# Model glider books by Martin Simons: Winglets

This is the material on the subject of winglets from Martin Simons' excellent books, this time from two of them. My comments marked [].

**From 'Model Flight'**

***4.15 Winglets and tip sails***

Ever since it was realised that the wing tips cause serious increases of drag, efforts have been made to prevent or reduce the wing tip vortices. The first attempts involved fitting large flat plates, vertically, at the tip. This does achieve some reduction in vortex strength, but air pressure changes are communicated from one place to another around whatever obstruction is put in the way. The high pressure region under the wing extends down on the inside of any tip plate, the low pressure zone on the upper surface, is felt at the top of the plate. Air therefore tends to flow around the tip plate, and the vortex, although weakened, does not vanish. At the same time, the air flows over the whole surface of the plate and this creates additional skin friction and form drag, so tending to reduce the total benefit. Tip plates of this simple form have not proved useful in practice.

More recently, various forms of *winglet* and *tip sail* have been developed and these have been applied with success to both full-sized and model aircraft (Figure 4.17). The idea of these devices is not merely to restrict and weaken the vortices, but to extract energy from them and use it to provide a useful additional forward-directed force. The net effect is a reduction of vortex drag, especially at low flight speeds and high angles of attack. Correct placement and design of the winglets is necessary if their benefit is to be realised. Badly placed, they do more harm than good.

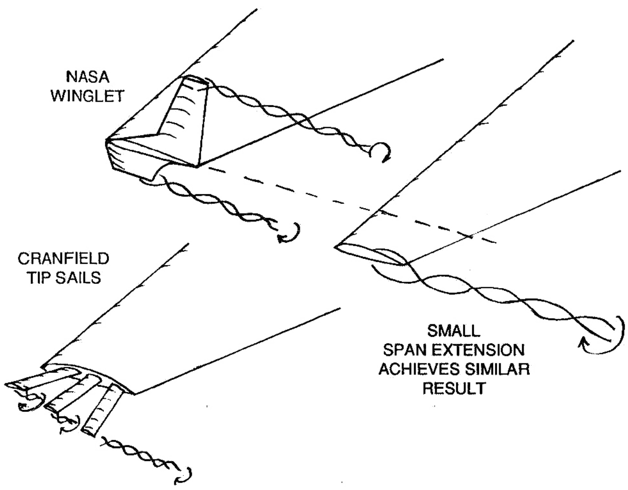


Figure 4.17 Winglets and tip sails

Again, the existence of the appendages increases the skin and form drag of the wing, so the full gain is not achieved. What is perhaps more important is that if the wing is extended in span, with a plain tip, it is easy to reduce the vortex drag by increasing the aspect ratio. In terms of structural complications, cost and simplicity of design, this is usually a better method of reducing vortex drag. Winglets find their most promising application when there is a strict limit on the total wing span of an aircraft, as is the case with some classes of model sailplanes in competition. Adding a well designed winglet, extending vertically upwards at the tip, does reduce vortex drag without increasing the total wing span, and so the model remains within the contest rules.

**From 'Model Aircraft Aerodynamics'**
[References to paragraphs and pictures elsewhere in the book have been marked thus {}]

6.17 WINGLETS

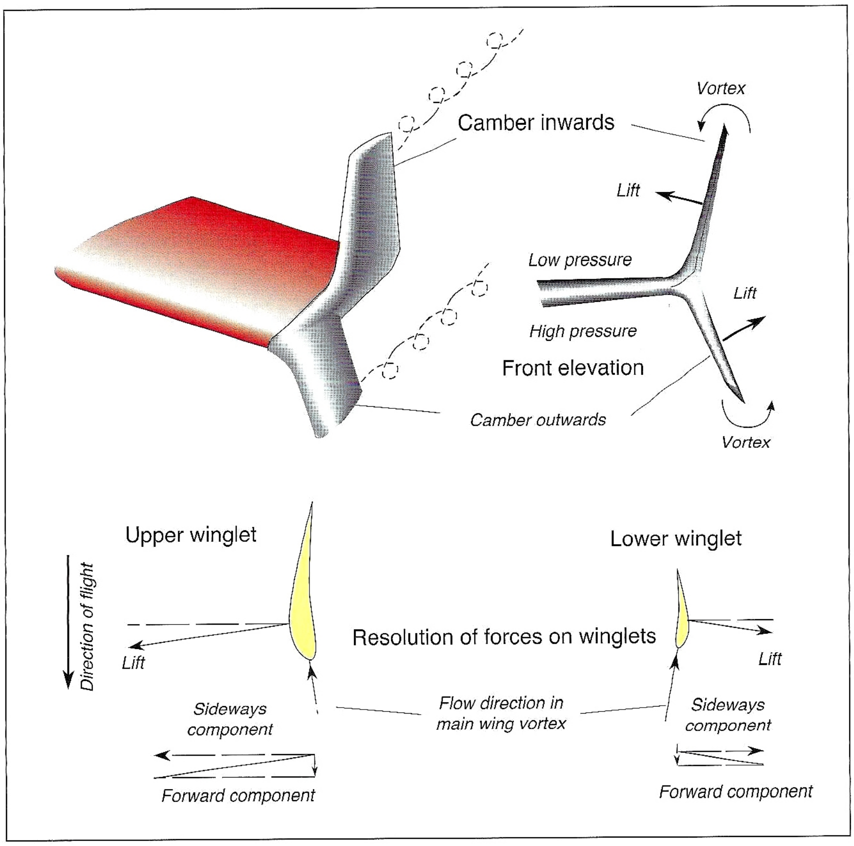


Figure 6.8 The Whitcomb winglet

Wing tip plates of the kind just described should be distinguished from winglets and tip sails, which are different in principle. A tip plate or body is intended to restrict or prevent the tip vortex. Winglets and tip sails are designed to use the vortex by extracting some of its energy. This not only weakens the vortex but, if the energy can be turned into a force in the right direction, there is a further small gain. Winglets of the type sketched in Figure 6.8 were first developed by R T Whitcomb. {As shown in Figure 5.1,} the vortex airflow round a wingtip is inclined outwards on the underside, upwards just beyond the tip, and inwards above. The precise angle of the flow to the direction of flight changes as the strength of the vortex varies at different angles of attack and flight speed.

An aircraft such as a commercial jet transport operates most of its time at one steady speed. It is possible to design a set of winglets that project into the vortex flow at such angles that they can, like small wings, extract some ‘lift’ force. If the winglets are set correctly this force will have a forward-acting component that can appear in the general force diagram for the whole airplane as an addition to the thrust. The bulk of the winglets lift will, however, be directed laterally and this will not only tend to bend the winglets themselves but will increase the bending loads on the wing main structure. Since the winglets generate lift, each tip will have its vortex. Compared with a main wing lacking winglets some saving in total drag does result at the designed cruising speed.

Winglets, as shown in the diagram (Figure 6.8) are cambered and twisted to meet the flow at each point at the most effective angle of attack. They are quite complicated to design and construct and are most efficient over a narrow range of flight speeds. If winglets are used it is most necessary to design them carefully and test them extensively before final adoption. They are not merely crude appendages stuck on the end of the wing. For them to work as intended, a great deal of work has to be done.

## 6.18 THE COMMERCIAL EQUATION

If an existing airplane is fitted with winglets, the increased bending loads compel some strengthening of the mainplane, adding weight, and there is a reduction in load carrying capacity. This may be compensated by the increased efficiency so that some fuel is saved. Clearly, whether the aircraft should or should not have winglets is finally determined not by aerodynamic considerations alone but by commercial factors such as the cost of the materials, the investment in design hours and wind tunnel testing time, and the price of fuel. That the winglets do work as their inventors claim is not doubted, but this does not imply they should necessarily be fitted to every commercial airplane nor to flying models.

## 6.19TIP SAILS

At about the same time as the Whitcomb winglets were being developed, J J Spillman at Cranfield was working on tip sails of the kind shown in Figure 6.9. These were inspired by the wing tip feathers of some large soaring birds, which are spread, fingerlike, to form a series of separate wing extensions with slots between.

Essentially, the Cranfield tip sails are intended to work in the same way as Whitcomb winglets, but there may be three, four or five sails, arranged radially and *en echelon* round the tip. Each sail is adjusted to extract lift from the flow in its neighbourhood and, as with the winglet, some of this force is directed forwards, the rest adds bending load to the wing. The results are comparable and the same economic considerations apply. As before, an increase in aspect ratio has the same effect.

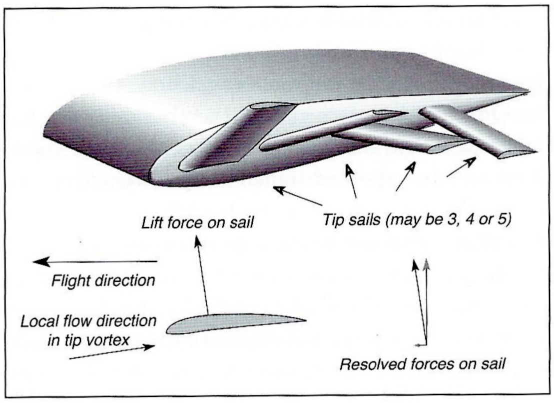


Figure 6.9 Spillman (Cranfield) tip sails

## 6.20 NASA TIP SAILS

Even more reminiscent of the bird wing, the NASA tip modification suggested in Figure 6.10 is intended to spread the tip vortex and reduce its strength, and this, too, reduces the vortex drag. Additional loads, as usual, must be borne by the mainplane structure and the slender tip ‘feathers’ are prone to flutter.

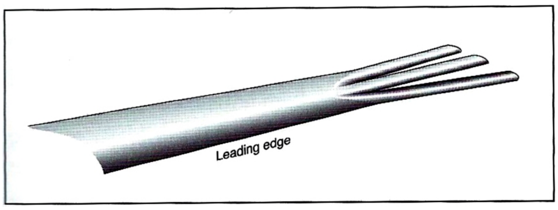


Figure 6.10 NASA wing tip sails

## 6.21 DISADVANTAGES OF WINGLETS

Winglets are intended to reduce vortex drag that is most important for flight at relatively high angles of attack. They are usually set so that they will be most effective at one speed. Airliners cruise for long periods at steady airspeeds close to the best L/D trim. The winglets will be set to give their best effect in this situation. At any other speed they will work less effectively because the main tip vortex itself changes, requiring the winglet to be set at another angle. The winglets also contribute parasitic drag. At high speeds in particular they will be a handicap because as airspeed rises vortex drag becomes less and less significant, while all forms of parasitic and form drag increase greatly {(Fig 4.10)}. For example, if the winglet is set at -7 degrees at its root (Fig 6.11), it will be fixed at this angle also when the aircraft is flying at an entirely different angle of attack.

Full-sized sailplanes now in production are usually built with winglets and many older aircraft are modified to permit winglets to be attached. The calculations required are extensive and must be supported by practical tests in flight. The gains are measurable but relatively small. Sailplanes need to fly fast between thermals as well as slowly for soaring, The idea of making winglets adjustable to different angles in flight has been mooted but, at the time of writing, has not been attempted in practice.

Winglets do, as a rule, improve aileron control and stability in circling. This, rather than any gain in performance, may justify their use.

It has been shown {in Chapter 5} that the most effective method of reducing vortex drag is by increasing the aspect ratio, i.e. increasing the wing span for a given total area. It follows that whatever the gain from using winglets, a similar improvement could always be achieved by an increase in aspect ratio. This could be done by fitting a simple wing extension. Such a span extension would, of course, increase the bending loads on the mainplane and would add weight, so the question is again decided by economics rather than aerodynamics. Nonetheless, whereas winglets require considerable research and, usually, wind tunnel testing to ensure they are of the most favourable shape and set at the best angle, to lengthen the wing is comparatively simple. Moreover, stretching a wing in this way is guaranteed to reduce vortex drag at all airspeeds. A longer wing is more prone to flutter problems and slower in roll than a short wing, but adding winglets to a short wing also increases the danger of flutter and the additional mass at the tip creates more rolling inertia. Even so, as the ETA demonstrates {(6.1)}, however high the aspect ratio, a winglet at the tip may help a little.

## 6.22 WINGLETS AND TIP SAILS FOR MODELS

As far as model aircraft are concerned, very few tests have been performed with winglets or tip sails. They are unlikely to produce benefits unless they are properly adjusted and very few modellers have access to wind tunnels for the necessary testing purposes. If there is no restriction on the wingspan of the model, it is safer to increase aspect ratio than to use winglets unless these have been correctly designed. There are, however, occasions when the wingspan is restricted by contest rules, or where an increase of aspect ratio (with a reduction in mean wing chord) might take the wing down to a low Reynolds number and so lose efficiency. In such cases winglets, especially of the Whitcomb type, offer some prospect of worthwhile gains.

The two-metre sailplane class is a case in point. In 1980 tests of a model in this category were reported by Chuck Anderson (in *Model Aviation,* May 1980, pp. 525). On a wing with 25.4 cm chord, of rectangular planform, aspect ratio 7.87, winglets as shown in Figure 6.11 were fitted. These seemed to improve the performance while remaining within the two-metre restriction. After twenty years the model concerned, and others of similar design, remained in use and flew competitively in their class. These winglets also had some less desirable effects on lateral stability and control. Such additions to the tips are rather vulnerable to damage, especially in ground loops or landings that end with the model upside down. For small freeflight models and even for F1A (A2) sailplanes, {as mentioned above (6.4)}, wing taper is not generally desirable but the addition of winglets or sails to a rectangular wing may prove worthwhile. The Reynolds number of the mainplane would be unaffected and the tip vortex, providing the winglets were well designed, would be reduced. Anderson’s two-metre sailplane, very wisely, was made with the angle of the winglets adjustable so that by repeated test flying, the best setting could be discovered.

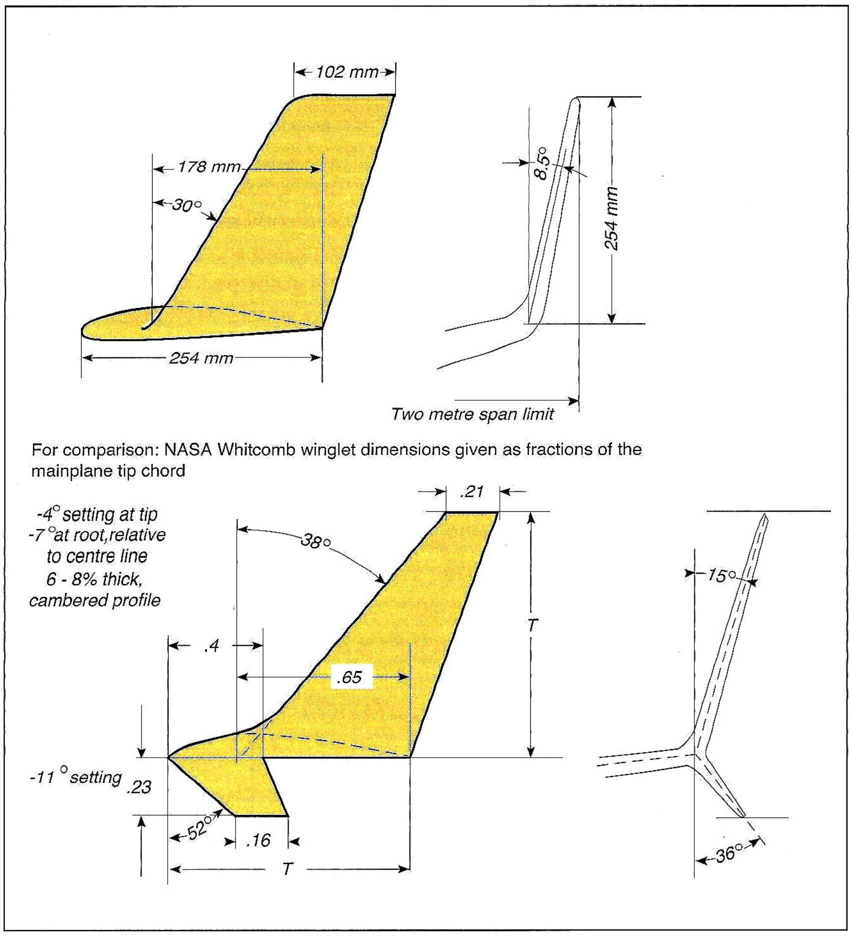


Figure 6.11 Winglets on a two metre sailplane (Chuck Anderson)

Noel Falconer used a refined winglet design on tailless sailplanes and electric powered models. Apart from saving drag, which is rather more severe on a sweptback wing, the winglets also serve as fins, providing very necessary lateral stability on the tailless aircraft.

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