AERODYNAMICS-1 GROUP PRESENTATION

"COMPARING AND CONTRASTING THE WING DESIGN OF THE ALBATROSS AND PEREGRINE FALCON"

09 NOV 2024

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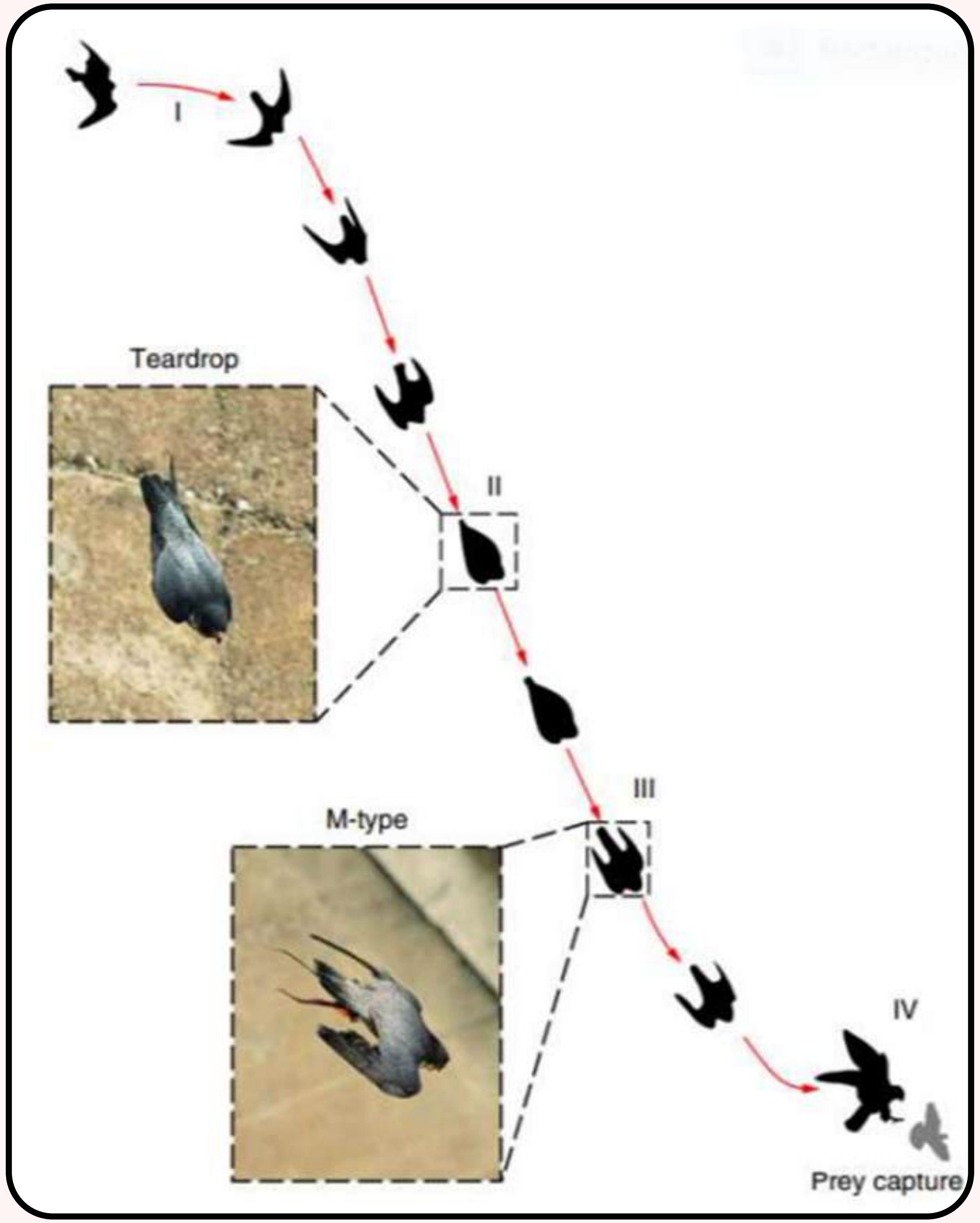
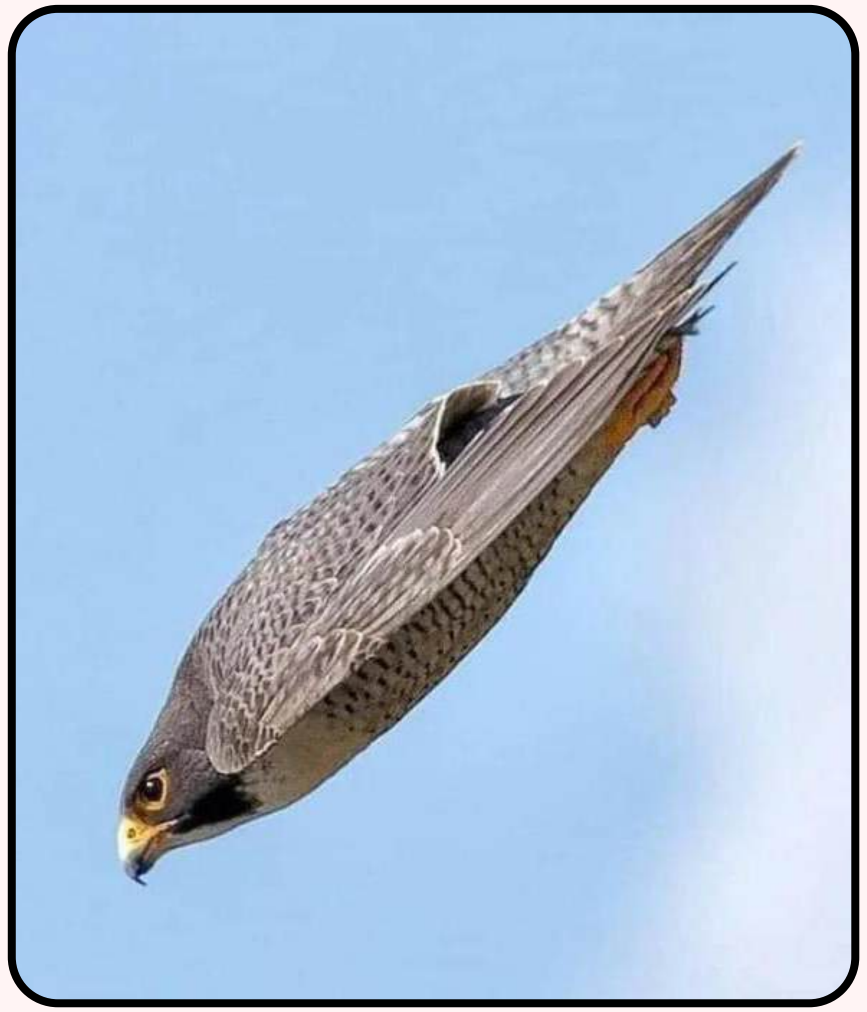
OBJECTIVES

- Investigate the aerodynamic characteristics that enable the high-speed flight of the peregrine falcon.
- Analyze the flight dynamics that allow the albatross to sustain exceptionally long-distance travel.
- Examine the aerodynamic features that contribute to the albatross's efficient gliding capabilities.

PEREGRINE FALCON





STOOP FLIGHT

Phase -1 : Beginning of Stoop Flight

↓

Phase 2 : Diving at maximum speed

↓

The intermediate phase between 2 & 3 has cuped wing configuration (C-type configuration)

↓

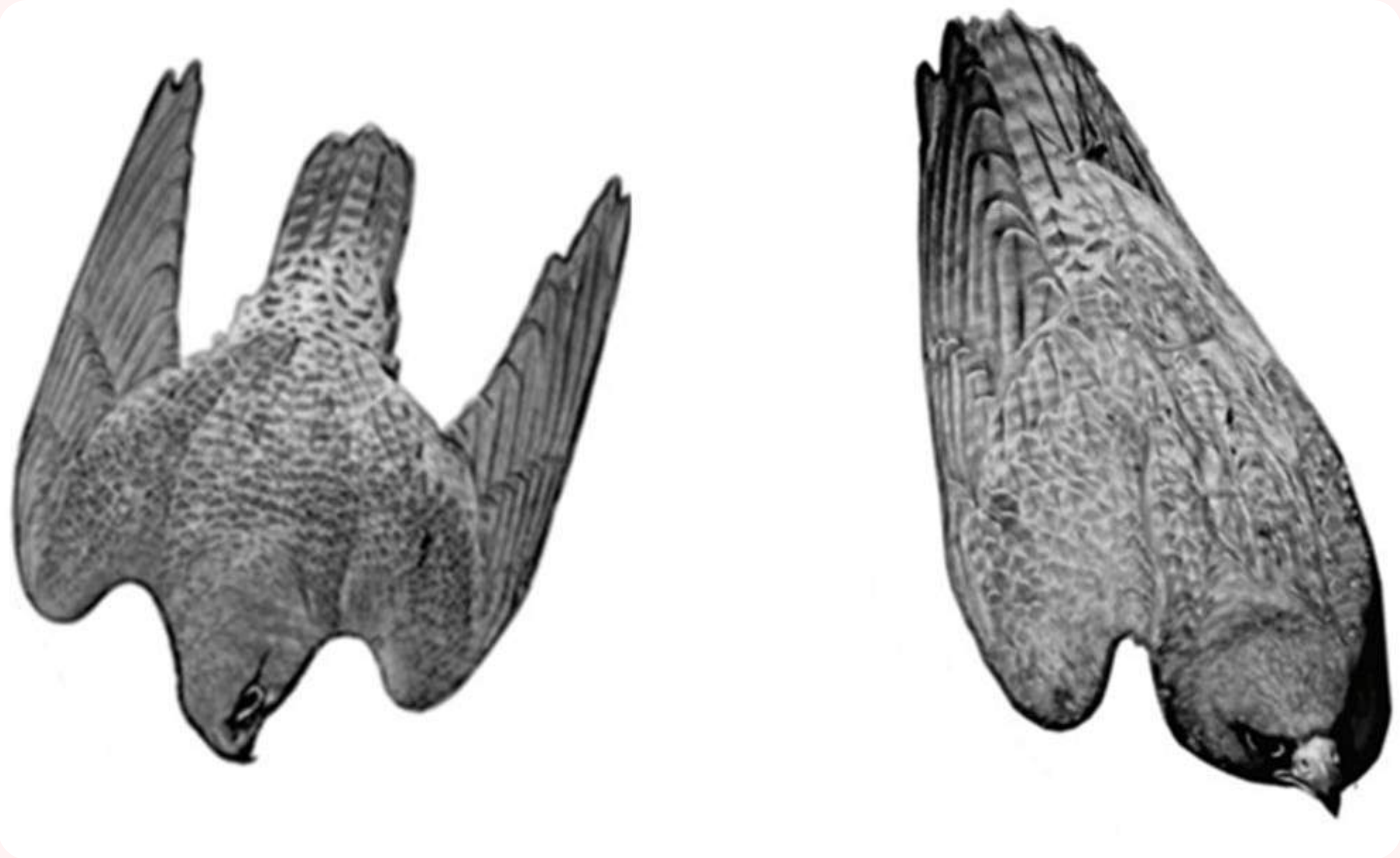
Phase 3 : Wings are slightly deployed to form M-Shape Configuration

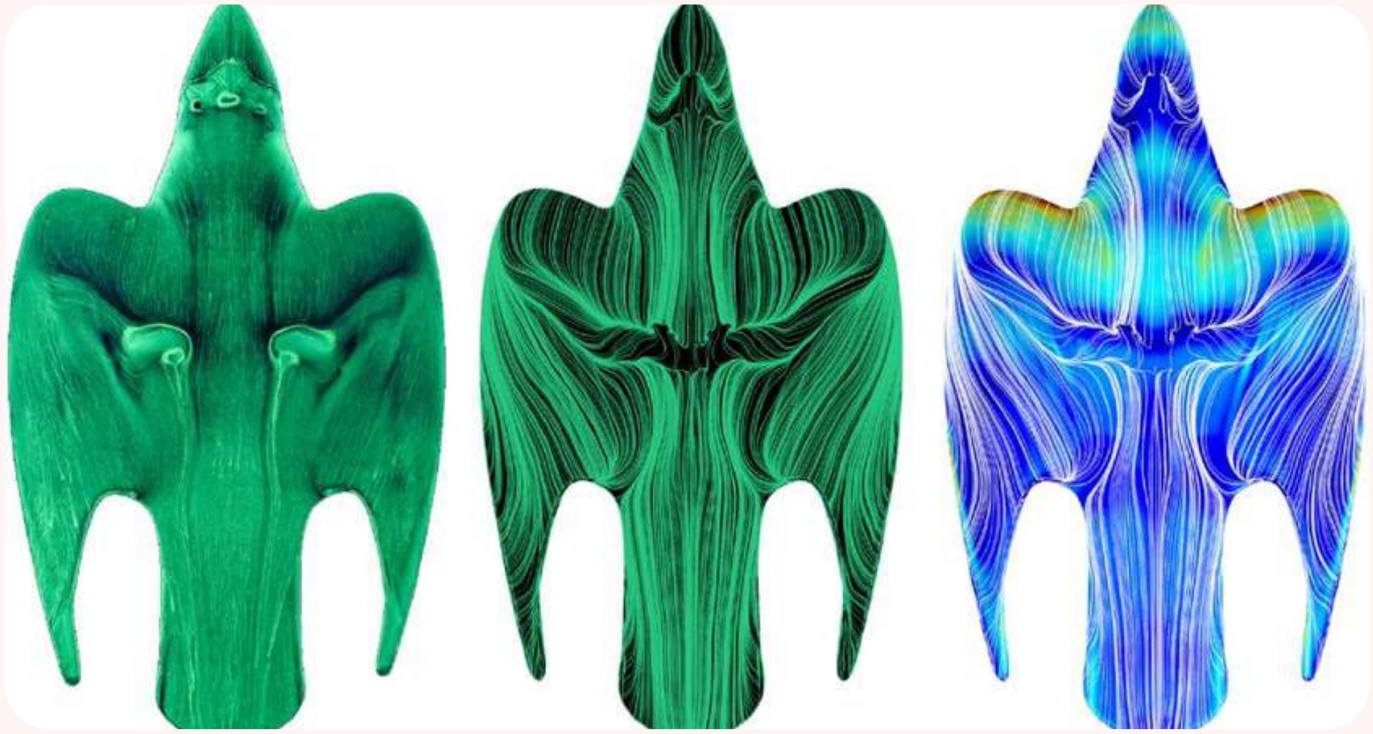
↓

Phase 4 : Pull Out Maneuver

AERODYNAMICS OF PEREGRINE FALCON

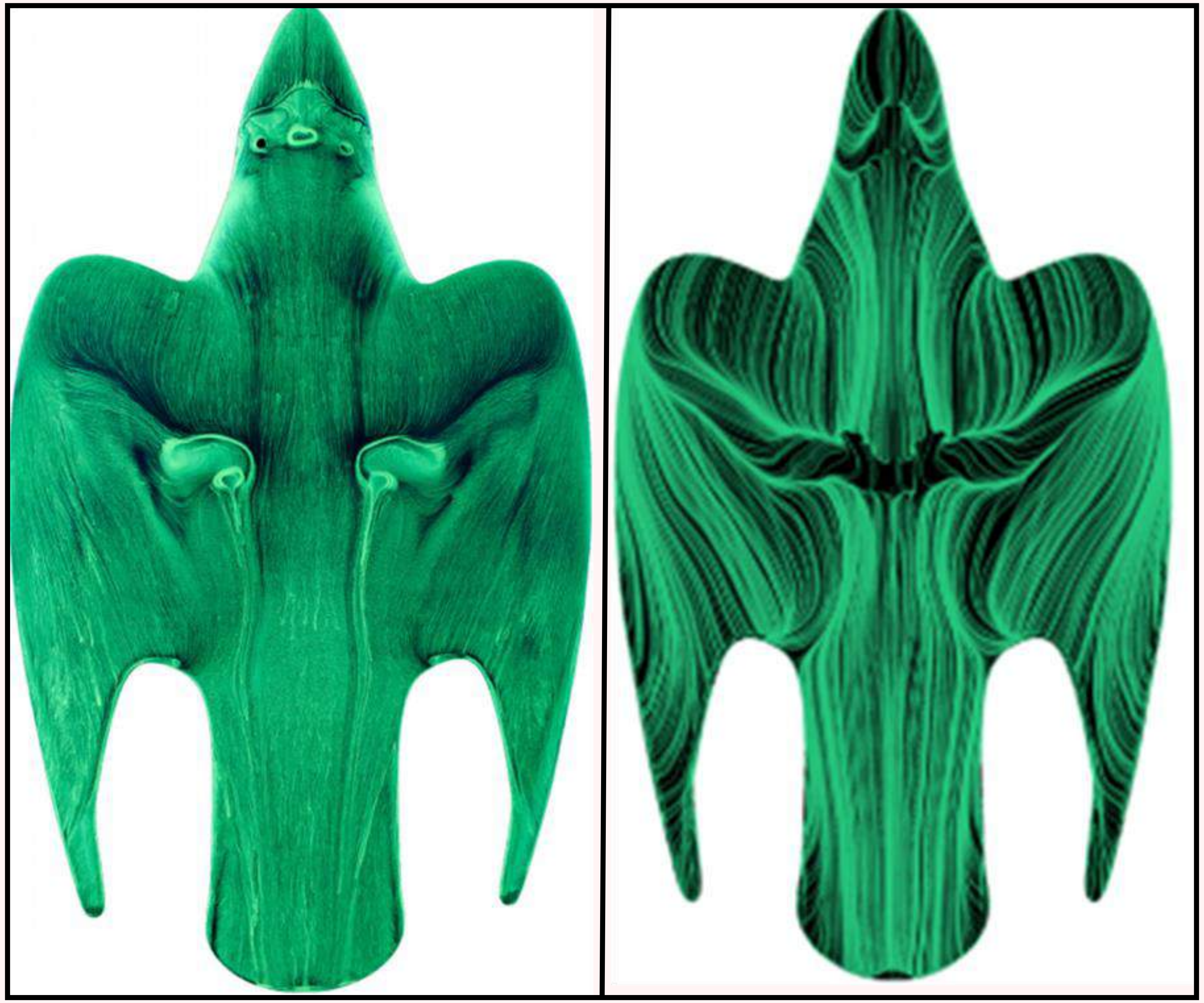
- Due to the streamlined nature of the falcon's body, we may think that its flight performance during stoop results from this characteristic.
- In reality, three-dimensional vortex structures strongly influence the stoop flight.



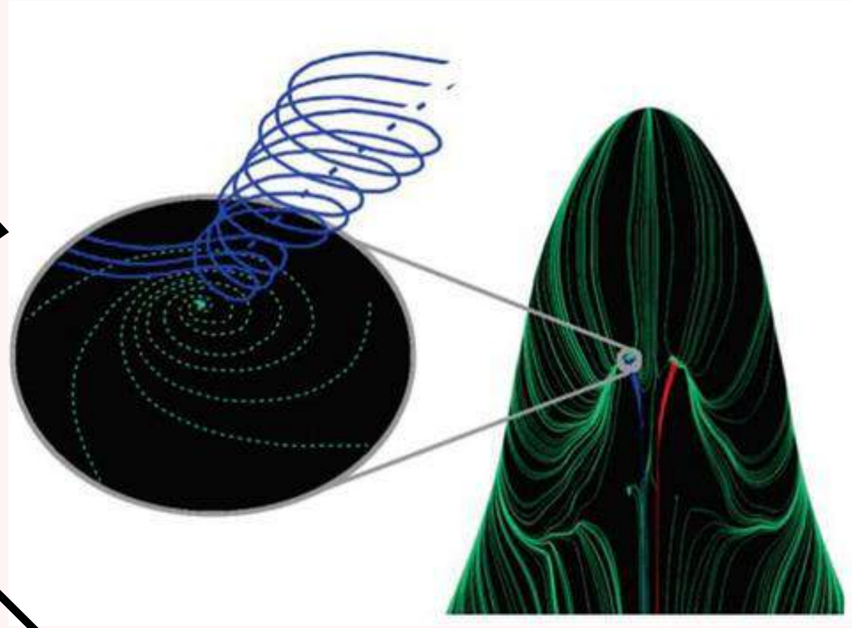


Understanding the Flow using Experiments and CFD

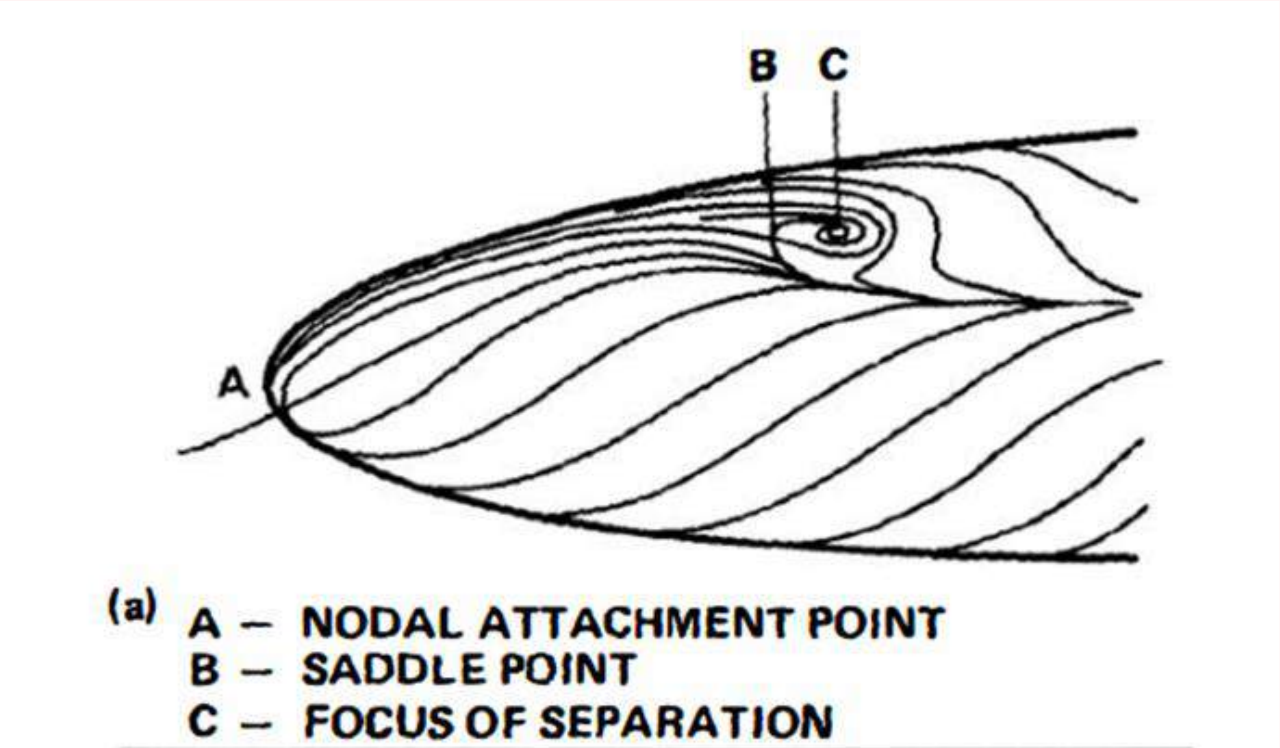
- Horn Vortex
- Horseshoe Vortex
- Dorsal Vortex
- Wing Vortex
- Tail Vortex
- Primary Feather Vortex

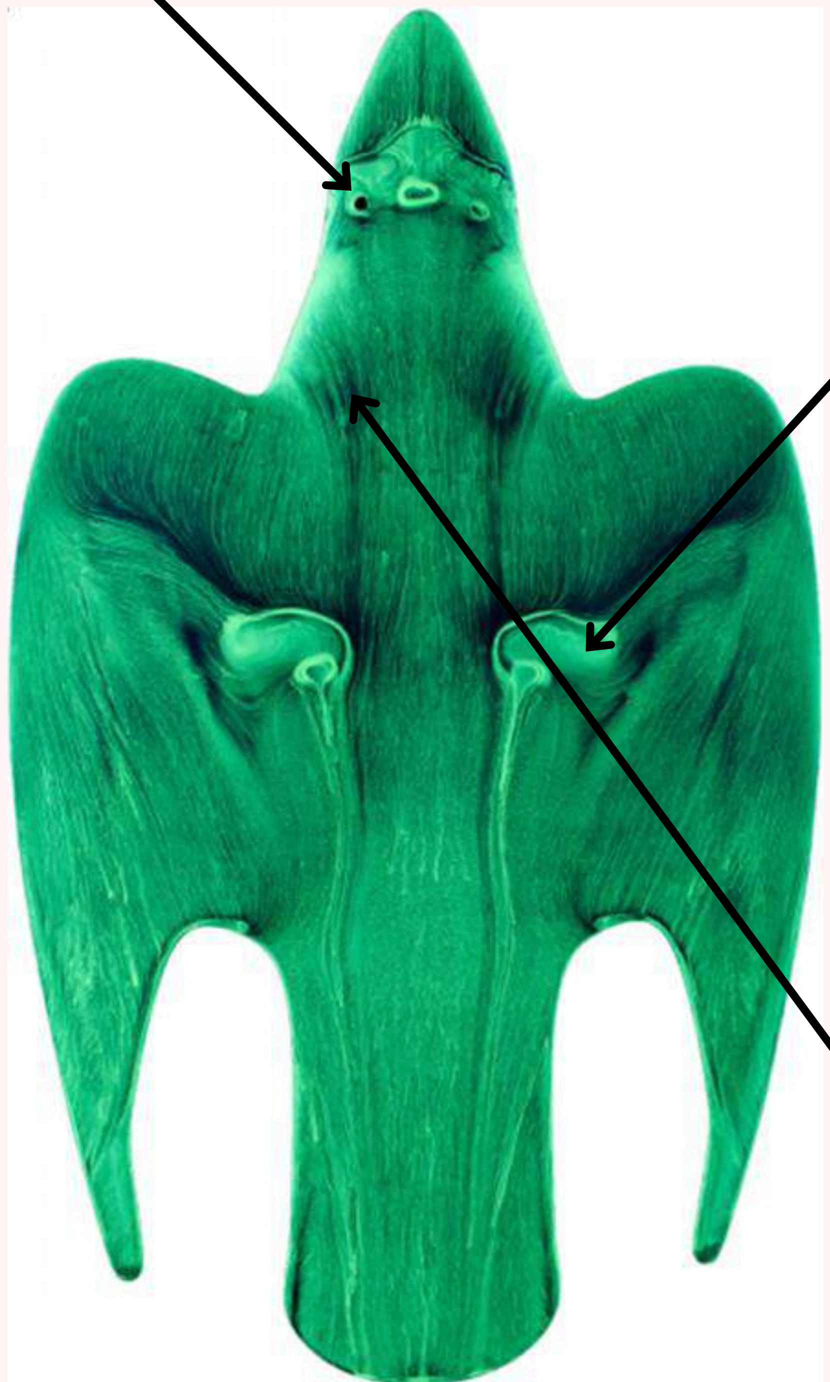


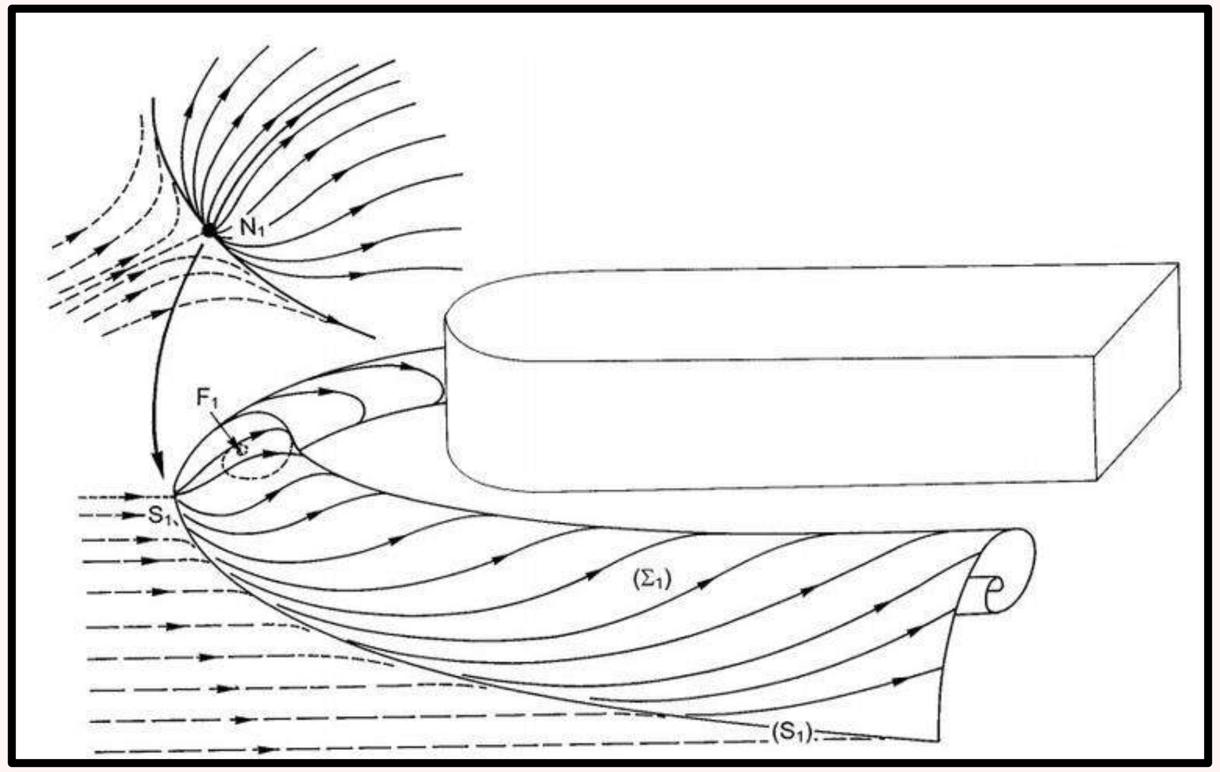
Horn Vortex

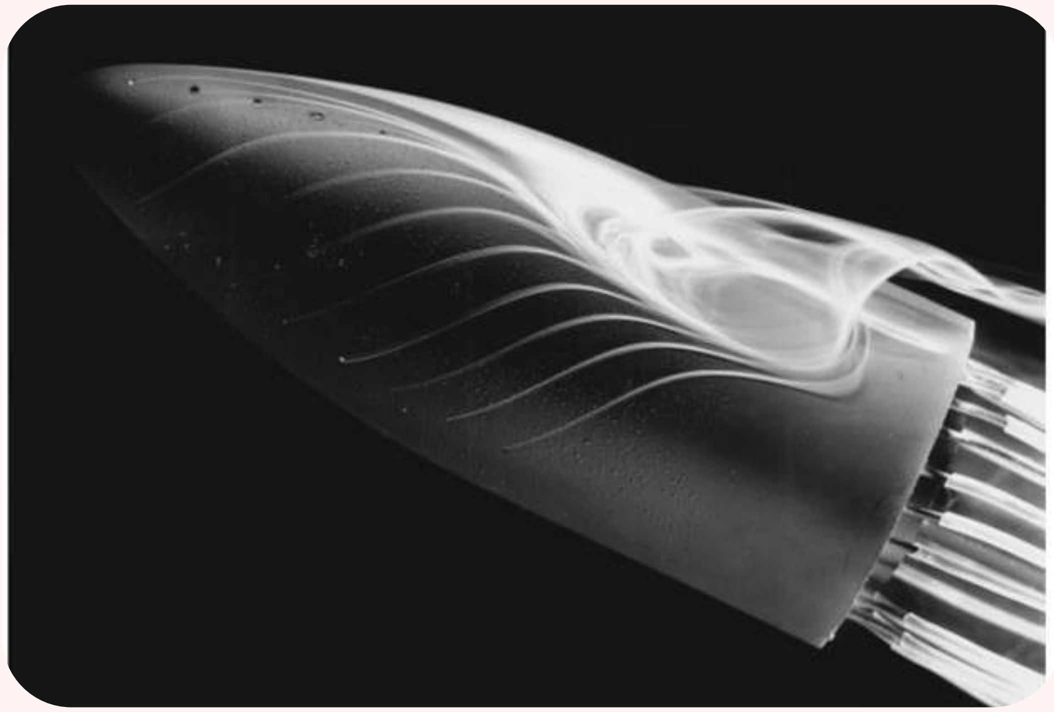


Dorsal Vortex

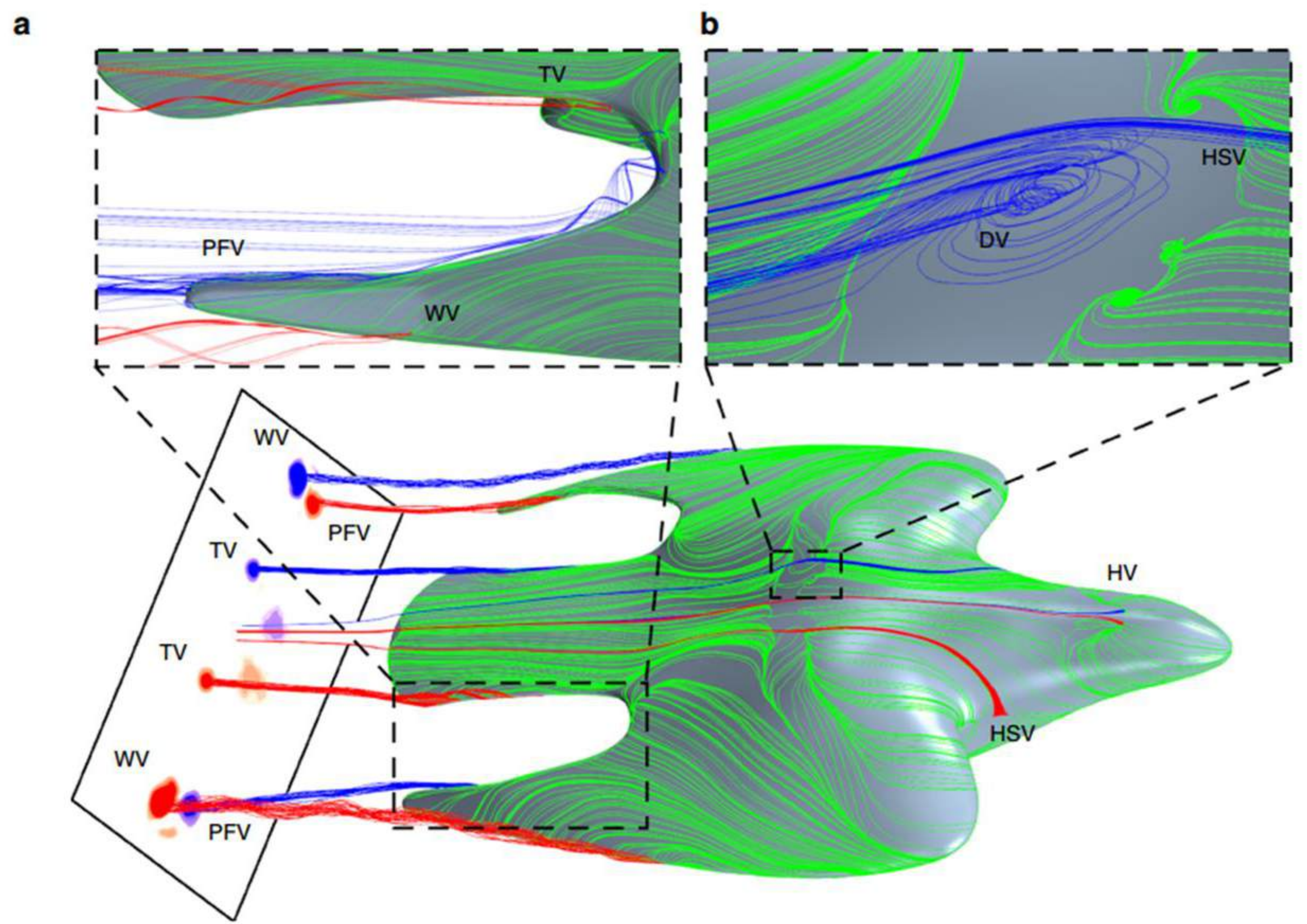








Horseshoe Vortex



a
b
TV
PFV
WV
DV
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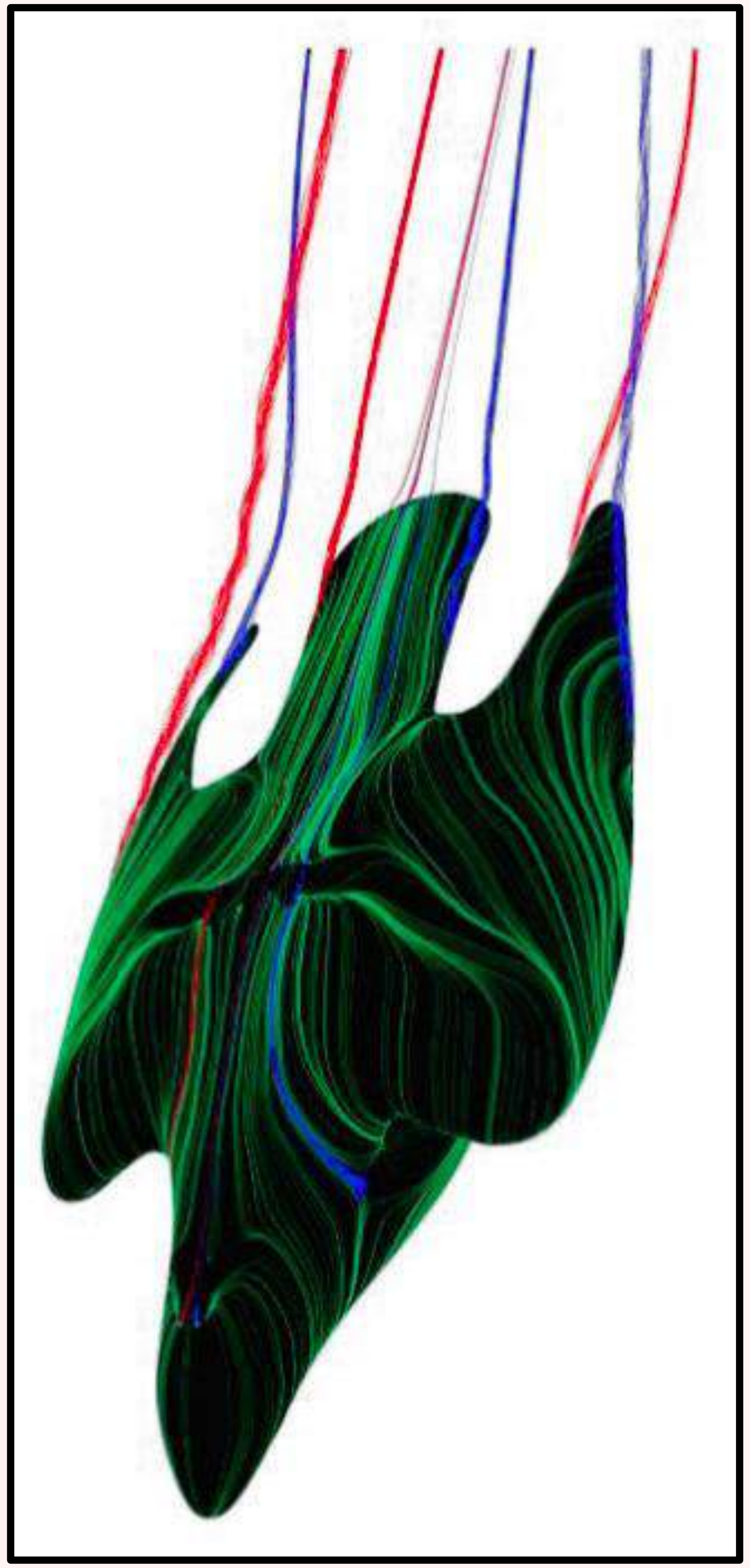
WV
PFV
TV
TV
HV
HSV
WV
PFV

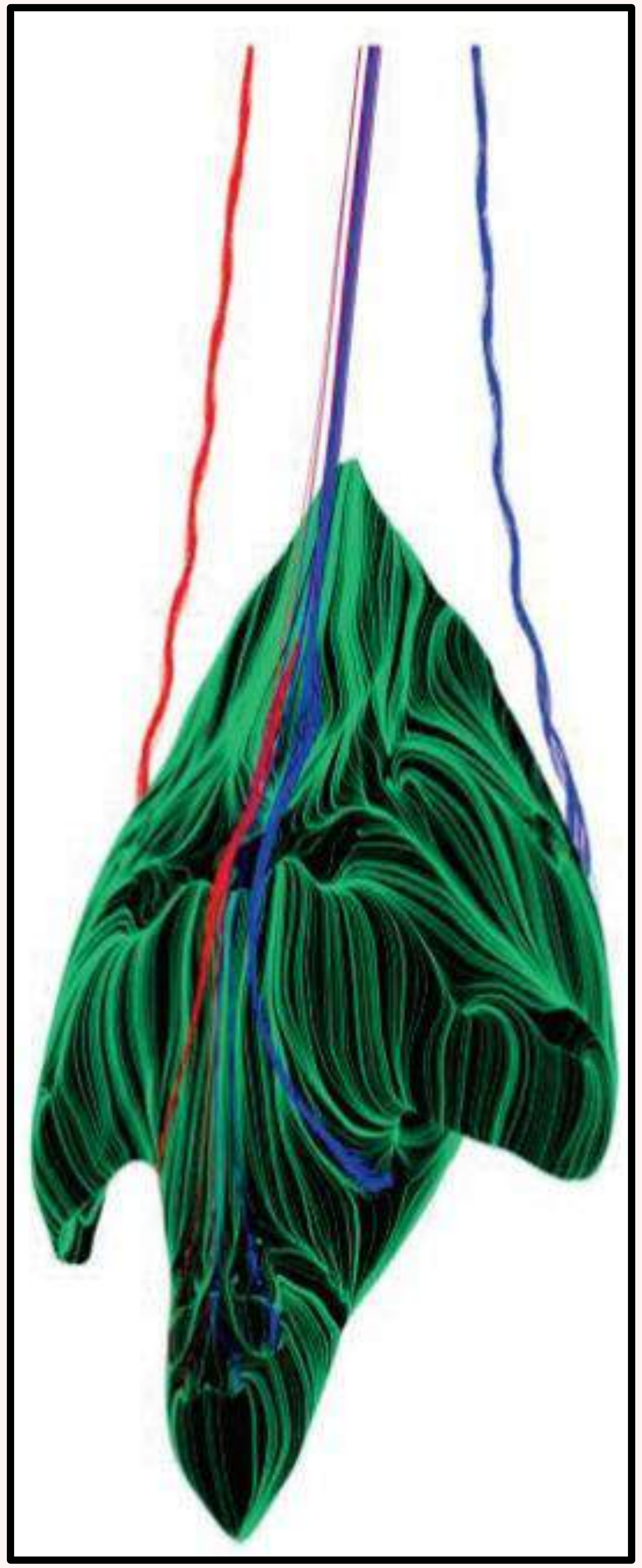
- Strong spanwise flow exists due to the **forward sweep of the wings** in M-Type Configuration which promotes flow reattachment.

- Weak spanwise flow exists in the case of the **C-Type configuration**.

- In **M-Type configuration**, the tail vortices help generate pitching and rolling moments.

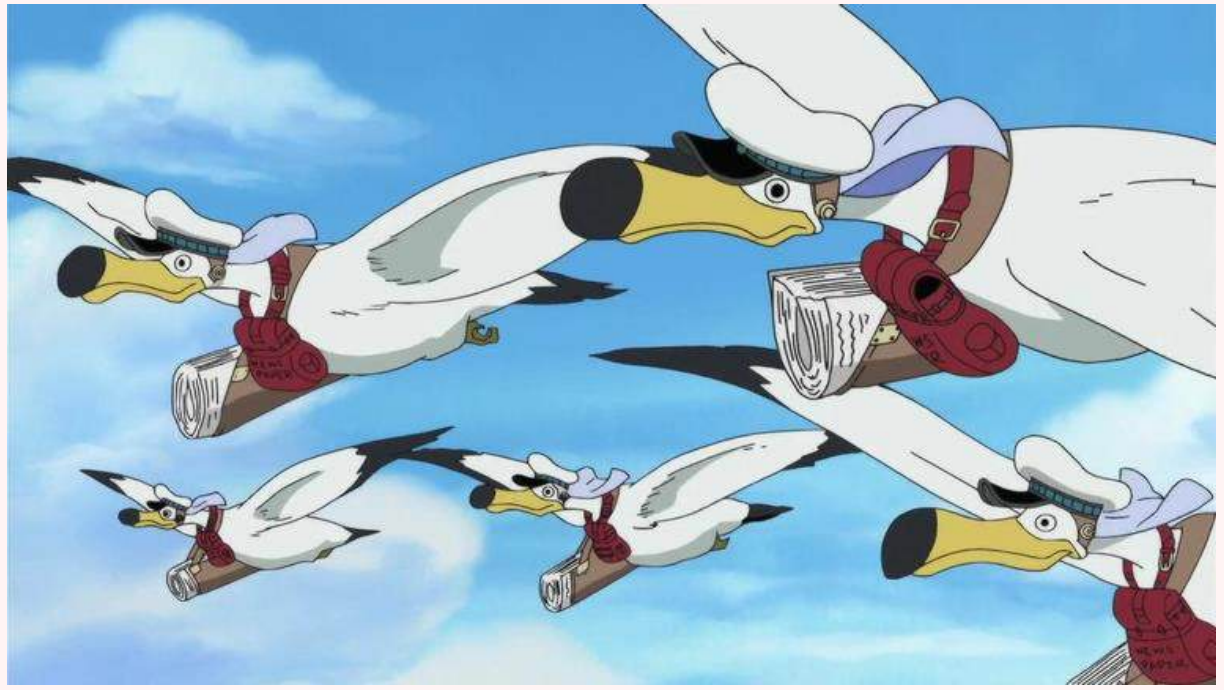
- Maneuverability of the falcon is greatly increased in the M-Type configuration by **vortex structures** that control the flow by suppression of separation and also due to **additional lift** generated by suction from stronger vortices similar to that on delta wings.





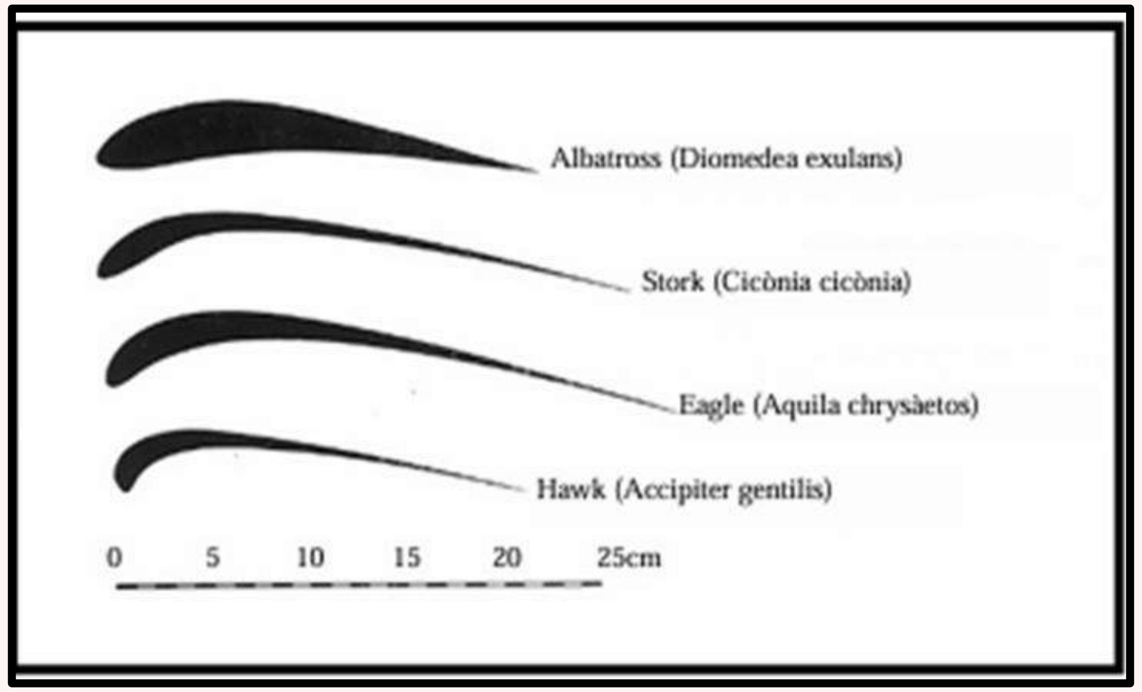
EFFORTLESS FLIGHT OF ALBATROSSES OVER SEA

- Albatrosses feeding trip may take 10 days over sea and cover 500 – 1000 km per day
- Even it can fly around the southern ocean without a single stop.
- It can fly for hours without flapping its wings.
- These birds spends 80-90 percent of their life over the sea.
- Achieves L/D around 20

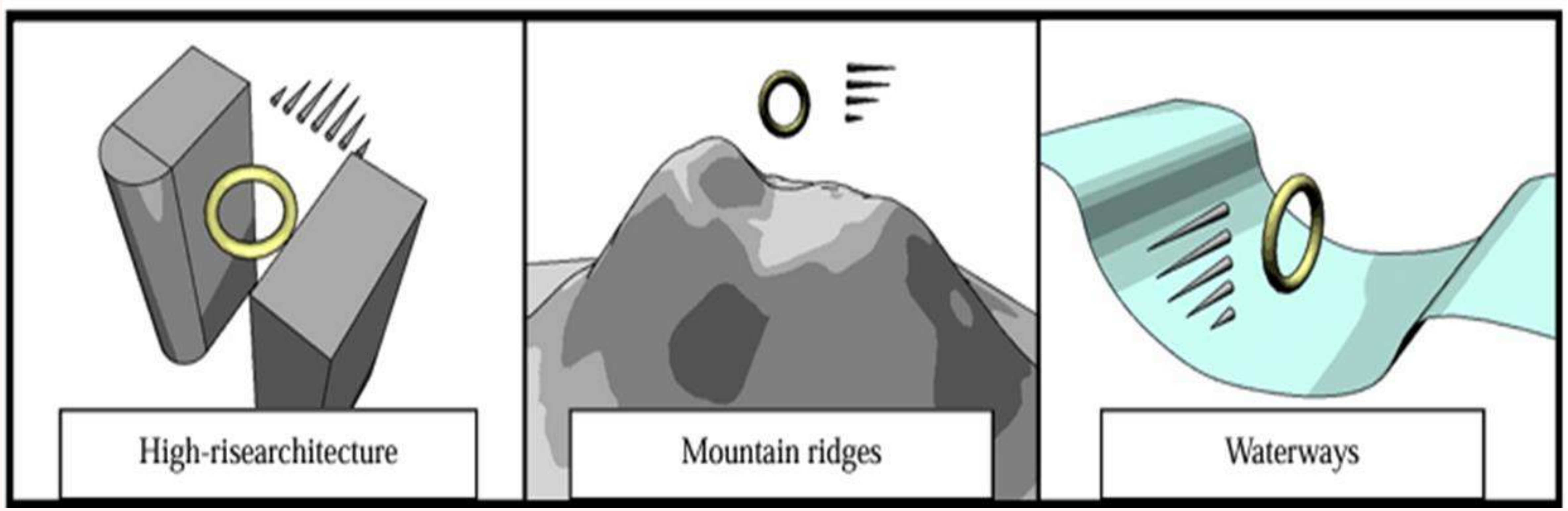


These feats sounds interesting right?
How does these birds managing to achieve these feats?

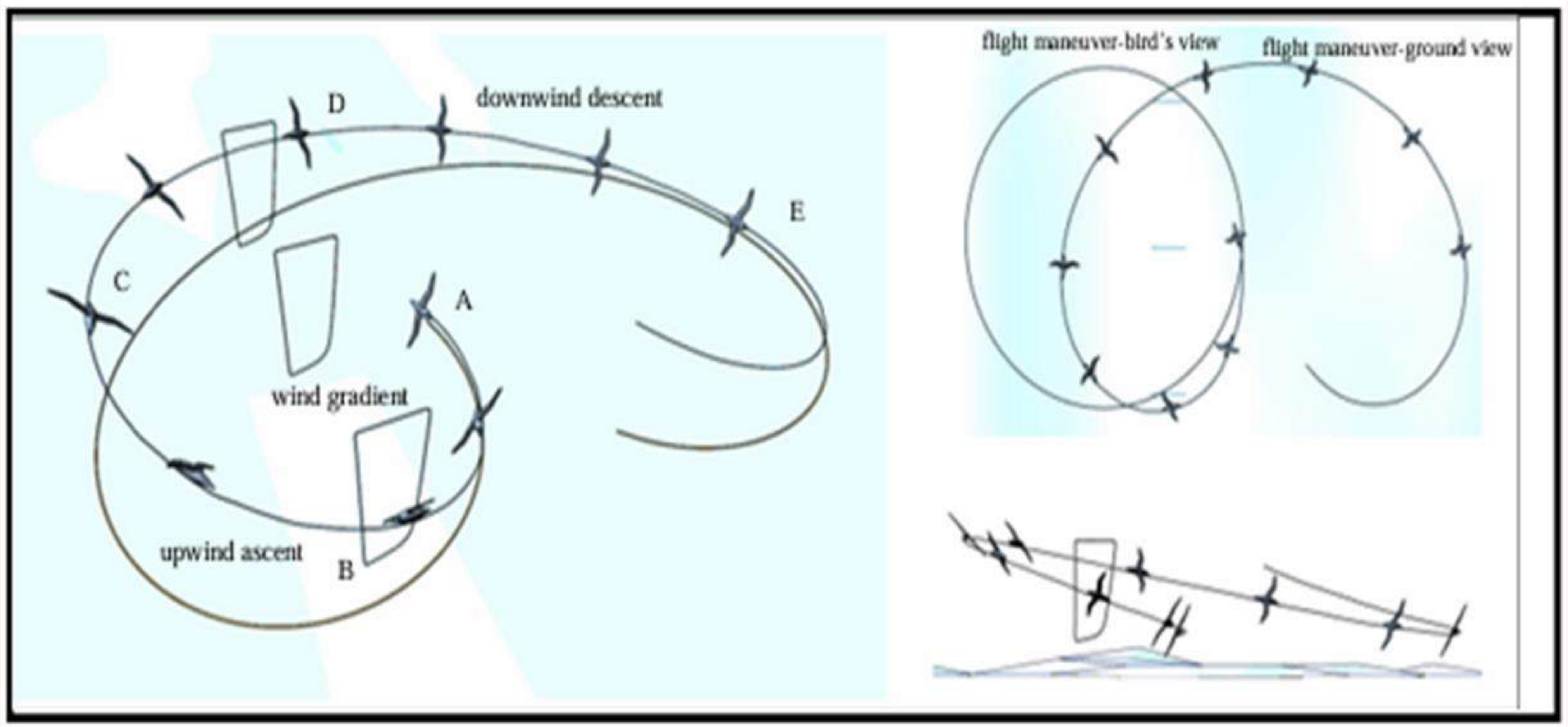
DYNAMIC SOARING



- Velocity gradients exist at different places
- Albatrosses uses these velocity gradients to soar effortlessly for long distances.
- It uses velocity gradients to generate lift and maintain its speed.
- Despite having less curved wing it can generate lift using velocity gradients.



Dynamic Soaring of Albatross

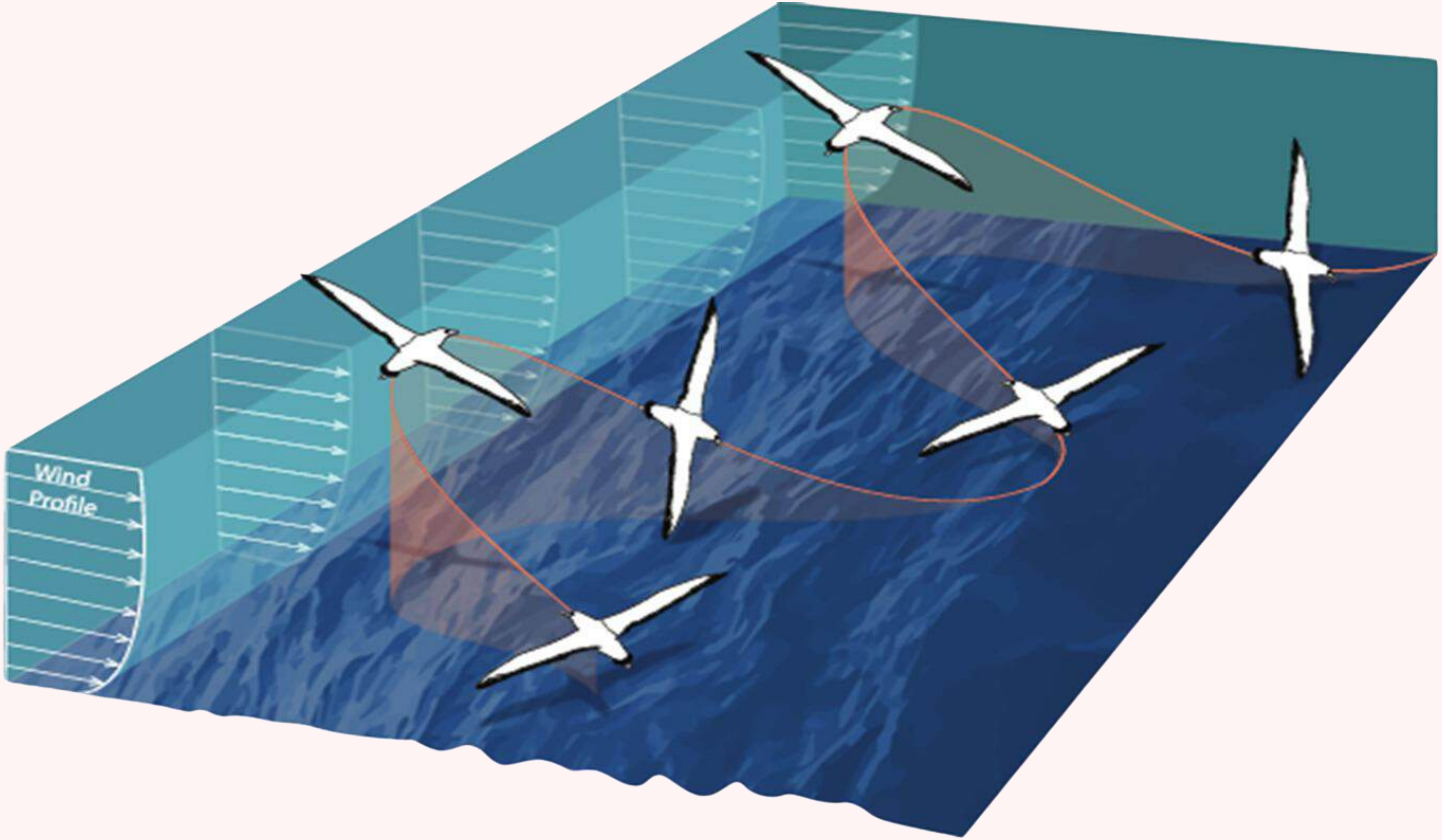


- **Phase A Upwind Ascent** : Bird begins ascending against the wind to gain altitude .

- **Phase B - Top of the ascent** : The bird reaches a high point in the flight and prepared to transition into a turn allowing to utilize the wind more efficiently

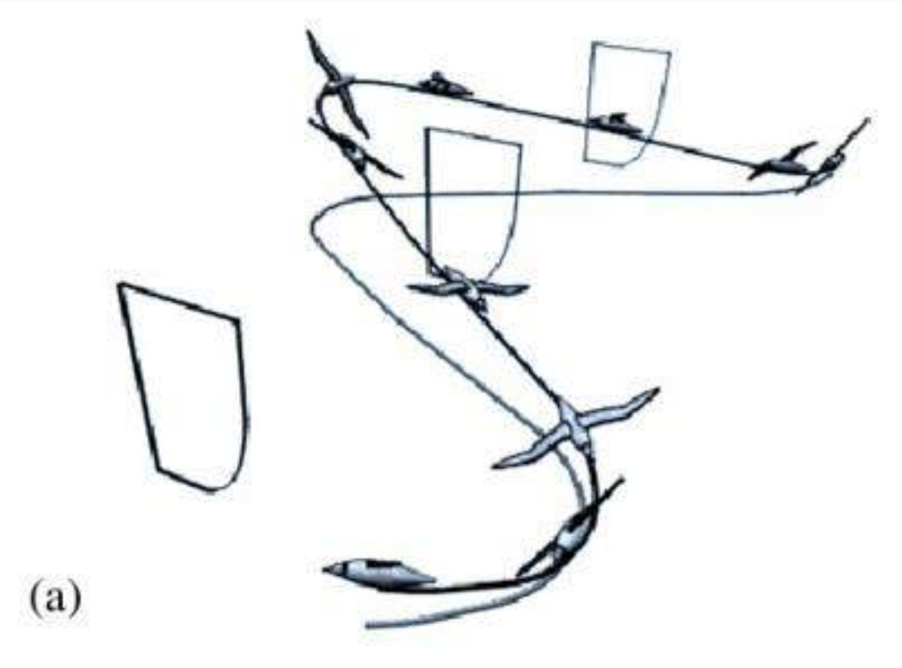
- **Phase C Downwind Descent** : This maneuver allows the bird to capture the benefits of the wind as it starts to decent and allowing it to conserve energy by gliding downwards

- **Phase D(Preparation for next cycle**- At the end of the descent the bird reaches a lower altitude and completes the downwind flight phase.

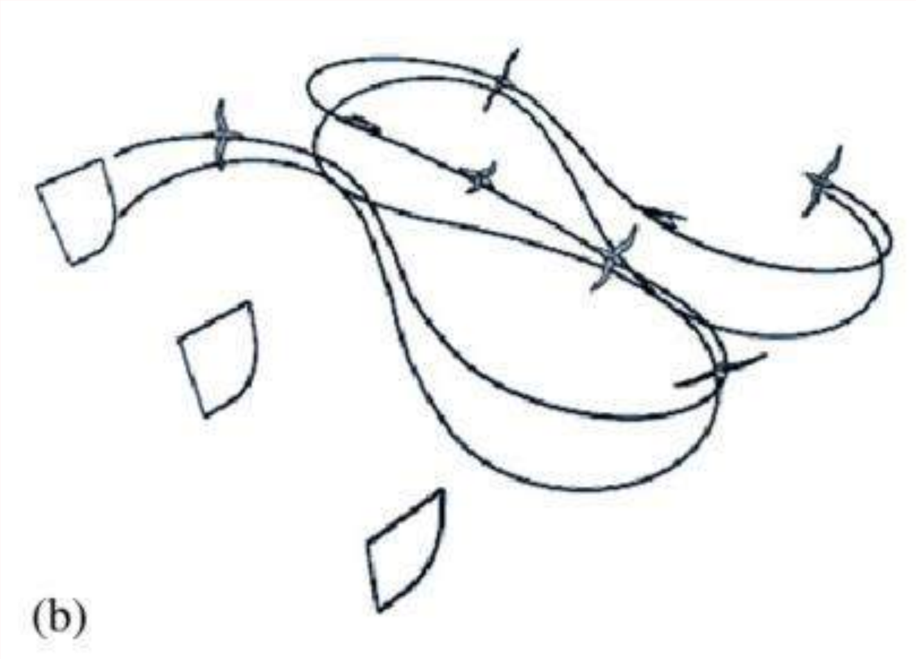


- By this way it can achieve speeds around 20 m/s

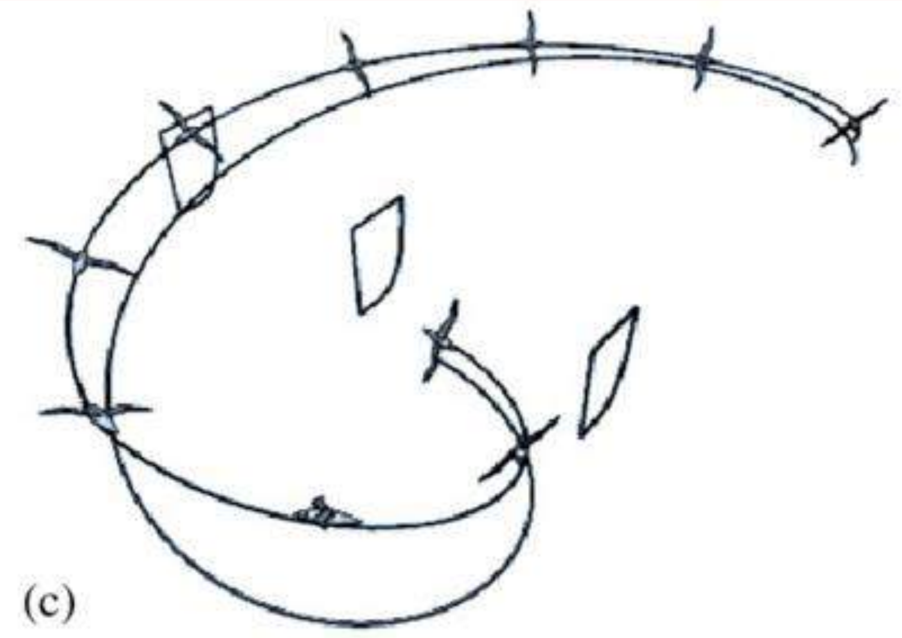
DIFFERENT MANOEUVRES OF ALBATROSS



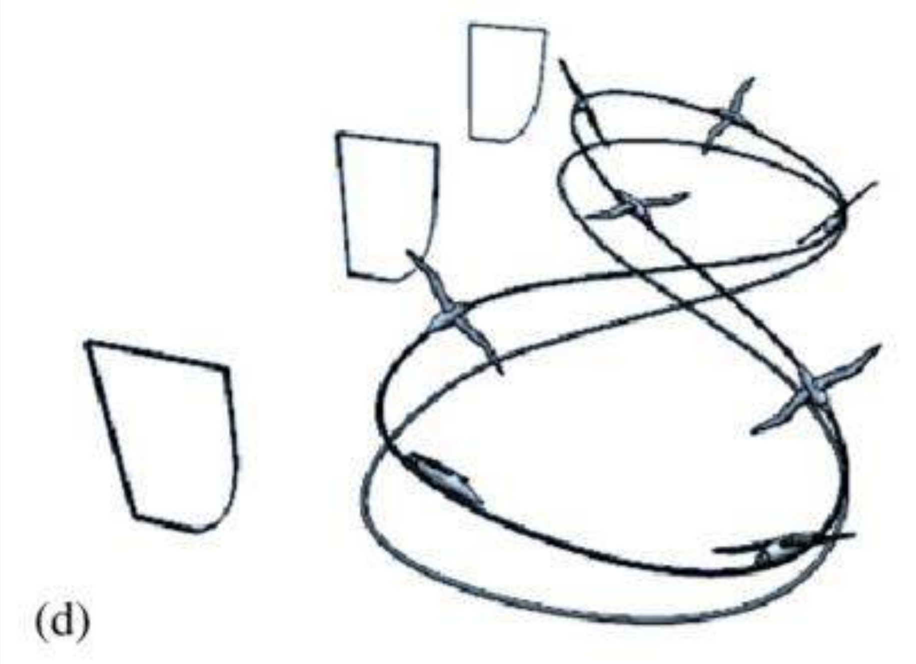
Cross Wind Snake Manoeuvre



Upwind Snake Manoeuvre



Circumnavigation Manoeuvre

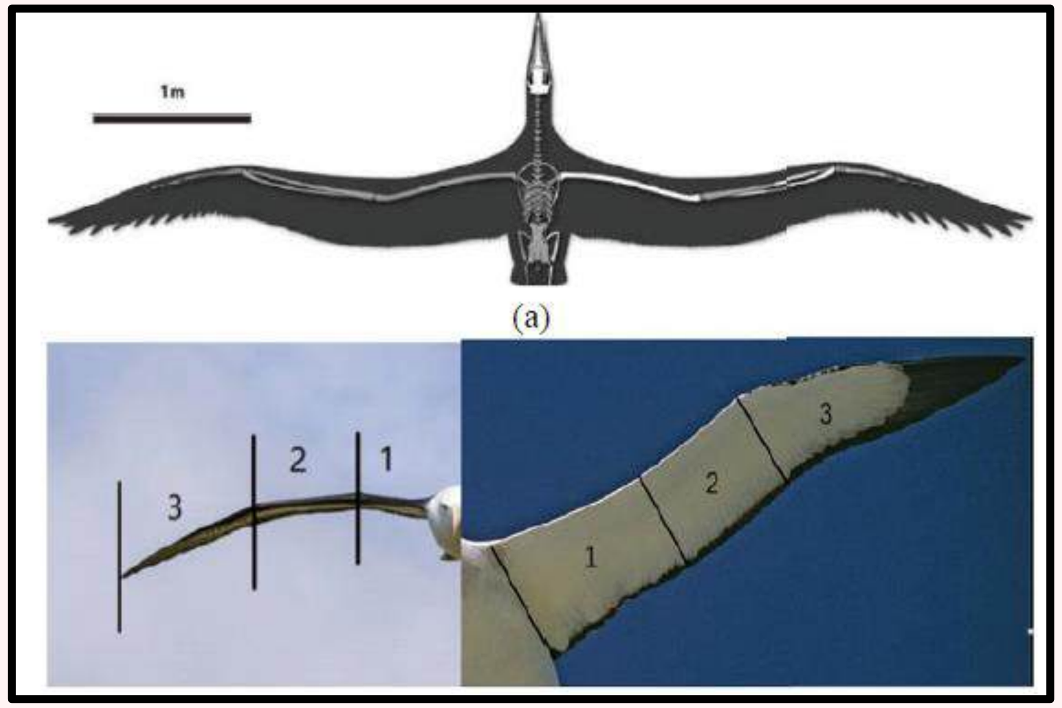


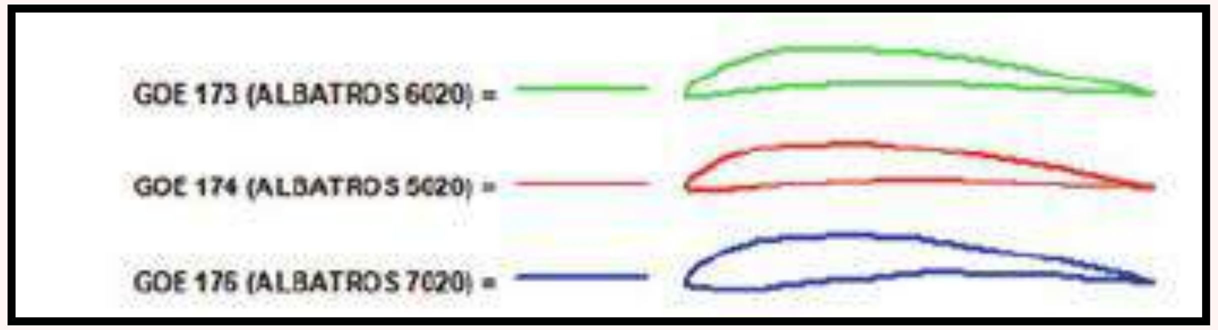
Snaking Hover Manoeuvre

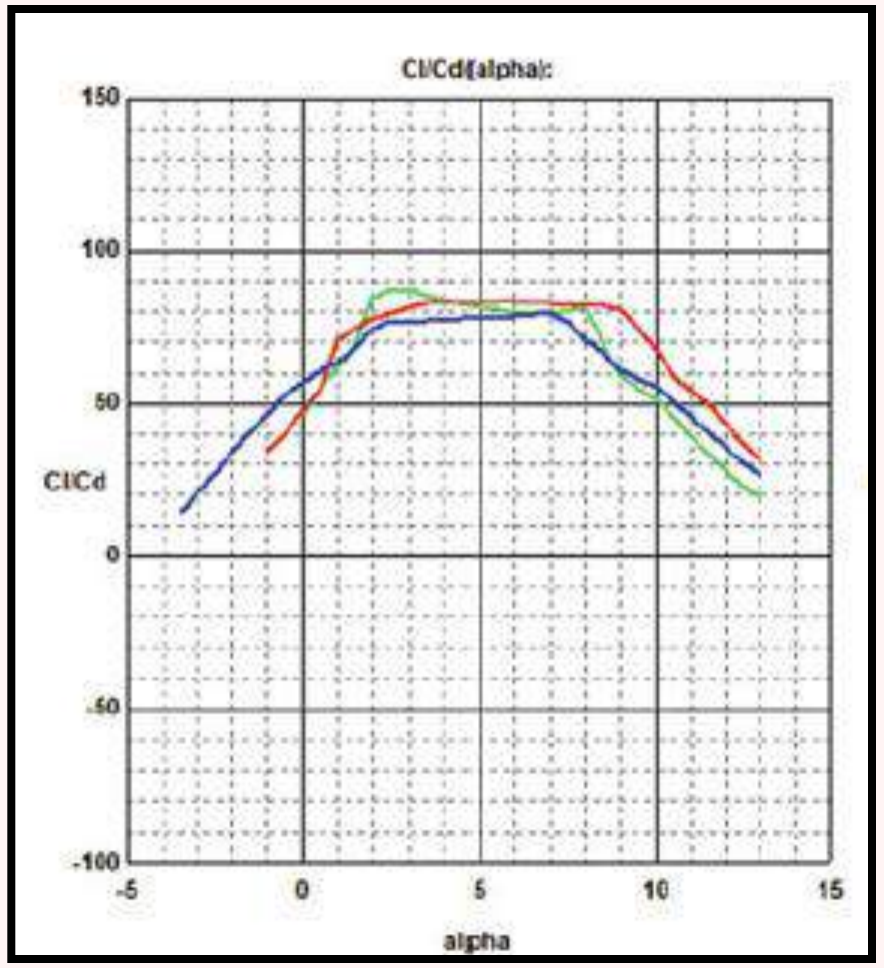
AERODYNAMICS CHARACTERISTICS OF ALBATROSS

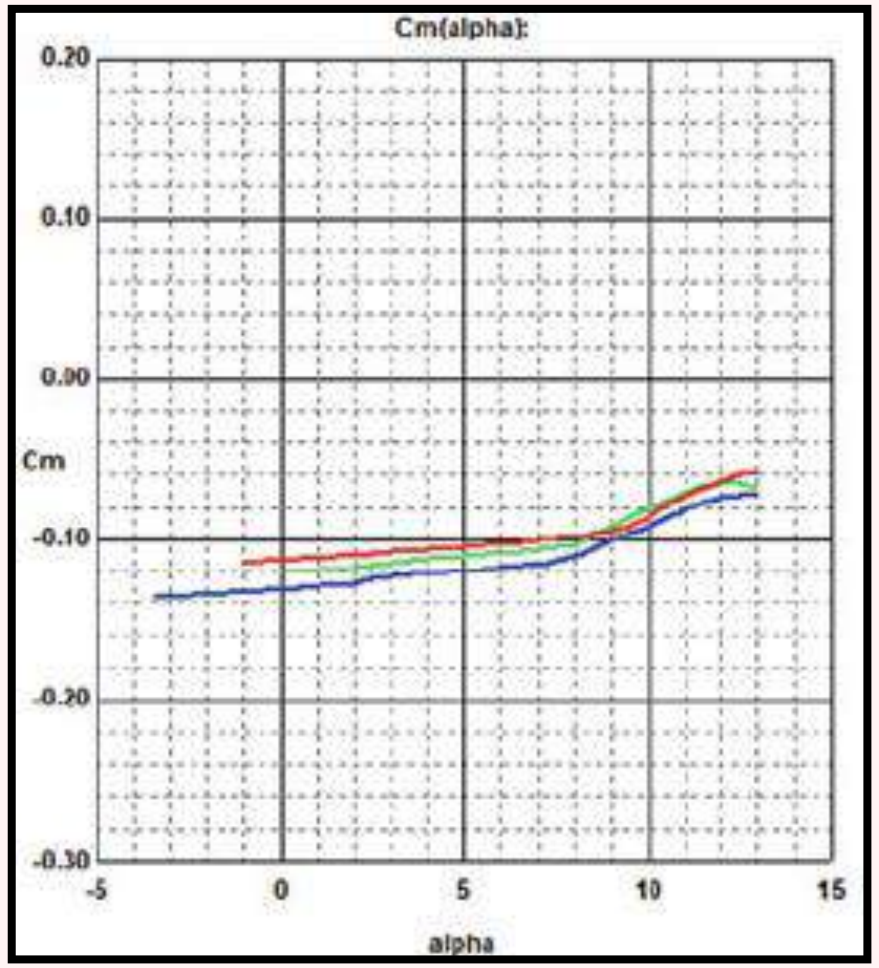
2D Analysis

- **GOE 174 (Albatross 5020) is an airfoil derived from albatross wings**





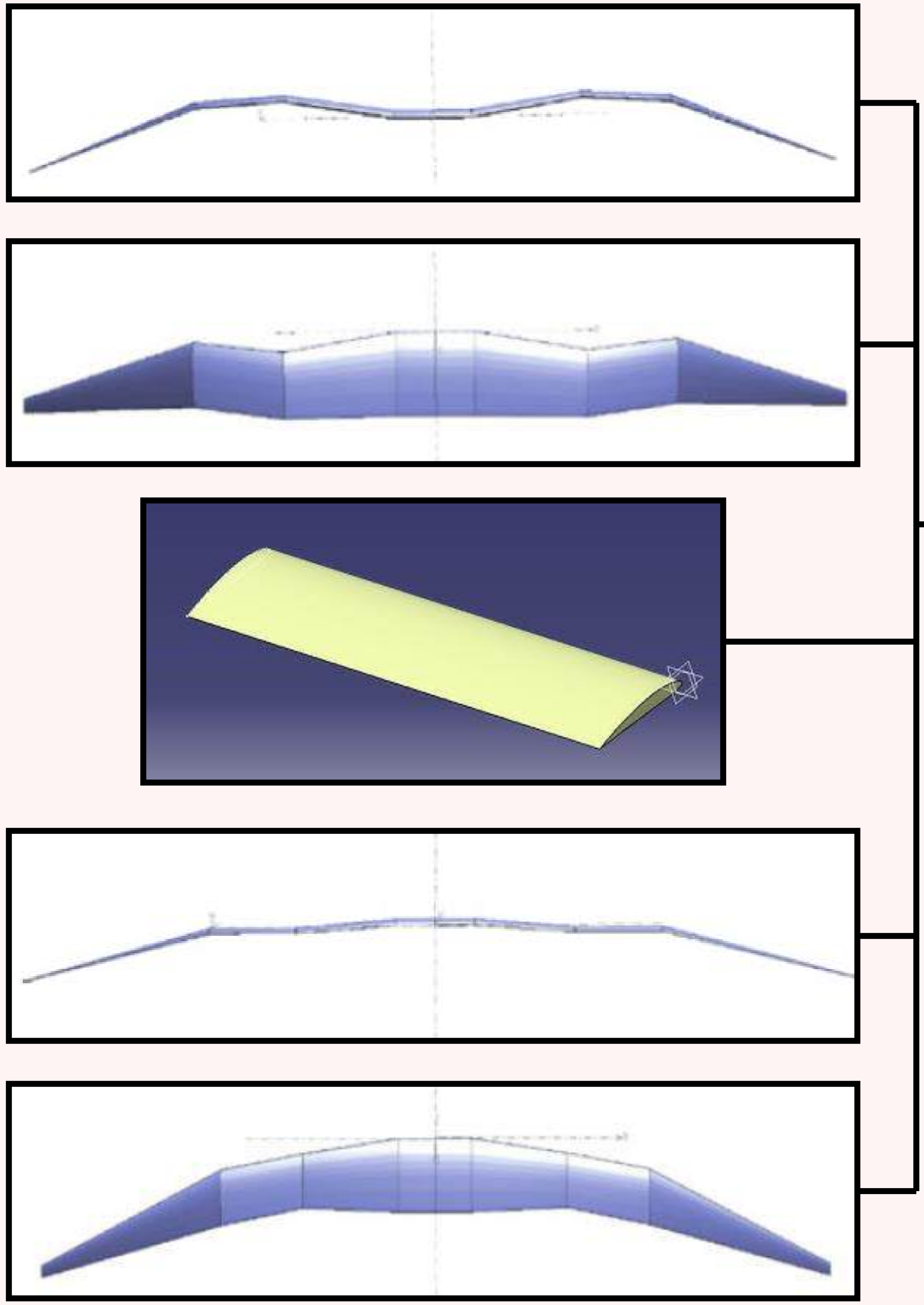


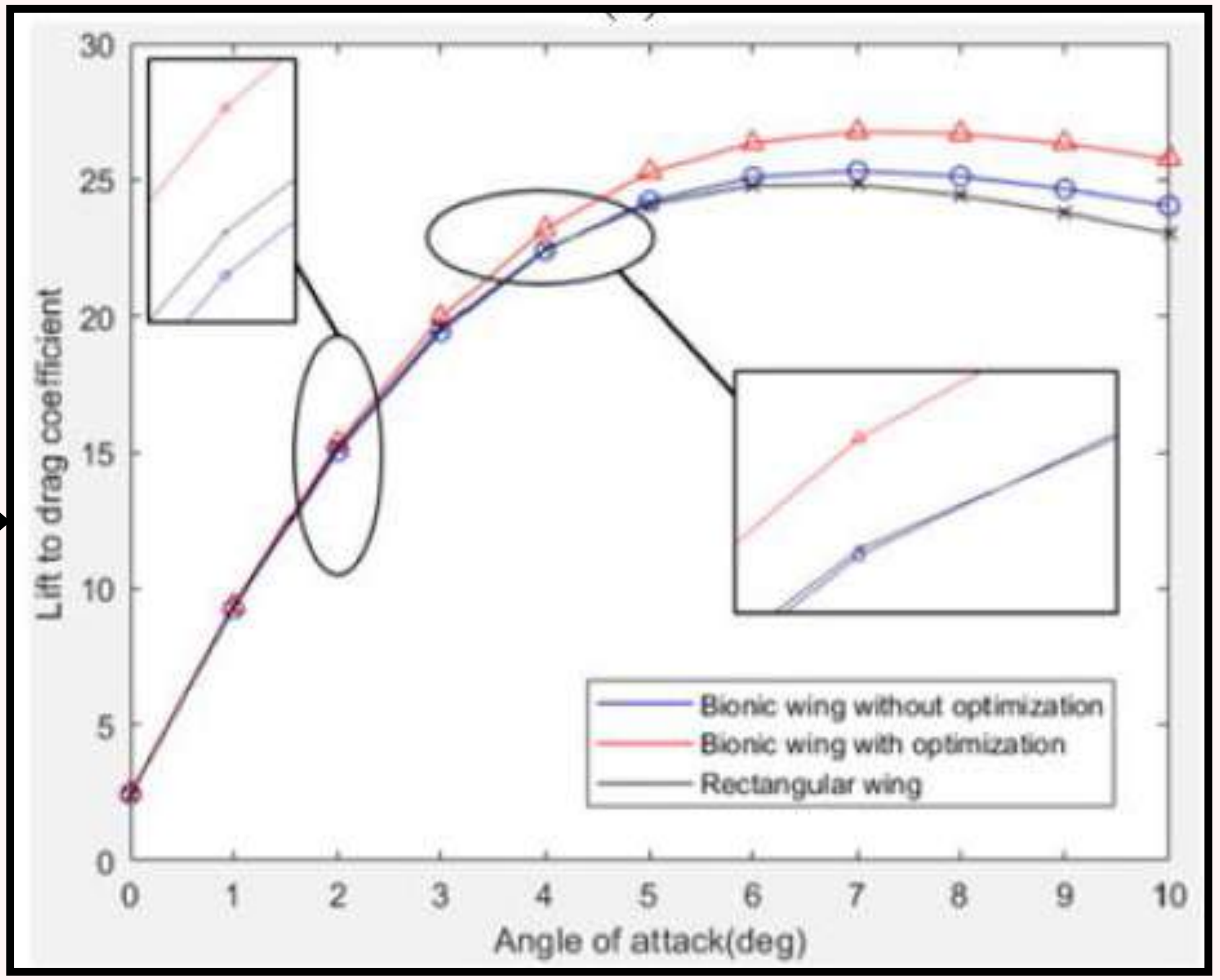


Parameters	Value
Wingspan	3110 ± 40mm
Wing Area	6226 ± 270 cm^2
Mean Aerodynamic Chord	201 ± 8 mm
Aspect Ratio	15.5 ± 0.6

AERODYNAMICS CHARACTERISTICS OF ALBATROSS

3D Analysis





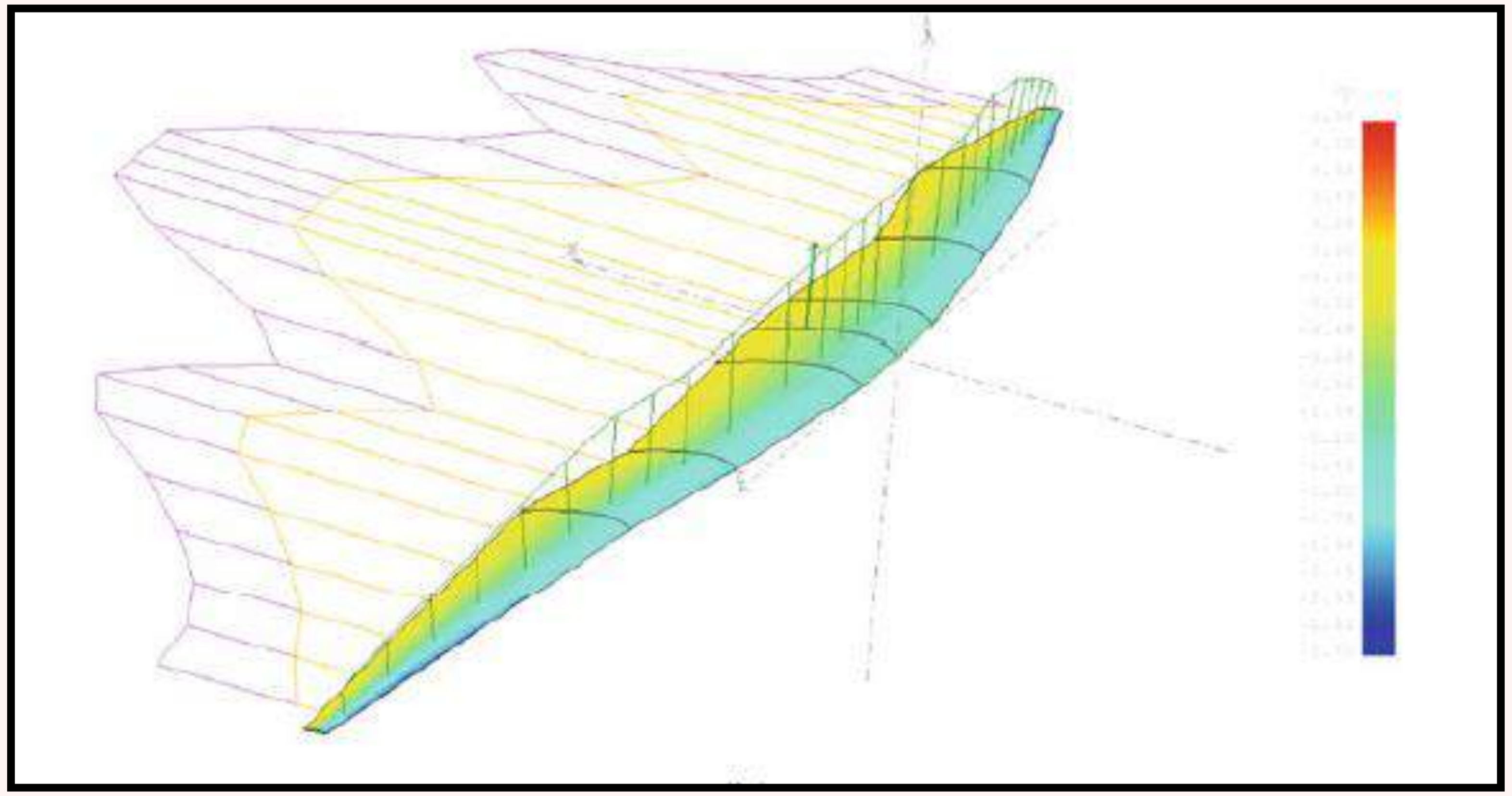
Parameters	Value
Reynolds Number	2.8 e05
Density	1.225 kg/m^3
Surface Temperature	15 deg centrigrade
Aerodynamic Viscosity	1.78e-5 Pa.s
Velocity	20 m/s

- **Lift-to-drag ratio of the bionic wing with optimization is 26.768, and the maximum Lift-to-drag ratio of the bionic wing without optimization and rectangular wing is 25.322 and 24.816, respectively.**

- **Therefore, compared with the rectangular wing,The maximum lift-to-drag ratio of the bionic wing with optimization increased by 7.87%. The maximum lift-drag ratio of the bionic wing was increased by 5.71% through optimization**

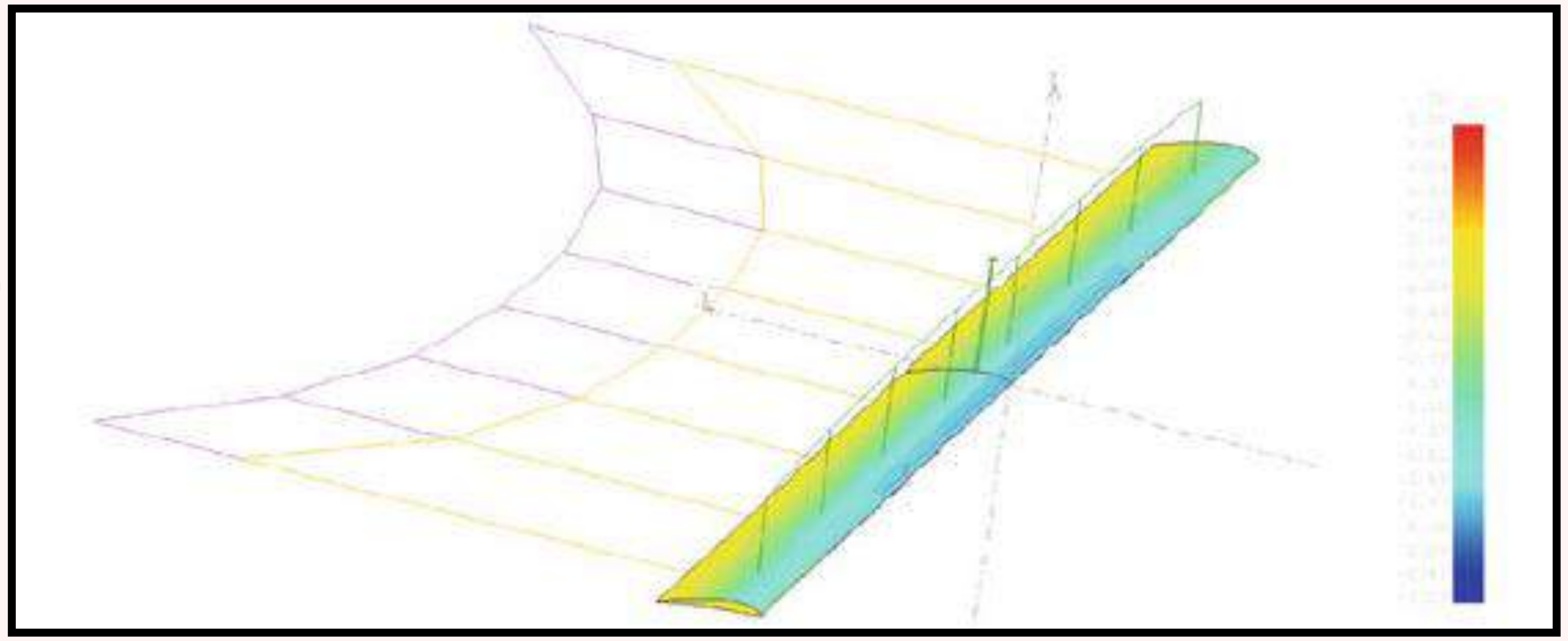
AERODYNAMICS CHARACTERISTICS OF ALBATROSS

a)

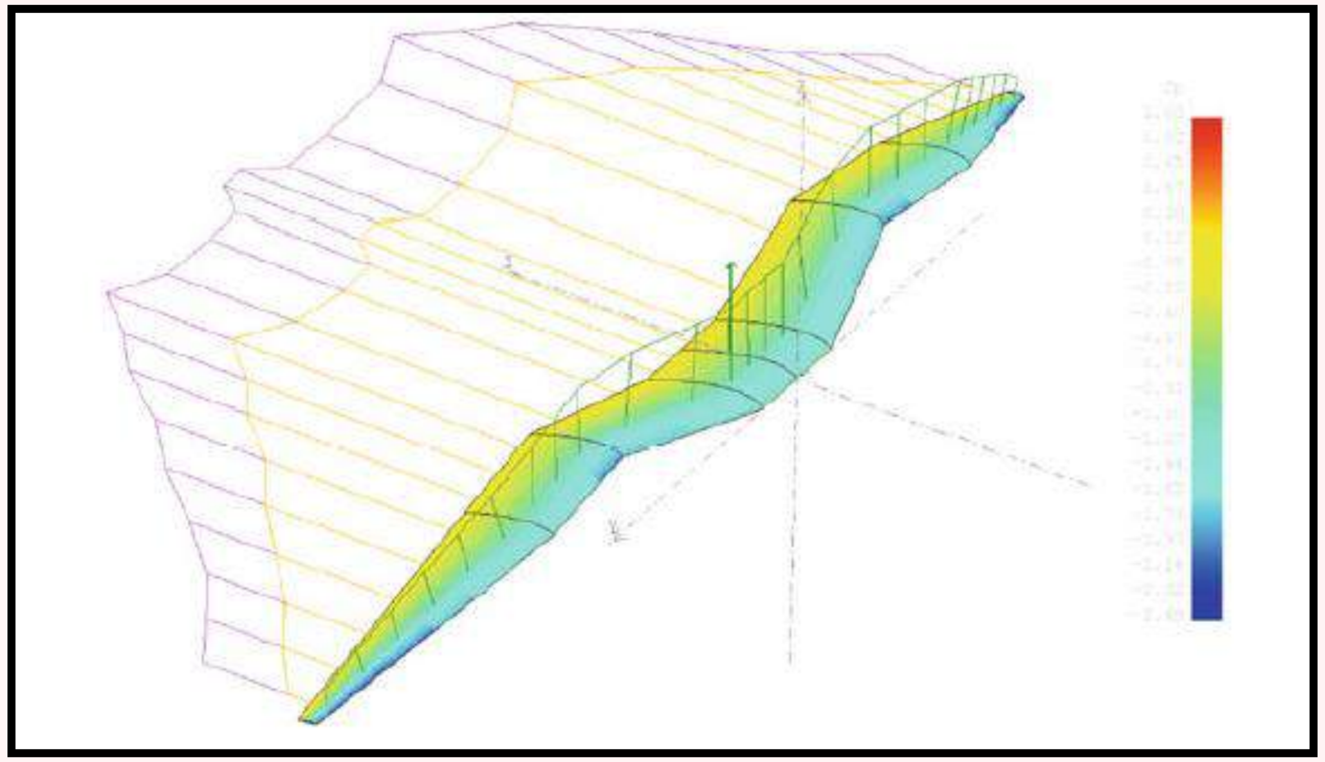


The pressure, lift, viscosity and induced drag distribution of the bionic wing with optimization (a),rectangular wing (b) and the bionic wing without optimization (c)

b)



c)



CONCLUSION

- The study explored the distinct phases of stoop flight in the peregrine falcon, highlighting how the bird dynamically adjusts its wing configurations throughout the maneuver to optimize aerodynamics and control.

- Detailed analyses, incorporating both experimental data and computational fluid dynamics (CFD), provided insights into the airflow patterns around different wing configurations, enhancing our understanding of aerodynamic performance.

- A unique flight strategy known as dynamic soaring, utilized by albatrosses to exploit wind gradients for energy-efficient flight, was examined, showcasing the remarkable adaptations of these birds.

- The aerodynamic properties of the albatross, specifically its gliding efficiency and ability to sustain prolonged flight over vast oceanic distances, were discussed in relation to its specialized wing structure and flight mechanics.

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THANK YOU