hinge bearings. Flight control cables were pre-formed tinned steel. Many surface control cables used die-swaged terminals and the secondary surfaces used sweat soldered or woven spliced connections.

The aircraft electrical system was powered by a G-1 24-volt storage battery rated at 34 amperes. A 100-ampere engine driven generator maintained the system which used a single wire aircraft ground. The open wire harnesses were supported and insulated as necessary and the engine compartment wiring was shielded and supported by rigid and flexible conduits. An external power receptacle on the right side (left side on D-30NT and P-51H aircraft) of the fuselage aft of the wing provided a connection for auxiliary power for maintenance and engine start in cold weather.
### Table 1 - Aircraft Dimensions

#### Fuselage
- **overall length**: 32 ft. 2½ in. (P-51H 33 ft. 4 in.)
- **frontal area of fuselage**: 13.4 sq. ft.

#### Wing
- **span**: 37.03 ft.
- **area**: 235.75 sq. ft.
- **root chord at center of airplane**: 103.99 in.
- **tip chord at 215 in. station**: 50 in.
- **taper ratio**: 2.16 to 1
- **aspect ratio**: 5.815
- **incidence at root**: 1°
- **dihedral at 25% line**: 5° (mean of upper & lower surface)
- **sweepback at leading edge**: 3° 35' 32" (P-51H 3° 39' 33")
- **washout at tip**: 0.81 sq. ft.
- **mean aerodynamic chord**: 79.6 in. (P-51H 80.17 in.)
- **leading edge MAC location relative to leading edge wing at root chord**: 8 in. above 6.1 in. aft.
- **airfoil section**: NACA-NAA low drag minimum
- **modified 662-212 of 1944 pressure at 0.4 chord airfoil camber**: 0.165 at center line to 0.115 at tip

#### Wing Flaps
- **area-each**: 16.11 sq. ft. (P-51H 15.537 sq. ft.)
- **span**: 114.75 in.
- **chord**: inboard 23 in. outboard 17 in.

#### Ailerons
- **span-each**: 6 ft. 11½ in.
- **area including tab**: 6.7 sq. ft. (P-51H 6.35 sq. ft.)
- **trim/booster tabs**: 4 in. x 26¾ in.
- **area**: 0.73 sq. ft.

#### Horizontal Stabilizer
- **span**: 13 ft. 2 in. (P-51H 14 ft. 10.16 in.)
- **area**: 27.98 sq. ft. (P-51H 35.50 sq. ft.)
- **incidence**: 2°; ½° with metal covered elevator

#### Elevator
- **area of both surfaces with tabs**: 13.05 sq. ft. (P-51H 12.85 sq. ft.)
- **maximum chord behind hinge line**: 17 in.
- **trim tab size-each**: 4½ in. x 31½ in.
- **area**: 1.0 sq. ft. each tab
- **shielded horn balance area-both**: 0.24 sq. ft.

#### Vertical Tail
- **area**: 20.68 sq. ft. (P-51D 22.42 sq. ft. (P-51H 25.13 sq.)
- **fin area**: 9.98 sq. ft. (P-51D 12.01 sq. (P-51H 14.89 sq.)
- **rudder area w/tab**: 10.70 sq. ft. (P-51D 10.41 sq. (P-51H 10.24 sq.)
- **length**: 74¼ in.
- **rudder tab size**: 5½ x 22 in.
- **area**: 0.81 sq. ft.
- **maximum chord behind hinge line**: 26 in.
- **fin offset**: 1°

#### Surface Control Movement
<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Mustang I, P-51</th>
<th>Mustang IA, A-36</th>
<th>Mustang II and P-51A</th>
<th>Mustang III and P-51B/C</th>
<th>Mustang IV and P-51D/K</th>
<th>XP-51F</th>
<th>XP-51G</th>
<th>XP-51J</th>
<th>P-51H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement</td>
<td>25° up 30° up 25° down</td>
<td>travel</td>
<td>30° left 30° right</td>
<td>30° left 30° right</td>
<td>30° left 30° right</td>
<td>30° left 30° right</td>
<td>10° up 10° up 10° down 10° down</td>
<td>10° down 10° down</td>
<td>15° left 15° right</td>
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<tr>
<td>reverse boost tab moved 18° to right</td>
<td>12° to left with full rudder deflection.</td>
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<tr>
<td>aileron</td>
<td>10° up 10° up 10° down 10° down</td>
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<tr>
<td>rudder</td>
<td>8° left 10° left 8° right 15° right</td>
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<tr>
<td>booster tabs were geared at 0.48° of travel to 1° of all travel.</td>
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<tr>
<td>wheel base</td>
<td>142 in.</td>
<td>142 in.</td>
<td>133 in.</td>
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</tbody>
</table>

#### Aircraft weights
- **Mustang I and XP-51**: 5,990 lb
- **Mustang IA and P-51**: 6,450 lb
- **A-36**: 7,240 lb
- **Mustang II and P-51A**: 6,800 lb
- **Mustang III and P-51B/C (without fuselage tank)**: 7,010 lb
- **Mustang IV and P-51D/K**: 7,635 lb
- **XP-51F**: 5,635 lb
- **XP-51G**: 5,750 lb
- **XP-51J**: 6,030 lb
- **P-51H**: 7,148 lb
1/60th scale of stations diagram for P-51D
F-6 photo ship data

Aircraft weights increased by approximately 100 pounds with the installation of two cameras and the necessary fittings. Most F-6 modifications retained full armament capability and as a result, would weigh slightly more than the fighter counterpart when fully loaded.

NAA cost to produce the Mustang was $26,741. Profit and government furnished equipment brought this figure to $58,698 in 1942. Mass production techniques reduced the total price to $50,985 by 1945. Cost was based on airframe weight of 4800 pounds at $3.59 per pound. The P-47 compared at $5.75 per pound and the P-63 at $6.74 per pound. The Mustang structure was comprised of 36,000 parts. Three hundred additional items were furnished as government equipment. 25,000 rivets were used in construction.

Table 2... Propeller Installation

<table>
<thead>
<tr>
<th>aircraft model</th>
<th>propeller</th>
<th>type</th>
<th>diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustang I NA-73, AG345 to AG367, and AG369 to AG377</td>
<td>Curtiss 3 blade, #614CC1.5-18, electric steel blades</td>
<td></td>
<td>10'6&quot; high pitch 58°; pitch 23°</td>
</tr>
<tr>
<td>Mustang I, NA-73, 83, Mustang IA, &amp; P-51 A-36, P-51A, and Mustang II (AG368 and AG378 and subsequent Allison installations)</td>
<td>Curtiss 3 blade #C.532D-F.32/ electric 50700; aluminum blades adaptable for de-icing provisions</td>
<td></td>
<td>10'9&quot;</td>
</tr>
<tr>
<td>P-51B/C and Mustang III</td>
<td>Hamilton Standard 4 blade, cuffed 24D50-65</td>
<td>hydromatic</td>
<td>11'2&quot; high pitch 65°; pitch 24°</td>
</tr>
<tr>
<td>P-51D and Mustang IV, P-51M (1)</td>
<td>Hamilton Standard 4 blade, cuffed 24D50-87 or -105</td>
<td>hydromatic</td>
<td>11'2&quot; high pitch 65°; low pitch 23°</td>
</tr>
</tbody>
</table>

Later versions of this propeller used de-icing provisions and a square tipped blade without cuffs was used on production.

blade # J-6523A-24 used Shank cuffs with de-icing (-105)
# K-6523A-24 used Shank cuffs (-87)
# 6547A-6 blades did not feature cuffs or de-icing provisions. The low-pitch ar on this blade was set at 22 when used with the V-1650-3 engine.

<table>
<thead>
<tr>
<th>P-51K and Mustang IVA</th>
<th>Aeroproducts, 4 blade, A-542-A1</th>
<th>Unimatic</th>
<th>11' high pitch 57.8°; low pitch 22.8°</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-51H, second XP-51G and XP-51J</td>
<td>Aeroproducts, 4 blade, A-542-B1 or B2</td>
<td>Unimatic</td>
<td>11'1&quot; high pitch 58°; low pitch 23°</td>
</tr>
<tr>
<td>XP-51F</td>
<td>Aeroproducts, 3 blade hub #H20-156, blade #H20P-156-23-M5</td>
<td>Unimatic</td>
<td>11'</td>
</tr>
<tr>
<td>XP51G</td>
<td>Rotol (British) 5 blade</td>
<td>oil operated hydraulic</td>
<td>11'</td>
</tr>
<tr>
<td>P-82</td>
<td>Aeroproducts, 4 blade, left hand-A-542F-D1 right hand-AL-542F-D1</td>
<td>Unimatic full feathering (89°) or electric de-icing provisions</td>
<td>10'11&quot; left hand; 10'11½&quot; right hand</td>
</tr>
<tr>
<td>experimental Mustang III FX953 Boscombe Down, England (April, 1945)</td>
<td>Hamilton Standard, 3 blade #23E50-495</td>
<td>hydromatic</td>
<td>11' high pitch 57°; low pitch 24°</td>
</tr>
</tbody>
</table>

flight tests indicated no appreciable change in performance with the three bladed propeller.
Table 3—Power Plants

<table>
<thead>
<tr>
<th>aircraft model</th>
<th>engine</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mustang I NA-73 and</td>
<td>Allison V-1710-39 # F3R</td>
<td>used in first production 770 a/c</td>
</tr>
<tr>
<td>Mustang I A, P-51,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA-83, Mustang IA, P-51,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and F-6A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-36</td>
<td>Allison V-1710-87 # F21R</td>
<td>production A-36, 500 a/c</td>
</tr>
<tr>
<td>P-51A, Mustang II</td>
<td>Allison V-1710-81 # F20R</td>
<td>production P-51A, 310 a/c</td>
</tr>
<tr>
<td>and F-6B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-51B-1NA, -5NA</td>
<td>Packard built Rolls-Royce</td>
<td>high altitude Merlin</td>
</tr>
<tr>
<td>P-51C-1NT, Mustang III,</td>
<td>Merlin V-1650-3</td>
<td></td>
</tr>
<tr>
<td>XP-51F, Mk 20 CA-17</td>
<td>Packard Merlin V-1650-7</td>
<td>medium altitude rated</td>
</tr>
<tr>
<td>P-51B-10NA, -15NA;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-51C-5NT, -10NT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mustang III and F-6C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-51D, all blocks</td>
<td>Packard Merlin V-1650-7</td>
<td></td>
</tr>
<tr>
<td>Mk-20 and 21 CA-18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-51K, all blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mustang IV, IVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-6D and F-6K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XP-51G</td>
<td>Rolls-Royce Merlin Mk 100 R.M. 14 S.M.</td>
<td>development engine</td>
</tr>
<tr>
<td>XP-51J</td>
<td>Allison V-1710-119</td>
<td>shaft driven blower, experimental</td>
</tr>
<tr>
<td>P-51H, all blocks</td>
<td>Packard Merlin V-1650-9</td>
<td>water injection high altitude engine</td>
</tr>
<tr>
<td>P-51M</td>
<td>Packard Merlin V-1650-9A</td>
<td>Simmonds automatic boost control</td>
</tr>
<tr>
<td>P-51L</td>
<td>Packard Merlin V-1650-11</td>
<td>P-51D with V-1650-9 engine without</td>
</tr>
<tr>
<td>Mustang Mk 22 and</td>
<td>Merlin 66 and 70</td>
<td>the water injection system</td>
</tr>
<tr>
<td>Mk 23</td>
<td></td>
<td>uprated -9 engine, orders cancelled after V-J Day</td>
</tr>
<tr>
<td>Mustang X</td>
<td>Rolls-Royce Merlin 61/65/70</td>
<td>Commonwealth Aircraft Corp. Australian</td>
</tr>
<tr>
<td>XP-82</td>
<td>Packard Merlin V-1650-11/21</td>
<td>production – 80 a/c used the Merlin 66 and 70 engine.</td>
</tr>
<tr>
<td>P-82B, C, D</td>
<td>Packard Merlin V-1650-23/25</td>
<td>Mustang Mark I a/c adapted to the British Merlin engine at Hucknall ’42</td>
</tr>
<tr>
<td>P-82E, F, G, H</td>
<td>Allison V-1710-143/145 # G6R/G6L</td>
<td>“two stage” supercharger</td>
</tr>
</tbody>
</table>
The North American XP-51 ... the very first Mustang delivered to the United States' government. Now owned by the EAA Air Museum, it is expected to be flying at Oshkosh this summer.

The Alpha and The Mustang
By Paul H. Poberezny

TODAY, A BEAUTIFULLY restored Northrop Alpha hangs from the ceiling of the Smithsonian's new National Air and Space Museum building ... and the very first North American P-51 Mustang delivered to the United States government is in a shop in Fort Collins, Colorado, nearing the completion of a very thorough restoration.

Seemingly unrelated, the paths of these two aircraft crossed a number of years ago and though none of the persons involved realized it at the time, the die was then cast for the future disposition of these two famous aircraft. It all came about through the friendship between myself and Foster Hannaford, Jr.

Foster was one of the very early members of EAA and attended many of our early fly-ins in Milwaukee and later in Rockford. At that time he owned the rights to the Rose Parakeet and had purchased the jigs, many parts, fixtures and several aircraft. He asked if I knew of someone who could take the drawings and bring them up to date so he could offer the design to the homebuilder as the Hannaford Bee. I made arrangements for Stan Dzik of Milwaukee to get together with Foster and they eventually consummated a deal. Dzik would draw up new plans in exchange for a 65 horsepower Parakeet ... or Hannaford Bee. This was accomplished over a period of several years.

During these early days Foster used to tell me about the various aircraft he had — several Northrop Alphas, a Jenny plus many engines, parts, machine guns and artifacts from the old days of aviation. Though he talked quite often about these items, I think most people never took him seriously — since no one ever saw them.
Foster seemed to drift in and out of aviation. We would see him on occasion at a fly-in or at a chapter meeting, or once in a great while at Headquarters. Other interests obviously occupied a portion of his time. Stan Dzik's beautifully drawn plans, for instance, were never sold. Although Foster received many inquiries and checks, he returned them and, gradually, the project drifted into oblivion. I am sure the drawings must still be somewhere in his personal effects.

I remember talking with Foster at the Burlington Airport some years back and during the conversation he stated that he had several Citabrias, Cubs, an old Waco and a German glider. This, too, was passed off with little thought. During this same period, my visits to the National Air and Space Museum and, in particular, their storage facility at Silver Hill, Maryland gave me the opportunity to see the many World War II aircraft in our national collection. At that time most were in crates and many were outside in the weather. Having been a fan of the P-51 Mustang since the beginning of World War II and having flown some 1400 hours in the P-51 (including the Models A, B, C, D and H), it was only natural that the sight of the once beautiful XP-51 in a warehouse at Silver Hill would attract from me more than the usual amount of attention. I am sure a number of the fine people of the Hill would attract from me more than the usual amount the Model's effects that had belonged to their son. I remember when asked if I could take something out of the trunk — something he would like to give to the EAA Museum in appreciation for our help in evaluating the materials his son had left.

Ben Owen of our staff went to the car and returned with a like-new Vickers aircraft machine gun. The Senior Hannafords and I discussed the problem and, along with Dick Wagner, traveled to Burlington. There we entered a small building, which had been used in connection with Foster's vending machine business, and were quite surprised to see a great deal of aircraft material — woods, tubing — hand tools, an old Waco cabin and, downstairs, a like-new J-3 Piper Cub.

A trip 30 miles further south brought us to a barn full of aircraft materials. Yes, there was a Jenny with fabric still on the wings, rotary engines, wing panels, cowlings, parts for a Northrop Alpha, engine cowling for a Ford Tri-motor and boxes and boxes of new Curtiss OX-5 parts. It was like being a blind dog in a butcher shop!

Still another hour's drive to a beautiful community in north Chicago brought us to the back yard containing the two Northrop Alphas Foster, Jr. had talked about. In a garage were a wing for a Jenny, shop equipment and a like new centersection for an Alpha. Another attached building contained propellers, carburetors, magnetos, etc. Yes, Foster had been right in his descriptions of the aviation artifacts he had stored away.

A cup of coffee with Mother and Dad Hannaford disclosed that Foster had also been quite a gun collector and had left a room full of all types. It was Mr. Hannaford's wish that the Jenny and the Northrop Alphas go to the EAA Museum, and we can well remember our pleasure in picking up all these parts and aircraft.

The Northrop Alphas were taken to EAA's Burlington, Wisconsin site and stored there along with many other parts and pieces, waiting for a day when they could be restored. The Jenny was brought to Headquarters and since has had the fuselage completely restored. The airframe, minus fabric, is presently on display to the public.

It was a little over a year ago when the National Air and Space Museum contacted us, asking if there might be a possibility that EAA would consider trading one of the Alphas for the XP-51. They had tentative arrangements with TWA, the former owner of the Alphas, to have

The Northrop Alpha suspended in the new National Air and Space Museum in Washington. It is to be opened to the public on July 4.
one of the historic aircraft restored in the airline's maintenance shop in Kansas City for permanent display in the new Air and Space building in Washington. A portion of the new edifice would be devoted to a history of air transportation and the Alpha, as the first example of a modern, all metal, monocoque transport aircraft, would be a key aircraft in a historical sequence that would include a Boeing 247, a DC-3 and others.

An agreement was reached in which the EAA Air Museum Foundation would give TWA permission to restore an Alpha, at which time the title would be transferred to the National Air and Space Museum in exchange for title to the XP-51. Shortly afterwards, TWA's semi arrived in Burlington... on a wintry, snowy day... to pick up the Alpha remains. Their crew was headed by Dan McGrogan — not surprisingly a long time EAA member!

At about the same time our Air Museum crew was bringing the XP-51 to Hales Corners from Silver Hill. The aircraft was inspected for corrosion, the paint was removed and a plan formulated to put this the most famous of all fighters back into the air. Darrell Skurich of Ft. Collins, Colorado, who is well known for his expertise in the restoration of World War II fighter aircraft, was selected to complete the task.

The airframe was shipped to Ft. Collins via semi truck and the engine, an early model Allison, was sent to METMA engine overhaul service in Minneapolis, which specializes in this particular engine series. It was overhauled and brought up to the most modern configuration — for the sake of safety and durability. Mr. Fred Young, president of Young Radiator, who has manufactured radiators for aircraft and other equipment for many years, took personal interest in the project and agreed to completely overhaul the all-important engine coolant radiator. Mr. Young was a pilot in World War I and has never lost his fascination for aviation.

Close-up of the freshly majored Allison. John Sandberg's shop in Minneapolis did the work. The engine installation of the P-51 prototype was engineered by famous race pilot Art Chester.

Presentation of a photo album on the Northrop Alpha to Foster Hannaford, Senior. Left to right, Mrs. Foster Hannaford, Jr., Foster Hannaford, Senior, Gene Chase, Director of the EAA Air Museum and Libby Hannaford, daughter of the late Foster Hannaford, Jr.

The Alpha during restoration in TWA’s maintenance facility in Kansas City.

Morton Lester, one of our EAA Air Museum Foundation Trustees, had previously mentioned in passing that he had purchased several war surplus propellers many years ago and wanted to donate them to the Museum. It turns out that one was a brand new propeller for the XP-51 — still in cosmoline. Another was an even more rare find, a propeller for the Grumman Duck the Museum owns.

Under the skilled hands of Darrell Skurich, the XP-51 will be back in the air in time for Oshkosh. In a little less than the one year that was originally estimated, the aircraft will again be in the same condition as when it was rolled out of the doors at North American. This aircraft, the fifth production P-51 built and the first delivered to the U.S. government, is truly a piece of history. Though its original color was plain aluminum and sporting a rudder with red, white and blue stripes typical of the immediate pre-war period, the aircraft was received by the EAA Air Museum in OD. It was elected to put the aircraft back into its original silver color, however, with the nicks and scratches the plane had accumulated over the years, it would have been impossible to polish it out to the standard we would have wished for such a historic airplane. So, it was decided to paint it in silver and AlumiGrip. The paint is being donated by Charlie Day of San Angelo, Texas.

One of the most fortunate things that has happened has been locating the NASA (then NACA) test pilot whose name appears on almost all of the pages of the log book, John P. Reeder. The XP-51 spent most of its active career as a research aircraft at Langley Field in Virginia. Mr. Reeder was the man who did most of the flying. He is still with NASA at Langley Field and has supplied a lot of material about the good ol’ days and the test flying of the aircraft. He will be with us at Oshkosh for three or four days this year. A Monocoupe owner, he is a sport aviation enthusiast and is interested in aviation history — because he helped make a lot of it. He has located a number of pictures of our XP-51 and we are still searching for others. ... any other person who may have history of this aircraft to share with us. We would like to assemble a book as a tribute to the aeronautical engineering, the hard work and enthusiasm that went into the making of this famous fighter that contributed so much to war effort and to the advancement of aeronautical knowledge.