Virginia Aviation History Project Report

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The NASA F53

By Norm Crabill and Ron Smith, NASA Retirees

In the late 1970s, I (Norm) was Head of the Special Projects Office of the Flight Research Division at the NASA Langley Research Center. One of our flight projects was the Storm Hazards Program. We developed this program in response to a request from the National Transportation Safety Board to investigate the problems airliners were having in summertime operations in and around thunderstorms. Our search for a suitable vehicle to do this included a B57 at Langley, an F4 somewhere, and at NASA's Lewis Laboratory at Cleveland, Ohio a single seat F106A and a two seat F106B. I selected the F106 type for its configuration simplicity (no horizontal tail to come off in extreme turbulence) and its availability, since Lewis had no immediate plans for them. The B model provided a rear seat for an equipment operator and a better windshield and canopy design to withstand lightning effects. The aircraft was eventually flown to LaRC in January 1979, not without some problems. Over Richmond, in the face of falling hydraulic pressure, the ferry pilot blew down the landing gear and the RAM Air Turbine for back-up electrical power and successfully landed at LaRC. After he shut down on the ramp in front of the NASA hangar, the ramp was drenched with hydraulic fluid.

The Langley pilots complained to me about "the piece of junk" I had given them and said they would never fly it. I told them the airplane would be completely refurbished and hardened against the effects of lightning by consultant Andy Plumer of Lightning Technologies of Pittsfield, MA. And we did. Bob Peterson of the electronics shop completely redid all electrical systems and avionics, and Crew Chief Mike Klebitz reworked all other systems, including eventually a new engine, until it was in first class shape. We installed a 10 channel digital recorder with nanosecond time resolution on loan from the Air Force Weapons Lab at Kirkland AFB, Albuquerque, and flew it altogether in about 200 flights from 1979 through 1987, getting struck by lightning 700 times, including 72 times in 40 minutes over New Bern NC, a record. And the pilots loved it; they actually kept track of who got the most

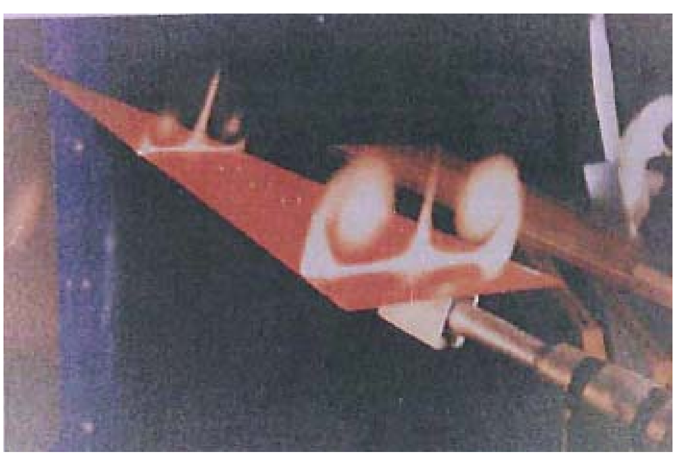

Figure 1 - Flow visualization showing two symmetric vortices on top of a 72 degree sweptback delta wing with no leading edge flap, as tested in the ViGYAN Low Speed Wind Tunnel by Dr. D.M. Rao

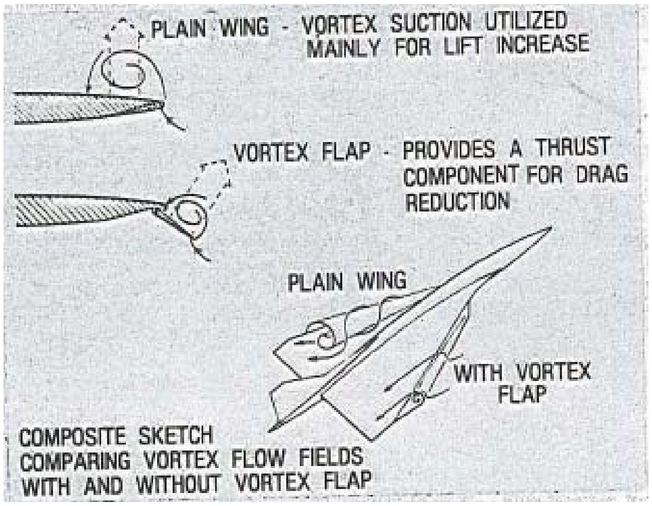

Figure 2 - The Leading Edge Vortex Flap Concept, courtesy Dr. Rao

strikes. Phil Brown, recently inducted into the Virginia Aeronautical Historical Society Hall of Fame, was the pilot on that record breaking flight.

So, what has all this to do with the "F53"? Well, we later got the F106A from NASA Cleveland and used it for spare parts for the F106B. At one time we had four F106's in the NASA Langley hangar, including one from the AFB at Minot ND that we hated to touch – it was the General's airplane and was in perfect shape. But we needed it for spare parts to keep the F106B flying.

One day, Ron Smith, one of my cohorts in the Special Projects Office, came into my office and asked if he could have the F106A, the second airplane we got from NASA Cleveland, for a wind tunnel project. I listened with amazement at what he wanted to do, and the innovative way he wanted to test the airplane in the Langley Full Scale Tunnel.

Here is Ron's story:

My history with the F106B began when I was at NASA Headquarters in the Systems Division, Military Technology Branch, and I was asked to review disposition of the two F106 aircraft at the NASA Cleveland Laboratory – either for research flights at Langley or at NASA's Flight Research Center in California. The plan for Langley's Storm Hazard Program as outlined by Norm was definite and made technical and timely sense, while FRC simply wanted the aircraft for some future, undefined, uses.

I recommended that the office responsible for the disposition of all NASA aircraft send it to Langley and so it was, arriving in January 1979.

In about 1982, I accepted a job in Joe Stickle's Flight Research Division at NASA Langley in Norm's Special Projects Office. I was interested in doing some flight test work on an idea that many Langley experts had recommended: a leading edge flap on a delta wing that would significantly improve the Lift to Drag ratio, leading to improvements in steeper climb-outs with reductions in takeoff noise and field length, maneuvering, and low-speed loiter characteristics. Projections, based on the work of NASA researchers like Dr John Lamar, Dr Neal Frink, and James Hallisy with Computational Fluid Dynamics flow models and model tests in wind tunnels, predicted improvements of as much as 40% on highly swept (40 to 70+ degree) wings. Figure 1 shows a visualization of

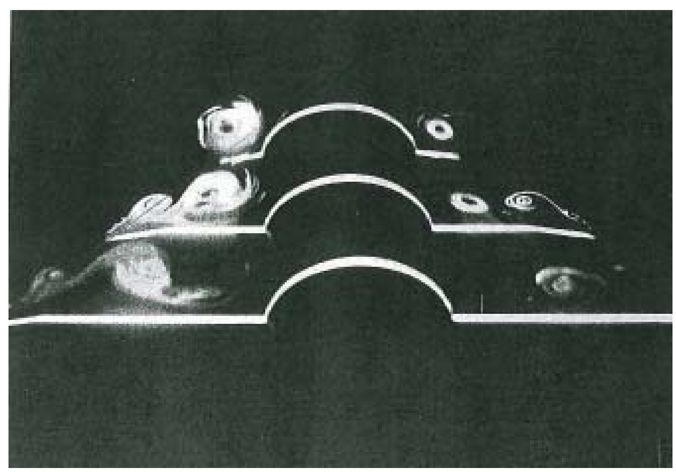

Figure 3 - Illustration of the multiple vortices on the top of a 60 degree swept delta wing model with leading edge flaps in a wind tunnel. The flow is from the top of the picture toward the bottom of this view. The white stripes running left-to-right (span-wise) show the position of the light sheet that also illuminates the vortices at three positions along the chord of the delta wing. Courtesy of Dr. Rao, ViGYAN.

flow over a 72 degree swept delta wing model in a wind tunnel, revealing two strong vortices; the pressure in these vortices is well below static pressure, contributing to the lift force. If these vortices could somehow be moved outboard onto a forward facing flap as shown in figure 2, these low pressures would provide a force acting forward, opposing the drag, and thereby increasing the Lift/Drag ratio.

Figure 4 - The F-53 in the Langley Full Scale Tunnel in 1984. That's NASA Engineer Long Yip standing next to it.

More tunnel tests on more moderately swept wings with leading edge flaps showed not just one vortex lying neatly on the Leading Edge flap, but multiple vortices. In figure 3, a view from the rear of a 60 degree swept delta at three positions along the wing-body configuration with a leading edge flap shows these multiple vortices, some affecting the flow over the leading edge flap.

A large scale proof-of-concept test was needed, and the F106B workhorse was ideal for that purpose. But before fitting such a device to the flight aircraft, I (Ron) proposed that we test it in a wind tunnel on the F106A we had for spare parts. The full-size airplane was too big for even the Langley Full Scale Tunnel, so I proposed we test half of it, mounted sideways on a platform in the tunnel. Which we did, see figure 4. That's NASA's Long Yip standing beside it, so you can see how even half of it fills the tunnel.

We eventually developed a flap configuration that gave significant improvements: L/D max went from about 6 to about 8.5. So we installed it on the F106B research airplane and test flew it, figure 5. Test pilot Phil Brown reported "…although pitch stability was reduced by adding the vortex flap,… the airplane has been, so far, only slightly more demanding to fly than the basic airplane and considerably easier to control than the simulator predicted. Final analysis of the flight data indicated a "…significant increase in sustained turn capability, e.g. an increase of 28% at Mach0.7…." [Chambers] However in-flight flow visualization techniques showed multiple vortices, with one originating ON the leading edge flap near the fuselage and migrating OFF the flap to run nearly DOWNSTREAM over the wing to the trailing edge, with another vortex originating farther along on the leading edge flap, and so on, along the entire leading edge. Figure 6 shows this in the flow patterns etched in an oil film on the flap and upper wing surface, similar to the flow pattern depicted in the model test shown in figure3.

Figure 5 - The Leading Edge Flap installation on the NASA F-106B parked on the ramp at NASA Langley Research Center in 1988. Tufts have ben installed to aid in flow pattern visualization.

Although the original analytical models predicted a single vortex would lie neatly on the flap as

Figure 6 - Flow patterns etched in an oil film on the flap and upper wing surface after a flight indicate multiple vortices originated on the flap and swept back over the wing, unlike the single vortex lying neartly on the flap as predicted by the early flow models.

depicted in figure 1, in the flight test with the multiple vortices the actual performance was very close to that predicted with the single vortex. "…These complex flow fields continue to challenge the capabilities of wind tunnels and Computational Fluid Dynamics …. [Chambers]

The final resolution of the Vortex Flap Experiment was that the flight tests gave confidence in the concept (even with the realities of the multiple vortices), but nevertheless we were too late to impact the next generation fighters, e.g. the F-22, as they went on to emphasize supersonic cruise, stealth, and supermaneuverability with vectored thrust.

The better knowledge derived from the flight test results and, later, comparison to the theory and model-derived estimates, made ready the tools of the technology of vortex control for that next generation aircraft at low speeds, even if not at transonic speeds .

Norm's closing remarks:

After the F106A was cut in half and tested in the Langley Full Scale Tunnel, I got a call from one of the pilots at NASA Cleveland, saying, if we were done with the F106A, they'd like it back for some flight test work they had in mind! After a moment, I said something like "…both halves?" and went on to explain the good use we had put that airframe to.

So, that's the story of the NASA F53 – it was one half of a Convair Delta Dart F106A!

The flight test airplane, the F106B, NASA tail number 816, is on display in the Virginia Air & Space Center in downtown Hampton Virginia, showing its use in both the Storm Hazards Program and the Vortex Flap Program. It is there for all to see.

Reference:

Chambers, Joseph R.: Innovation in Flight - NASA SP 2005-4539