Voodoo makes its first record pass while API owner Joe Clark (blue t-shirt) watches. (Scott Germain)

VOODOO'S WING OF SPEED

HOW ADVANCED AERODYNAMICS FROM API MODIFIED A P-51D FOR A NEW SPEED RECORD

STAFF REPORT

This view shows the modified *Voodoo* wing to advantage. (David Horn)

For aviation speed seekers, the Holy Grail of flight is the 3-km "Absolute Speed Record" as officially recognized by the *Federation Aeronautique Internationale* (FAI), the governing body for sport aviation airplane records. The 3-km straightaway record rules were initially established for the single category of piston engine propeller-driven airplanes. Later, with the advent of the jet engine, the rules were expanded to include new powerplant groups governing turboprop, pure jet, and rocket. FAI Class C-1, Group I, covers land-based piston-engine, propeller-driven airplanes and is the most coveted prize in sport aviation.

The most recent challenge to the title for C-1 class airplanes was successfully flown from a remote airfield near May, Idaho, on 2 September 2017 by Steven Hinton, in the Reno Championship modified P-51D Mustang racer *Voodoo.*

So, what is involved with such an effort? The two principal elements of physics that determine the ultimate speed of an airplane are thrust and drag. No newsflash here! The magic rests in just how these two opposing forces are resolved.

Once Hinton and the *Voodoo* air race team decided to go for the record, the focus became one of how to reduce airplane drag. Hinton approached Joe Clark, founder of Aviation Partners, Inc. (API), with the hope that the Seattle-based company known for its advanced technology winglets on Boeing 737 and other airliners might provide technical expertise in airplane drag reduction. Clark was subsequently persuaded to sponsor the record attempt and provide full support of API's engineering talent.

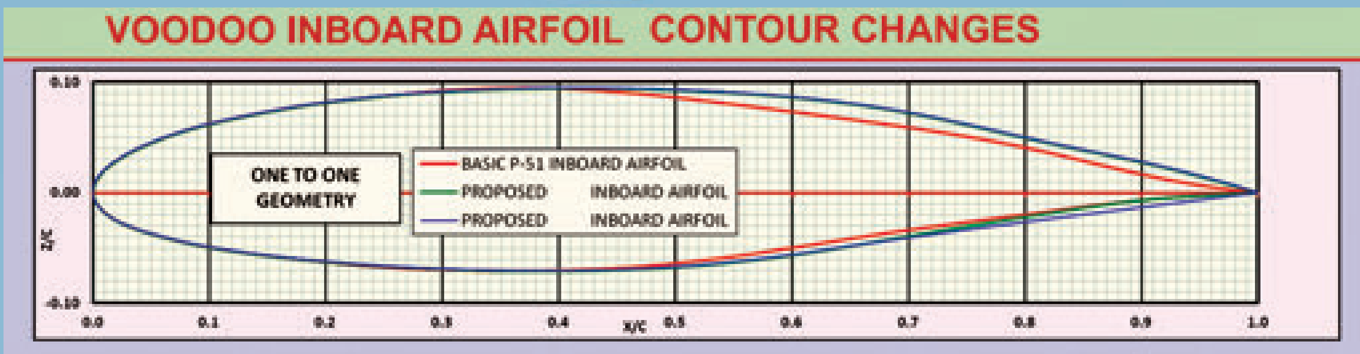
A little history is useful at this point. The original North American Aviation (NAA) P-51 Mustang wing design incorporated NACA high-speed 66-series airfoils. At the time, these airfoils represented the best shapes for reducing wing drag by preserving laminar boundary layer flow over a greater chord length than earlier designs. The NACA had some limited wind tunnel test data for the new airfoils but no full scale airplanes had flown with them. NAA's Mustang would eventually prove out the design. Much of the Mustang's impressive performance was directly linked to the wing design.

Now, some 75-years after the first flight of the XP-51, API was signed up to use its Computational Fluid Dynamics (CFD) technology to study the wing on *Voodoo* and attempt to reduce the associated drag. Aerodynamics engineer Danny Sikavi was assigned the task. The wing was removed from *Voodoo* and a laser survey of the wing surface was conducted to provide accurate geometry details for use in the CFD analysis.

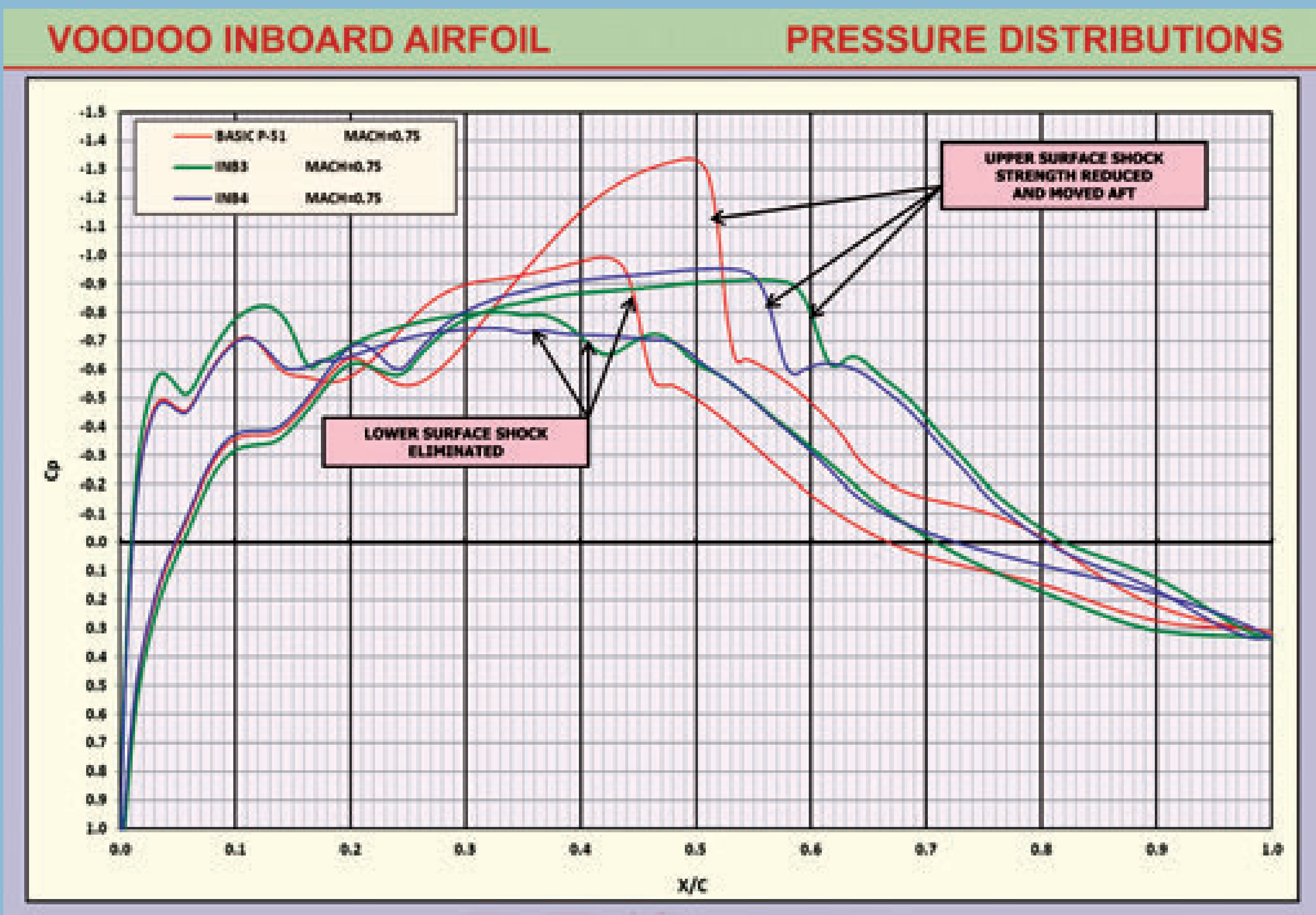
The analysis showed a significant exponential increase in wing drag at Mach 0.68 due to the formation of local shockwaves on the inboard portions of the wing. Danny knew that *Voodoo* would need to achieve a true airspeed of 550-mph at the proposed airport site at 5000-ft density altitude. This would equate to Mach 0.725!

CFD analyses provide detailed plots of wing surface pressures, which reveal the location and strength of drag producing

Voodoo flashes overhead with its Vintage V-12s' Merlin making a sound not quite heard before. (Scott Germain)



Airfoil showing the stock Mustang wing and the *Voodoo* wing. (API)



Graph showing *Voodoo's* inboard airfoil pressure distribution. (API)

shockwaves. Experienced aerodynamicists can use this information to reduce the formation of shockwaves by tailoring the local surface shape.

Danny's CFD analysis showed that the inboard wing airfoil shape deviated from the original NACA coordinates in order for NAA to provide increased space for the landing gear and fuel

The *Voodoo* wing under modification at Yolo Airport. (API)

tanks. The increased wing depth moved the point of maximum thickness further forward thus compromising the potential high-speed performance of the original airfoil design by introducing strong local shockwaves.

The dominant source of wing drag was identified. It was now up to Danny to design a new surface contour that would reduce or eliminate the shockwaves. An iterative design process using CFD was used to develop a contour that placed the point of maximum airfoil depth farther aft on the wing. The new contour shape also reduced the strength of the shockwaves to a point that the airplane would theoretically achieve the necessary design speed of 550-mph.

Furthermore, Danny's design would not require any structural changes to the wing.

The next step was to modify the wing. Using the geometry coordinates from the new CFD design, API machined thin high-density foam panels that were then bonded to the wing surface. The entire wing was then sealed and finished glass smooth. The wing was reattached to the fuselage and the racer was flown (in company with father Steve Hinton in a P-51D) to Joe Clark's Idaho ranch airport where, on 2 September, Steven Hinton flew the required four passes over the surveyed 3-km course at an average speed of 531.53-mph to achieve a new Class C-1e record and prove the value of the aerodynamics.

Congratulations to Steven and the exceptional *Voodoo* team! Also, our hats are off to Joe Clark and his engineers at API who can take pride in their associated technical achievement. **MI**