Clarence D. Cone, Jr., Winglets and Clap and Fling

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The notice in *Flight International* 20-26 October, 2009 read

WINGLET PIONEER WHITCOMB DIES

OBITUARY Richard Whitcomb of winglet fame has died aged 89. Described as the most significant aerodynamic contributor of the second half of the 20th century, the NASA Langley engineer's major accomplishments include the area rule fuselage and supercritical wing designs. His development of winglets in the 1970s came after an article on birds led him to refine an existing concept.

What article, by whom, and what was the existing concept? Kathy Barnsdorff, of NASA media relations, says the story of Whitcomb's inspiration was oral tradition at NASA, and the tradition does not identify the article.

In 1962 Clarence D. (Don) Cone Jr. published "Thermal Soaring of Birds in the March 1962 issue of *American Scientist* (pp. 180-209). It described how the wingtip feathers of vultures separate themselves vertically when the birds glide slowly, the forwardmost feather being highest, the rearmost feather lowest. "The Soaring Flight of Birds," also by Cone (*Scientific American*, April, 1962, pp. 130-140), has a drawing of a gliding vulture that shows the vertical separation of the tip feathers.

Because of the vertical separation, the tip vortices of the feathers are separated vertically, which reduces the induced drag. Without the vertical separation, the vortex of the second feather would form in the vortex of the first, and if of equal strength would result in a vortex with twice the constituent velocities and four time the energy. Were there seven feathers in all, the energy of the resulting vortex would be something like 49 times that for a single feather rather than 7 times in the case of vertically-separated feathers.

In early 1975 I had become interested in induced drag, and got in touch with Cone, who, in a southern accent on the telephone (I never met him), explained that he was now working "in the cancer area." He sent me NASA Technical Report R-139 (dated 1962, published 1963) "The theory of induced lift and minimum induced drag of nonplanar lifting surfaces," one of which had vulture-like, vertically-separated "feathers" at the tips.

When winglets first appeared, two per wingtip, the first pointing down, the second, longer one pointing up, I felt that I had been there before, so I wrote to Whitcomb about Cone's work.

In a reply letter to me dated Aug. 4, 1977, Whitcomb wrote "C. D. Cone's paper on 'Thermal Soaring of Birds' in *American Scientist*, was extremely interesting. Also his technical report [NASA R-139] on 'The Theory of Induced Lift and Minimum Induced Drag of Nonplanar Lifting Systems,' gives the best description of the physical phenomenon involved with nonplanar systems."

Whitcomb went on to say that later NASA work suggested that Cone's analog method of calculating induced drag was invalid, his results for reductions in induced drag were too large, and that NASA research on non-planar wings started before Cone. (Vertical plates on wingtips, oriented fore and aft, had been around for a long time. Louis Garami's "Strato-Streak" model airplane had them in the forties.)

The sequence in Whitcomb's letter could fit the obituary's, "an article on birds lead him to refine an existing concept," and gives no suggestion that the article on birds was by someone other than Cone. Further, I know of no other article on birds that talked about non-planar wingtips.

(As a side issue, Whitcomb went on, "I share your concern about the pressure drag of the separated tip feathers of birds. The feathers undoubtedly increase the lift coefficient somewhat but this effect would probably not be sufficiently great to justify their presence," and he wondered if the rough surface of feathers had unexpectedly low skin drag. *I. e.*, winglets are good for airliners but it is hard to see why they are good for birds, which fly at low Reynolds numbers where the even lower Reynolds numbers of separated tip feathers would give them very high drag. He held the same opinion years later, on the only occasion when I actually met him.)

Returning to *Flight's* obituary, I would have written "His development of winglets in the 1970s came after an article on birds, most likely by NASA aerodynamicist Clarence D. Cone, Jr., led him to refine an existing concept."

Clap and fling

Now go back in time. In 1973 Professor Torkel Weis-Fogh of Cambridge University in England proposed a novel mechanism of flight in which a hovering or slow-flying insect or bird would clap its wings together over its back and then fling them apart, leading edges starting first, with the result that lift would build up very quickly, the "bound vortex" of each wing, necessary for lift, being the "starting vortex" of the other. He called the mode "clap and fling" ("Quick estimates of flight fitness in hovering animals, including novel mechanisms for lift production." *J. Exp. Biol.* [1973], **59**, 169-230). M. J. Lighthill provided calculations on the mechanism ("On the Weis-Fogh mechanism of lift generation." *J. Fluid. Mech.* [1973], **60**, part 1, 1-17).

In Cone's 1975 mailing to me was a long paper on bird flight (Clarence D. Cone, 1968, "The Aerodynamics of flapping bird flight." Special Scientific Report No. 52: Virginia Institute of Marine Science, Gloucester Point, Virginia) on pages 69-70 of which (the paper has been typed more than once, and the pagination varies) was a description of clap and fling, except that the wings were "impulsively" started moving apart and their leading edges did not start moving before their trailing edges.

Oh, I thought, and wrote to Weis-Fogh, including pages 69-70 of Cone's paper, and calling Cone's proposal "a sketchy account of the clap and fling mechanism." Weis-Fogh replied, saying that he was ignorant "of the existence of this [Cone's] internal document," and that Cone's mechanism differed from his in that, "Vorticity is still shed in the wake until the circulation reaches the correct value, so a 'starting vortex' must be formed." When I saw him later at a scientific conference in Cambridge, UK, Weis-Fogh gave no further explanation.

Then he published "Unusual mechanisms for the generation of lift in flying animals" in the *Scientific American* (Nov. 1975, pp. 80-87), which dealt with clap and fling and did not mention

Cone. I wrote a letter to the editor describing the situation, noting that Weis-Fogh's "clap and fling does not require impulsive acceleration of the wings, and is therefore a practical motion for flying animals to use." Referring to the shed 'starting vortex,' mentioned by Weis-Fogh, my letter said "these vortices are so close to each other that the associated flow is very localized and has very little energy. Quite soon, as viscosity diffuses the vorticity, the equal and opposite starting vortices will annihilate each other, leaving the situation that Cone predicted."

The magazine said it would send a copy to Weis-Fogh.

In a few days a note came from from Sir James Lighthill saying that Weis-Fogh had died tragically. Distressed that I might have driven him to suicide, and because he could not reply to my letter, I withdrew it. The inquest found that Weis-Fogh had died from whiskey and barbiturates. He had been treated for depression following the death of his first wife in a car accident.

I have been told that Weis-Fogh's files contained everything that Cone ever wrote.

Weis-Fogh's obituary in *The [London] Times* (Nov. 20, 1975), written by Professor Lighthill, Weis-Fogh's mathematical collaborator, mentioned his "absolute integrity." I asked Professor Lighthill if he would mention Cone's contribution in future publications on the subject, and he said no. Two further attempts to get recognition for Cone generated no interest.

As far as I know there has been no published recognition of Cone's partial anticipation of Clap and Fling, though in a book review (*Science*, March 27, 1981, p. 1415) K. E. Machin wrote that in 1968 (no further citation given) Cone had introduced the use of vortices in analyzing bird flight.

Today's winglets, one per wingtip, are far from the several feathers of Cone's vultures (though similar to two of the wingtips in his NASA Technical Report R-139), while Weis-Fogh's clap and fling is much more practical than Cone's impulsively-accelerated wings, but were it not for Cone, winglets and clap and fling might not exist.