On the Effect of Winglets on the Performance of Micro-Aerial-Vehicles

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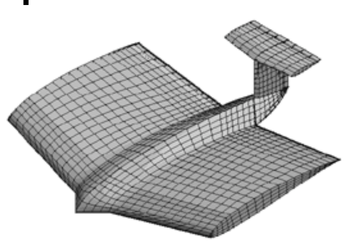
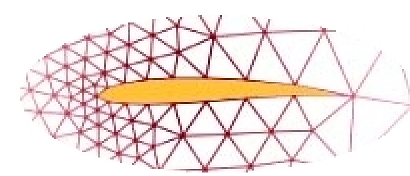




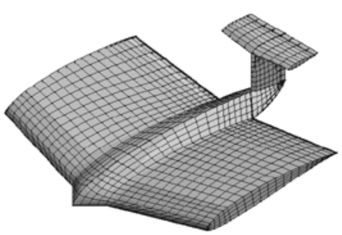
Winglets in everyday use

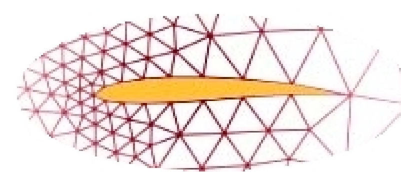
- **Boeing business jet**

- **Air Berlin 737-800**

Outline

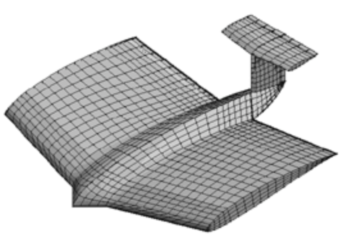
- Definition of an MAV
- Aerodynamic considerations
- Winglets
- Computational approach
- Current results
- Ongoing work
- Conclusions

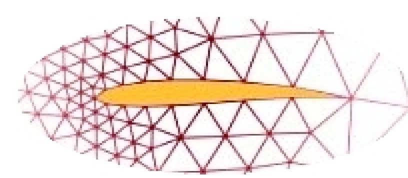




What is an MAV?

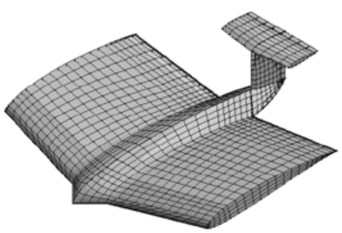
- Maximum dimension: 150 mm
- Mass 60-80 grams
- Operates at Re = 50,000 - 200,000
- Capable of carrying a payload (20g)
- Equipped with high tech surveillance equipment
- Multi-disciplinary research problem
  - » Airframe
  - » Propulsion
  - » Avionics

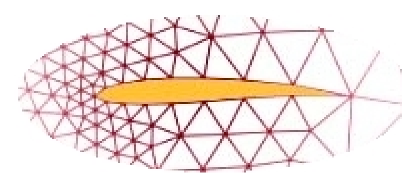




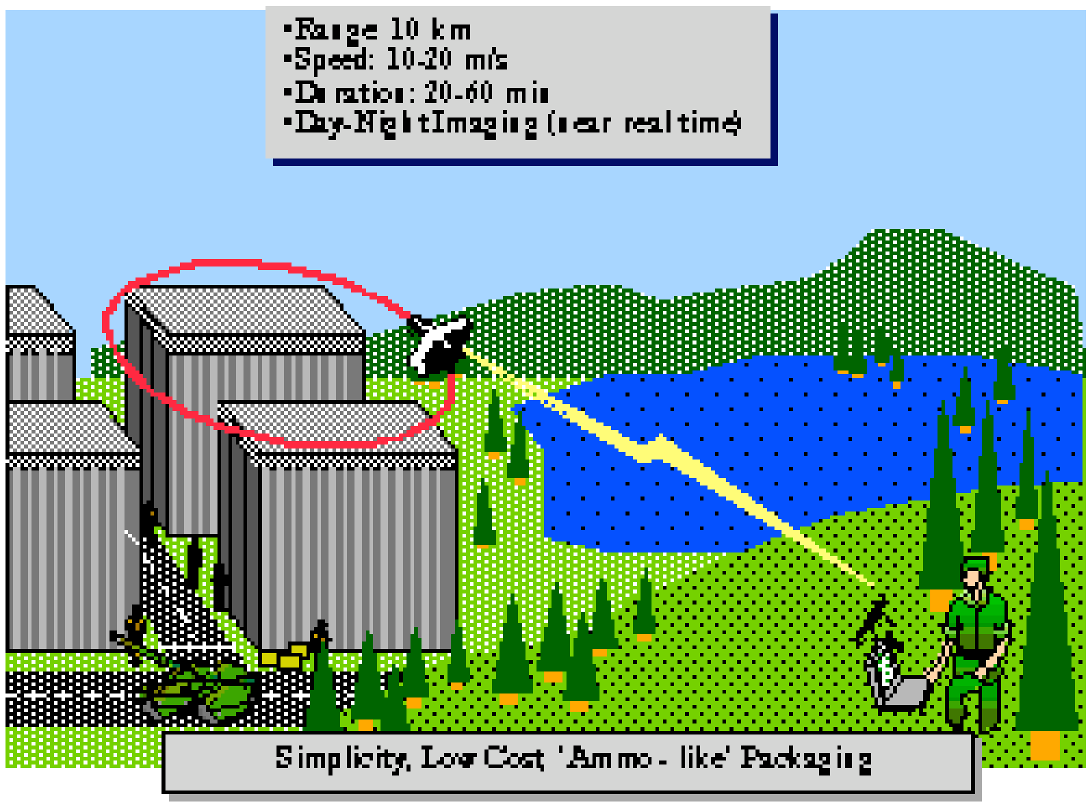
MAV missions

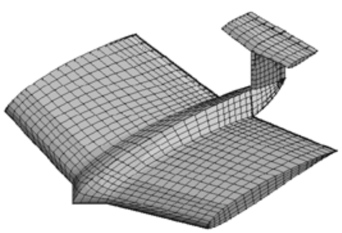
- Surveillance
- Sensor placement
- Detection of chemical and biological threats

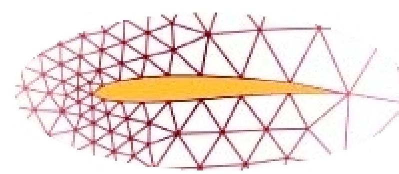




MAV operation

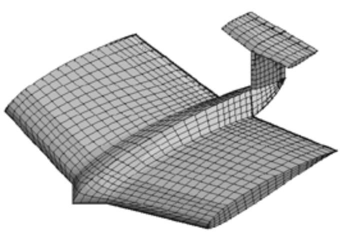


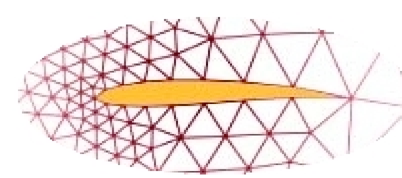




Problem Characteristics

- Low aspect ratio and short span
  - Size restriction
- Low Reynolds number
  - Size restriction and low speed
- Unsteady freestream
  - Low altitude

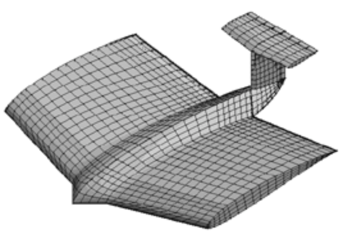


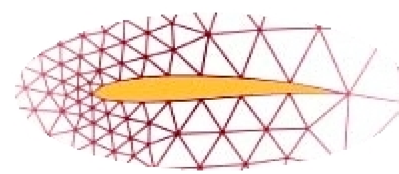


Aerodynamics

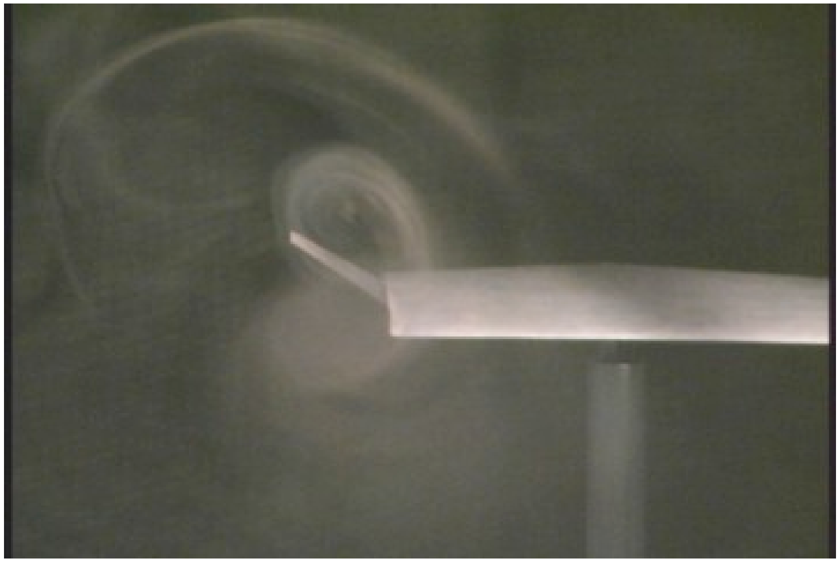
- **Maximize lift**
  - Payload
  - Range
  - Endurance
- **Induced drag**
  - Tip-vortices

Dryden Flight Research Center ECN 3831 Photographed 1974
B-727 vortex study NASA photo



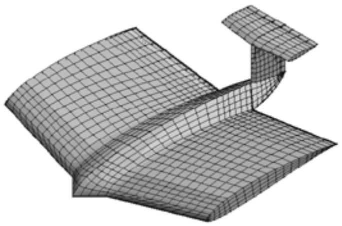


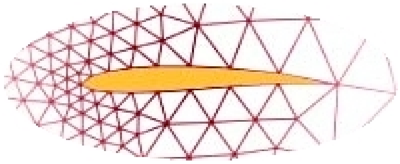
Why winglets?



Effect of Winglets

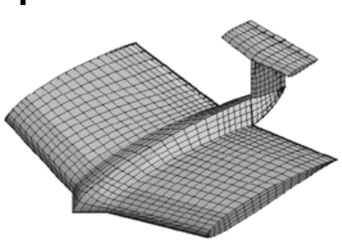
- Limited downwash
  - Increase in lift
    - » Important to enable payload carriage
  - Drag reduction
    - » Induced drag, potentially total drag
    - » Success stories
      - Sailplanes
      - Transonic aircraft
      - Business jets

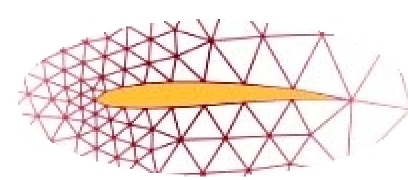




Motivation for the current study

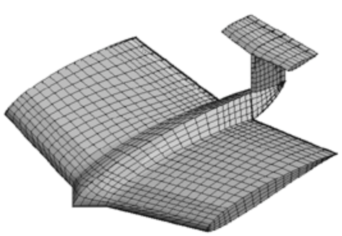
- Lack of published data for the full Re-range where MAVs operate
  - Data exists for Re > 100,000
- No computational studies of winglets for MAVs available
  - Investigate the effect of winglets only
  - Success with other applications
- Provide a database that can be used by future researchers or MAV-designers

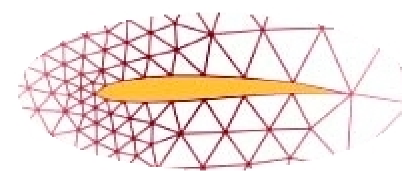




Computational Approach

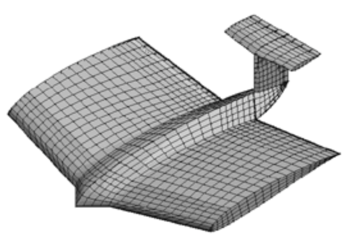
- **COBALT**
  - Compressible Navier-Stokes solver
    - » Run incompressible at Mach = 0.1
  - Finite Volume Method
  - Riemann Solver
- **Gridgen**
  - Block-based grid generator

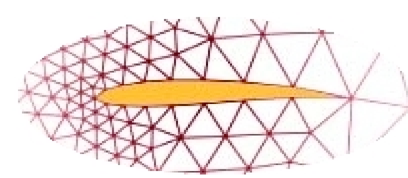




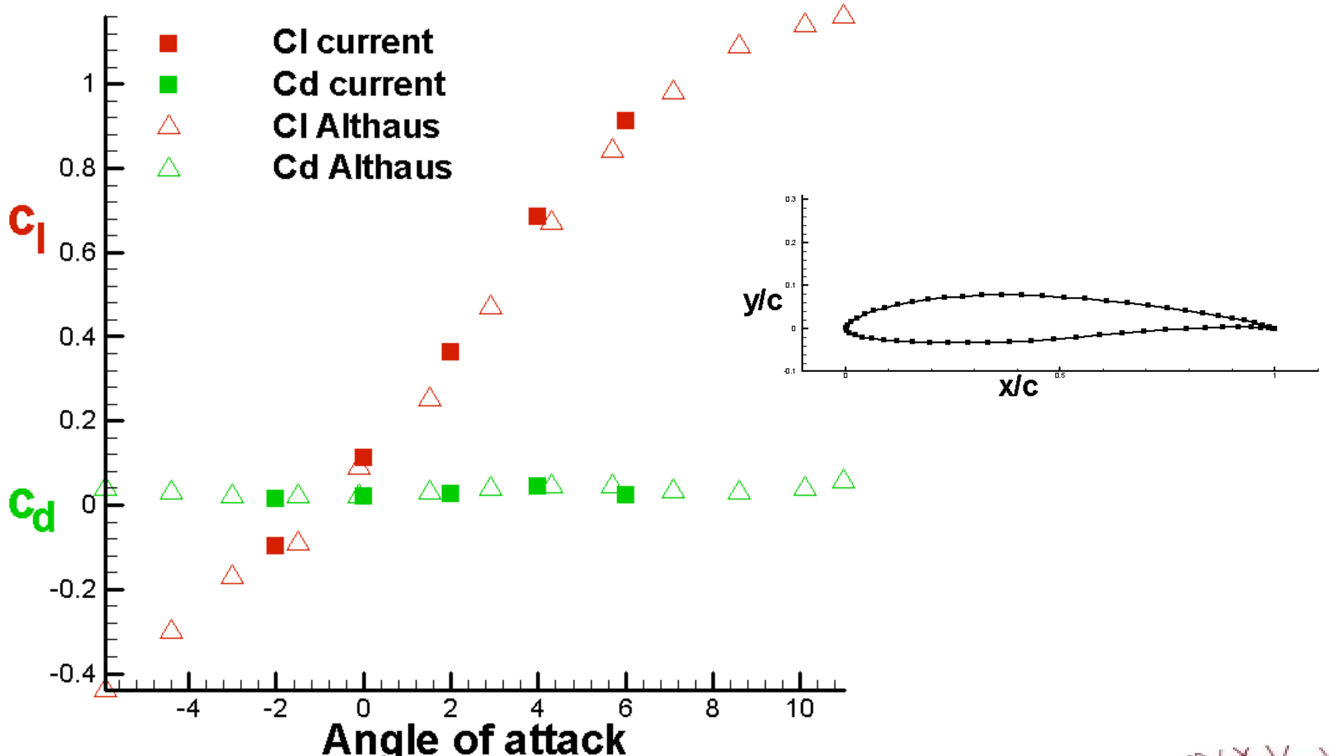
Validation and Verification

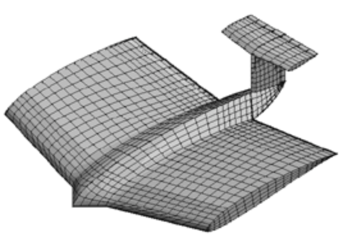
- **Required for reliable computations!**
- **Validation**
  - Does the computation model real life?
  - Compare with experimental results
- **Verification**
  - Are the equations solved correctly?
  - Compare with analytical solutions or other computational results

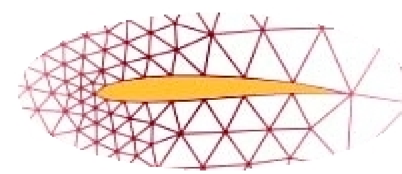




Eppler 211, Re= 60,000 Validation

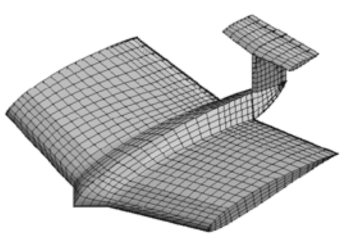


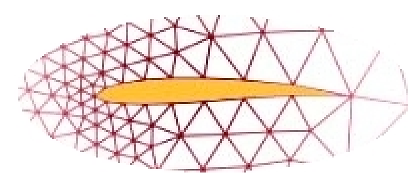




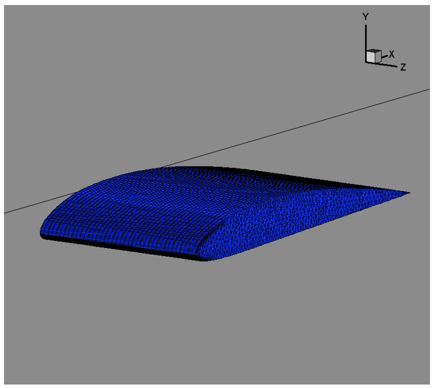
3-D work

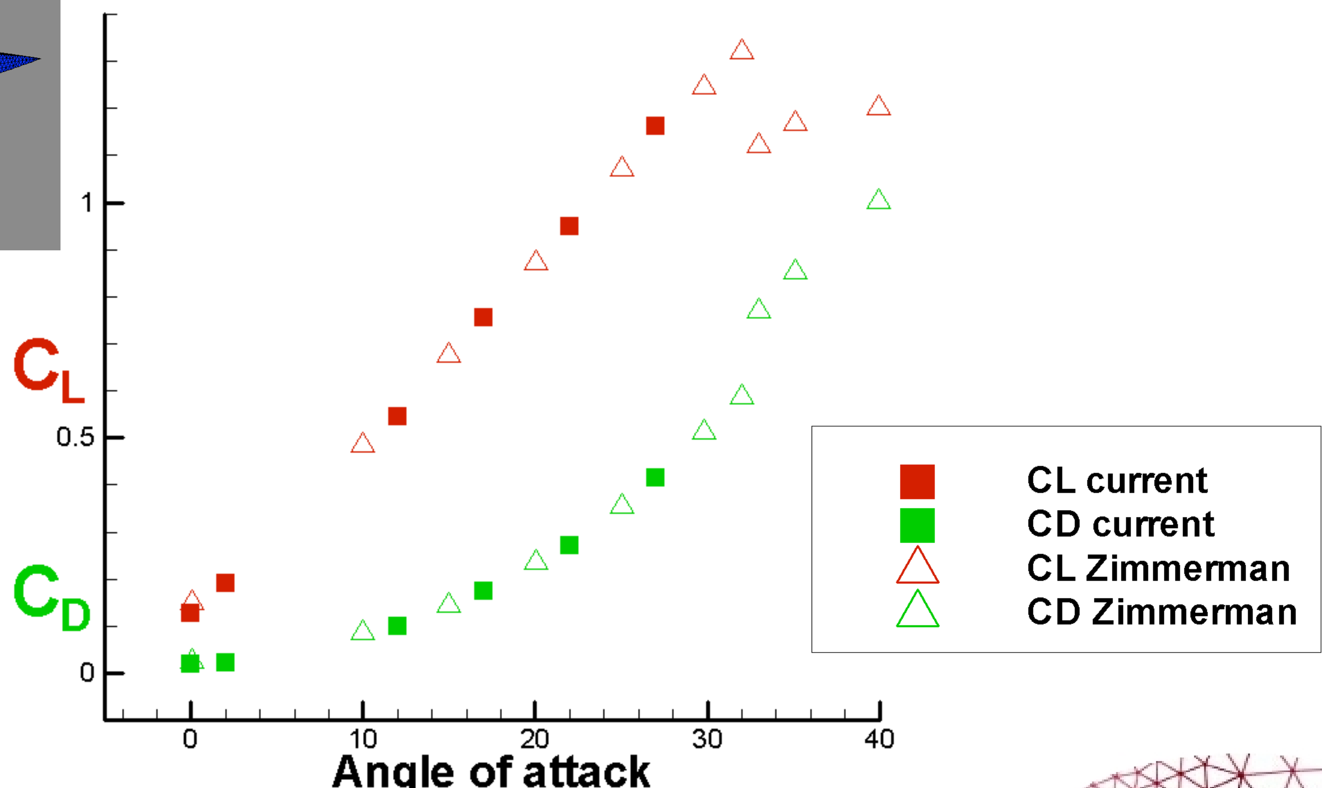
- Baseline model vs. wing-winglet model
- How do the winglets affect
  - Lift
  - Drag
  - Lift-to-drag-ratio
  - Stability and controllability

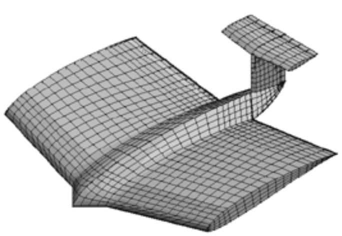


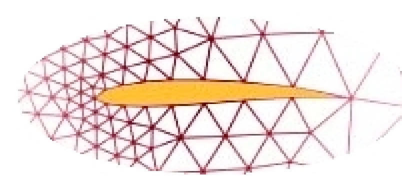


Clark-Y wing
AR = 1, Re = 860,000
Validation

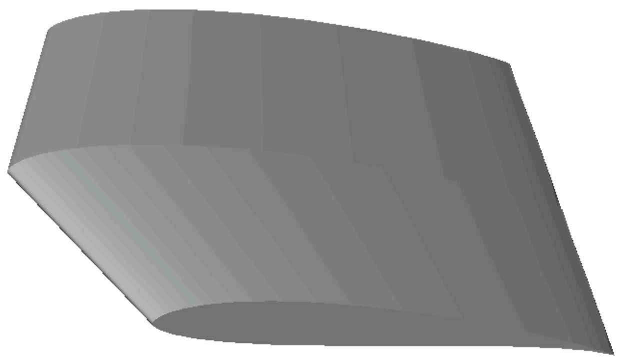








Baseline Model



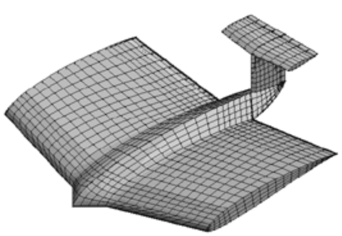
- Eppler 212
- Root chord 150 mm
- Tip chord 127 mm
- Straight trailing edge
- Span 150 mm

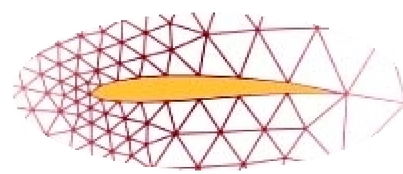
Winglet 4b

- 25.4 mm span
- 78 mm tip chord
- Leading edge sweep angle 26.6˚
- 90˚ cant angle
- Thickness 1.6 mm

Winglet 5b

- 25.4 mm span
- 8 mm tip chord
- Leading edge sweep angle 26.6˚
- 90˚ cant angle
- Thickness 1.6 mm





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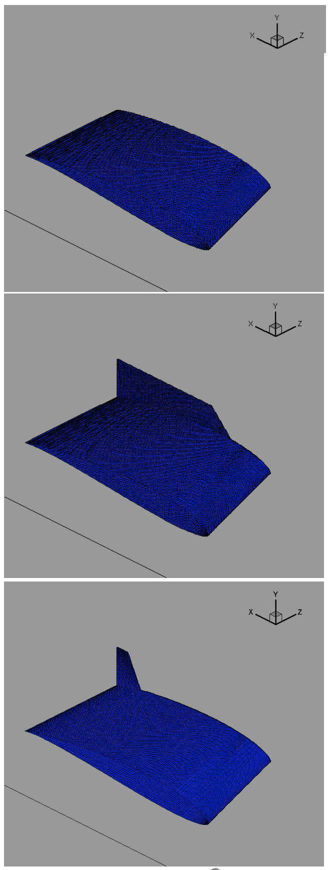
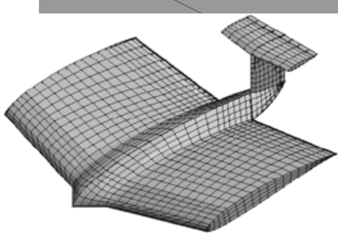
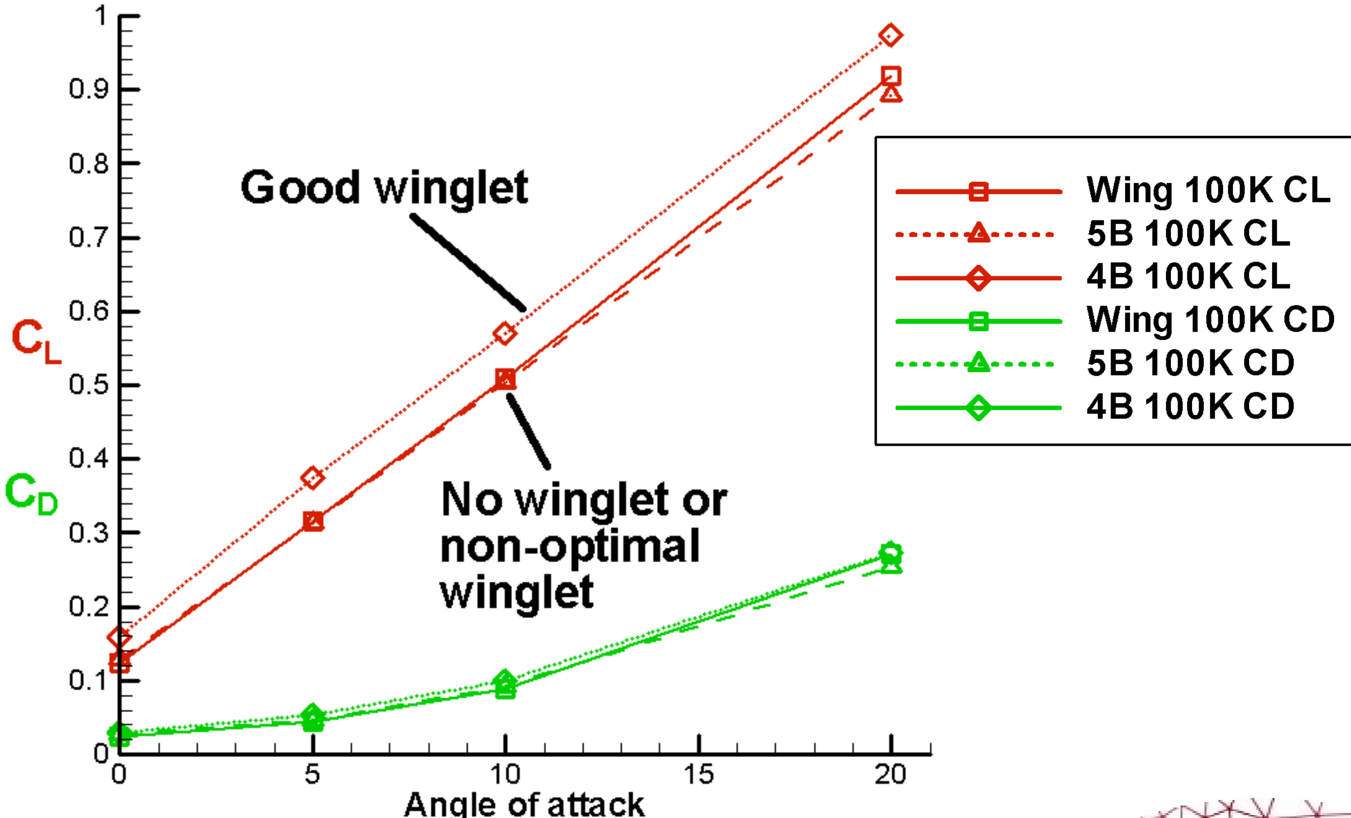
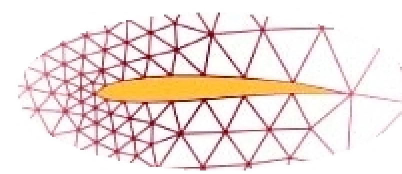
UNSTEADY WIND TUNNEL

Effect of Winglets, Re =100,000







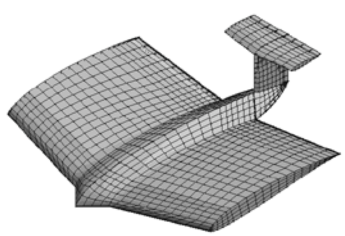


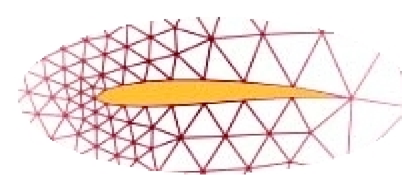
Ongoing work

- **Complete computations to optimize winglets**
  - **Re = 50,000-200,000**

- **Analyze the effect of winglets on the stability of an MAV**

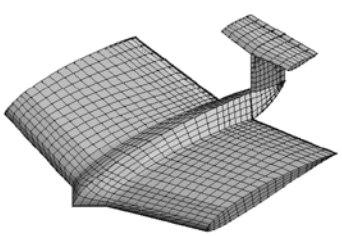
- **Provide guidelines for choosing winglets for MAV-applications**

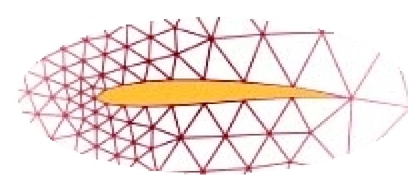




Conclusions

- MAV definition
  - Aerodynamic considerations
- Computational method
  - Validation and verification
- Winglets can improve both the lift and the lift-to-drag-ratio when properly chosen
  - Careful: possibility of adverse effects!





Acknowledgements

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