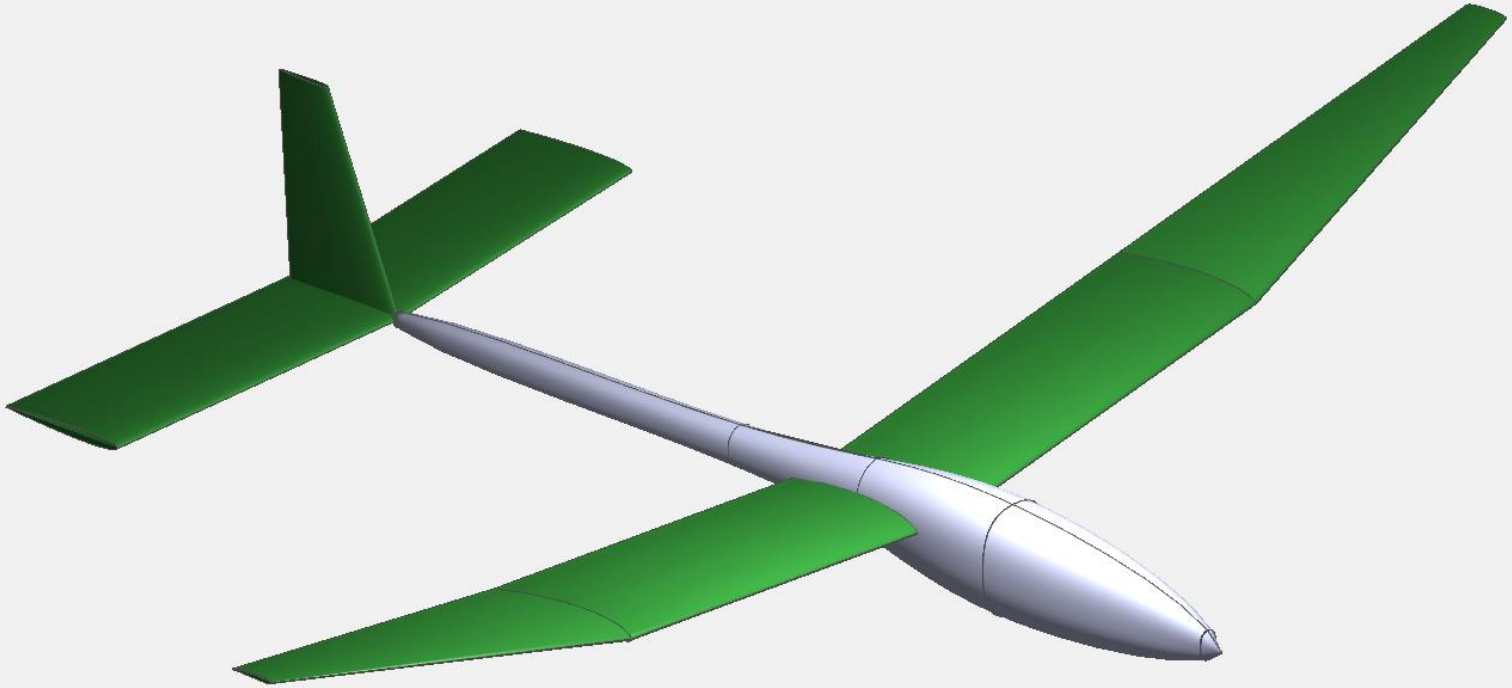
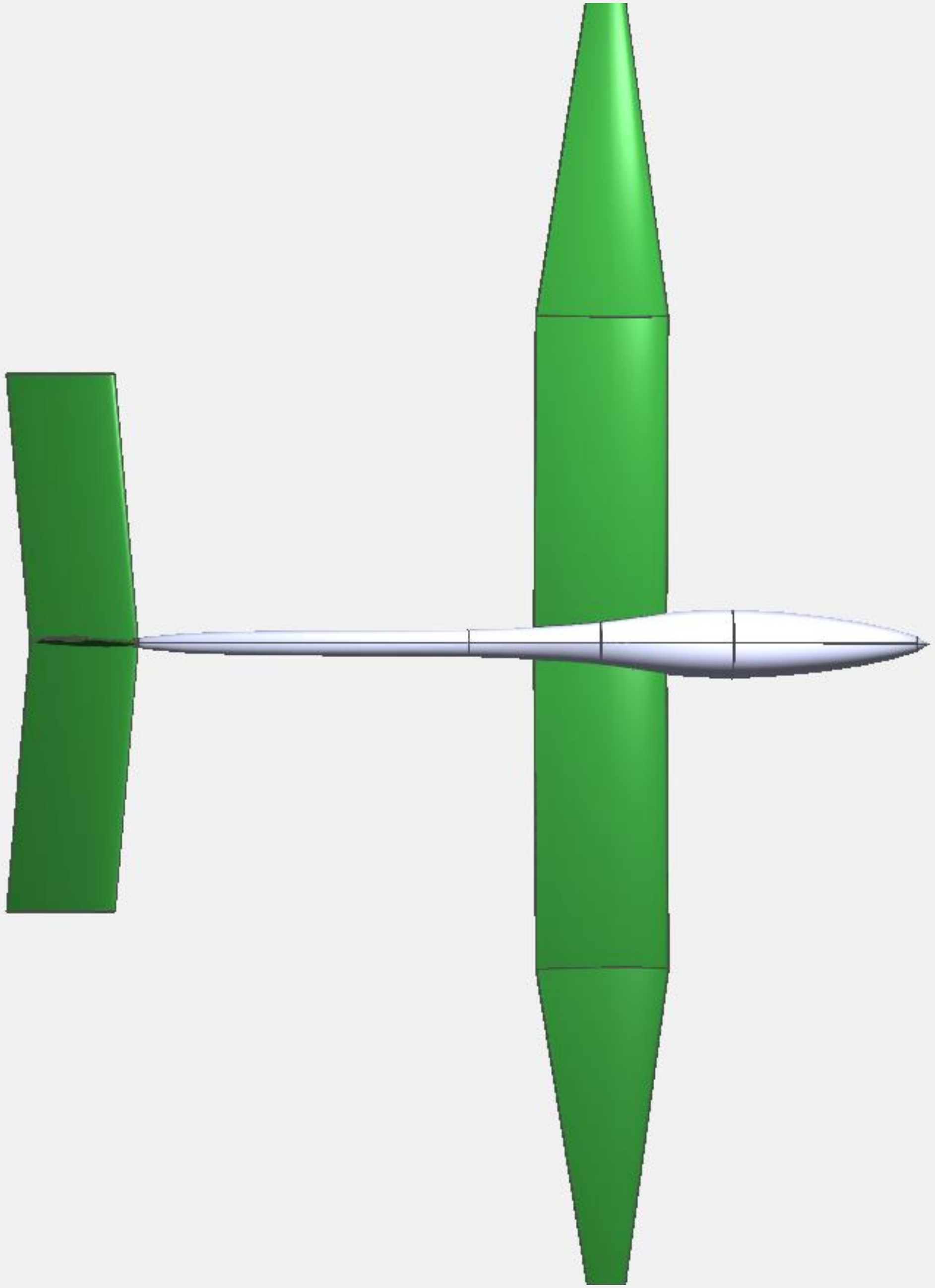
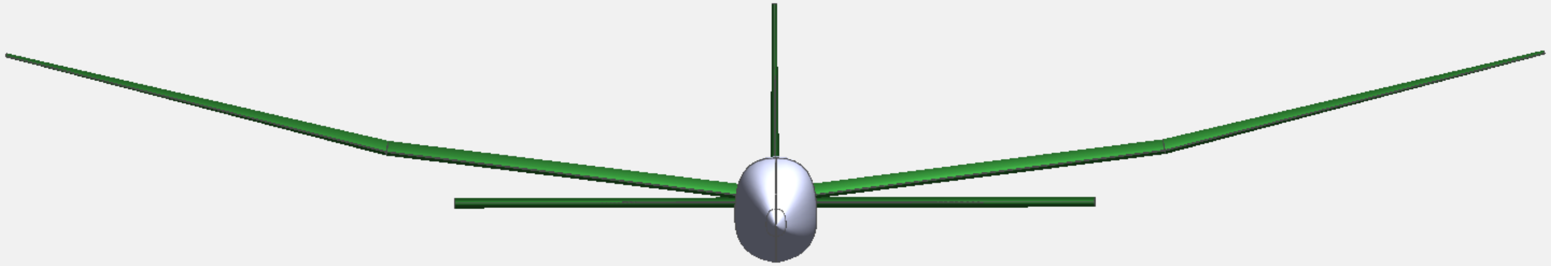
V3 Aerodynamics Design Proposal





Solar Drone V3 Mockup

Wing Span	=	10.000	m
xyProj. Span	=	9.807	m
Wing Area	=	8.200	m^2
xyProj. Area	=	8.063	m^2
Plane Mass	=	0.000	kg
Wing Load	=	0.000	kg/m^2
Tail Volume	=	1.843	
Root Chord	=	1.000	m
MAC	=	0.886	m
TipTwist	=	0.000°	
Aspect Ratio	=	12.195	
Taper Ratio	=	0.280	
Root-Tip Sweep	=	2.062°	



Design Inspiration

Airbus Zephyr [1]

Airfoil Choice

Selig and Donovan airfoils excel at minimizing drag under low-Reynolds number conditions. They are ideal for use on RC sailplanes [2] [3].

SD6080

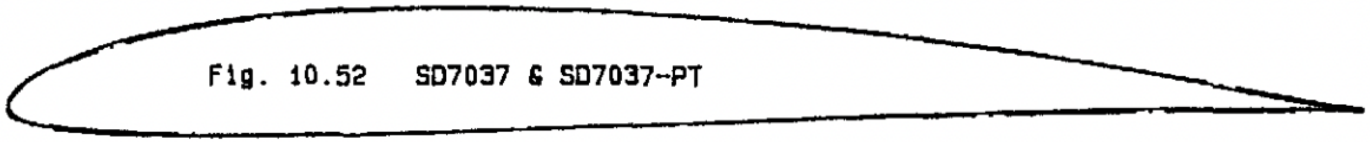
Thickness: 9.18%

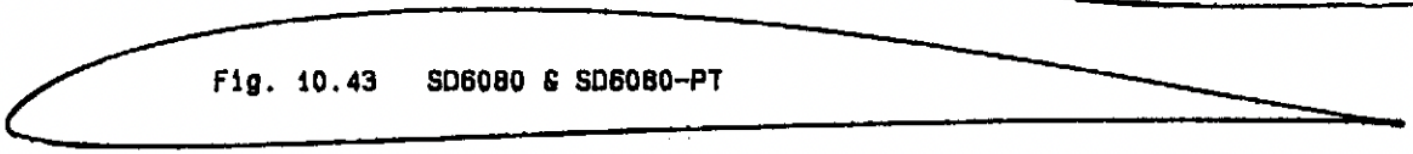
Camber: 3.74%

SD7037

Thickness: 9.20%

Camber: 3.02%





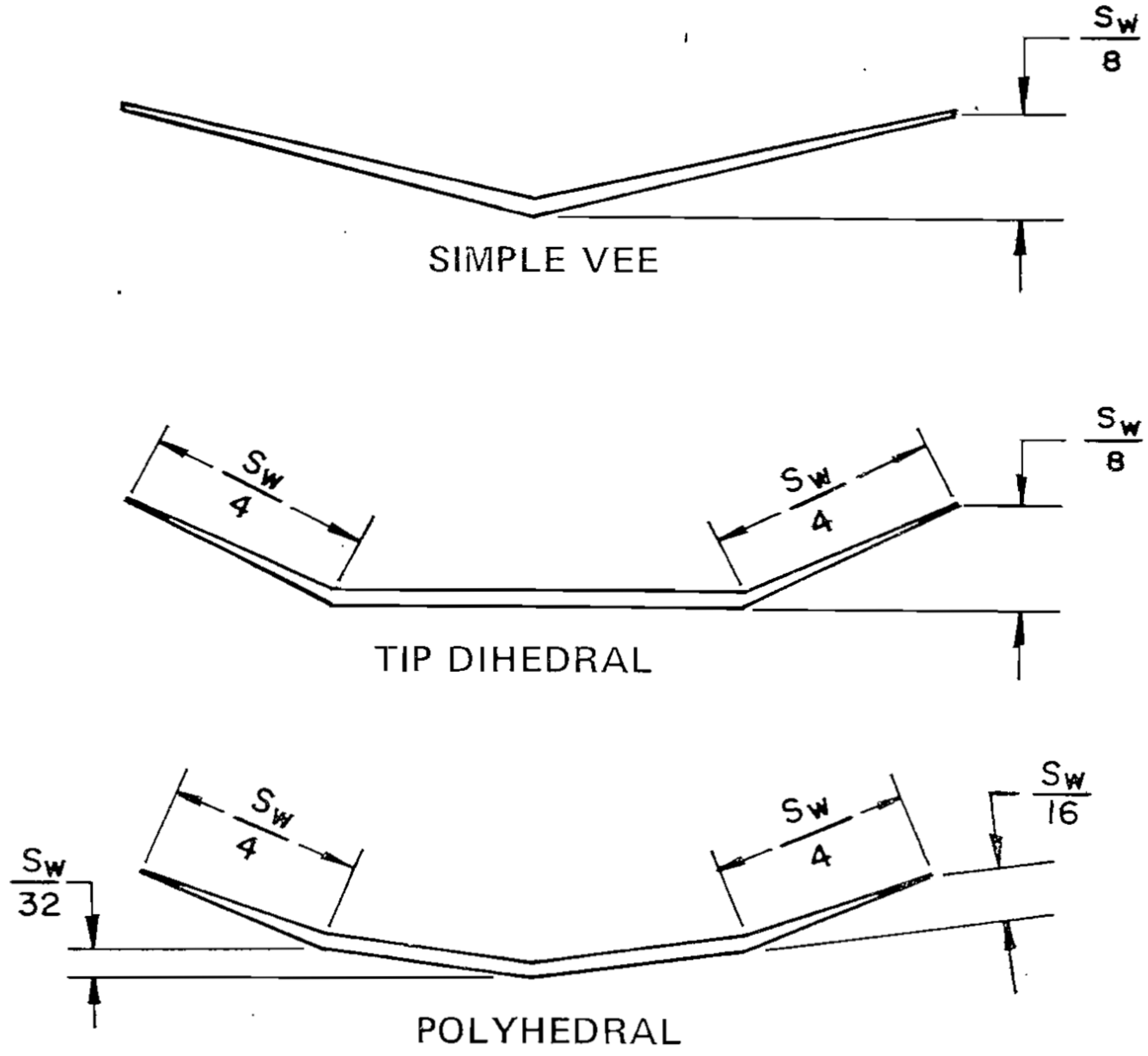
Wing Design - Dihedral

for… S_W = wingspan

Must consider manufacturing limitations and aerodynamics.

Simple Vee and Polyhedral will provide a less flow-disruptive junction between fuselage and wing.

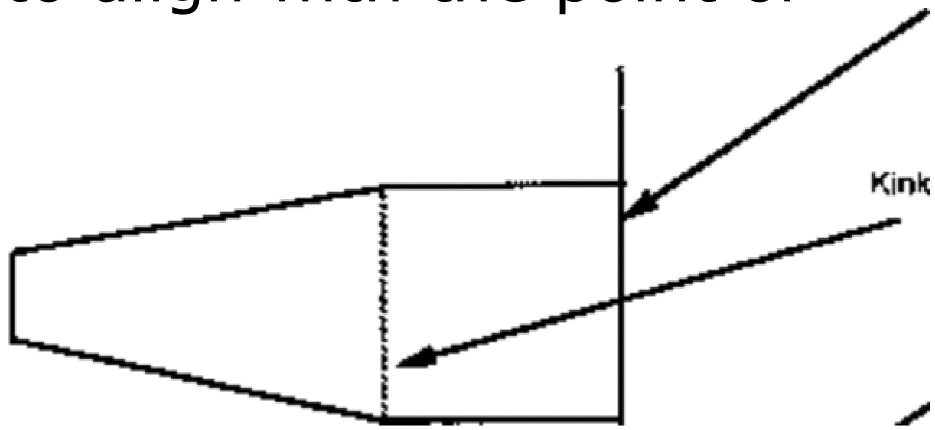
Polyhedral would be preferable if manufacturing capabilities permit [4].



Wing Design – Sweep + Taper

For low-speed, long-endurance flight conditions, such as those expected for the solar drone, little to **no sweep is best** [5].

A **double-tapered wing** will be employed to reduce induced drag while preserving planform area for solar panel placement [6]. The central ¼ of the semi-span will be rectangular while the outer ¼ have a sharp taper of $\boldsymbol{\lambda = 0.28}$ (determined geometrically). A kink located at ¼ semi-span is chosen to align with the point of increased dihedral.



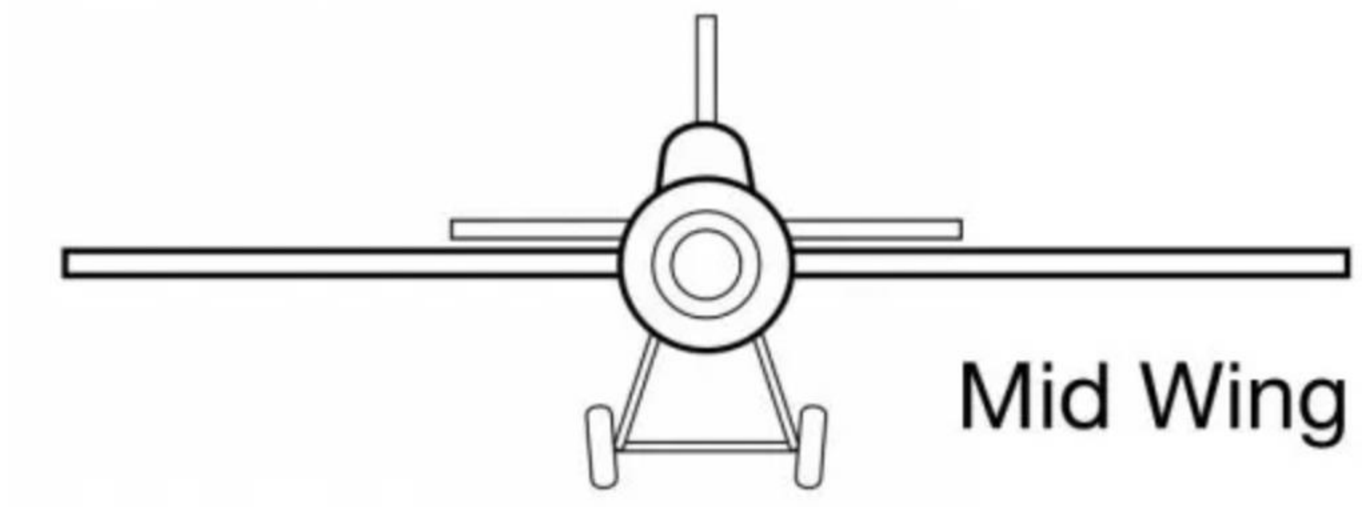
Wing Design – Wingtips

Blended wingtips, such as the ‘sharklets’ made by Airbus, have been shown to increase UAV range by as much as 10% [8].

[9]

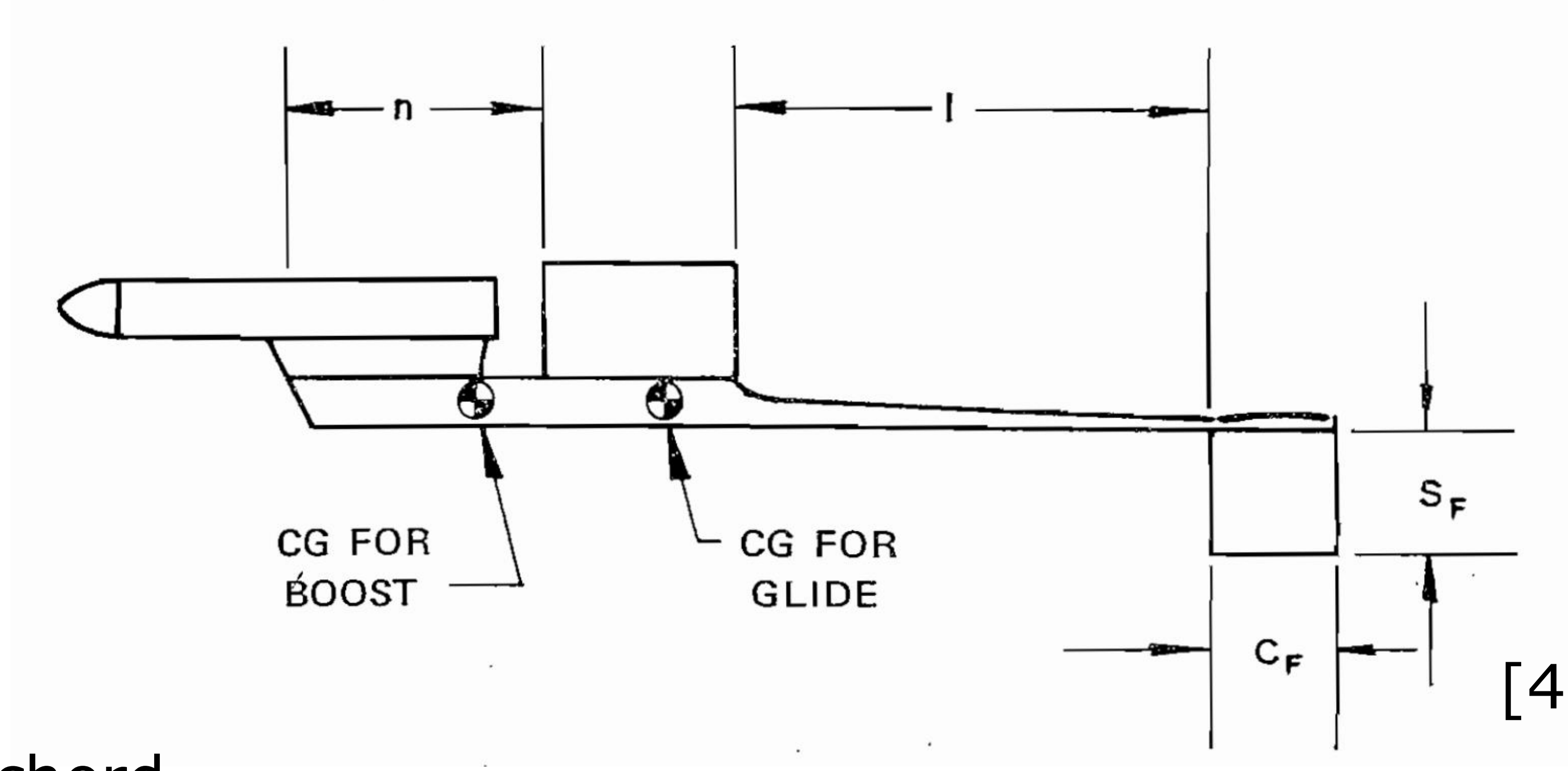
Wing Design – Fuselage Junction

A **mid wing configuration** provided the most stability at the cost of responsiveness and nimbleness [7]. This is a worthwhile trade-off for our purposes.



[7]

Fuselage Design



[4]

for $c_w =$ wing chord…

$\Longrightarrow l = 0.4 s_w = 4 c_w$ *from wing trailing edge to horizontal stabilizer leading edge*

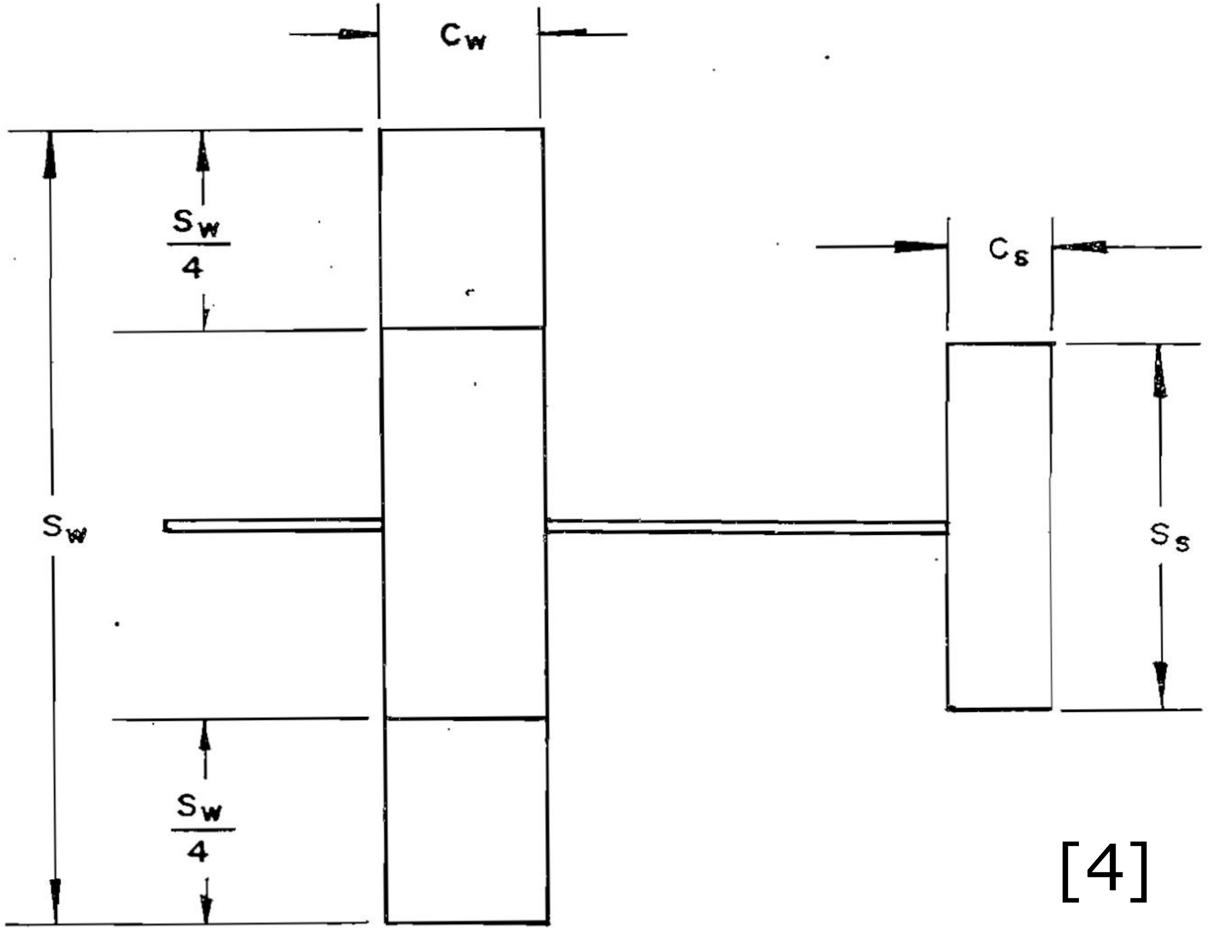
$\Longrightarrow n = 1 - 2 \cdot c_w$ *from nose to wing leading edge*

Empennage Design

let… $A_h =$ horiz. stabilizer area
$A_f =$ fin area

for $AR = 10\ldots$ [10]

$s_w = \text{wingspan} = 10c_w$
$A_w = \text{wing planform area} = 10c_w^2$
$A_s = \text{horiz. stabilizer area} = 3.33c_w^2$
$A_v = \text{vertical stabilizer area} = c_w^2$



[4]

A **conventional empennage** design, versus a T- or V-shaped design, is preferable. [11]

Horizontal Stabilizer

Horizontal stabilizer aspect ratios are typically half the aspect ratio of the wing [11]. A **rectangular stabilizer with no dihedral** is acceptable and results in easier manufacturing.

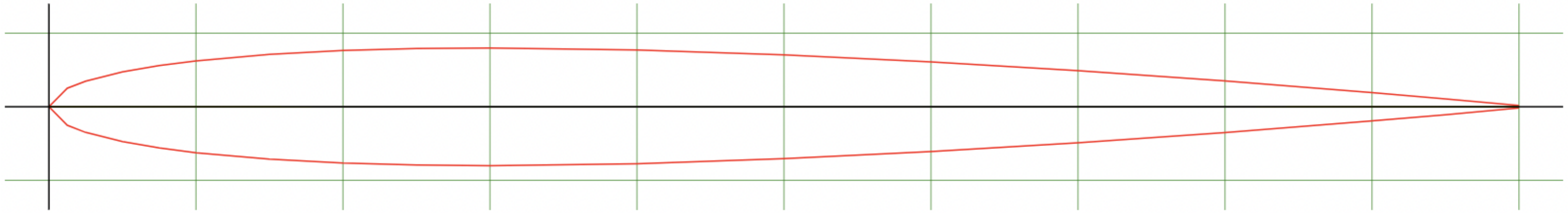
$$\therefore\ s_s^2 = 5A_s \implies s_s = \text{horiz. stabilizer span} = 4.08c_w$$

$$\therefore\ c_s^2 = \frac{1}{5}A_s \implies c_s = \text{horiz. stabilizer chord} = 0.816c_w$$

Horizontal stabilizer should be swept 5° more than the wing [11]. Since we use an unswept wing, the horizontal stabilizer will be **swept back 5°**.

Horizontal Stabilizer

The horizontal stabilizer should be ~10% thinner than the wing [11]. Symmetric airfoils are standard. We select **NACA0008** [12]…



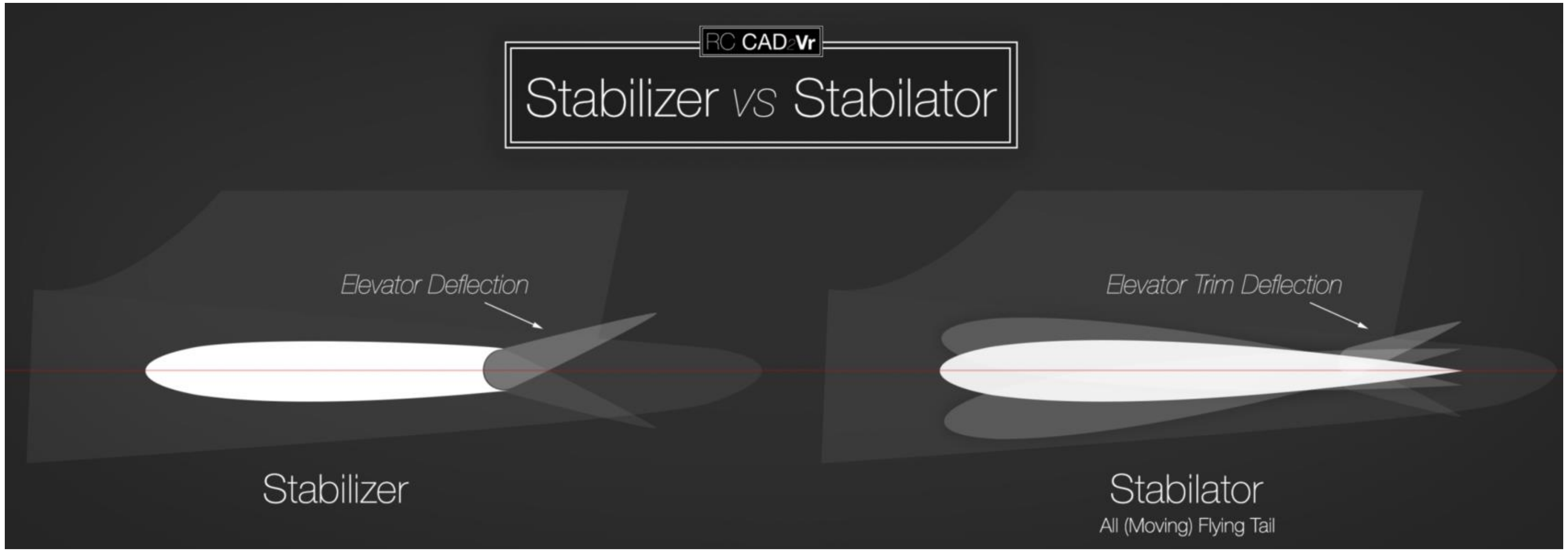
An **angle of incidence of 2° - 3° downwards** should be applied to produce negative lift [11].

The elevator should extend **~90% of the semi-span** [11]. The elevator should account for **25% - 40% of the chord** of the horizontal stabilizer. Elevators are deflected downwards by a maximum of 15° - 25° and upwards by a maximum 25° - 35°.

Alternative Elevator Approach

Varying the angle of incidence will allow the entire horizontal stabilizer to function as an elevator, called an ‘all-moving tail’ [11].

This can be used if it is easier to manufacture and implement.



[13]

Vertical Stabilizer

Standard aspect ratios for vertical stabilizers are 1.3 – 2.0 [10]. We select the mean of 1.6…

$$\therefore\ s_v^2 = 1.6A_v \implies s_v = \text{vertical stabilizer span} = 1.265c_w$$
$$\therefore\ c_v^2 = 0.625A_v \implies c_v = \text{vertical stabilizer chord} = 0.791c_w$$

For low-speed flight, a **sweep angle of < 20°** should be used [10]. A **taper ratio of 0.3 – 0.6** should be used, with c_v representing the mean chord length. The vertical stabilizer must be a symmetric airfoil [10]. We again select the **NACA0008**.

The rudder should extend **90% of the span** of the vertical stabilizer and constitute **25% - 40% of its chord**. Rudders are deflected by a maximum of 25° - 35° [10]

Propeller Placement

We elect for a push prop configuration…

Pros

- Improved visibility for cameras and sensors at nose [14]
- Improved airflow over wings, thus reduced drag [14]
- Thrust force aft of CG increases stability [14]
- Common feature of UAVs
- Unique design compared to other student organizations

Cons

- Leads to a back-heavy design
- Reduction of prop efficiency by ~15% [14]
- Introduced difficulty to the design and manufacturing process (especially wiring of the motor)
- Prop clearance during takeoff may necessitate longer landing gears, increasing parasitic drag

Propeller Placement - Inspiration

[14]

[14]

Works Cited

[1] Airbus Achieves...

[2] Selection of Airfoils | Model Airplanes

[3] Airfoils at Low Speeds

[4] Design Rules for Boost and Rocket/Gliders

[5] Mechanism analysis of hysteretic aerodynamic...

[6] Taper Ratio

[7] Types of Aircraft Wings

[8] A Review of Wingtip Devices

[9] Types of Blended Winglets

[10] Full configuration drag estimation...

[11] Empennage General Design

[12] NACA0008

[13] Stabilizer v. Stabilator

[14] An Influence of Pusher Propellor...