Final Project

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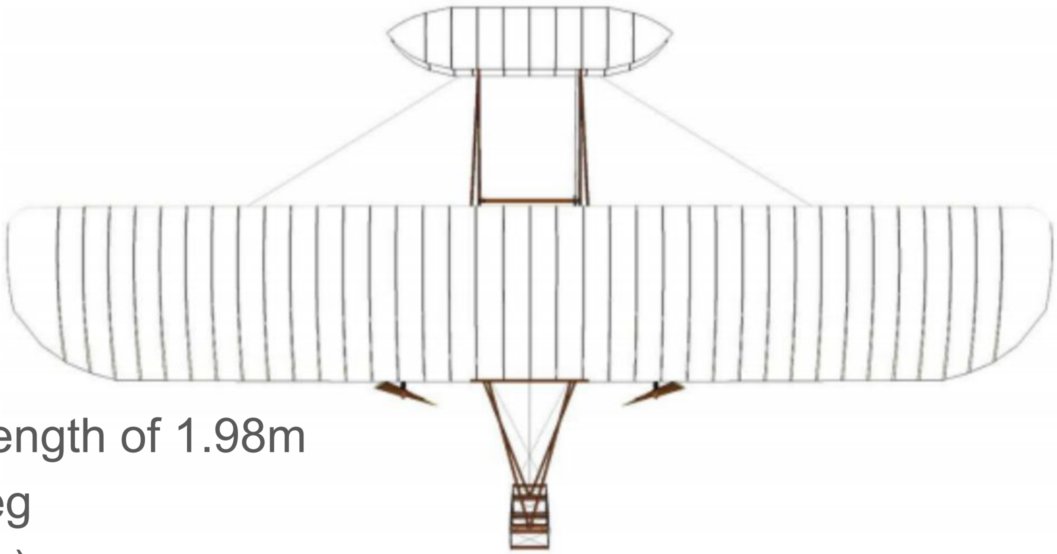
Wing Design

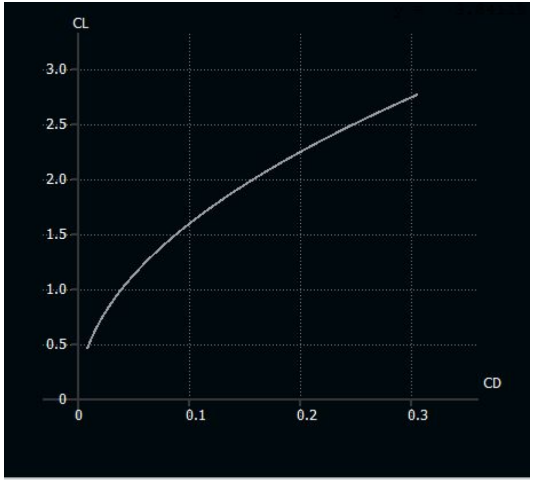


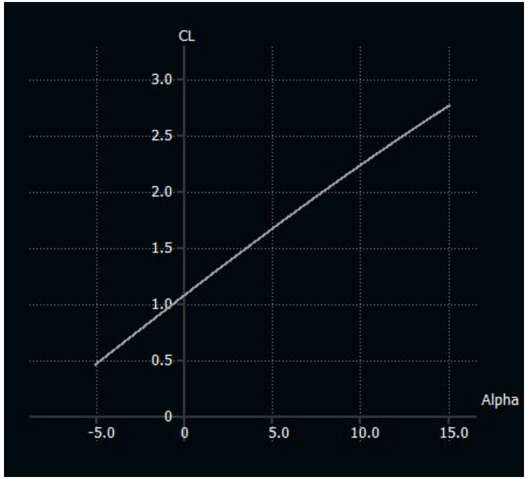
- Base airfoil: NACA 2404
- Camber adjusted to 5%
- Span of 12.29m and chord length of 1.98m
- Angle of Incidence: 3.417 deg
- Wing anhedral: 10in (2.3 deg)
- Second wing for biplane
- Assumed approx. rectangular wings

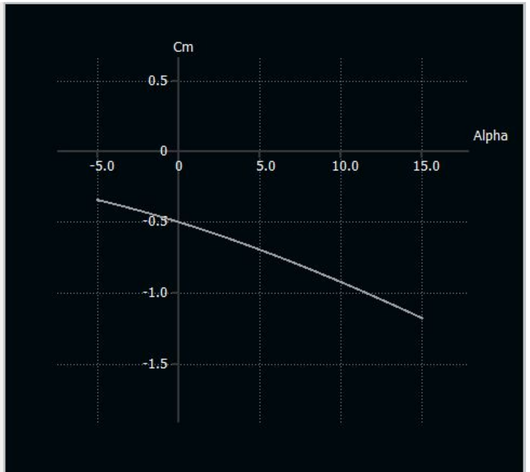
Aerodynamics Characteristics of Wright Brothers Wing

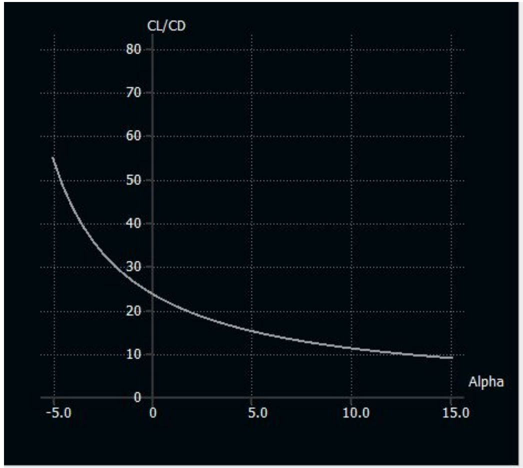
$-5° < \alpha < 15°$

$U_{inf} = 20$ m/s

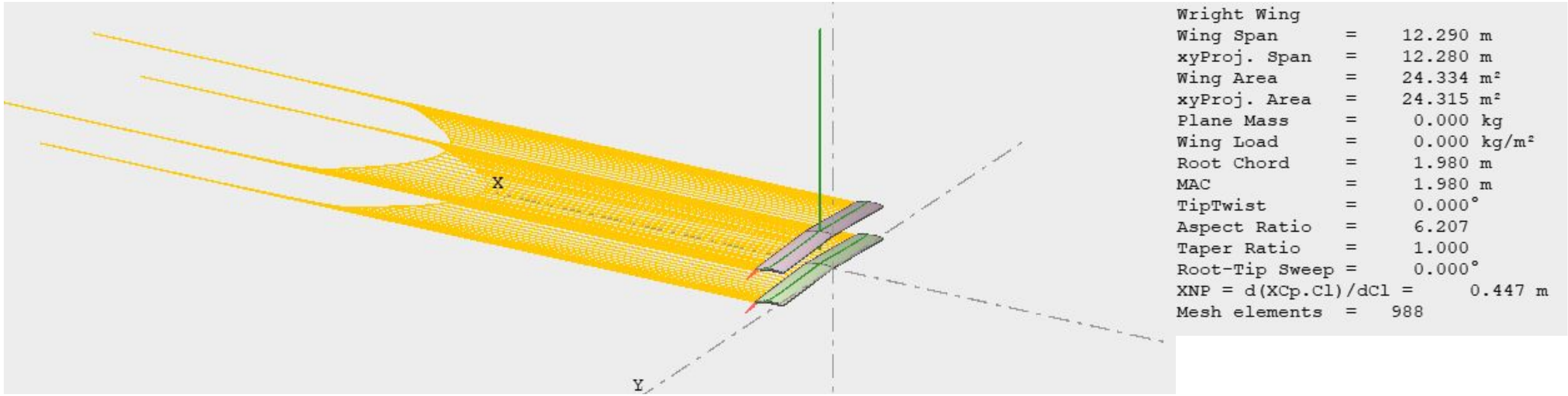


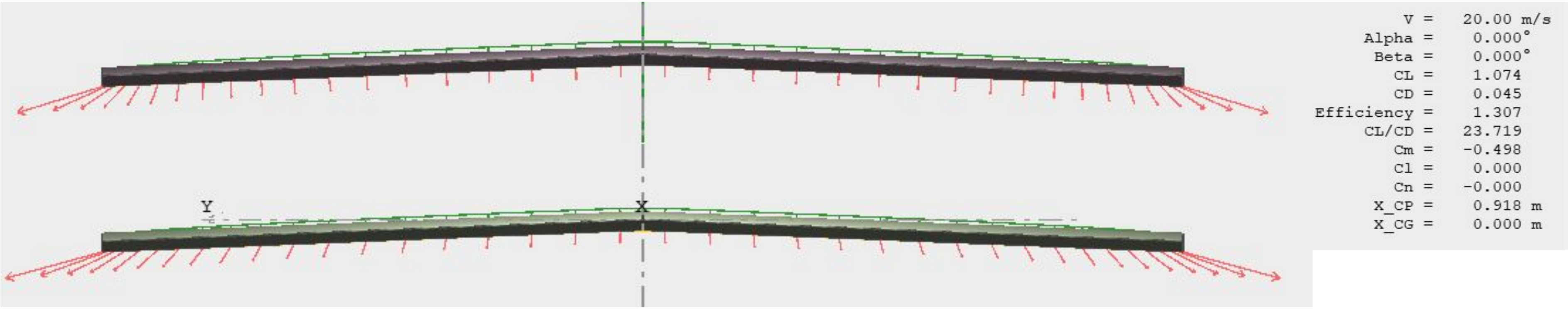






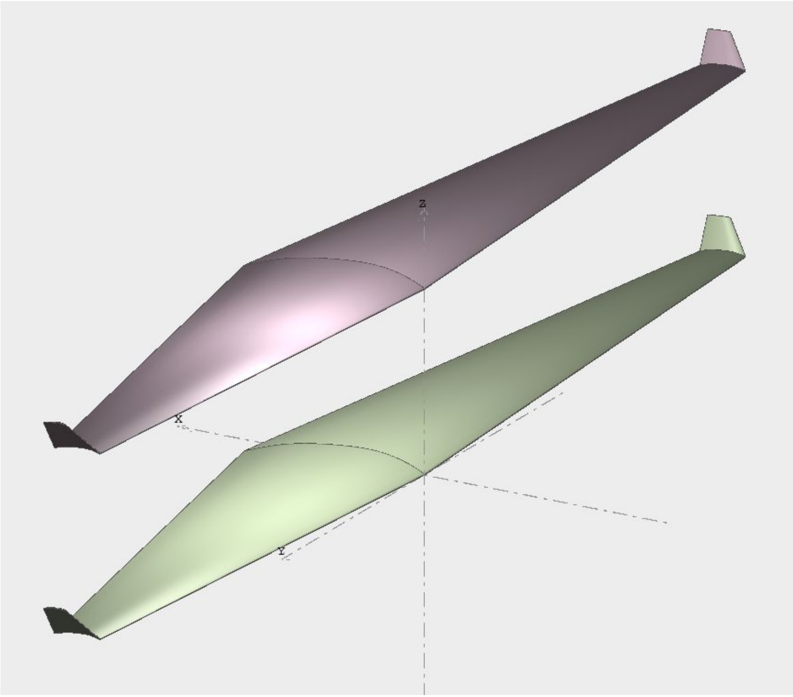
Induced Drag(yellow), Downwash(red) and Lift(Green)





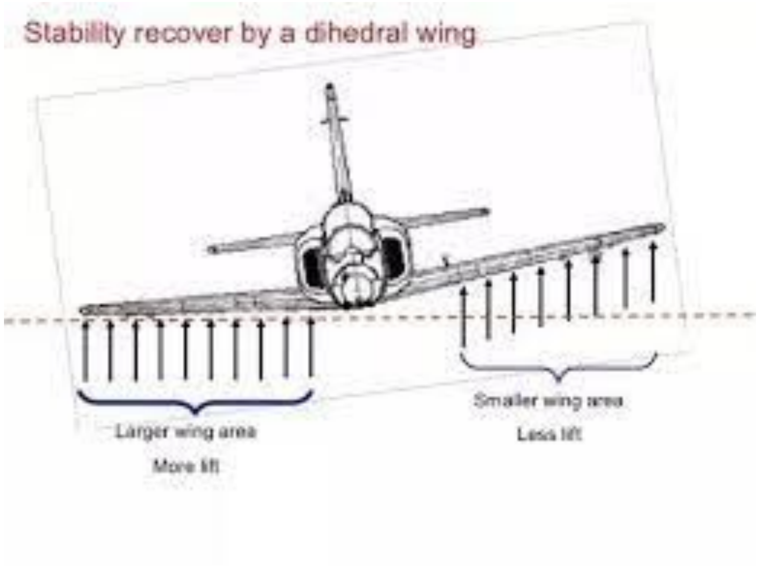
Changes to Design

- Three characteristics: dihedral angle, taper ratio, airfoil profile
- Dihedral angle: +2.5 deg
- Taper Ratio: 0.25
- Camber increased to 8%
- Added winglets



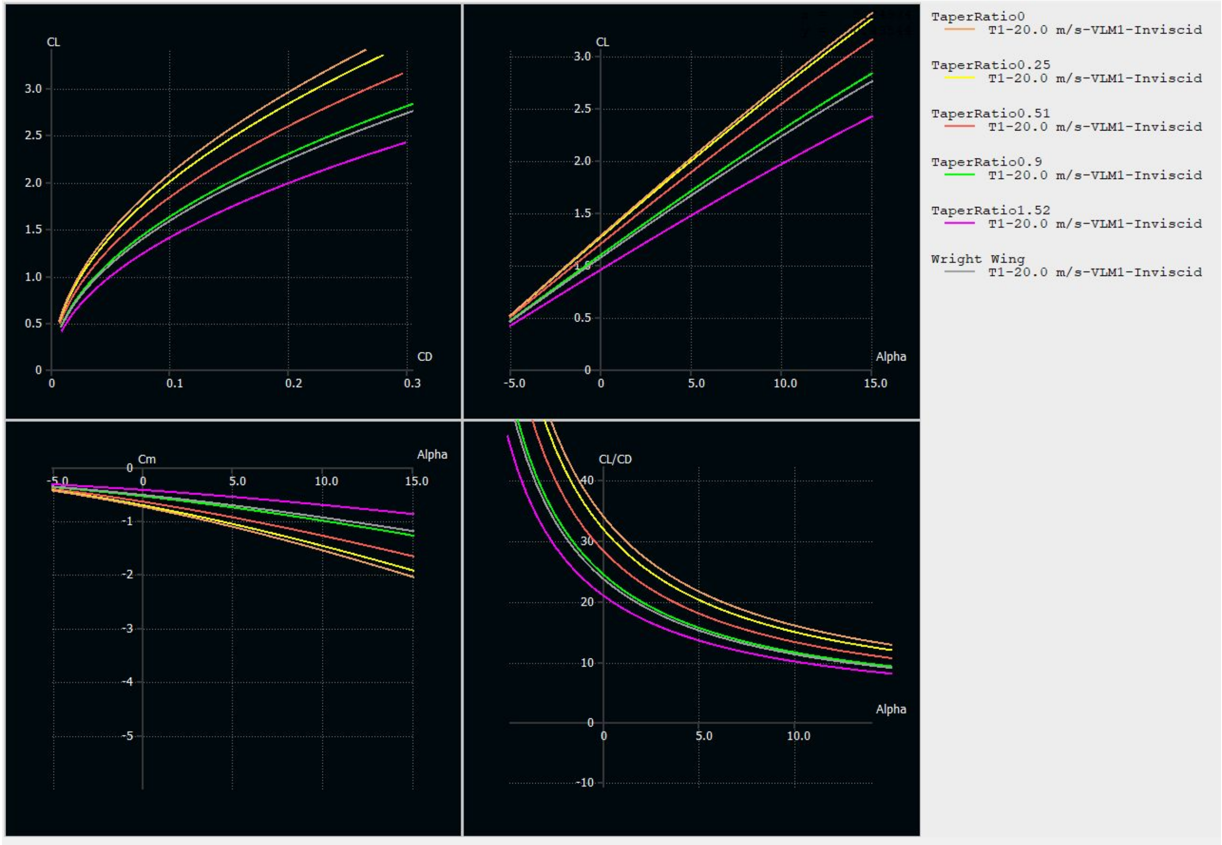
Dihedral angle

- Dihedral angle improves the roll stability
- Increased dihedral angle also results in reduced lift and increased induced drag



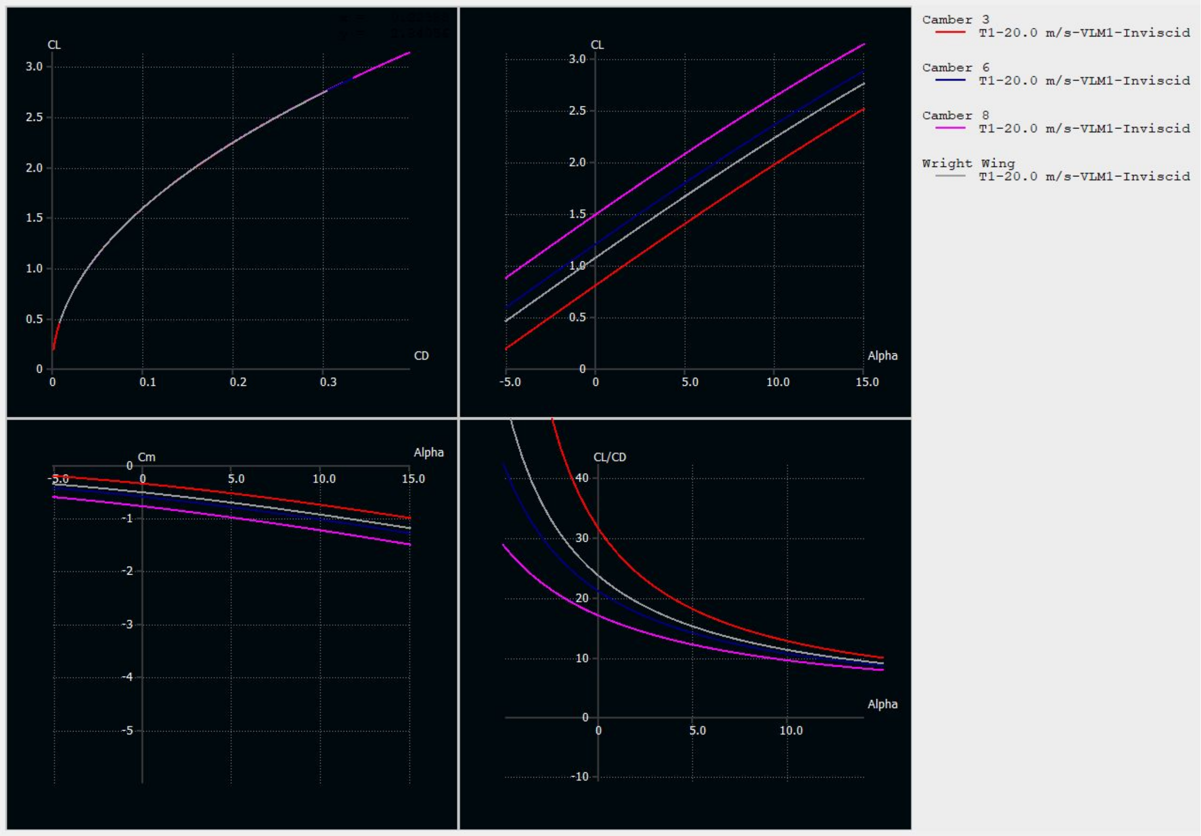
Taper Ratio

- Cl vs Cd significantly increases as taper ratio decreases
- Cl increased
- More negative Cm
- Cl/Cd also improved



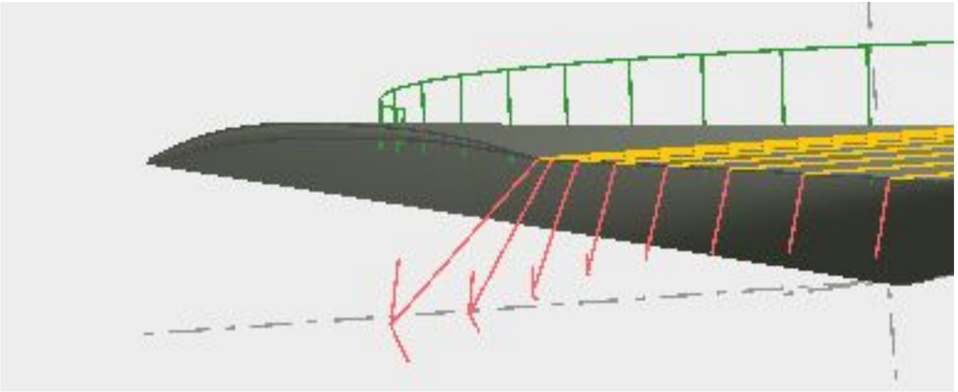
Airfoil Profile - Camber

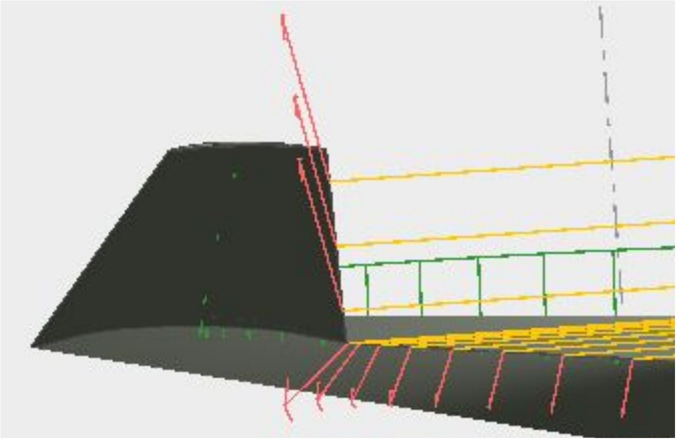
- Same Cl vs Cd
- Cl significantly increased
- More negative Cm



Airfoil Profile - Winglets

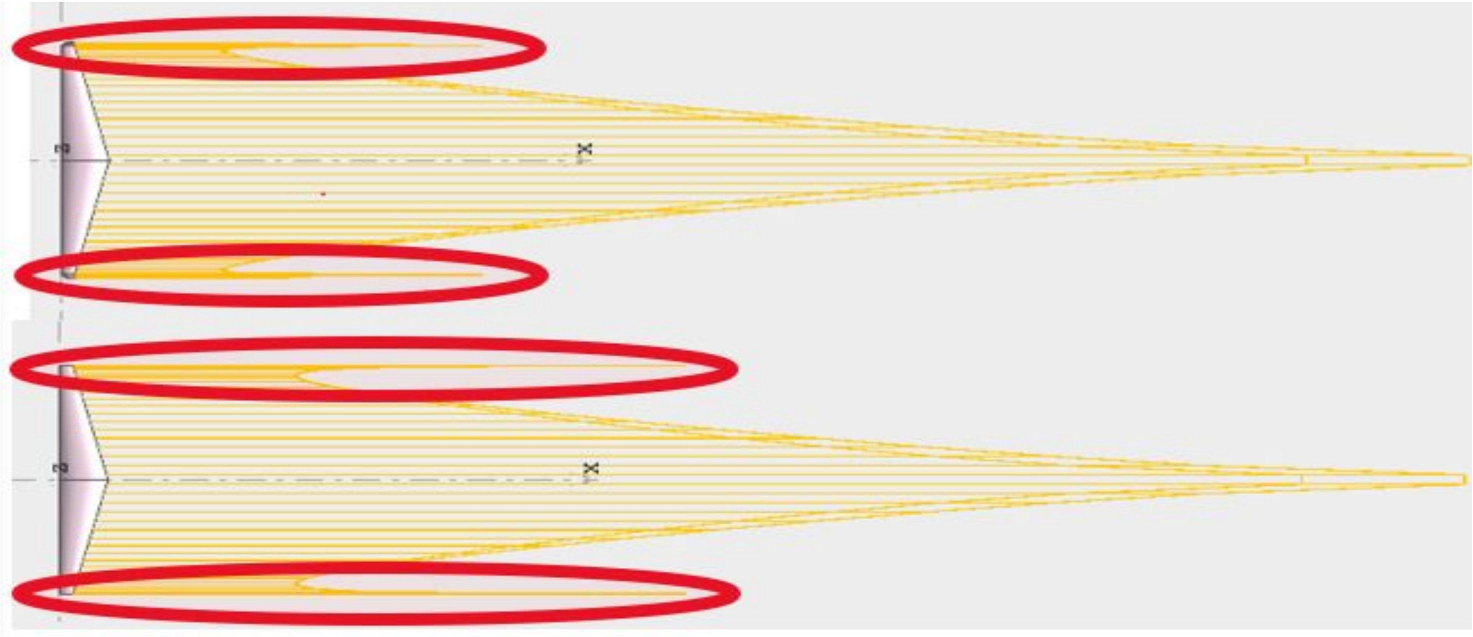
Winglets reduce and redirect downwash(red) at the wingtips by mitigating the effects of wing-tip vortices which form primarily during take off and landing (especially applicable in our case). Case without winglets (Left) directs downwash down, whereas the case with winglets (right) directs down wash both upward and downward.





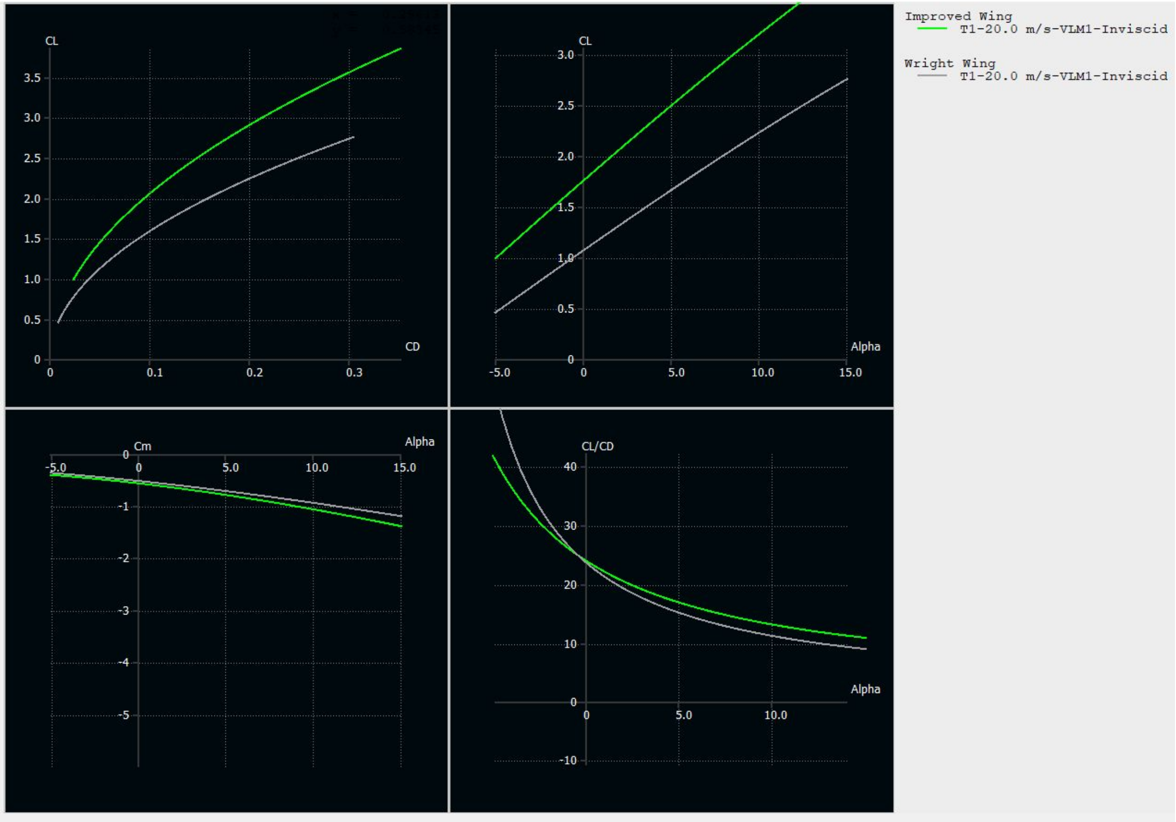
More On Winglets

Induced drag(yellow) is subsequently reduced as it is proportional to downwash. The induced Drag stream is much shorter with winglets(top) than without(bottom).



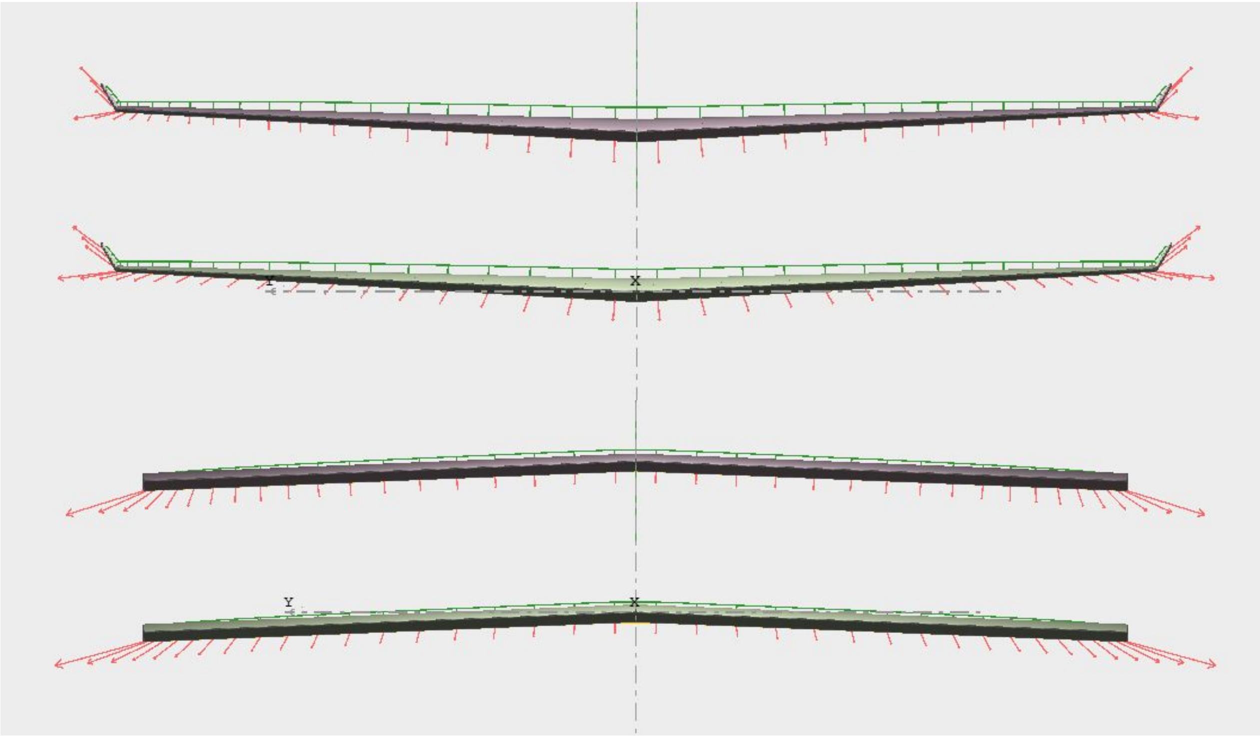
Overall improvements

- Drag polar significantly improved
- Cl significantly higher
- Cm similar but slightly more negative
- Cl/Cd is higher for positive alpha



Downwash and Lift

- Winglets redirect downwash at wingtips
- Lift (green) is more for new design

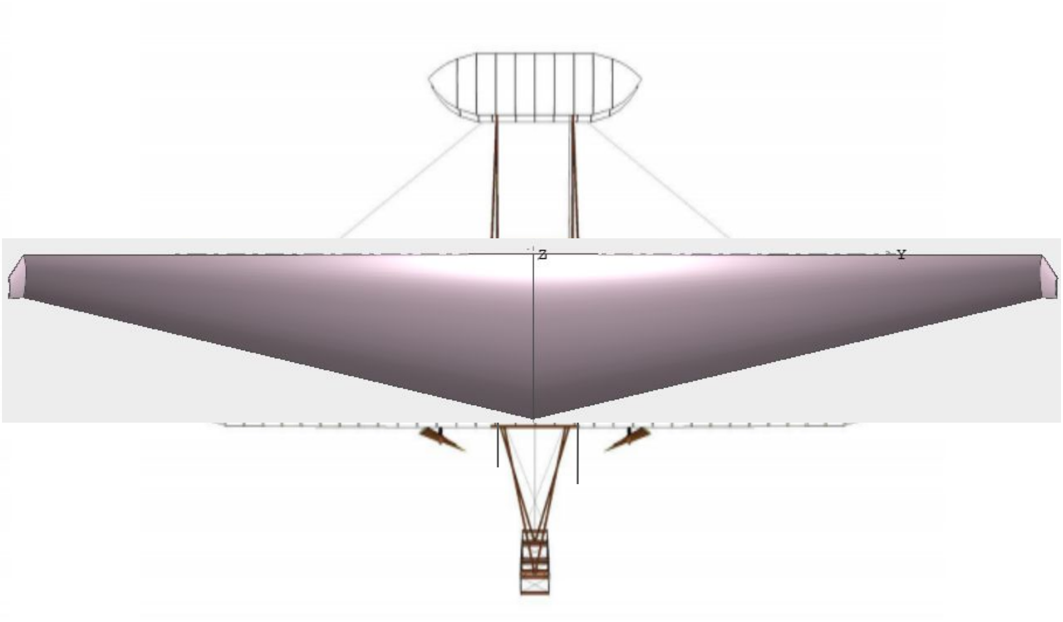


Top: New design, Bottom: Wright Flyer

Other Considerations

- Sweep: Sweep reduces drag at high speeds and increases longitudinal stability. At lower speeds, flow is pushed spanwise and leads to decreased lift.
- Significantly less material used in design (15.358m^2 vs 24.315m^2) while still increasing the total lift

Before vs. After



Slide assignments

Jay 7,8,9,10

Alex 5,6,11,12,13

Xander: 1,2,3,4