Qualitative Investigation of a Leading-Edge Hinged Control Surface for MAVs

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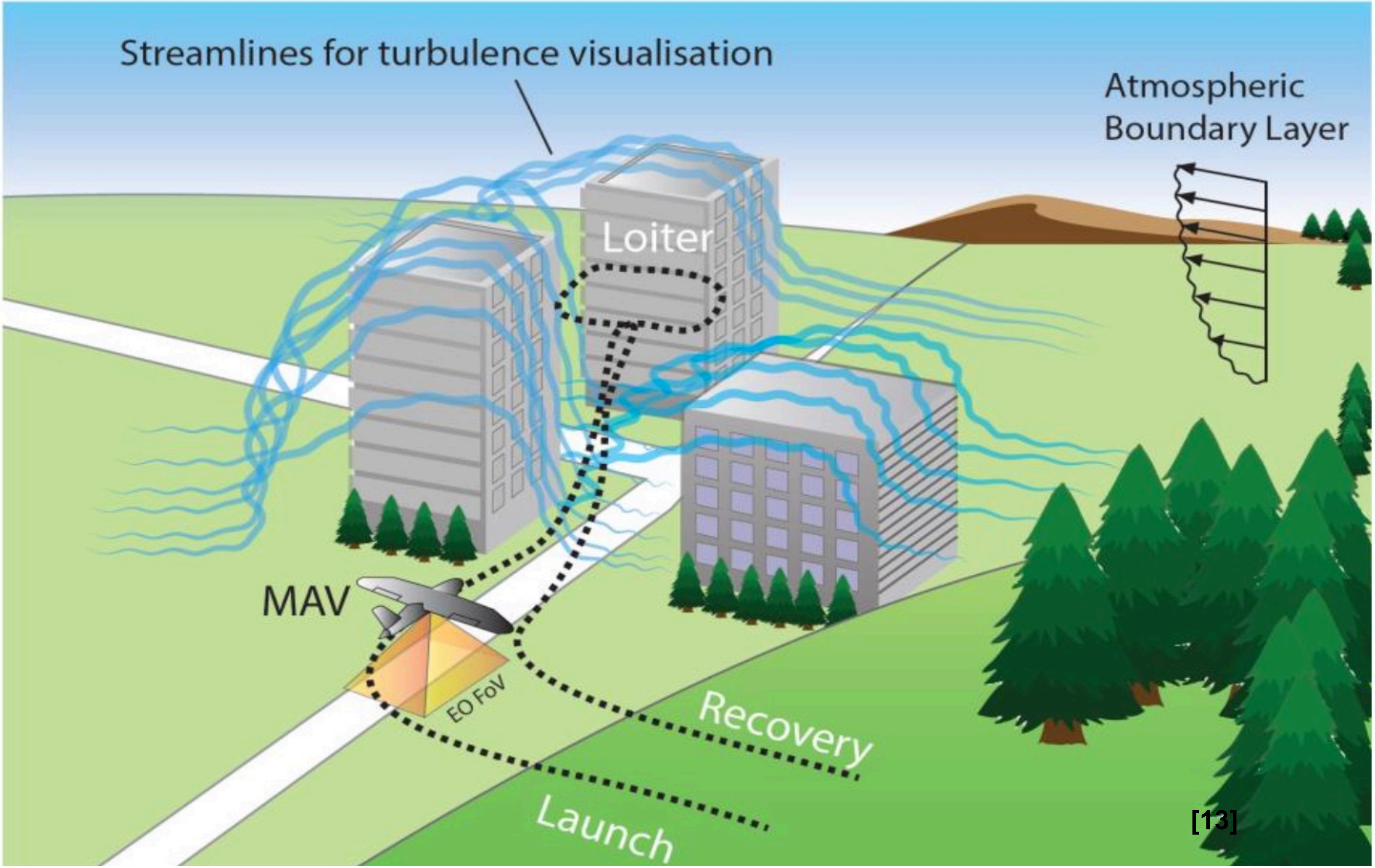
MAVs Mission Profile



Control Issues with MAV Flights

[178]

Review of MAV Challenges

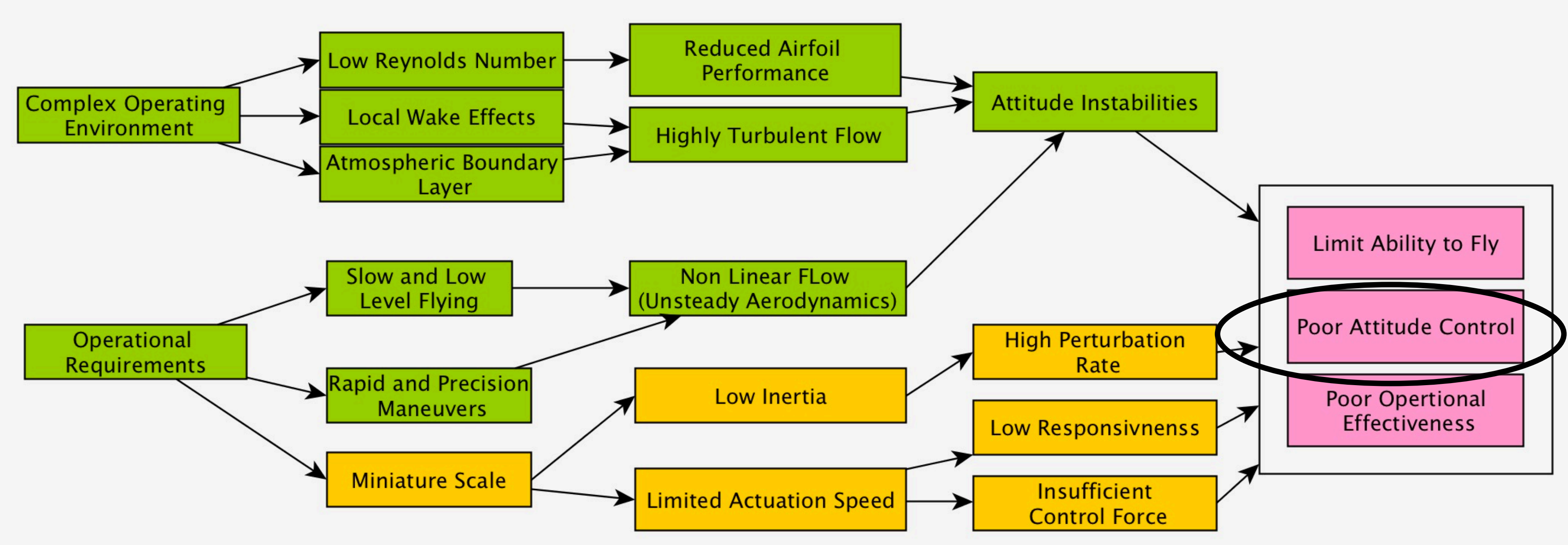


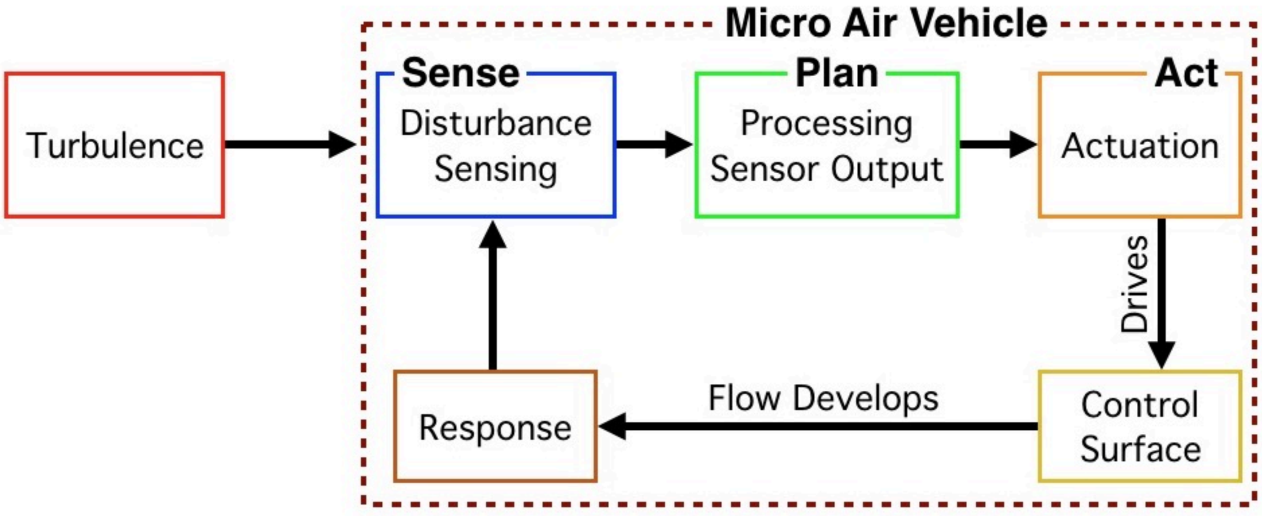
Figure 4: Unique constrains of MAV contributing towards poor attitude control, modified from **[13]**

MAV Controls – Passive and Active Controls

- **Passive:** produce aerodynamic forces **through design features** of the aircraft.
  - Parametric changes of inertia, wing loading, geometry **[39]**
- Only attenuate limited frequencies of perturbations

Aircraft control surfaces

- It is near **impossible to manually fly** MAVs in turbulence **[38,45,46]**



SPA Cycle

Biological or Bio-Inspired Solutions

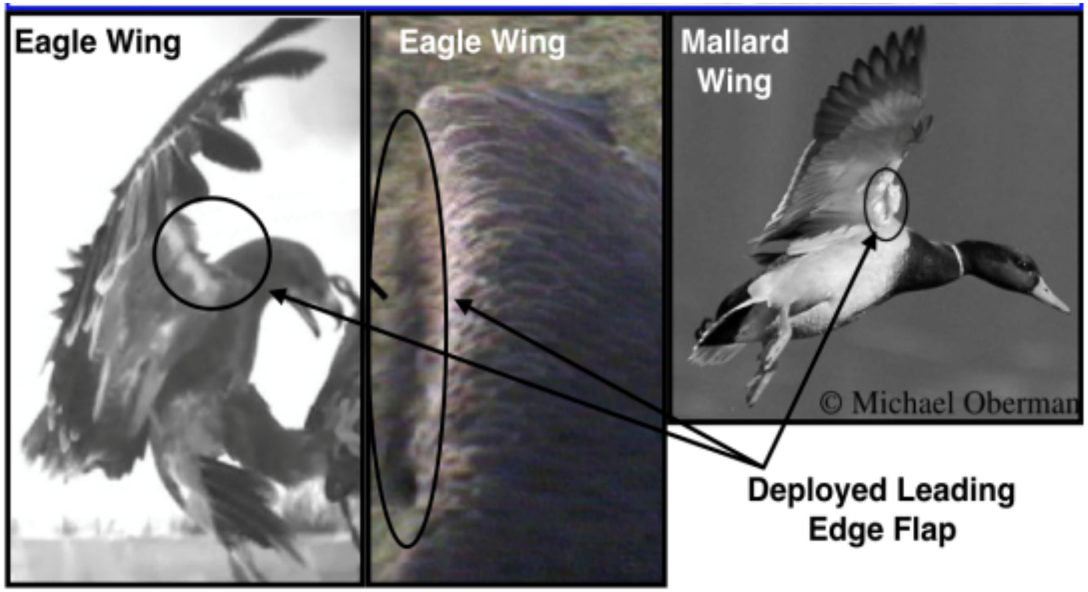
- Capable of **generating large forces** very quickly

- Observations of birds → discovery of auxiliary devices and sensory mechanics **[115]**

  - Alula **[128,129]**
  - Pressure based sensing **[47,48]**, Flexible Wing **[50-53]**
    - **Embryonic and limited flight-proven**

- Feathers at the covert region, leading edge flaps **[98-100]**
  - Permit large angles of attack and low speed flight

- **Potential flow control mechanism!**



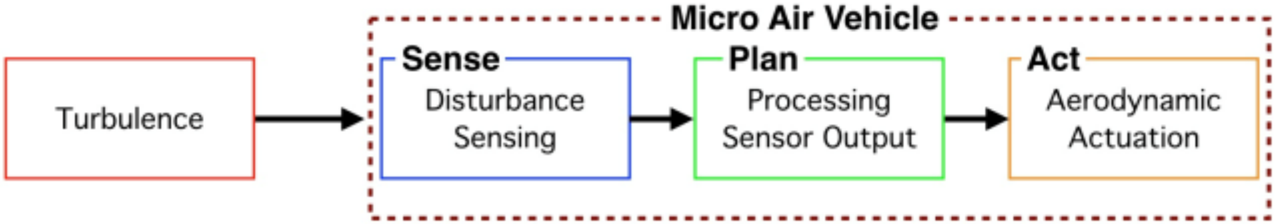
Leading edge feathers on birds [128,138]

Decomposing the Controllability Issue

Traditional Attitude Sensing
(RMIT Wind Tunnel)

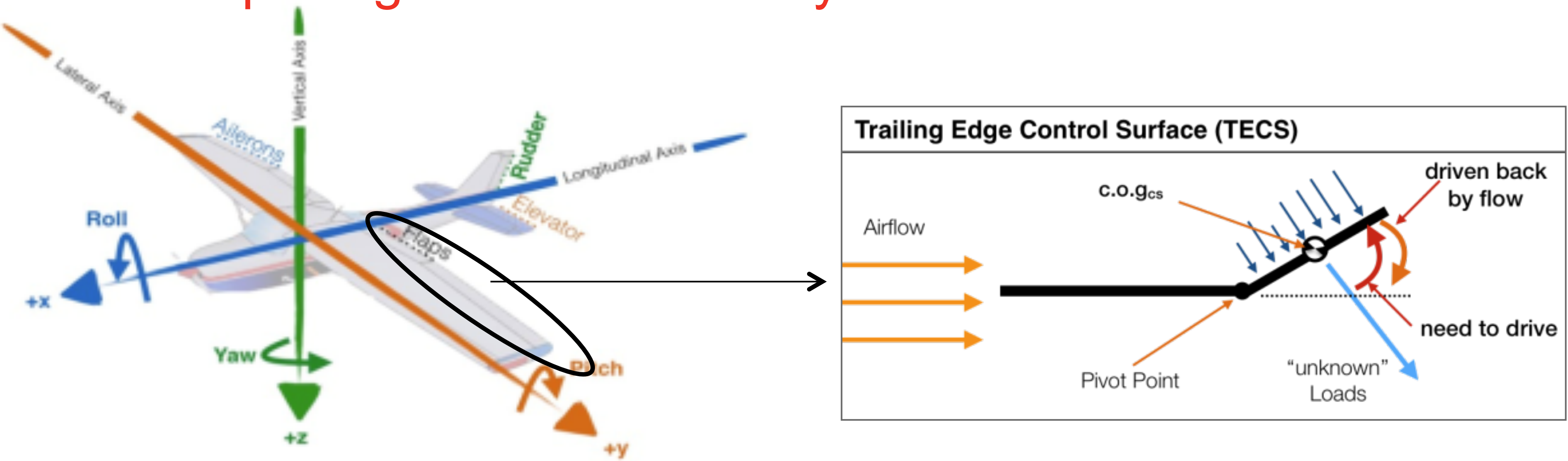
Phase Advanced Attitude Sensing
(RMIT Wind Tunnel)

[Prior work by 48, RMIT University]



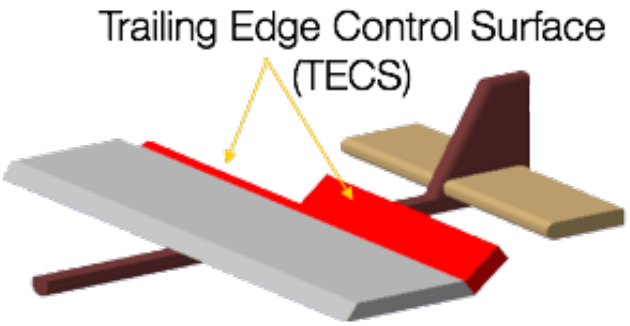
- **Issue is not software related, purely mechanical** → Limited actuation power and speed **[48]**
  - **Extremely high work load on actuators**

Decomposing the Controllability Issue

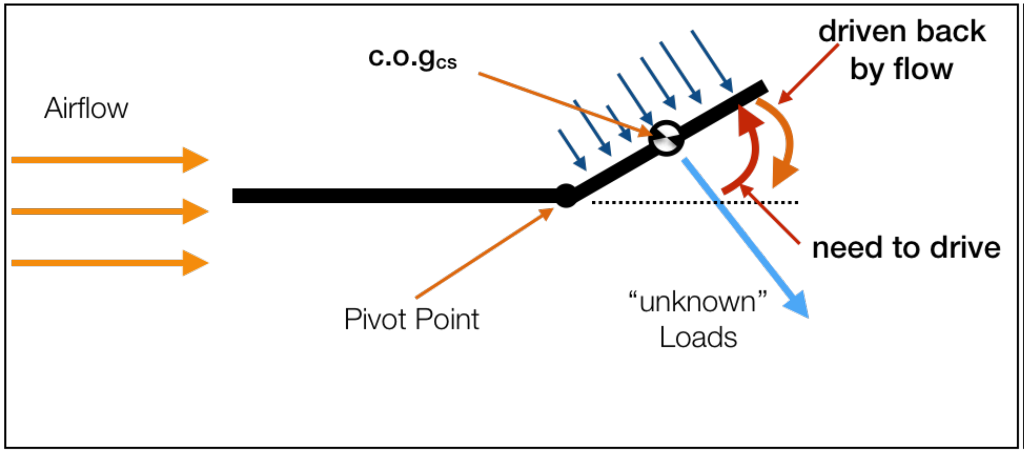


- Existing control surface placement and turbulence response systems:

  1. **Cannot actuate fast enough !** – going against the flow to reach a deflection
  2. **Cannot get enough control authority !**



Trailing Edge Control Surface (TECS)


Airflow

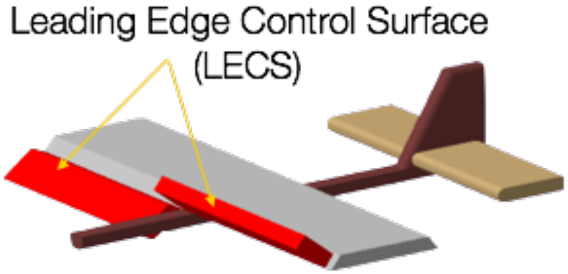
c.o.g_{cs}

driven back
by flow

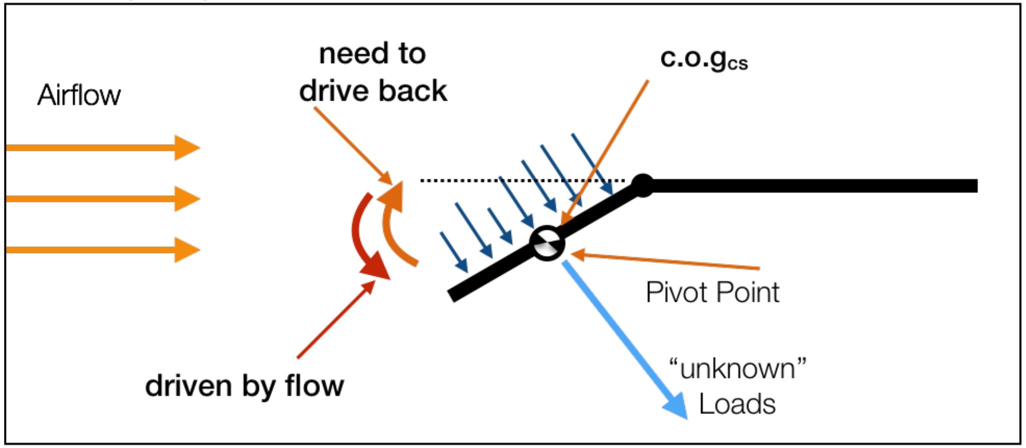
need to drive

Pivot Point

"unknown"
Loads



Leading Edge Control Surface (LECS)


Airflow

need to
drive back

c.o.g_{cs}

Pivot Point

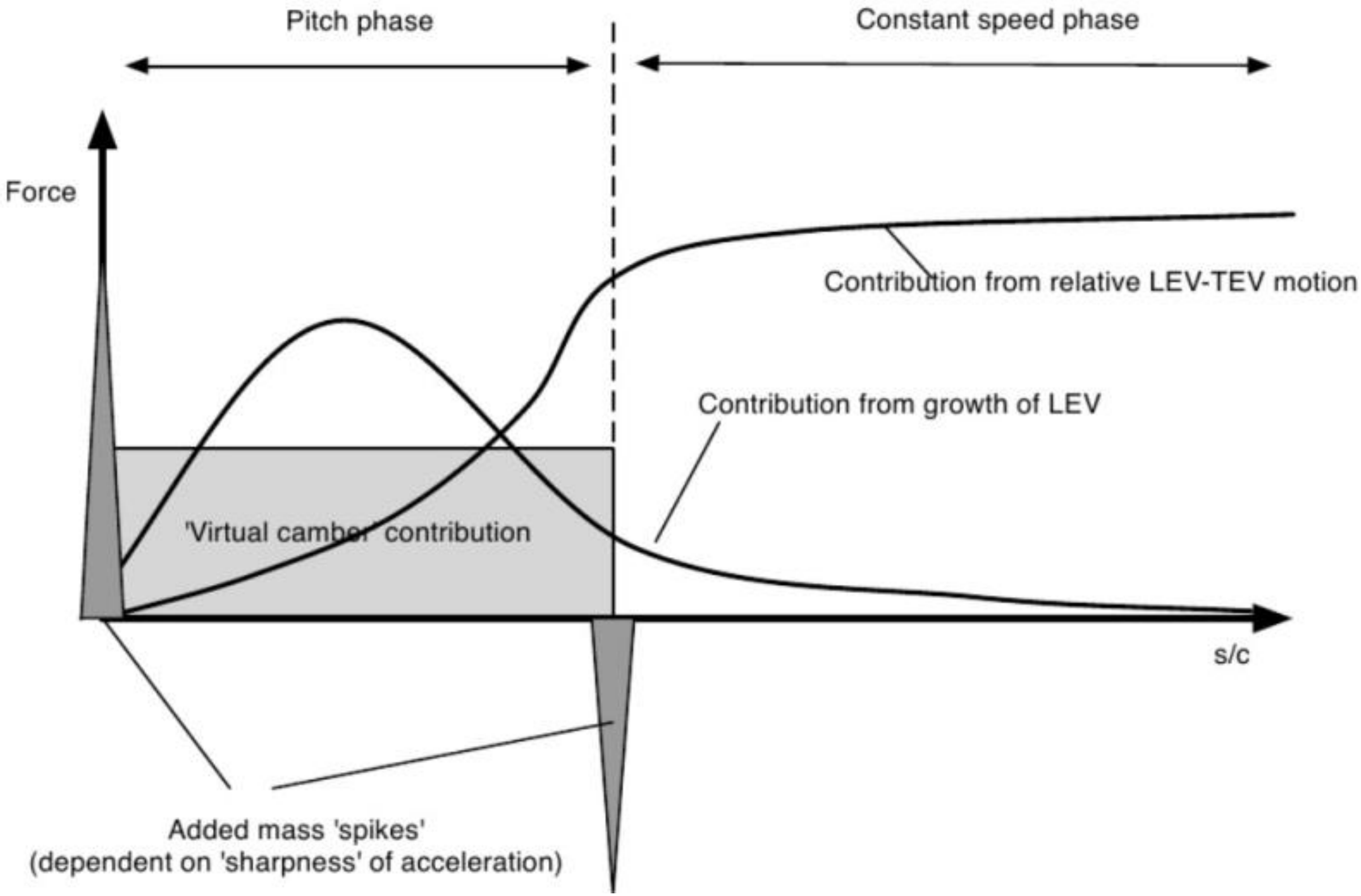
driven by flow

"unknown"
Loads

- Statically deflected leading edge flaps found to enhance airfoil performance by augmenting lift and limiting drag, specially at higher angles of attack **[17]**

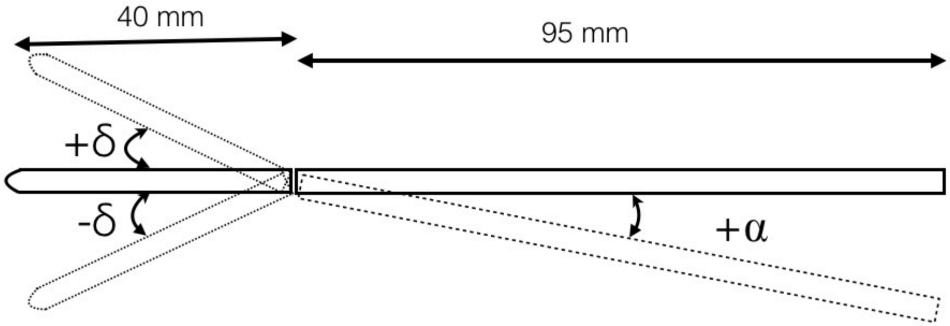
Dynamic Effects

- **Limited study of the dynamics of Leading Edge flaps / devices**



Schematic diagram showing different force contributions for a pitching plate **[61]**

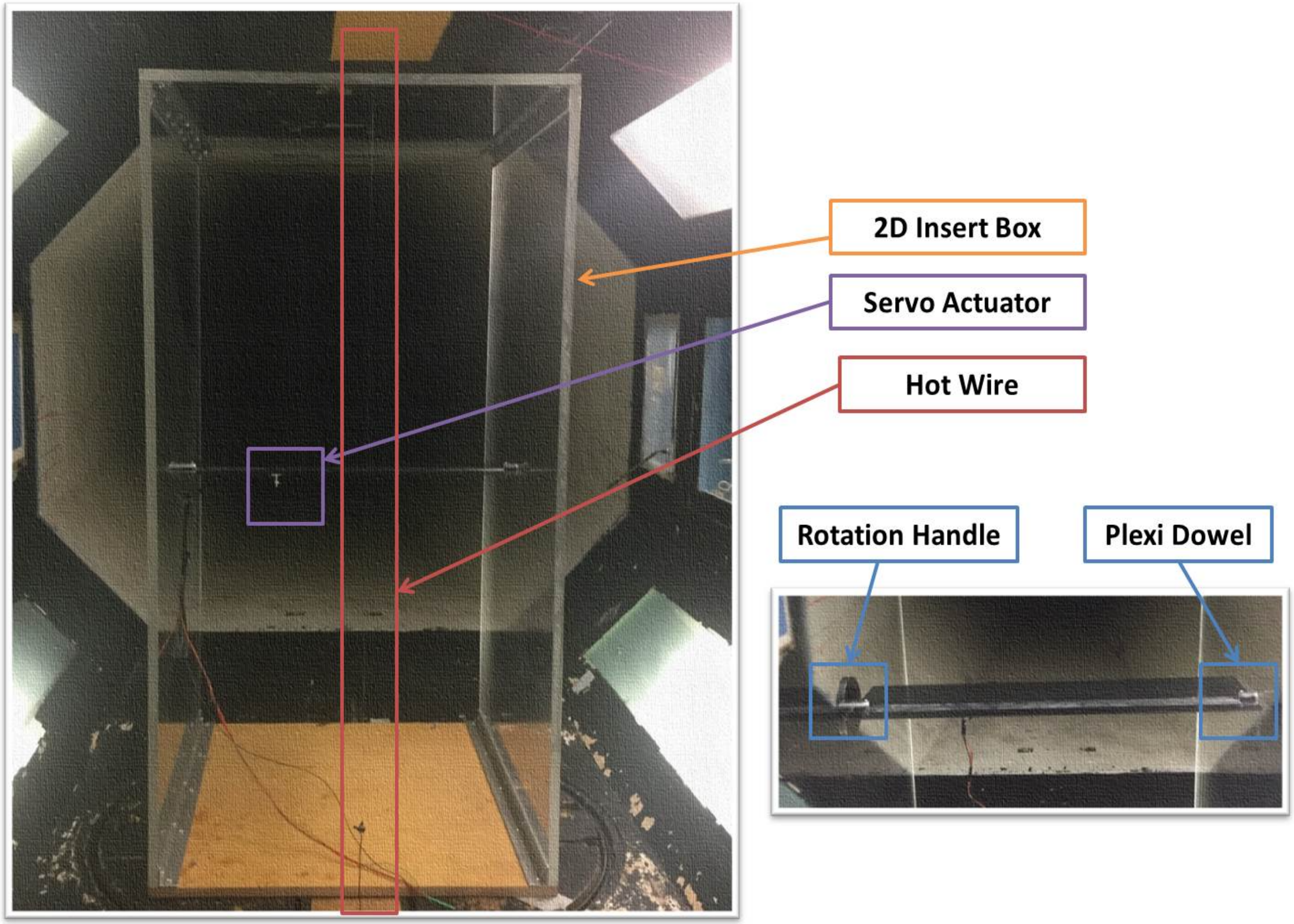
Smoke Flow Visualization



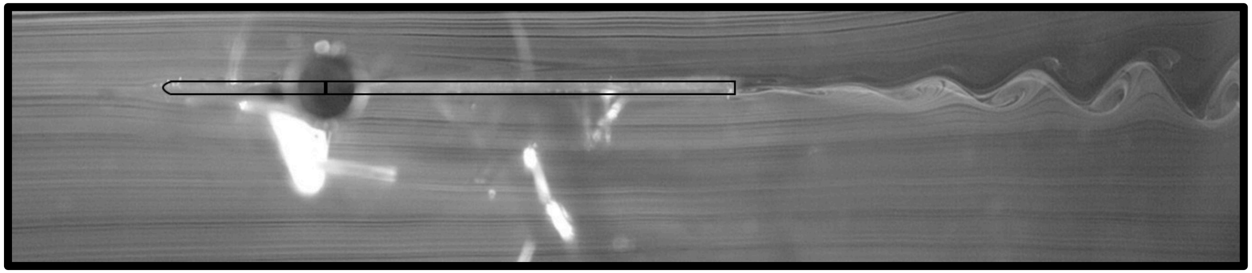
- Flat Plate airfoil 1% t/c
- RJX 1001 servo Actuator
- Phantom Miro M310 high-speed camera

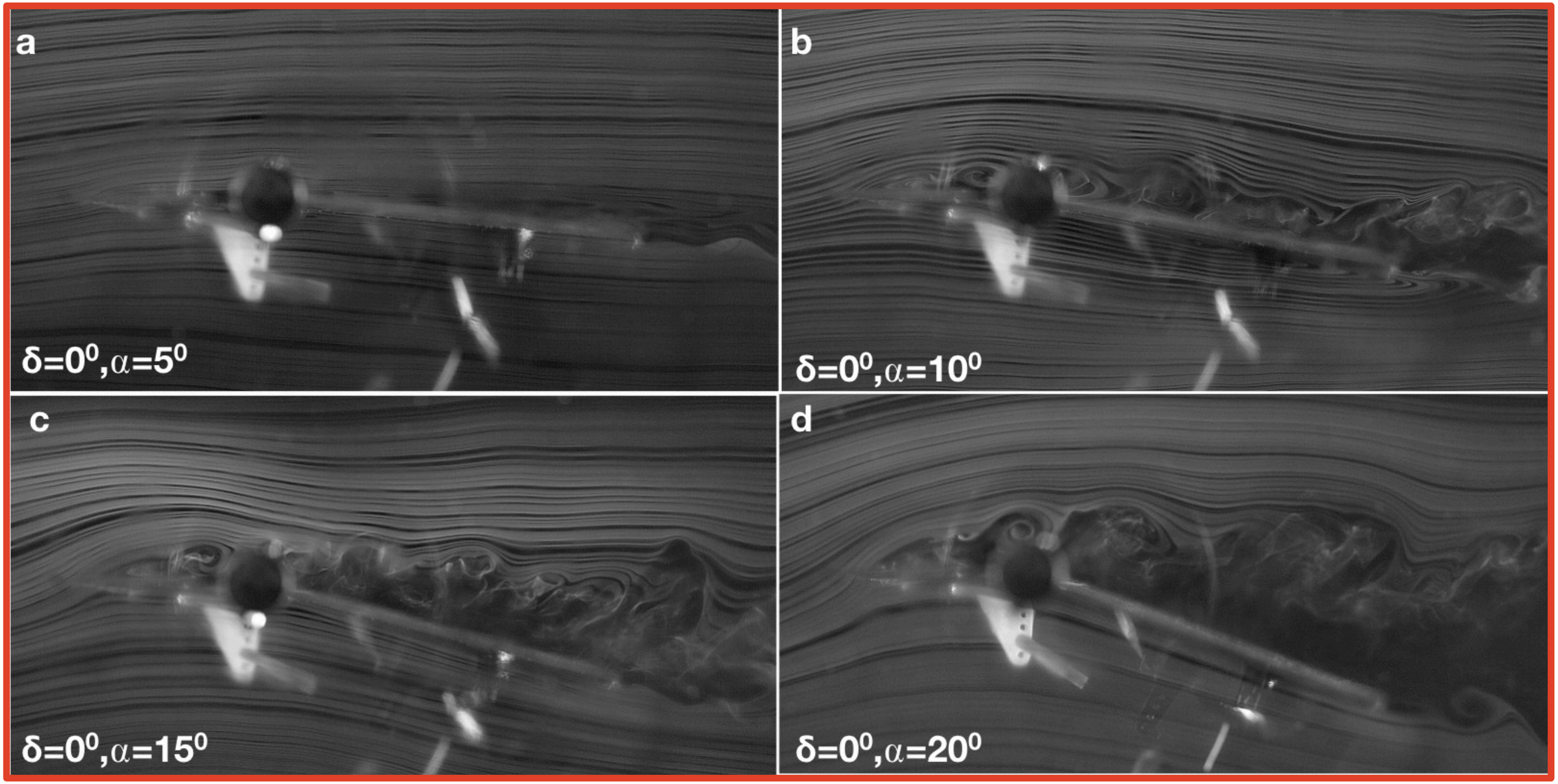
Pitching Kinematics

- Two cases of control surface deflections
  - “fast” deflection, k=0.14
  - “slow” deflection k=0.002
- Constant acceleration

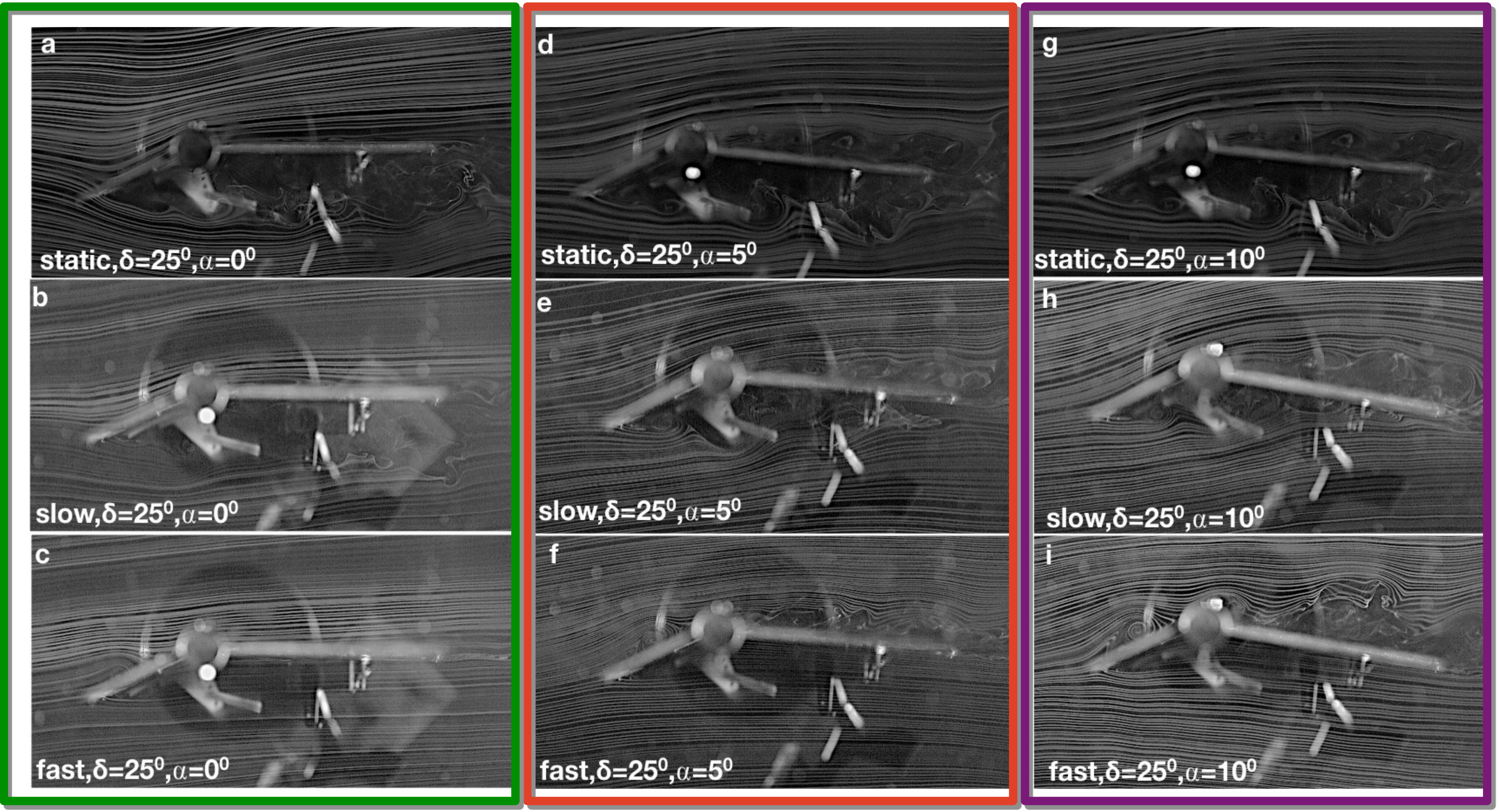


Static Analysis

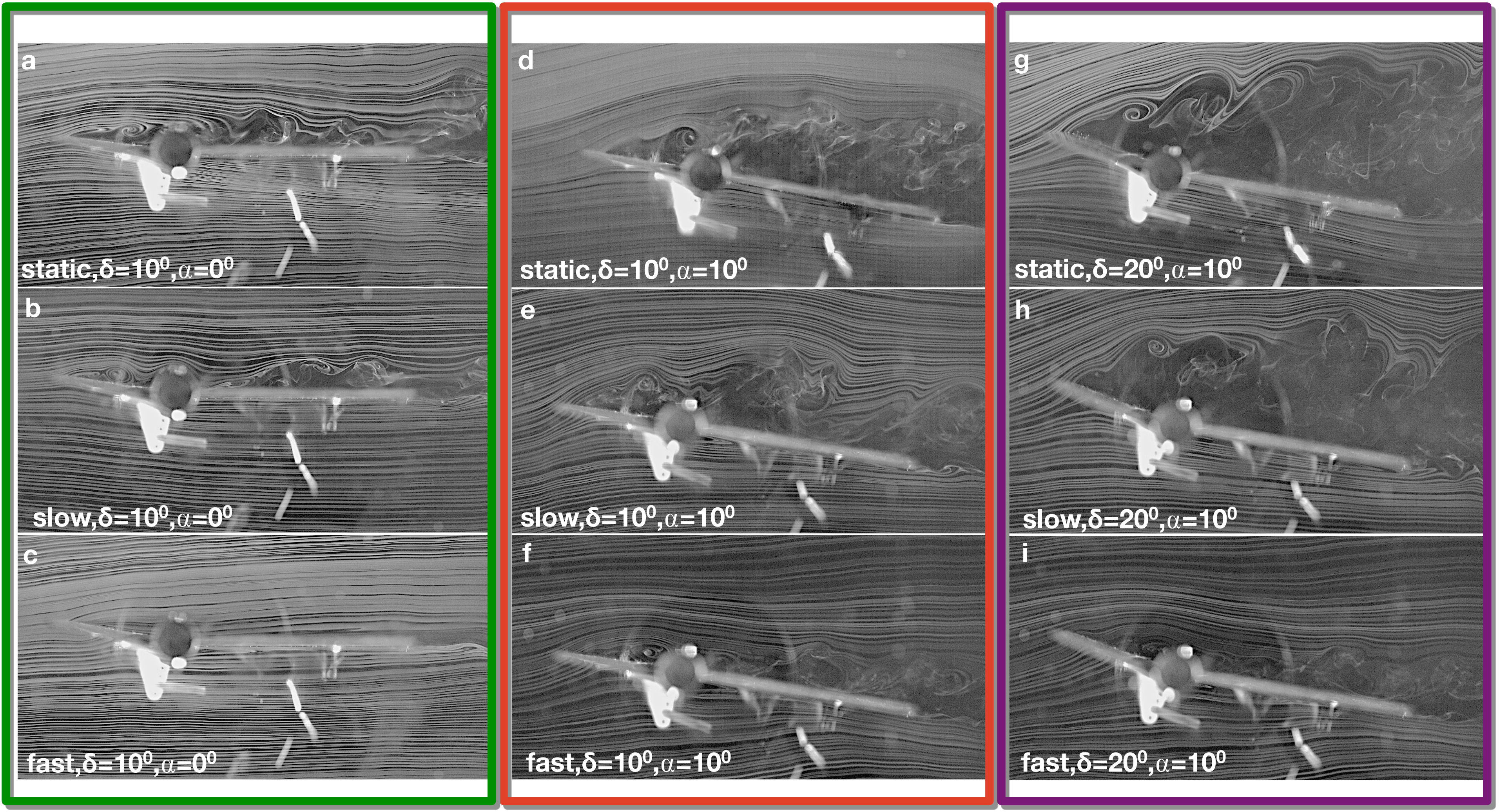




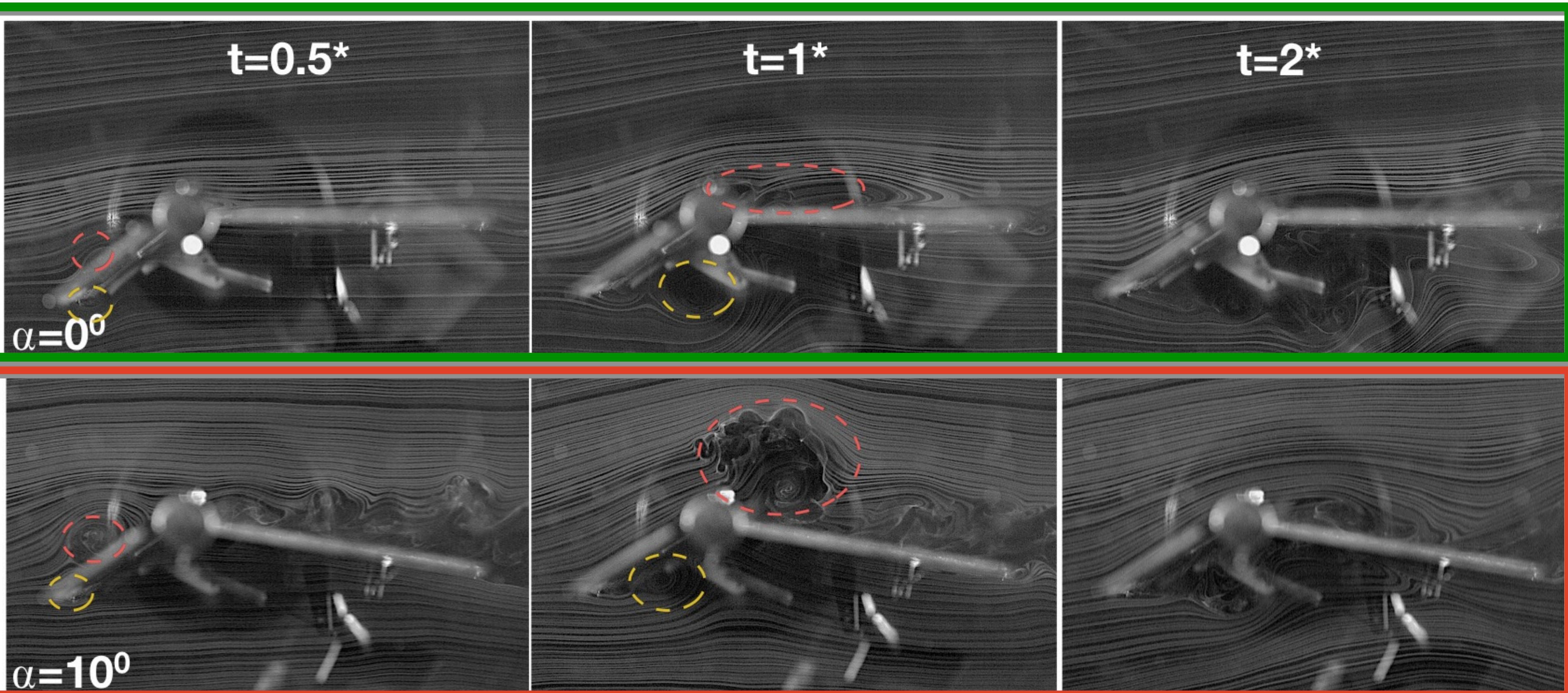
Dynamic Analysis



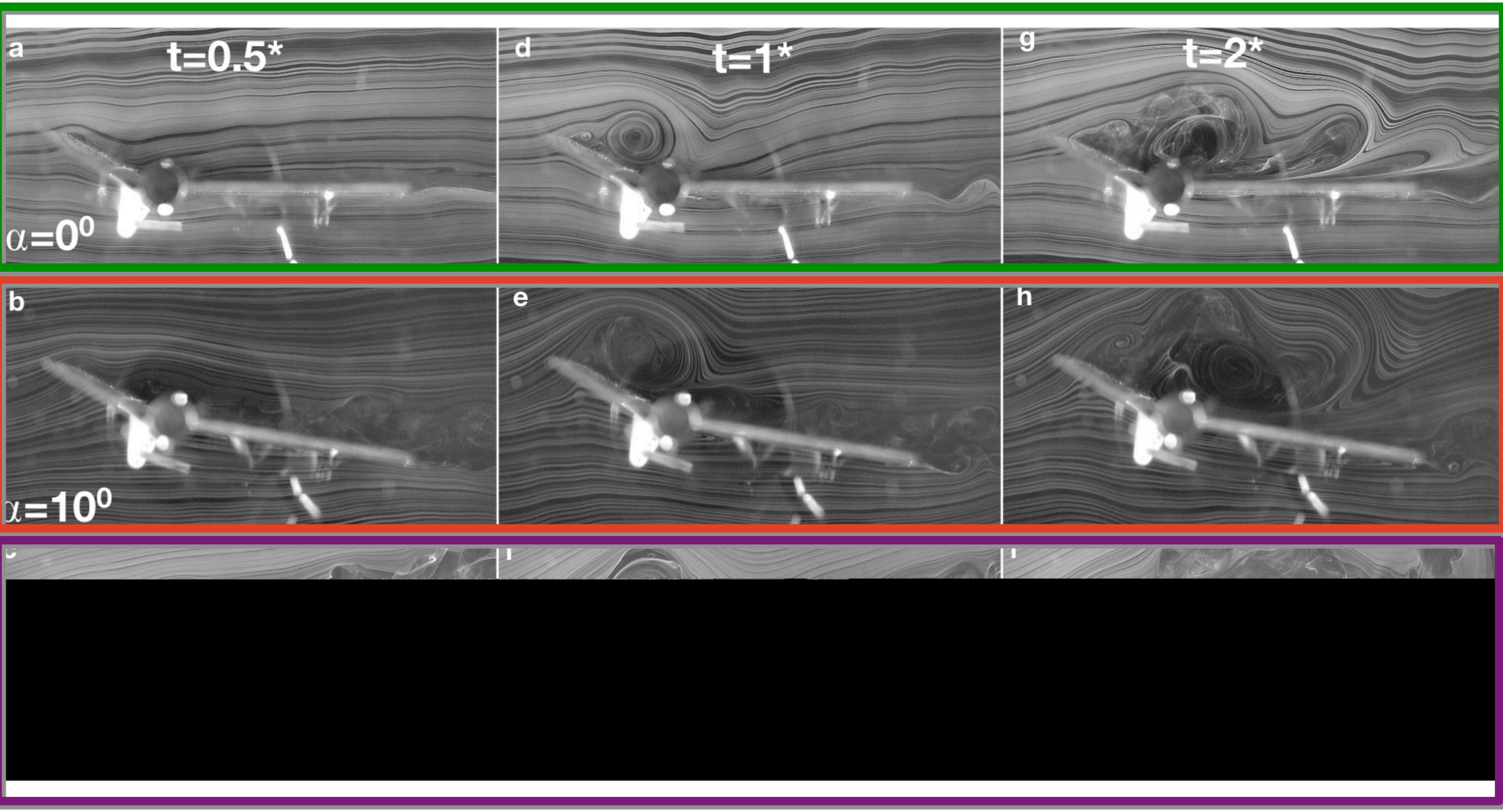
Dynamic Analysis



Flow Characteristics against time



Flow Characteristics against time

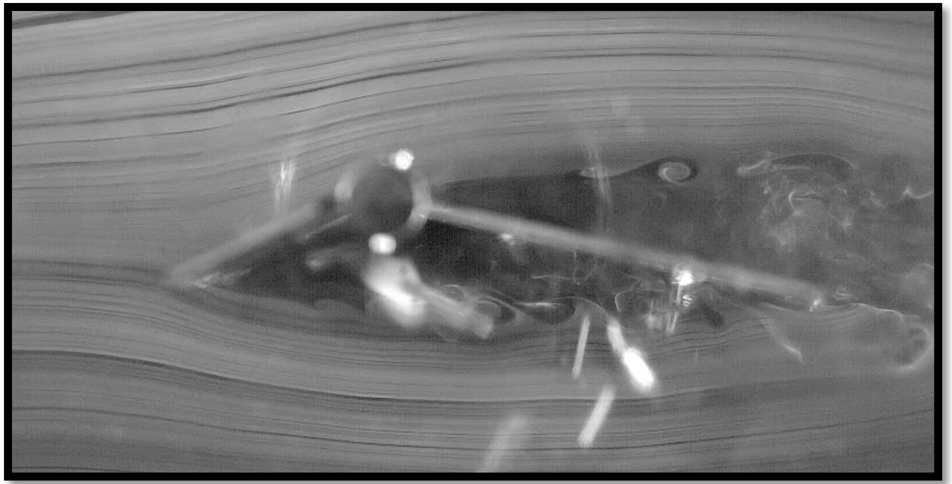


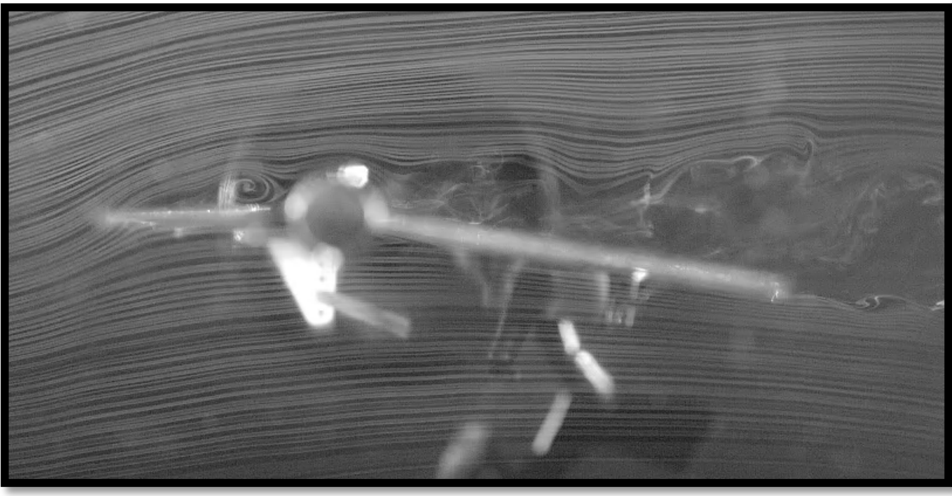
[redacted]

Conclusion

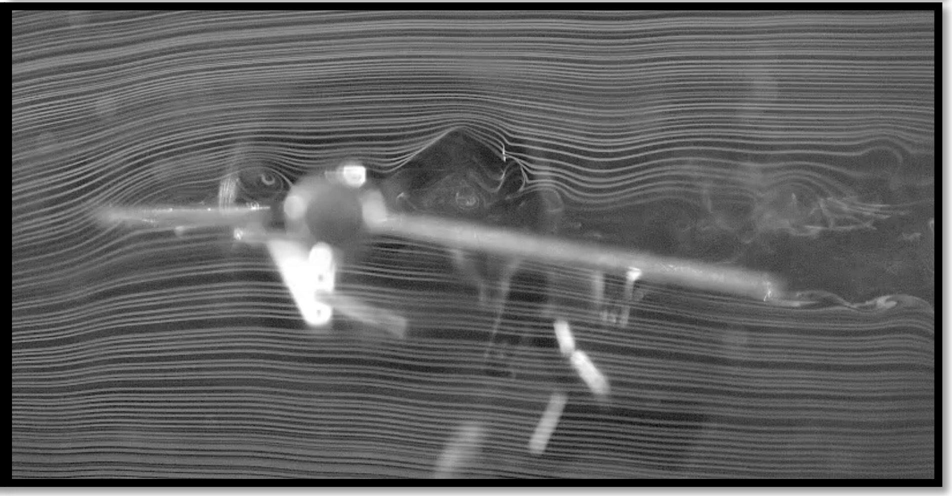
- increasing actuation rates on leading edge hinged control surfaces promoted flow attachment on the airfoil
- flow structures are strong function of LECS angle of attack and actuation rate
  - potential solution towards achieving high responsiveness and authority required for steady MAV flight in turbulence

STATIC CASE





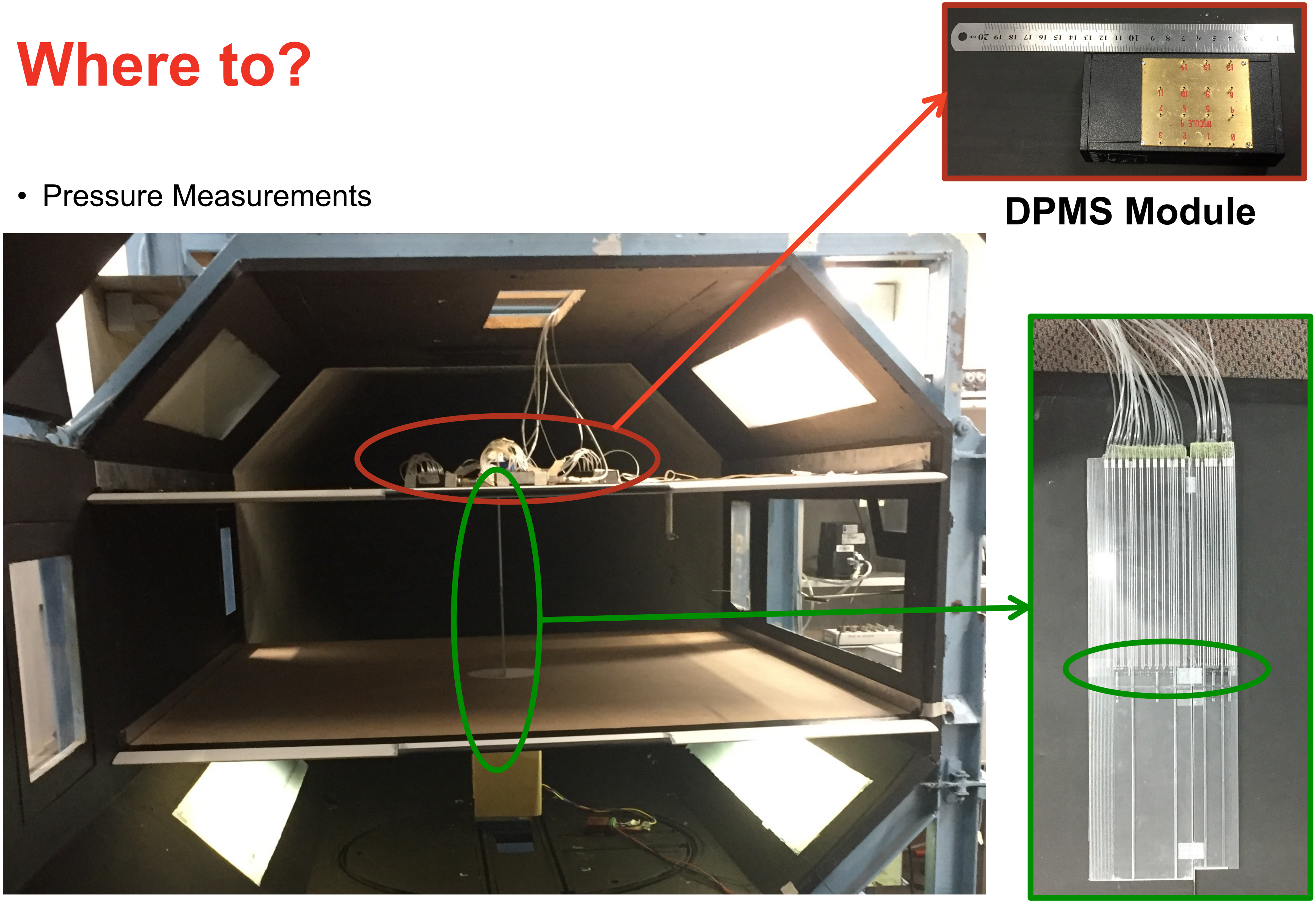
SLOW CASE



FAST CASE

Where to?

- Pressure Measurements



DPMS Module

Wing

THANK YOU FOR YOUR ATTENTION

Any Questions?

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[178] 178 https://s-media-cache-ak0.pinimg.com/564x/4d/cc/05/4dcc05ac139c018222909f432ec3752f.jpg

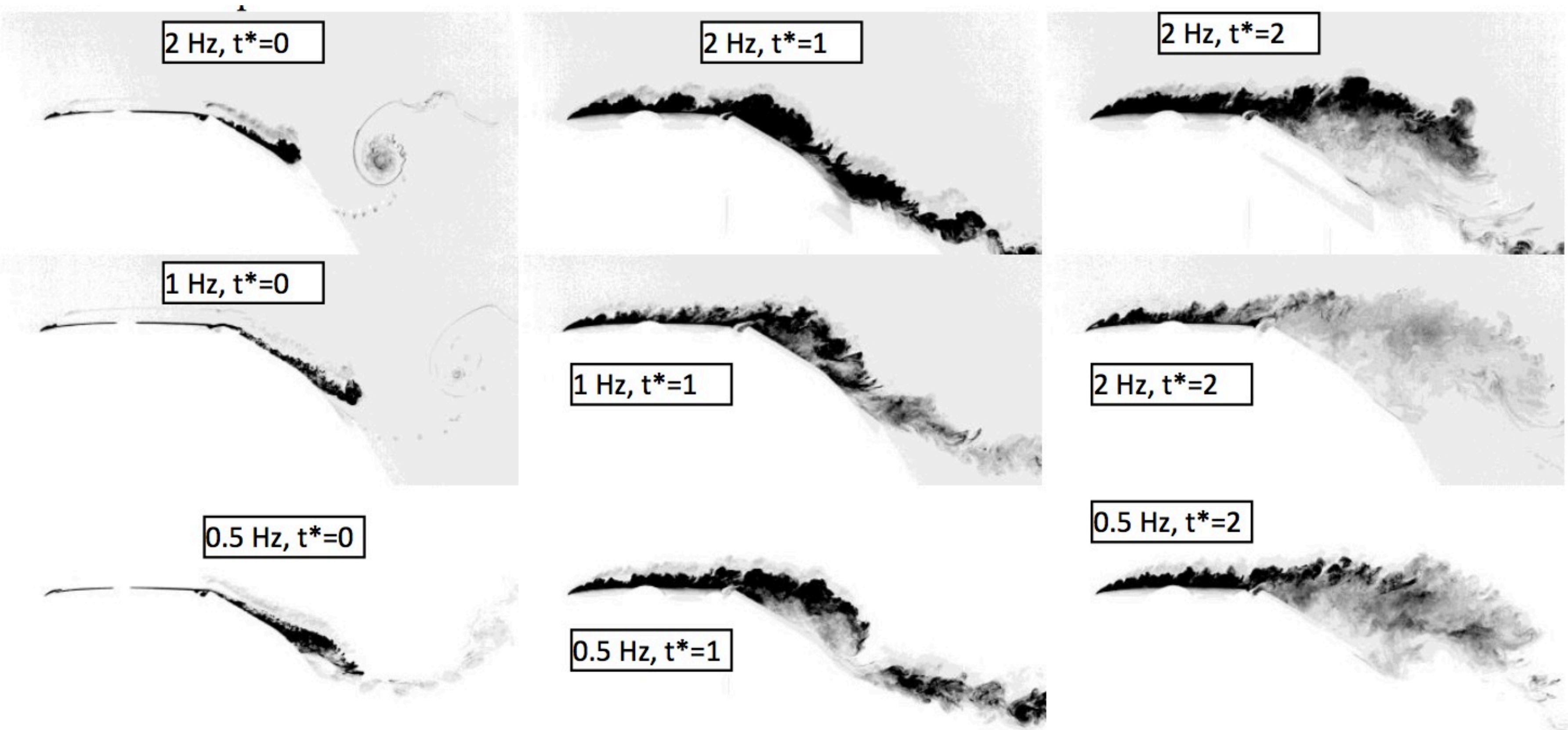


Figure 2. Dye injection from front-element leading edge, with front element at 0 incidence and flap deflected from 0 to 30 degrees. Top row: actuation at 2Hz, or 0.25 convective time. Middle row: 1Hz, or 0.5 convective time. Bottom row: 0.5Hz, or one convective time. Left column: flowfield seen immediately upon the flap reaching its resting position at 30 degrees deflection. Middle column: one convective time later. Right column: two convective times later. [98]

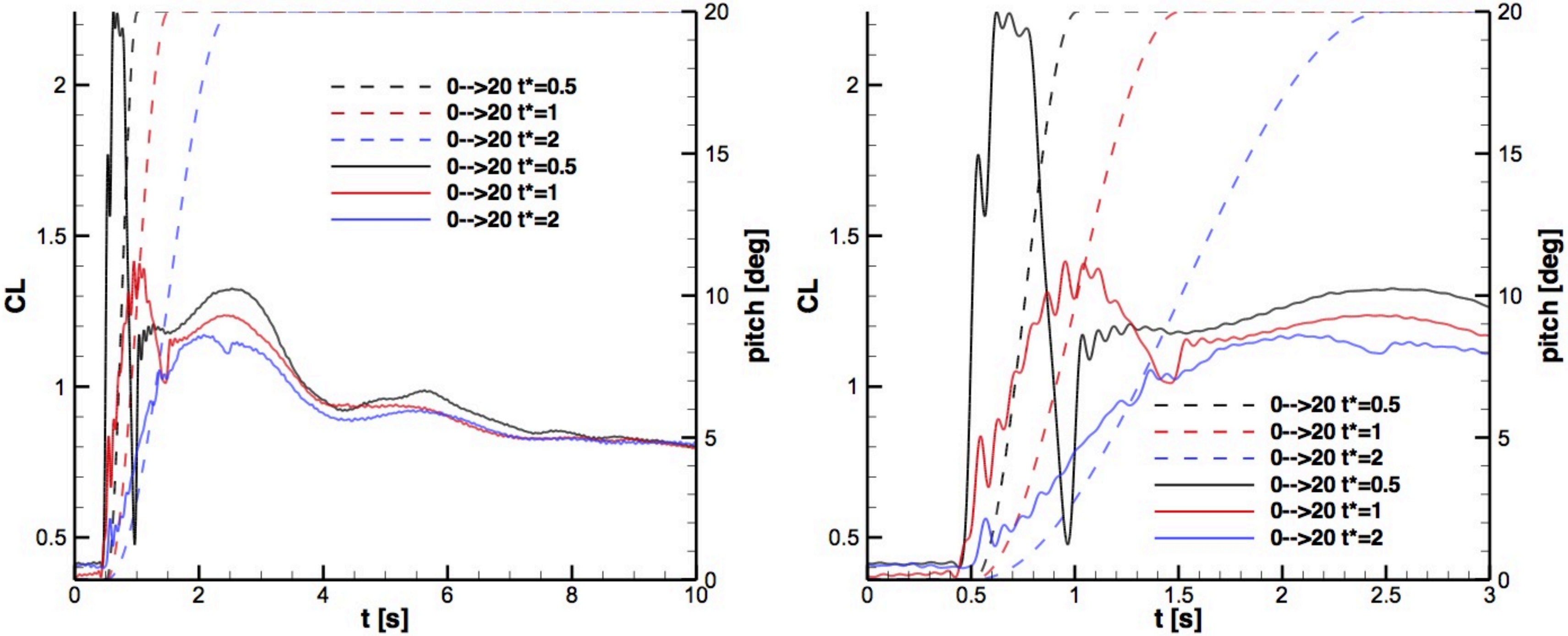
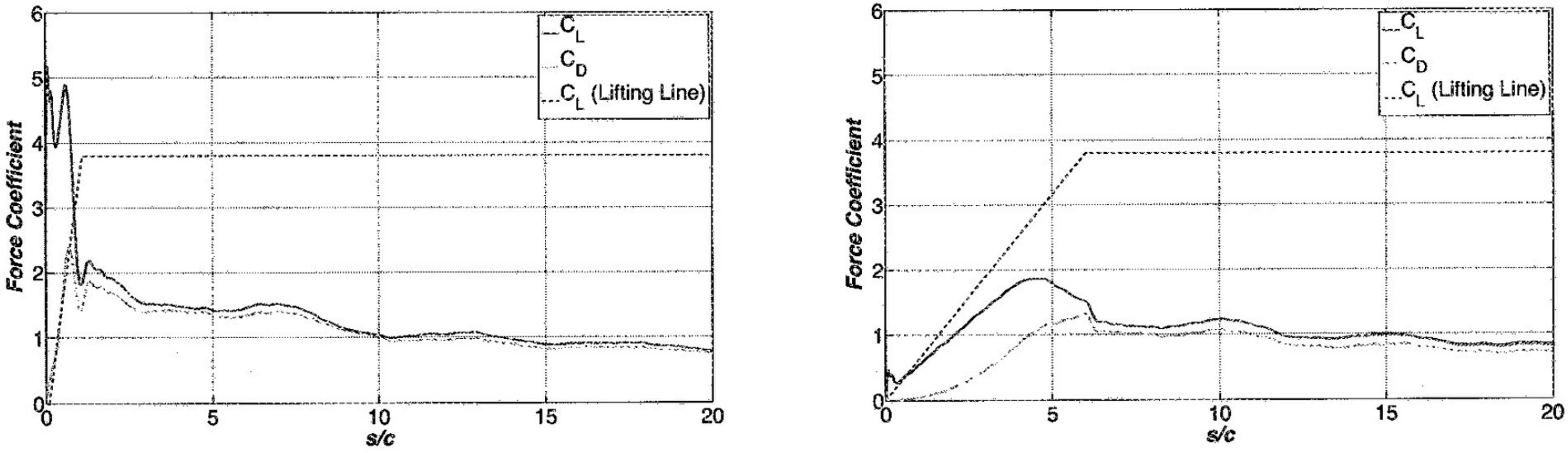


Figure 4. Lift history over 10 convective times (left) and zoomed-in to first 3 convective times (right). Front element at 20^0 incidence, rear element moving from 20^0 lab-frame incidence (that is, coplanar with the front element) to 0^0 lab-frame incidence.

Effects of Actuation Rates



(a) Forces Pitching over 1c.

(b) Forces Pitching over 6c.

[92]

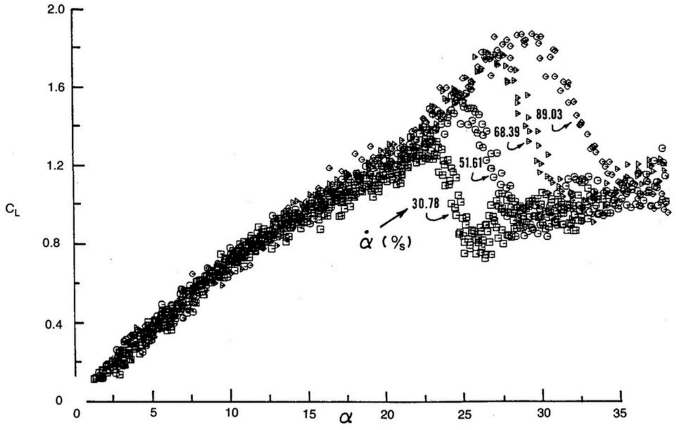


Figure 1.22: Coefficients of lift at various pitch rates

[93]