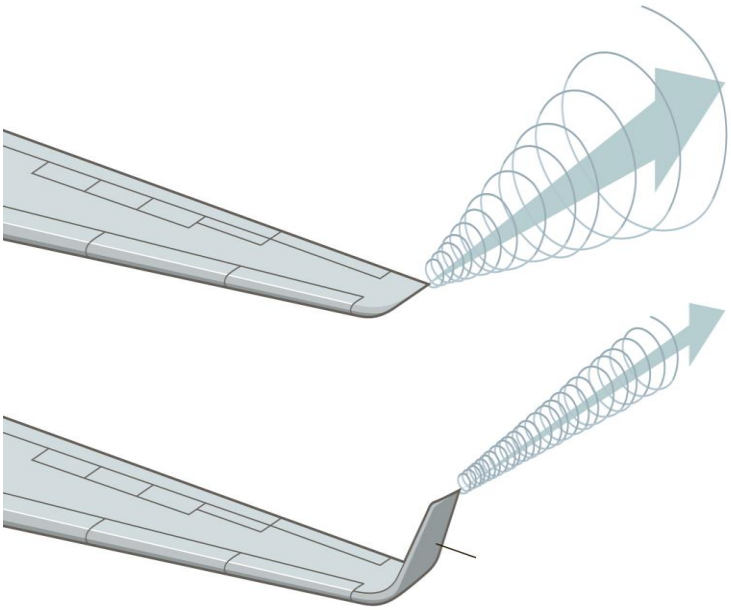


# Effect of Winglets on Drag and lift of an Aerofoil


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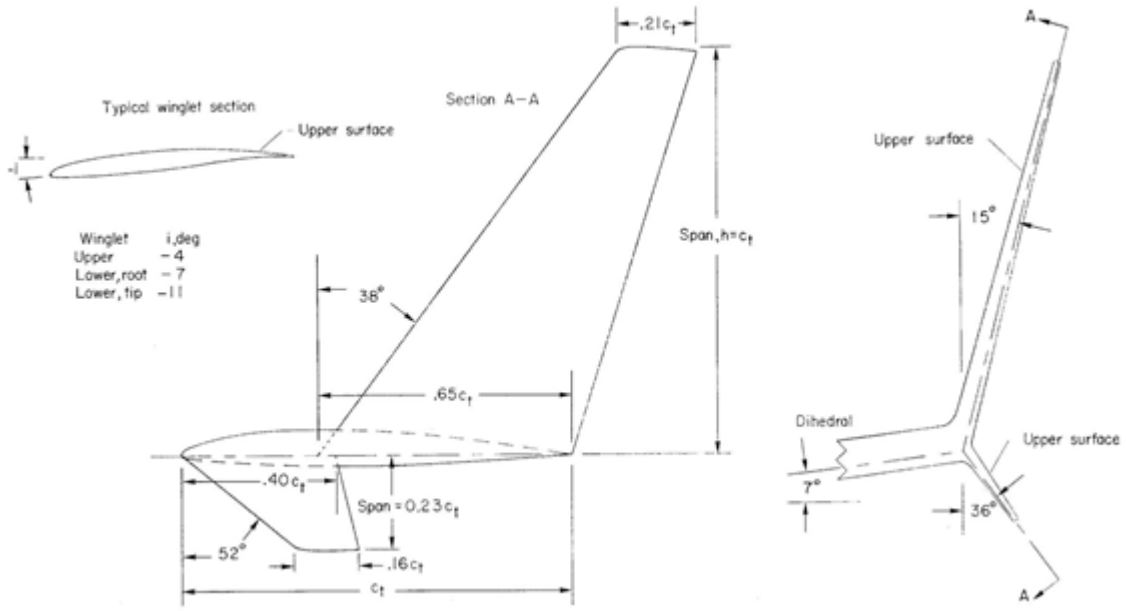
# Introduction

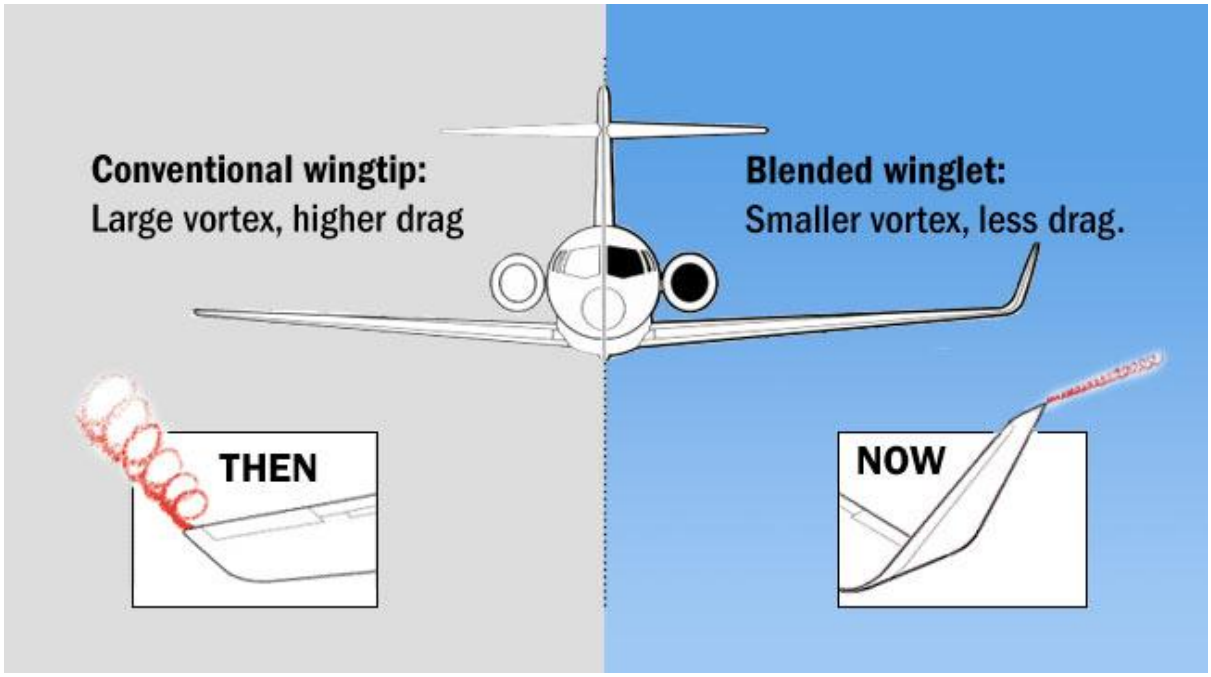
A winglet is a device used to improve the efficiency of aircraft by lowering the lift induced drag caused by wingtip vortices. It is a vertical or angled extension at the tips of each wing. Winglets improve efficiency by diffusing the shed wingtip vortex, which in turn reduces the drag due to lift and improves the wing's lift over drag ratio Winglets increase the effective aspect ratio of a wing without adding greatly to the structural stress and hence necessary weight of its structure.
In the 1970s, biologists began to look at the flying characteristics of soaring birds such as eagles, hawks, condors, vultures, and ospreys. Each of these birds has high lift wings with "pin" feathers at the ends that produce slotted wingtips. Biologists found that the pin feathers worked to reduce drag during gliding flight, as well as being used to provide roll control, in the same manner as ailerons on aircraft. These multi-winglets are quite often long and prominent, as in the case of the California Condor.

In 1976, shortly after an energy crisis sent fuel prices skyward, Richard Whitcomb, a NASA aerodynamicist, published a paper that compared a wing with a winglet and the same wing with a simple extension to increase its span. As a basis for comparing both devices, the extension and the winglet were sized so that both put an equal structural load on the wing. Whitcomb showed that winglets reduced drag by about 20 percent and offered double the improvement in the wing's lift-to-drag ratio, compared with the simple wing extension.

Winglets are being incorporated into most new transport aircraft, including business jets, the Boeing 747-400, airliners, and military transport.
Many other researchers have investigated their behaviour, designing winglets for commercial and general aviation aircraft as well as for sailplanes.

Furthermore, the added friction and interference drag has to be cancelled out by the forward thrust generated by the winglet lift. The upward angle (or cant) of the winglet, its inward or outward angle (or toe), as well as its size and shape are critical for correct performance and are unique in each application.

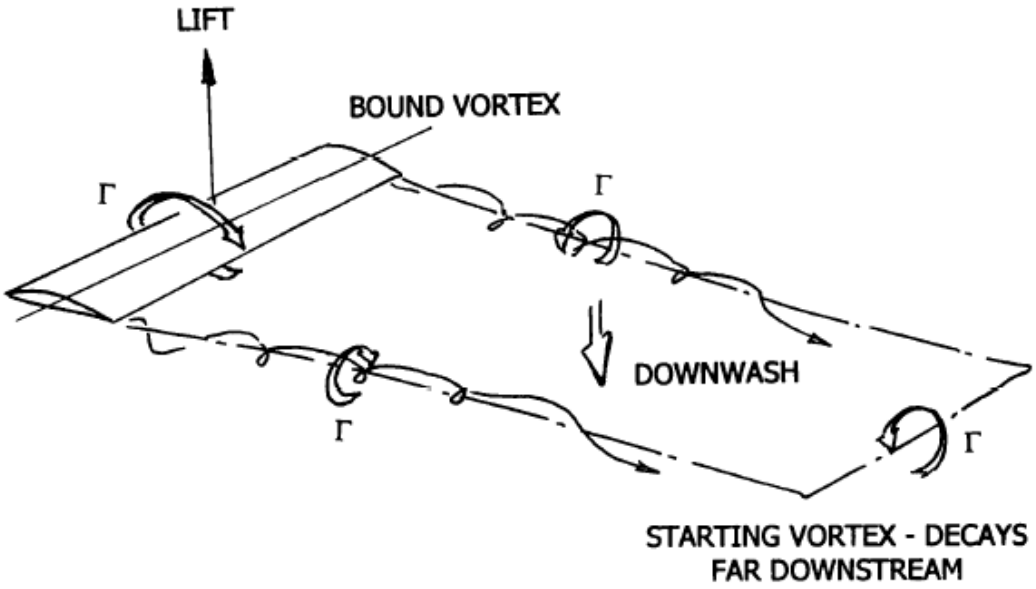

Typical winglet section
Upper surface
Winglet i,deg
Upper −4
Lower,root −7
Lower,tip −11
Section A–A
.21$c_t$
Span,$h=c_t$
38°
.65$c_t$
.40$c_t$
Span = 0.23$c_t$
52°
.16$c_t$
$c_t$
A
Upper surface
15°
Dihedral
7°
Upper surface
36°
A


Conventional wingtip:
Large vortex, higher drag
Blended winglet:
Smaller vortex, less drag.
THEN
NOW

# Theory and Basic Definitions

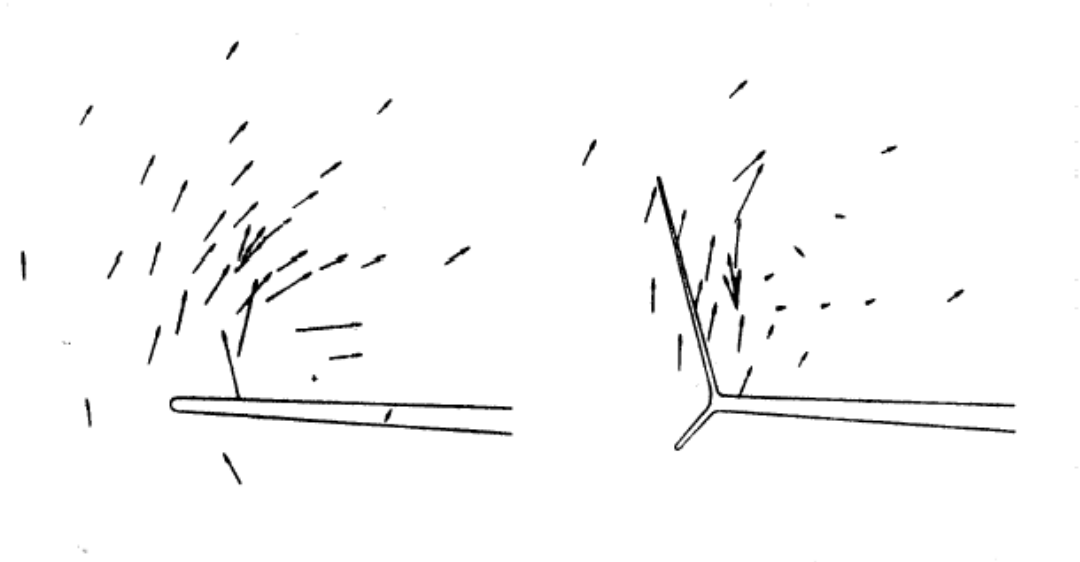
## Winglet theory:

Due to circulation about the horseshoe vortex, there exists an induced downwash-which in turn produces induced drag.




**Vortex Formations**

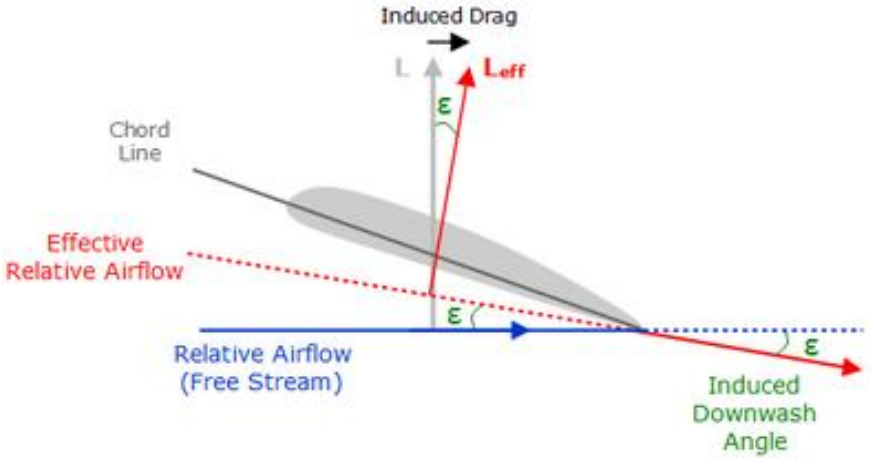
Adding winglets alters the flow at the tip which in turn decreases the downwash, ultimately reducing induced drag.



**Reduction of Induced Drag by adding Winglets**

## Induced drag:

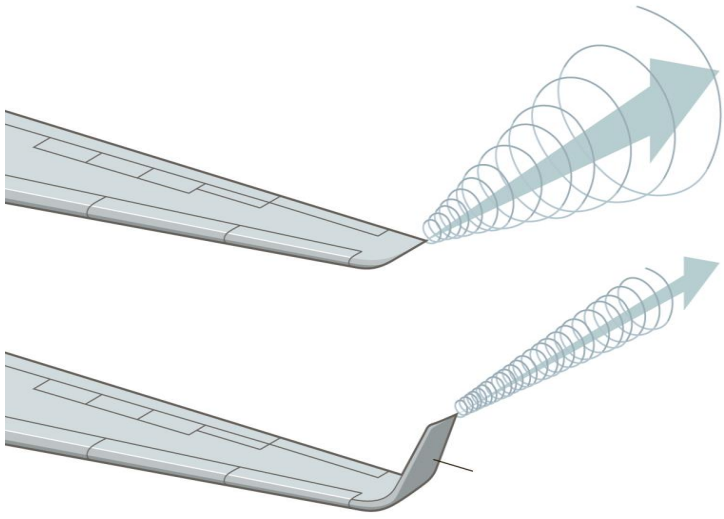
Induced drag is a force that occurs whenever a moving object redirects the airflow coming at it. It is also called as "*Drag due to lift*" as it a source of wing drag.




## Winglet benefits

Winglets belong to the class of wingtip devices aimed to reduce induced drag. Selection of the wingtip device depends on the specific situation and the airplane model. In the case of winglets, the reduction of the induced drag is accomplished by acting like a small sail whose lift component generates a traction force, draining energy from the tip vortices.

The wingtip might be considered a dead zone regarding to the aerodynamic efficiency, because it generates lots of drag and no significant lift. The winglet contributes to accelerate the airflow at the tip in such a way that it generates lift and improves the wing loading distribution, which is related to the induced drag.



In addition, the aircraft will fly at a slightly lower angle of attack for the same lift coefficient. Thus, it should always be possible to obtain significant drag reductions by using wingtip devices even for high-aspect wings.

Away to avoid this design issue is to employ raked wingtips like Boeing did for its 767-400 aircraft. Thanks to winglets the aircraft will climb to initial altitude faster and save fuel due to a more efficient climb profile. Otherwise, the aircraft can take off at lower thrust settings, which reduce the aircraft noise footprint and extend engine life.

# GOALS

Calculating lift and drag forces as well as lift and drag coefficients help to fill in the equations used for evaluating performance. Range, endurance, and take off distance are just a few examples of the types of performance that can be evaluated, compared, and optimized. For this research, performance will focus mainly on improvements to CL/CD, with consideration given to the root bending moment.

**UAV Performance Evaluation**

The performance improvements can be measured in terms of range and endurance. Using eqn. (1) estimates for the range can be compared. Using eqn. (2) estimates for the endurance can be compared. Table VI lists the values for the predicted performance improvements for this particular case. Using the optimized blended winglets, the maximum value for CL/CD is increased by 28%. This results in a 71% increase in endurance and the range is increased by 28%. The root bending moment at the stall angle of 15◦ is increased by 17%. The blended winglet also performs better than the Whitcomb winglet. The predicted performance improvements for the blended winglet are 15.61% and 33.96% better than the range and endurance respectively for the Whitcomb winglet. The root bending moment for the blended winglet is only 5% more than the Whitcomb winglet. Since the design parameters for the notional UAV require a winglet that is 1 meter high the comparison of the optimized winglet to the Whitcomb winglet is more relevant than the comparison to the configuration with no winglet. The added bending moment at the root will require more structural strength, which means the overall structure will be heavier. The performance improvements for the bended winglet are greater for the overall increase in the root bending moment when compared to the Whitcomb winglet. Fig. 11 plots the predicted performance for the model with no winglets, a Whitcomb winglet, and the optimized blended winglet.

$$\mathbf{R} = \frac{\eta_{pr}}{c}\frac{L}{D}\ln\frac{W_0}{W_1} \tag{1}$$

$$\mathbf{E} = \frac{\eta_{pr}}{c}\sqrt{2\rho_\infty S}\frac{C_L^{3/2}}{C_D}(W_1^{-1/2} - W_0^{-1/2}) \tag{2}$$

Wing1includesthewing only, wing 2 includes the the wings, lower winglets and and a straight upper winglet. Wing 3 includes the wings, lower winglets and blended upper winglets. Table VI displays the predicted lift and drag coefficients produced using the Tornado VLM. CL/CD|%1 is the percentage increase in CL/CD|max of the winglet design over the no winglet. CL/CD%2 is the percentage increase in CL/CD|max of the blended winglet design (Wing 3) over the Whitcomb winglet design (wing 2). Vortex Lattice Method (VLM) model predicts the CL/CD|max value for wing 3 is 29.46, CL/CD|max for wing 2 is 25.43, and CL/CD|max for wing 1 is 23.00. The equates to an 15.9% increase for wing 3 over wing 2, and 28.1% improvement over wing 1.

## RESULTS

## Force Measurements

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