The Effects of Biomimetic Morphing Wings on Small Scale Vehicles

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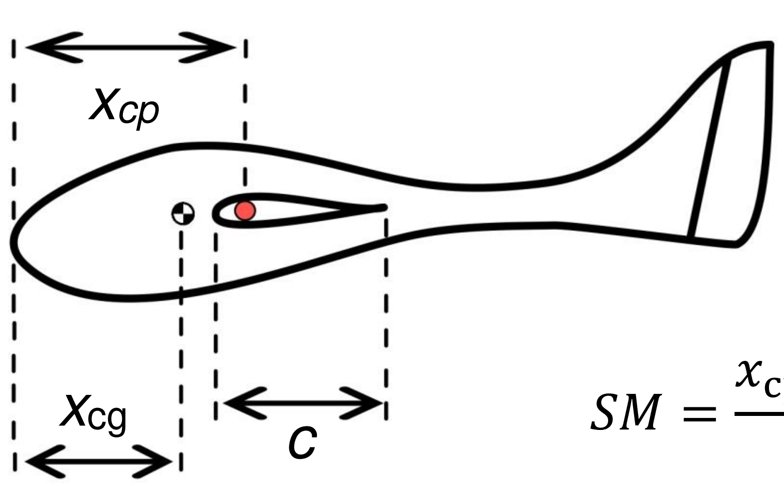
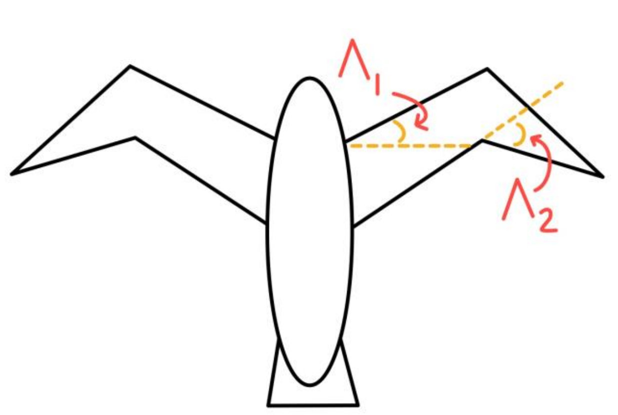
Introduction

- Small scale vehicles are more sensitive to external forces and, therefore, more prone to instabilities during flight.
- Professor Geoffrey Spedding and Ph.D. student Yohanna Hanna study the aerodynamic properties of morphing wings. By creating a family of bird-like wings with varying inboard and outboard sweep angles, their research examines the effects of these angles on stability in addition to flight efficiency.
- Planes typically have a fixed wing configuration while their biological counterparts have the ability to reconfigure wing shapes.
- Stability: The ability of a body to return to its original condition of equilibrium following a disturbance.
  - Can be quantified by calculating static margin (*SM*), with the distances between the nose to the center of gravity (x_{cg}) and the nose to the center of pressure (x_{cp}) normalized by the chord length (c).



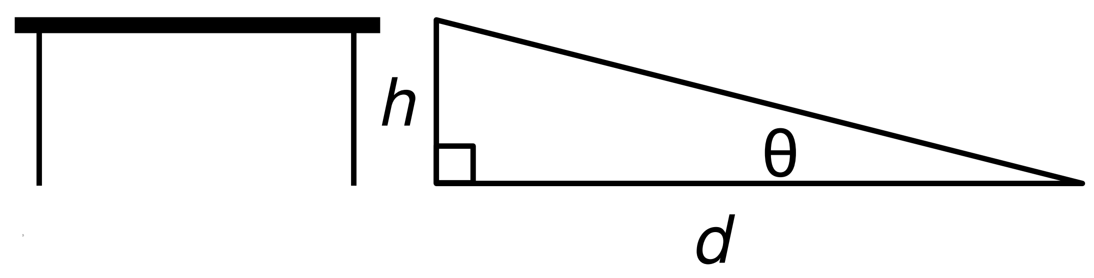
$$SM = \frac{x_{cp} - x_{cg}}{c}$$

Experimental Setup



Glider Number	Λ_1	Λ_2
1	0º	0º
2	0º	30º
3	30º	0º
4	30º	30º
5	-30º	0º
6	-30º	30º

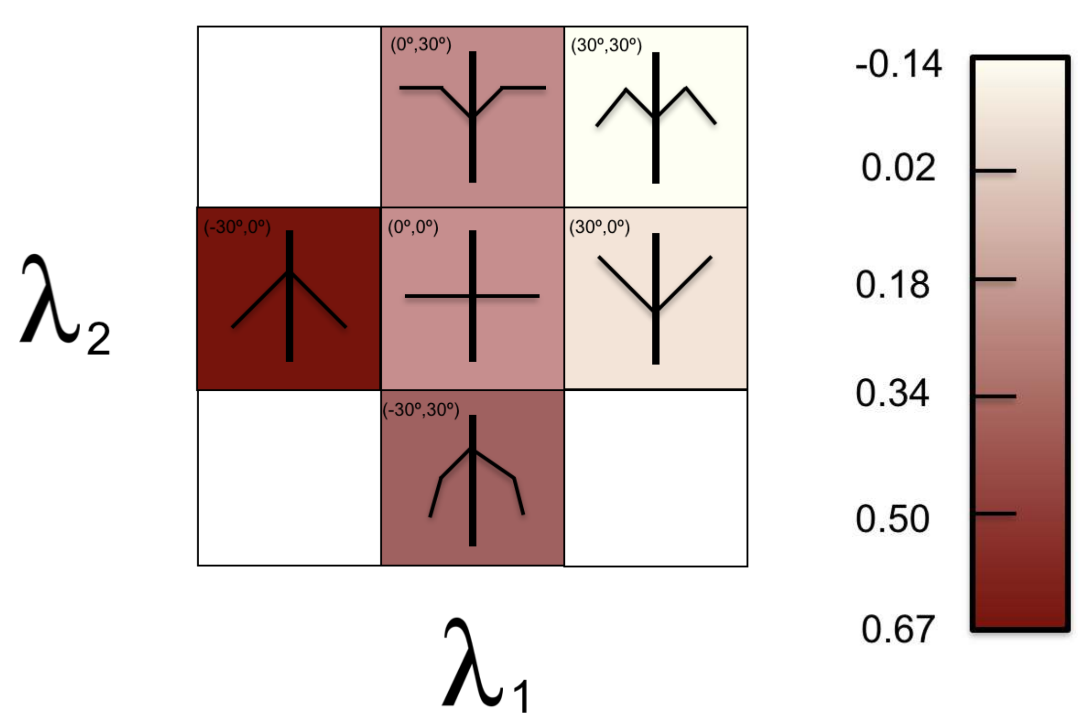
- By cutting the wings of foam gliders, six different wing configurations were created with varying inboard and outboard sweep angles. The surface area of the wings were preserved across all six gliders.



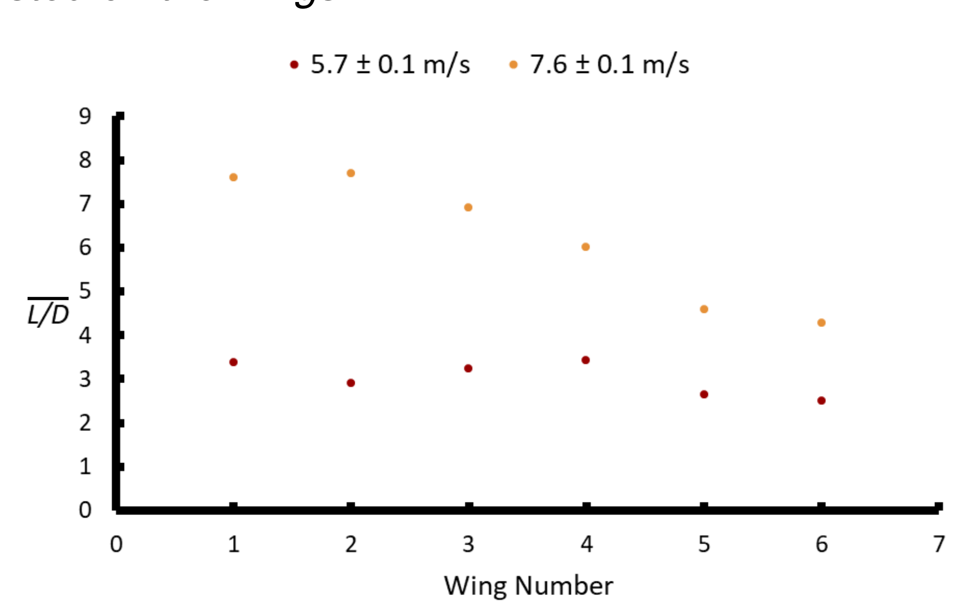
$$\tan\theta = \frac{h}{d} \qquad \cot\theta = \frac{L}{D}$$

By measuring the horizontal distance flown (*d*) and change in height of the glider (*h*), the glide angle (*θ*) can be determined. Using trigonometry, the lift to drag ratio (*L*/*D*) can be calculated.

Results and Discussion



The diagram above depicts the six various wing configurations positioned by their respective inboard and outboard angles. The color gradient illustrates the static margin value for each glider wing. The graph below shows the average L/D for two different speeds tested on the wings.



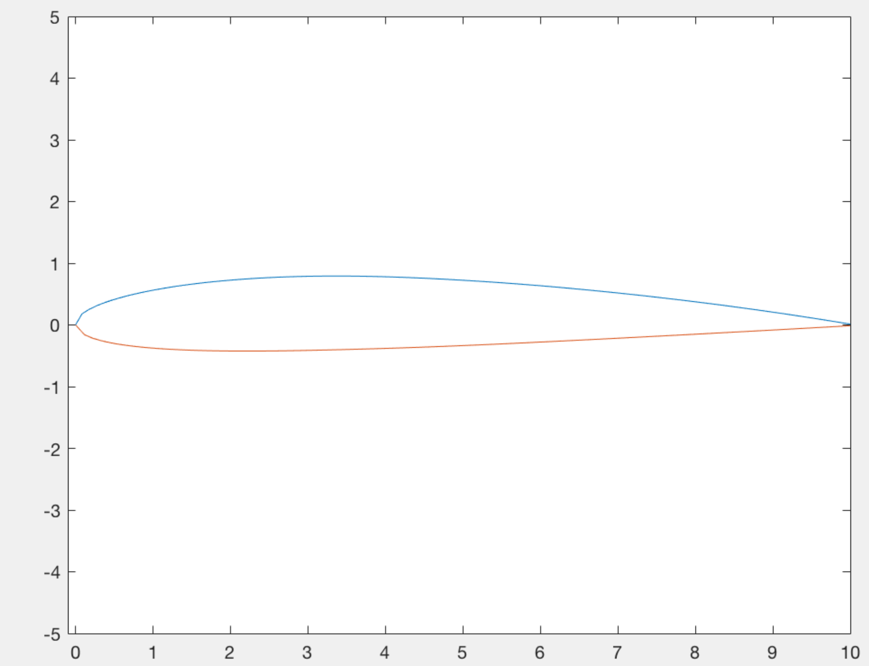
- At low speeds, wings that were swept forward generally performed better or were very similar to the original unswept wing.
- At an increased launch speed, however, wings that were swept inboard, both forward and backward performed visibly worse. During test flights, these wings also experienced more prominent moments of pitching and stalling.
- Wing configurations with an inboard angle of -30º performed the worst in terms of *L*/*D*, and also had a particularly higher static margin than the other wings, meaning the center of pressure was farther behind the center of gravity. This could have contributed to the greater pitching moments that were observed during flight, in which both wings tended to pitch down.
- Wings 3 and 4 (both swept 30º), which tended to pitch up and stall, also had negative static margins.

Conclusion

- Free flight tests are important preliminary procedures to visually compare stability and moments in the air throughout different wing configurations.
- Although there were connections between *L*/*D* and stability with wing number, more tests would be needed to support a general conclusion.

Relation to STEM Coursework

Through this SHINE project, I was able to apply previous knowledge of trigonometry and algebra to calculate *L*/*D* and static margin. My computer science and rocketry classes helped me in terms of familiarity with programming and some aerodynamic concepts.



Skills Learned

- Basic aerodynamic concepts and flight mechanics
  - Vectors and resultant forces
  - Lift and Drag
  - Moments (Pitch, Yaw, Roll)
  - Stability and Static Margin
- How to effectively and consistently conduct meaningful flight tests
- SolidWorks
  - Used CAD to design preliminary launch bed for flight testing
- MATLAB
  - Programmed code to plot four-digit NACA airfoil series with modifiable dimensions (example pictured above)

Acknowledgements

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