
Aerodynamic Variables and Loads Estimation Using Bio-Inspired Distributed Sensing

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Overview

Introduction

Motivation

Research Problem

Research at UoB

Current Research

Concluding Remarks

Motivation: Why Bio-Inspired Distributed Sensing?

Amazing Kestrel!!!

Kestrel Hovering and Hunting in Cornwall

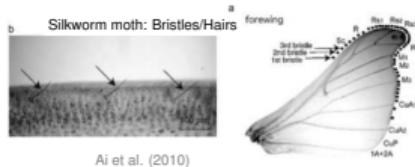
Paul Dinning, 2015

<https://www.youtube.com/watch?v=7j60sP7zL6w>

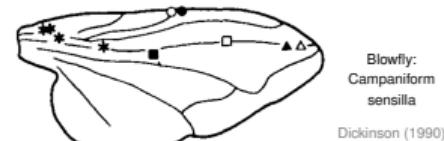
Motivation: Why Bio-Inspired Distributed Sensing?

Insects

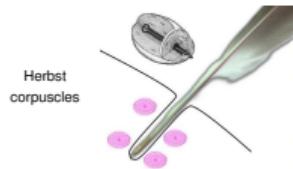
Flow Sensors



Force Sensors



Birds



Bats

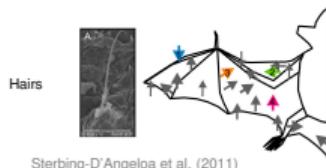
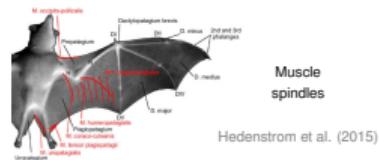


Figure: Biological sensory systems



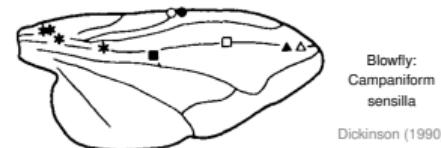
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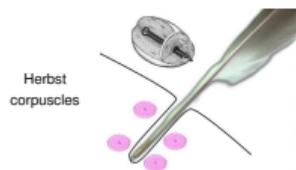
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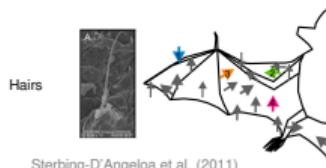
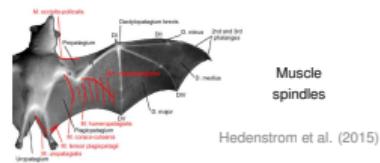
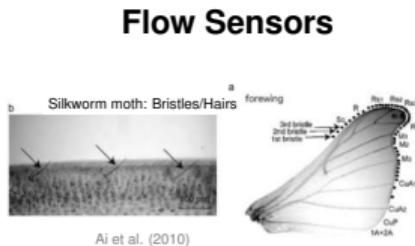


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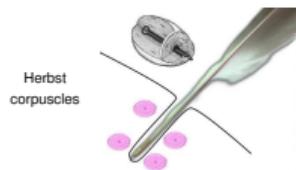


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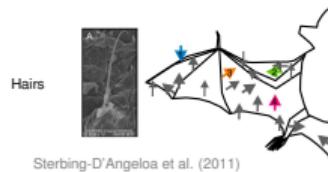
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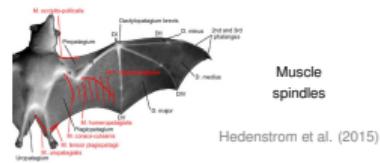
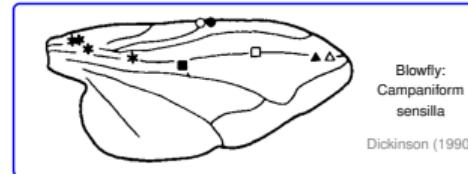
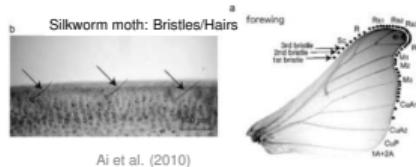


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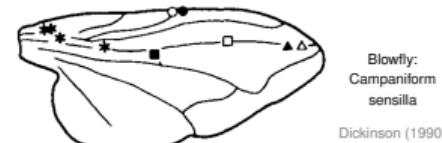
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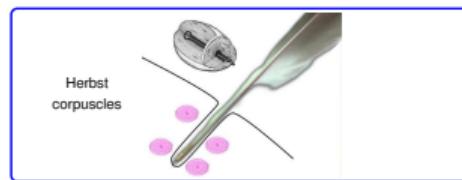
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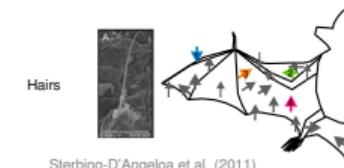


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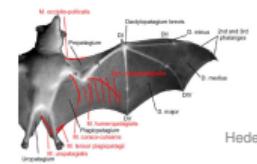
Hairs



Muscle spindles



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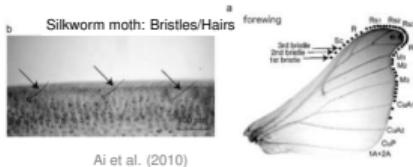


Muscle spindles

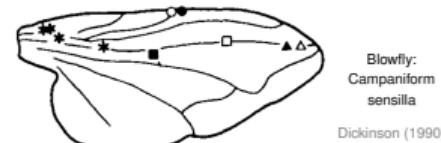
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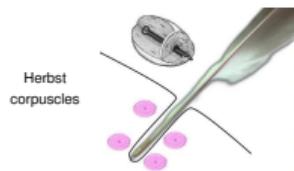
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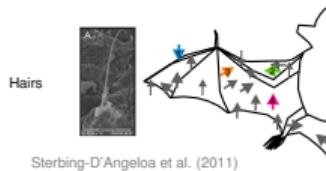
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Muscle spindle

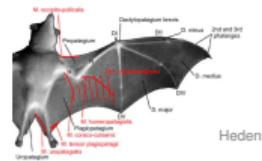
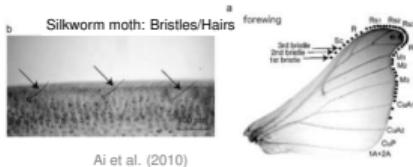


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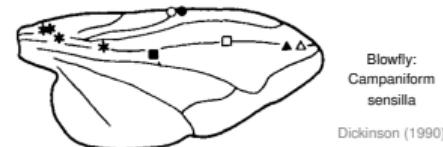
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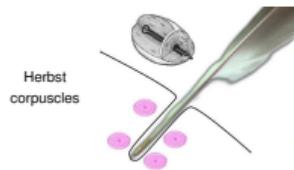
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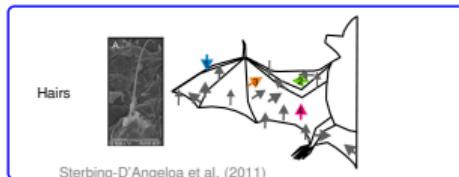
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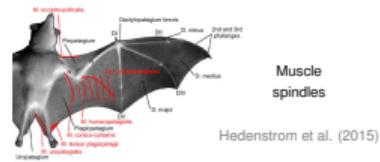
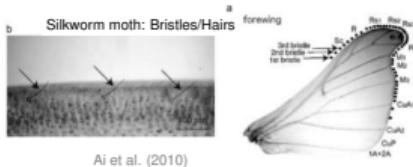


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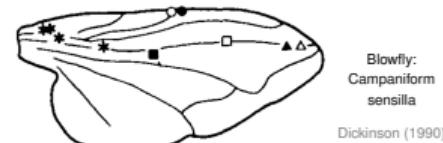
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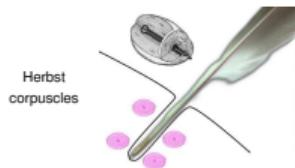
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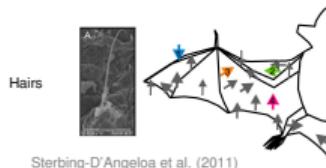
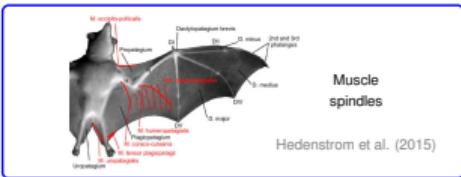


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spindles



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Motivation: Why Bio-Inspired Distributed Sensing?

- ❖ Current UAV autopilot technologies

- ❖ Challenges

- ❖ Potential use of force and flow information

Motivation: Why Bio-Inspired Distributed Sensing?

❖ Current UAV autopilot technologies

- Inertial
- Single point air speed
- GPS
- Vision

❖ Challenges

❖ Potential use of force and flow information

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Motivation: Why Bio-Inspired Distributed Sensing?

❖ Current UAV autopilot technologies

- Intrinsic nonlinear dynamics
- Classic control strategies limitations
- Limitations of inertial controls

❖ Challenges

❖ Potential use of force and flow information

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- ❖ Current UAV autopilot technologies

- ❖ Challenges

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Motivation: Why Bio-Inspired Distributed Sensing?

❖ Current UAV autopilot technologies

- Availability of aerodynamic variables
 - Improved flight dynamics model
 - Stall detection

❖ Challenges

- Earlier gust detection
 - Gust rejection/alleviation
- Localised information
 - Localised control
 - Load tailoring

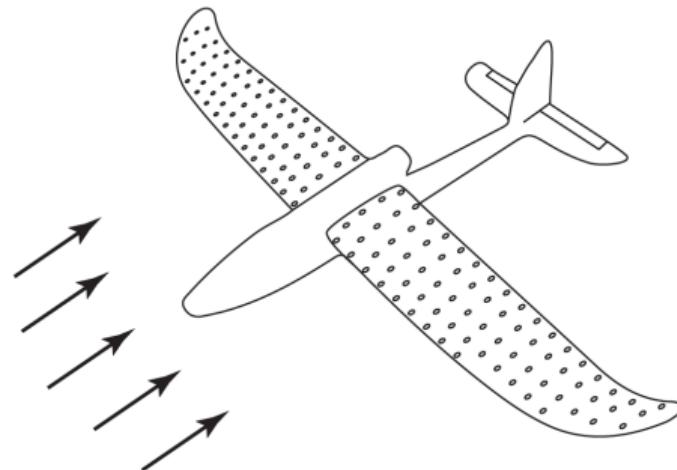
❖ Potential use of force and flow information

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.

To achieve this we aim to:

- ❖ Develop distributed sensing system for UAV
- ❖ Integrate with conventional flight control system
- ❖ Measure response to gusts/turbulence
- ❖ Develop flight control systems

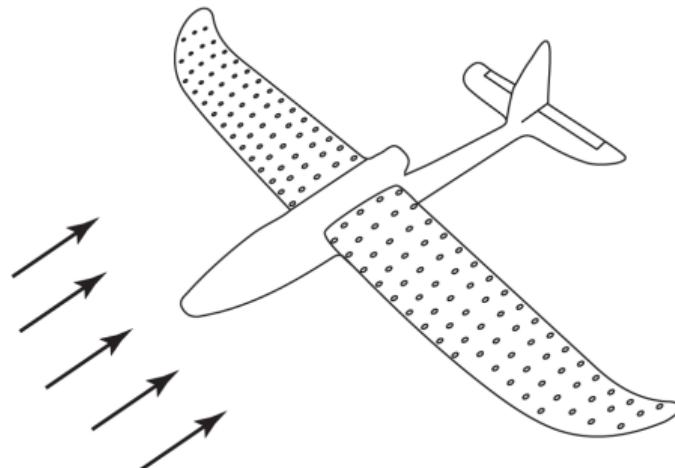


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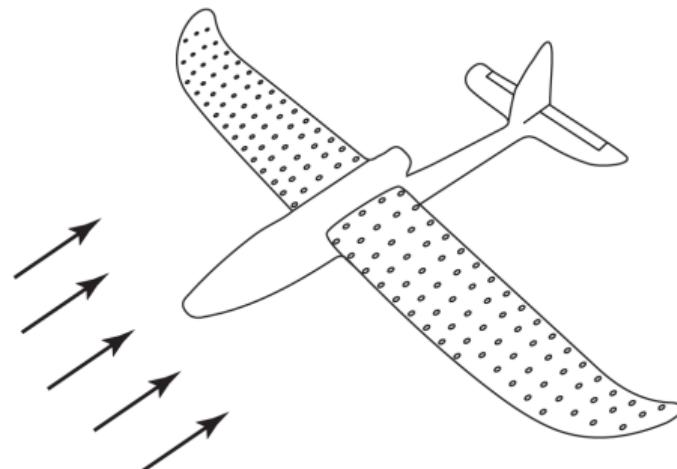


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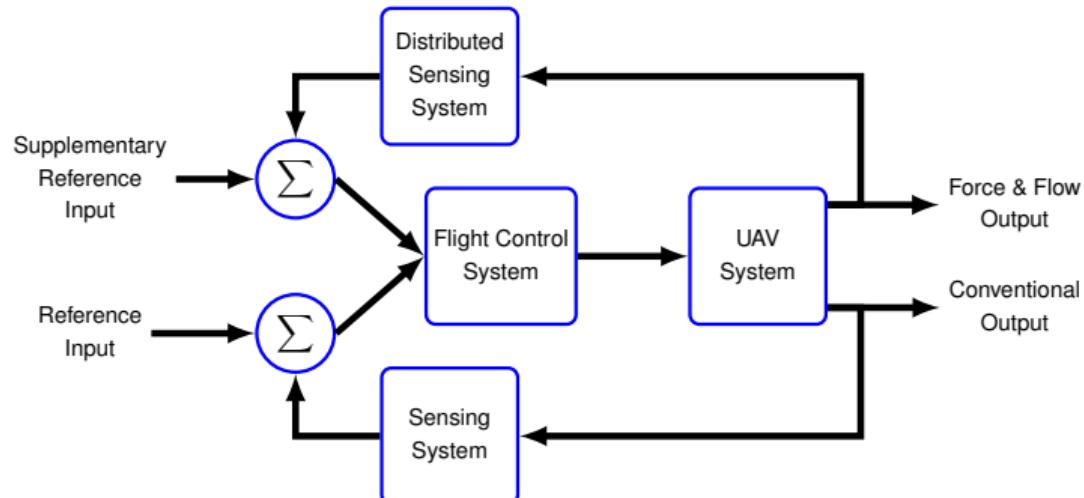


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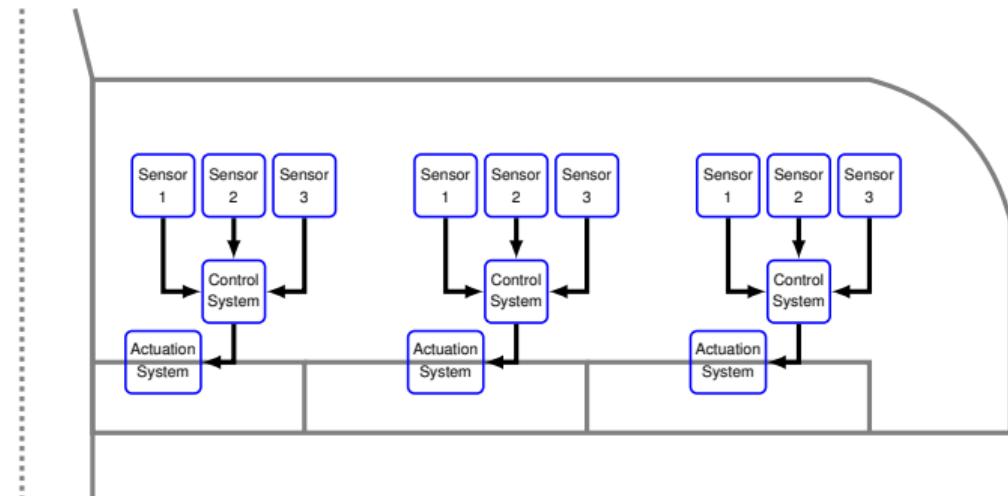
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Previous Research at UoB

What did we learn?

- 👉 Strain & pressure signal show significant changes during movement
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- 👉 Similar performance to IMU-based control
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- 👉 Information not available using IMU

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What did we learn?

- 👉 Strain & pressure signal show
 - Linear response with AoA
 - Stall markers
- 👉 Similar performance to IMU-based control
 - Strain → roll control
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Current Research at UoB

Research focuses on:

- ❖ Pressure and strain sensing experimental platform
- ❖ Calibration & characterisation experiments
- ❖ Closed loop control algorithms

Divided into two phases:

- ❖ Phase 1: Wind tunnel experiments
- ❖ Phase 2: Outdoor flights experiments

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Wing model instrumentation:

- ☛ Chord-wise array of 30 pressure ports in two sections
 - ☛ Span-wise array with 16 strain gauges
 - ☛ Servo actuated control surfaces
 - ☛ MCU-based data acquisition system using, sampling 100 Hz
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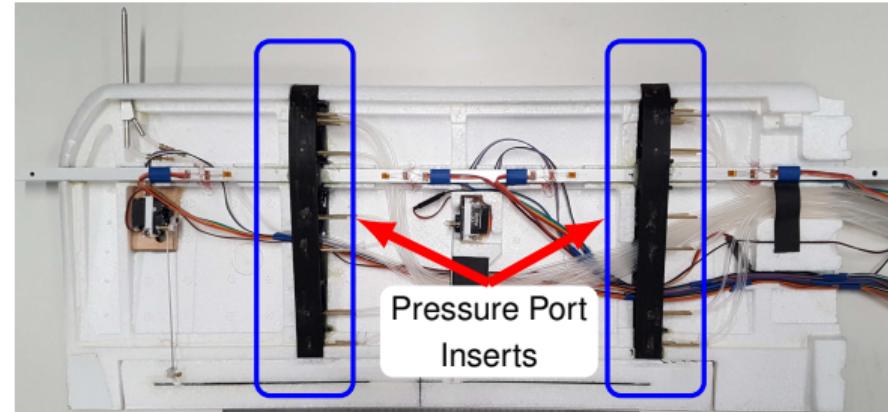


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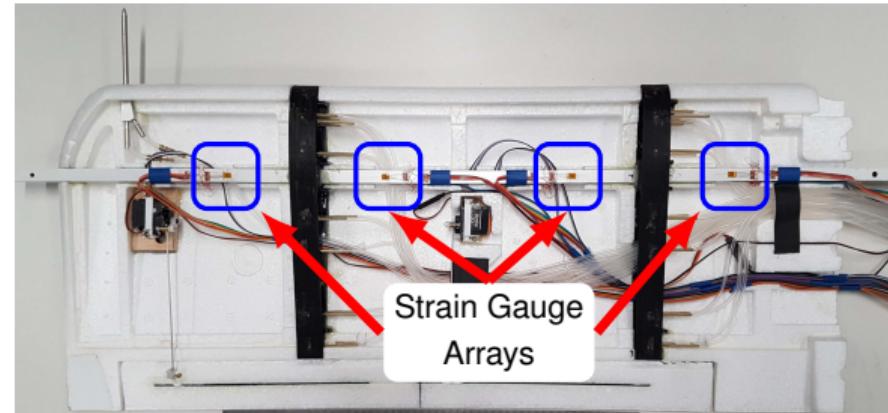


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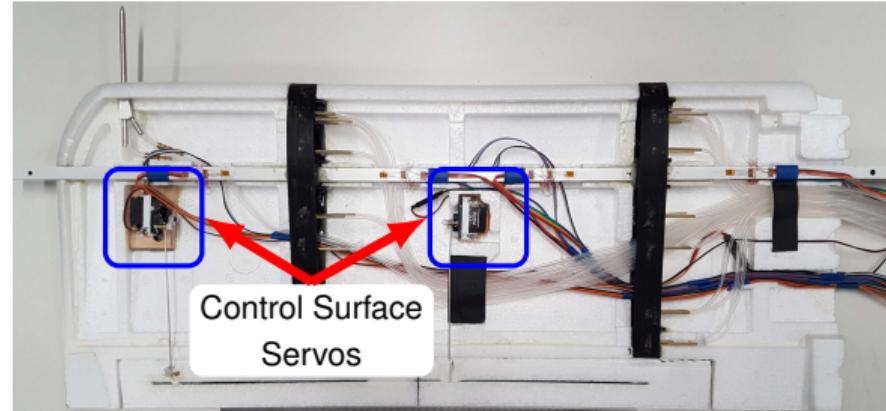


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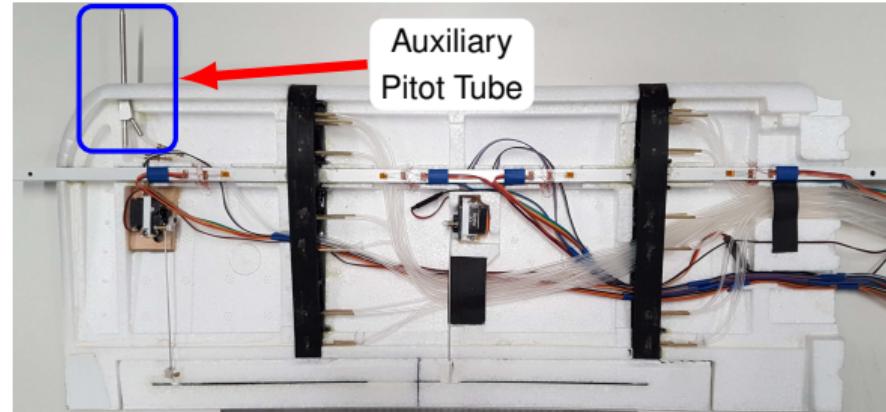


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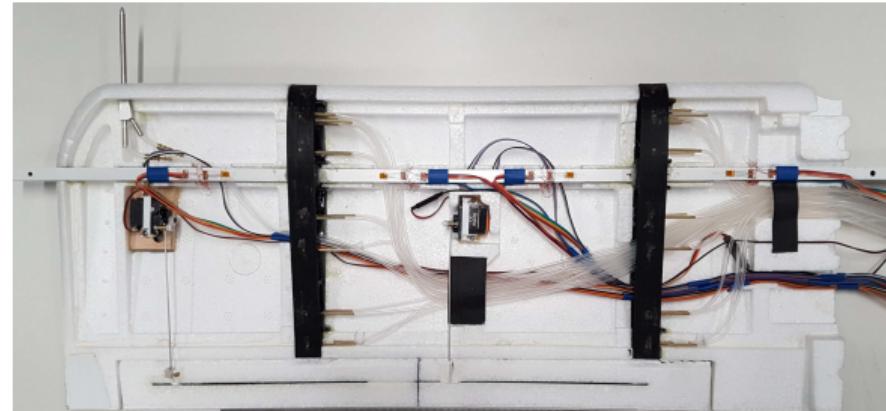


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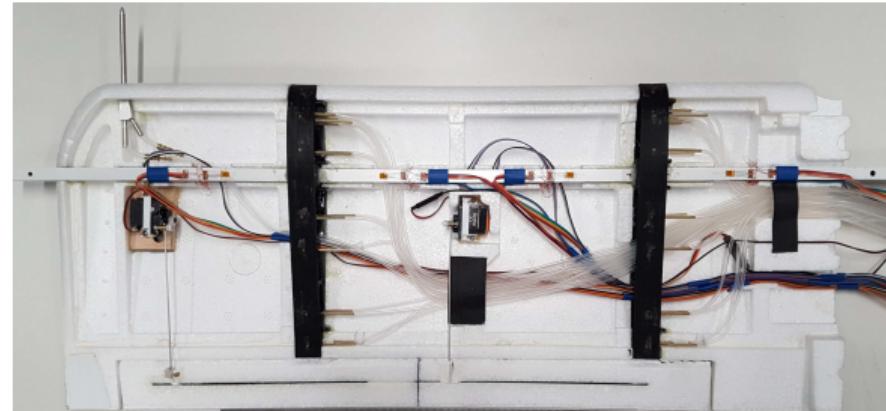
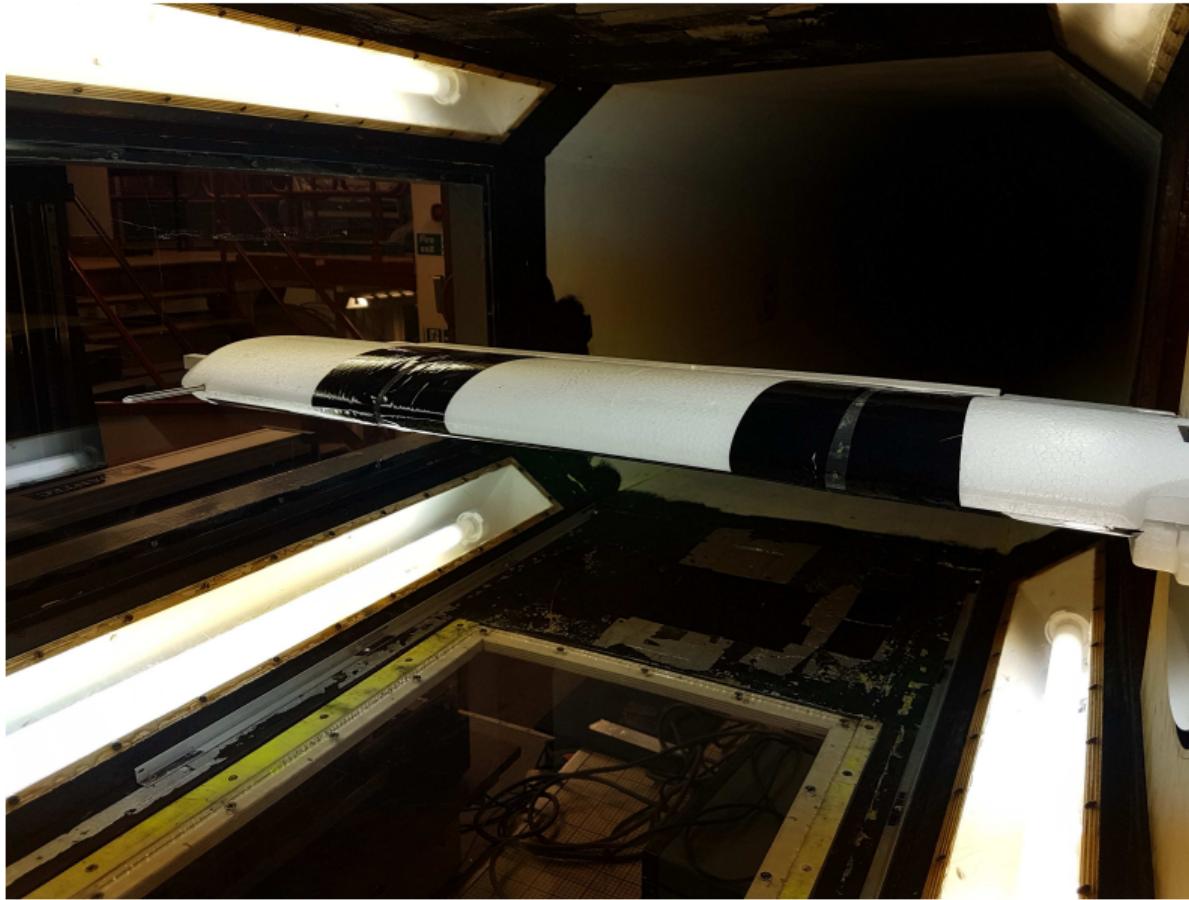


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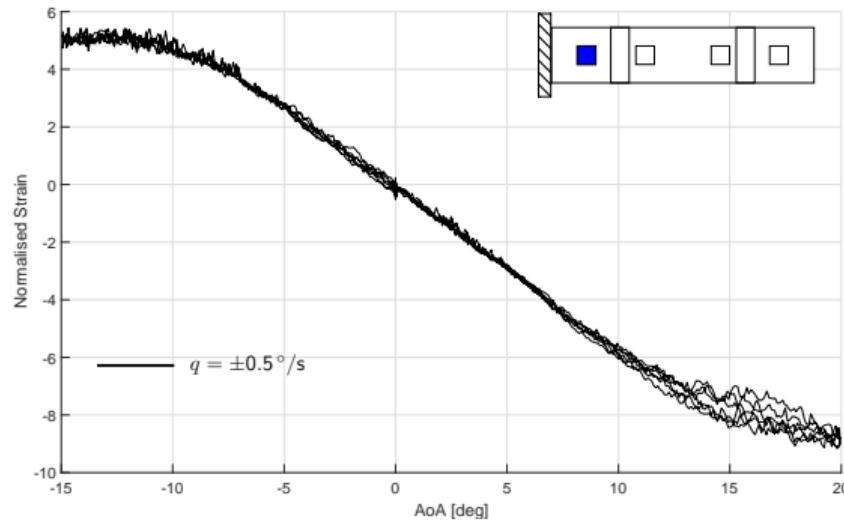


Figure: Strain response for various q values

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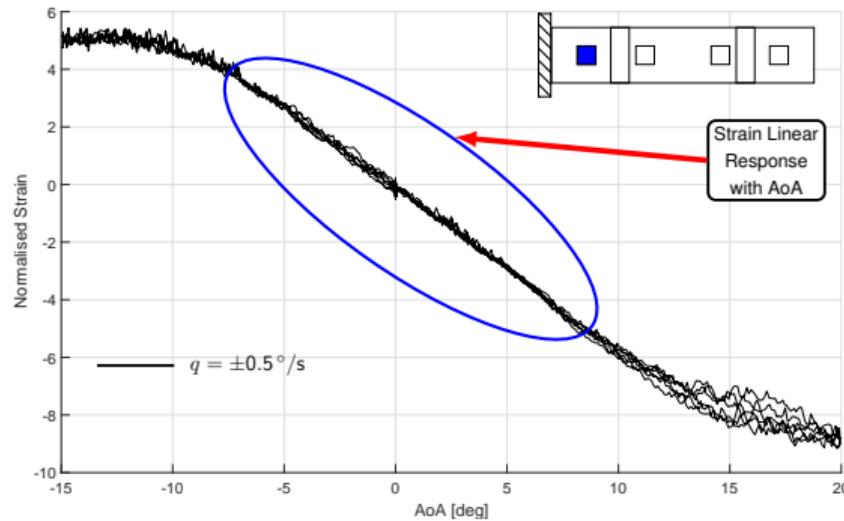


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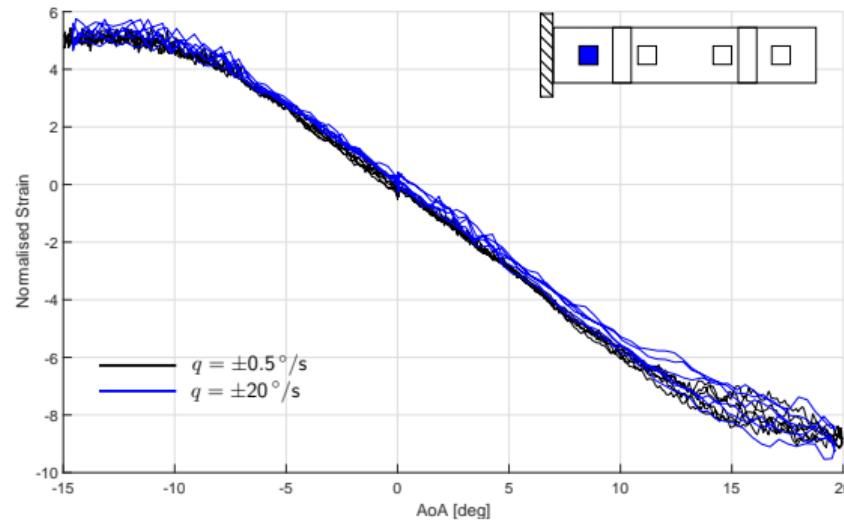


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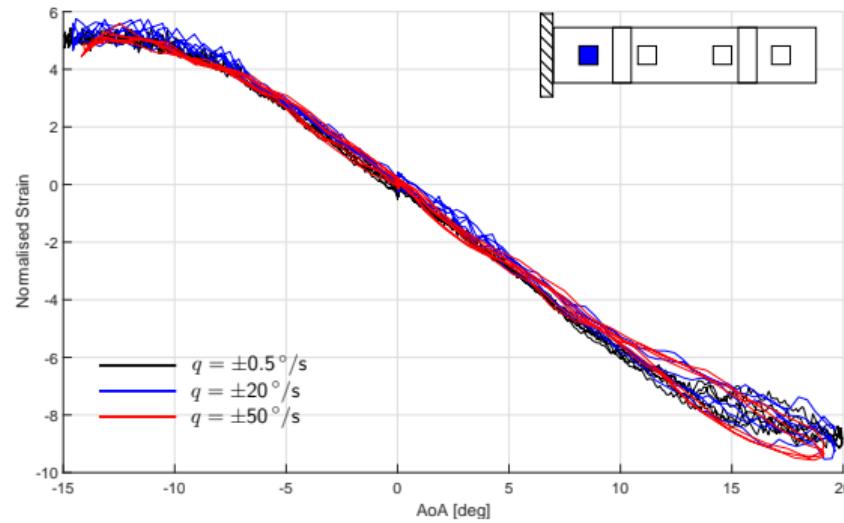


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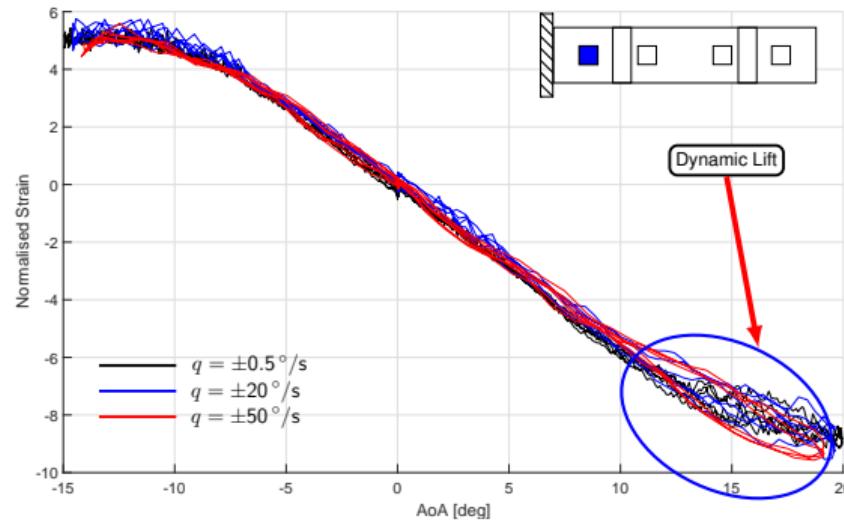


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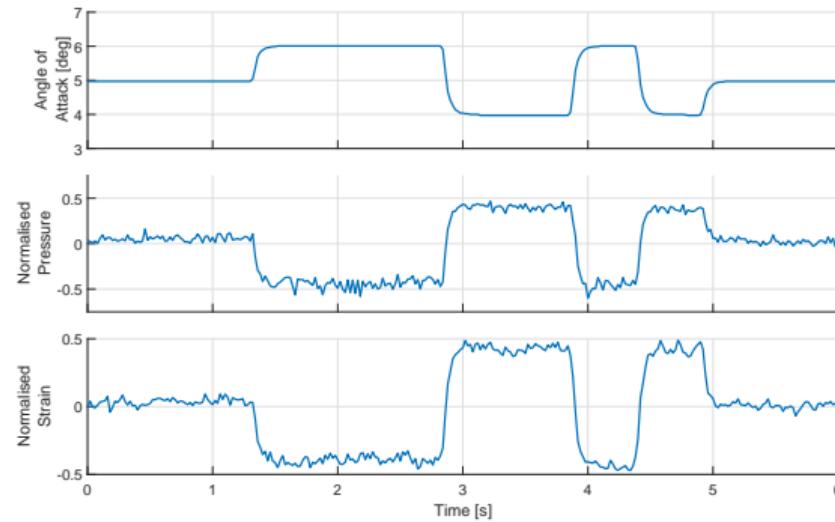


Figure: Pressure & strain response to dynamic input

Current Research at UoB

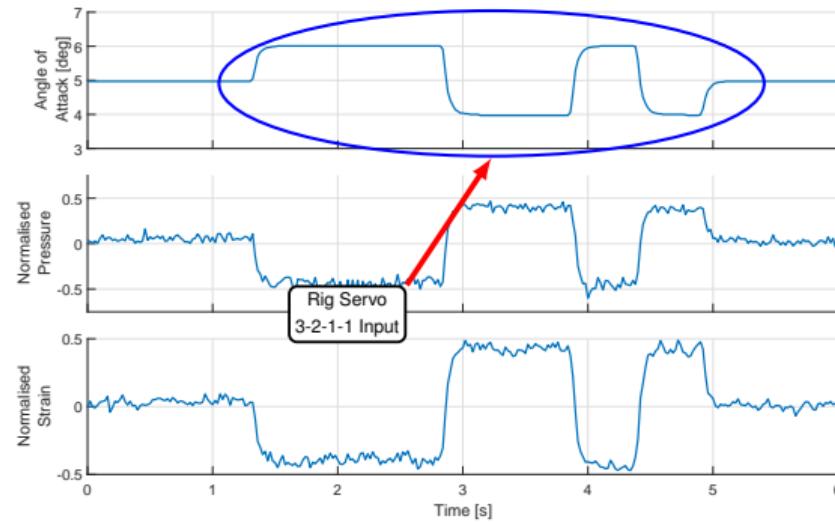


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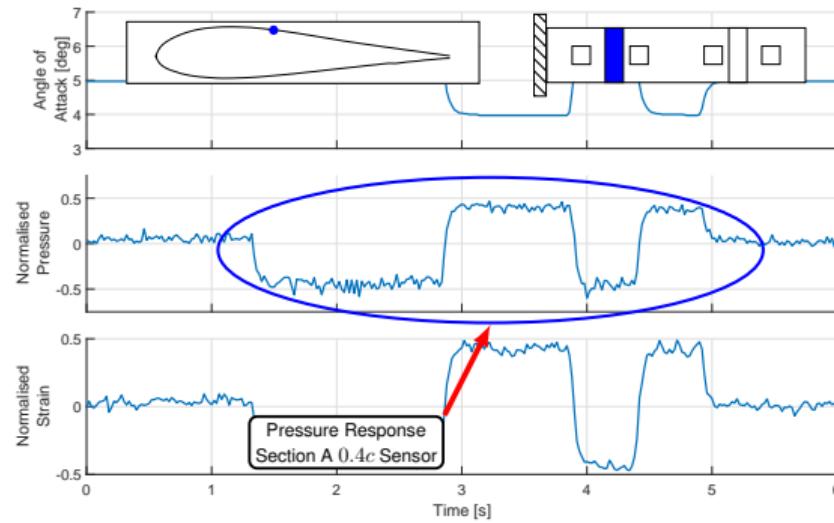


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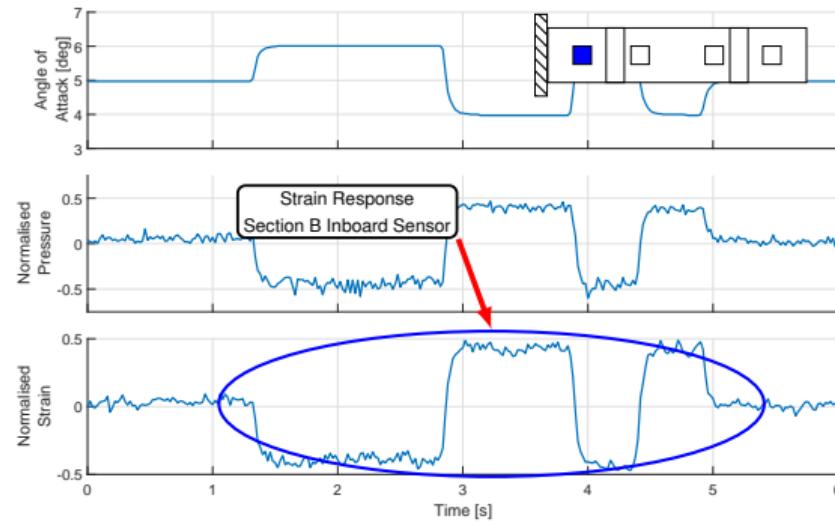


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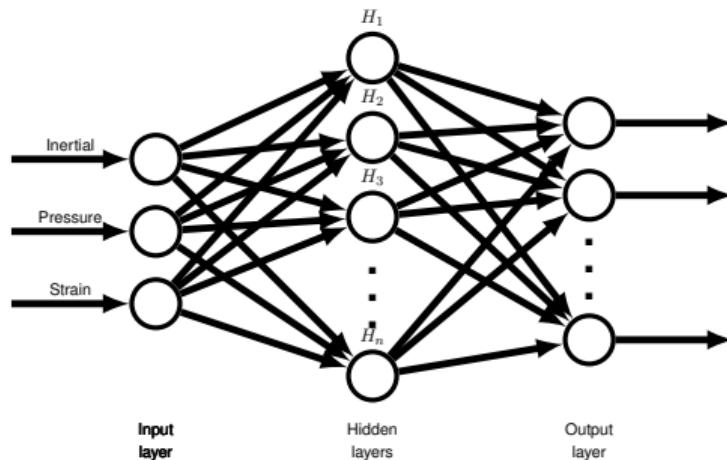


Figure: Possible UAV control strategies

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- ❖ Use strain and pressure signals to estimate
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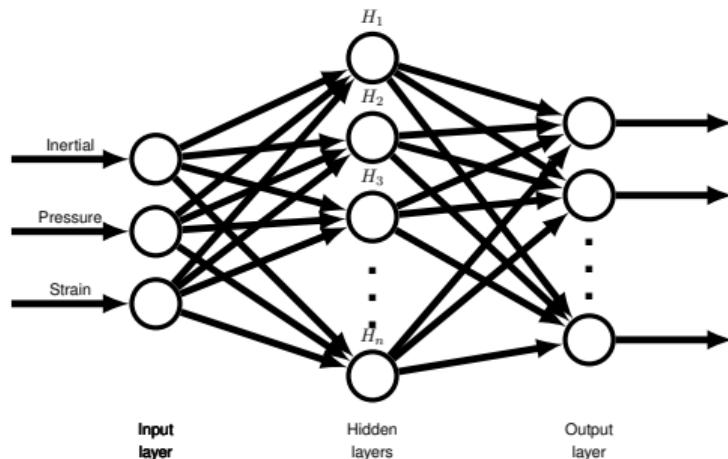


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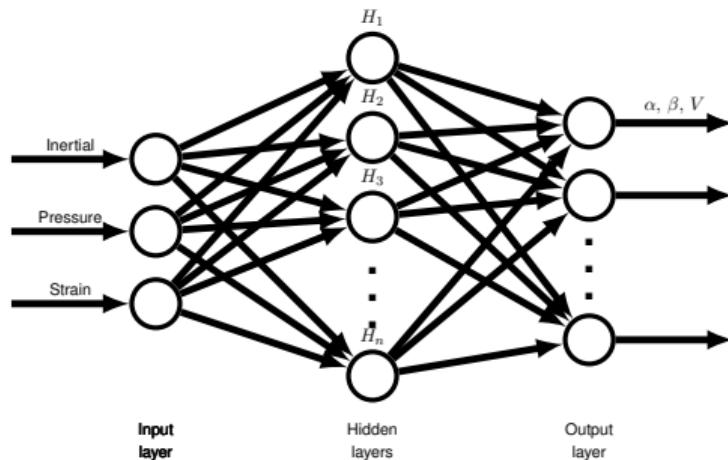


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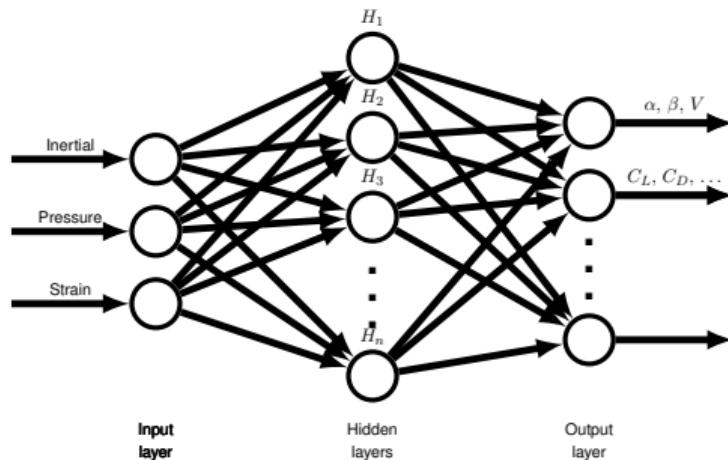


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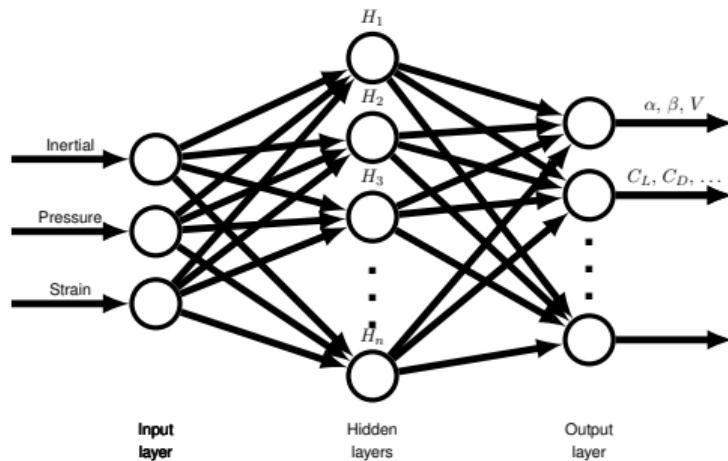


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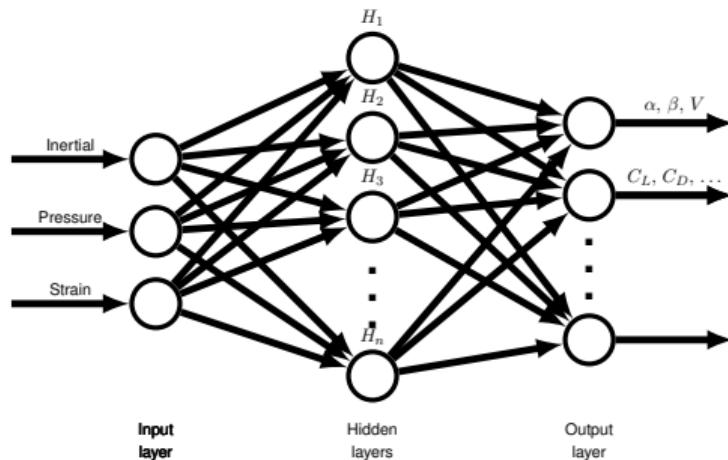


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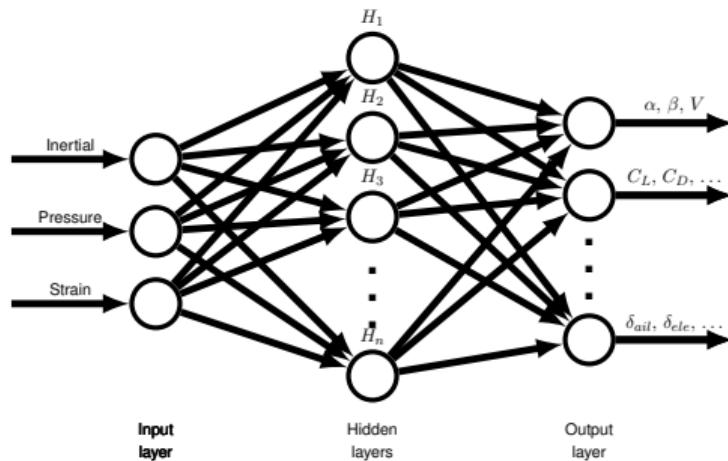


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Concluding Remarks

❖ Lots of information on pressure and strain data

❖ Challenges:

- Sensors

- Processing

❖ Questions remain:

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Thank you

We would like to thank Dr Kieran Wood and Dr Tom Richardson for their involvement in the
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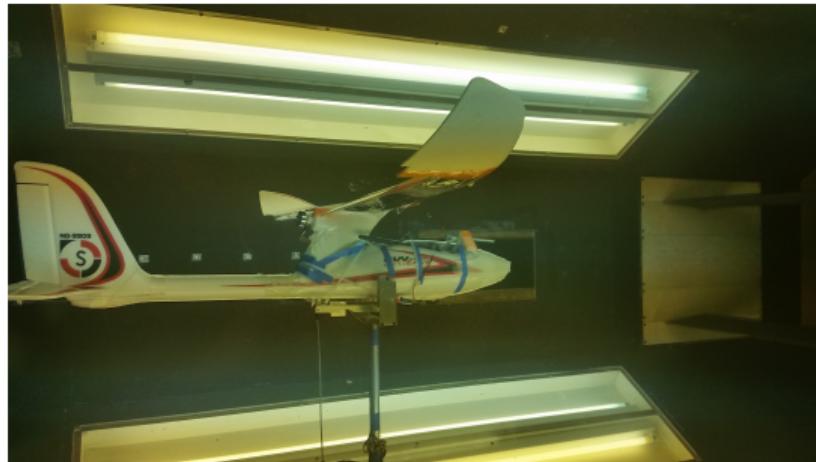


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- ❖ Implement closed loop roll control using strain sensing
- ❖ 12 full-bridge strain gauges and amplifiers distributed along spar of wing
- ❖ Wind tunnel characterisation

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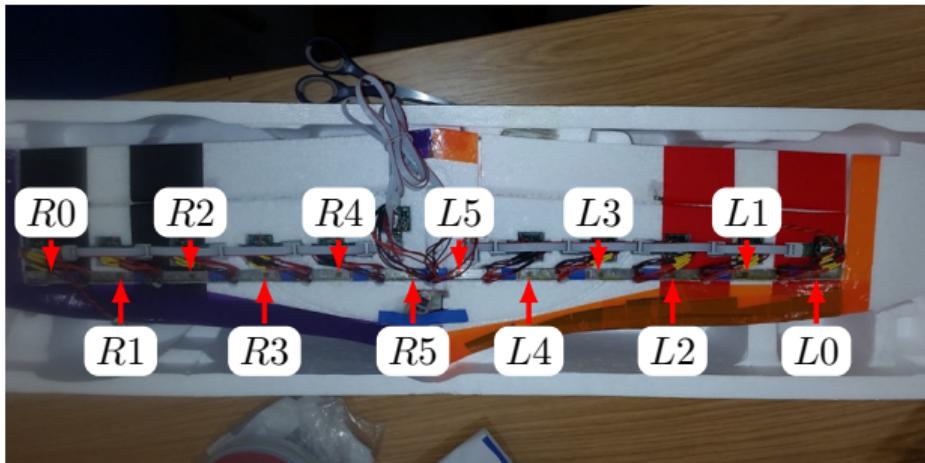


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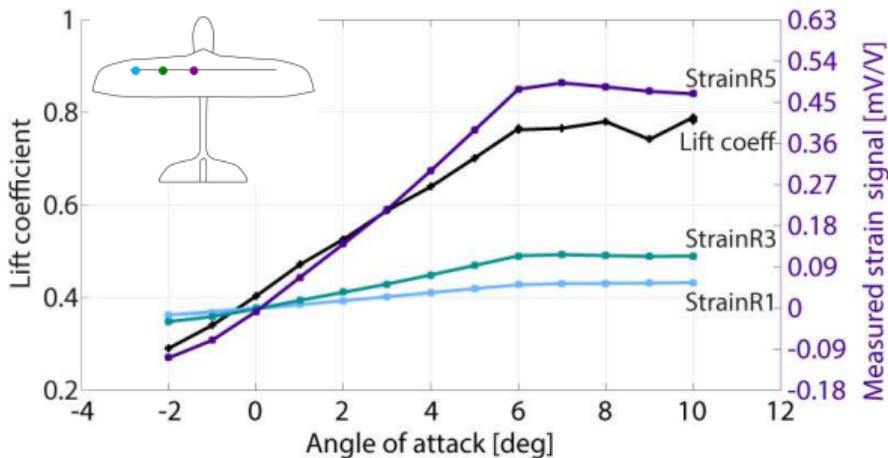


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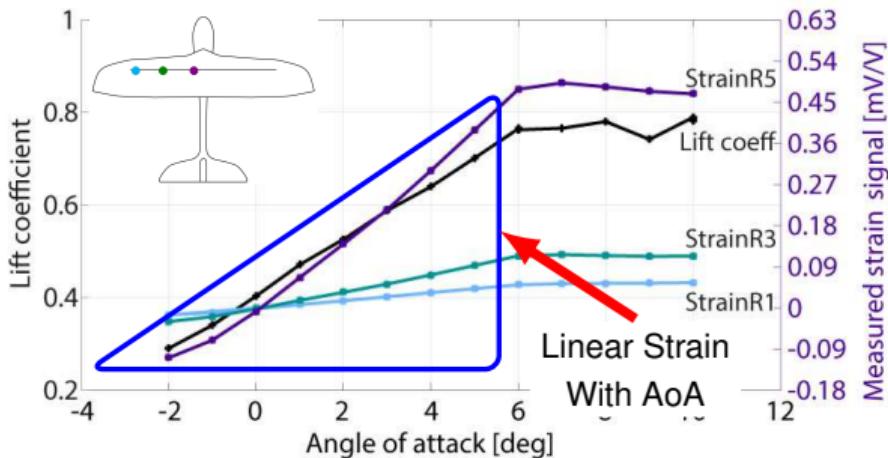


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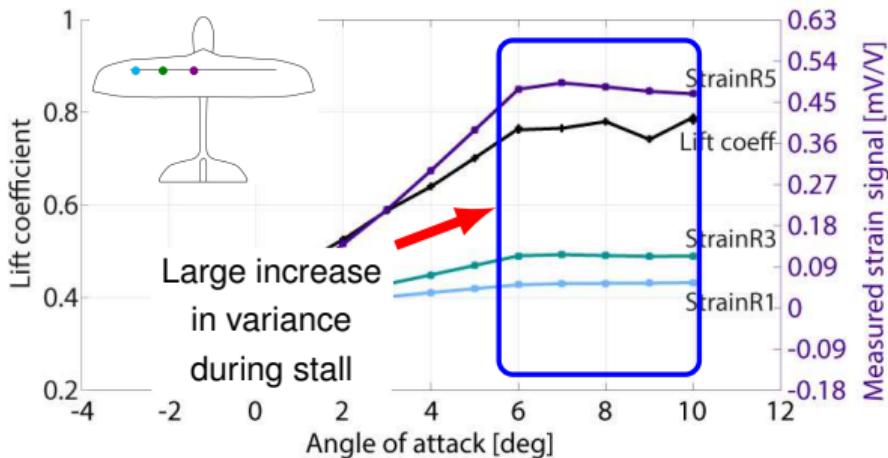


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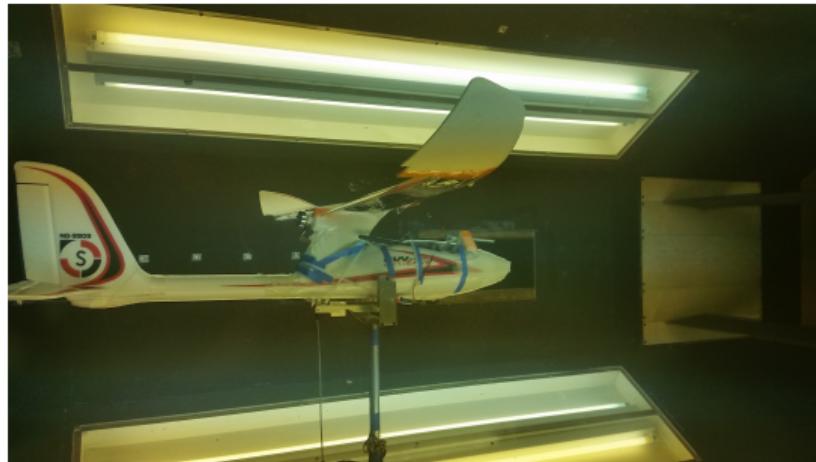


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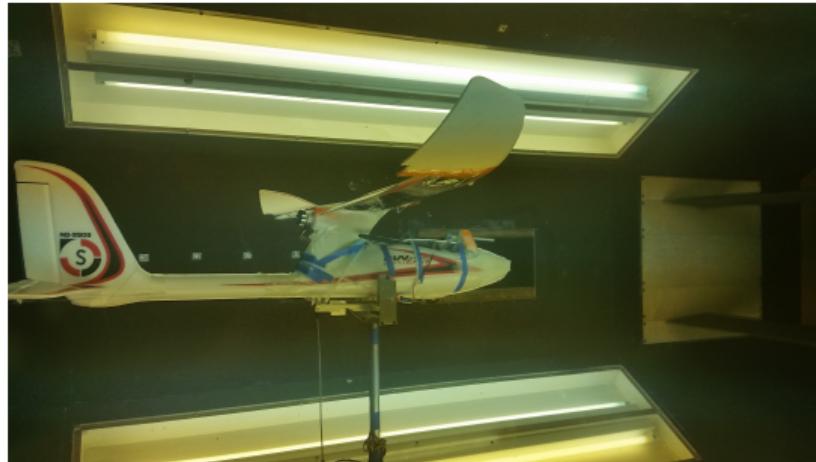


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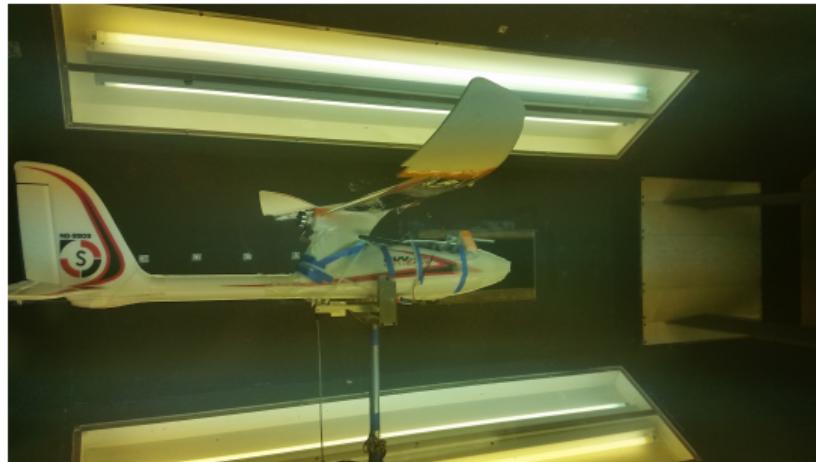


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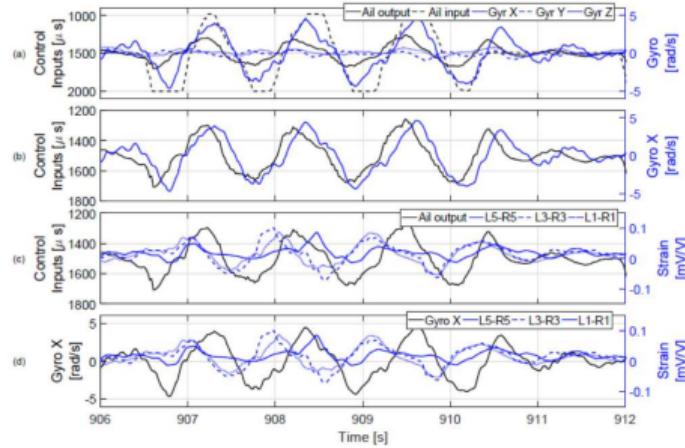


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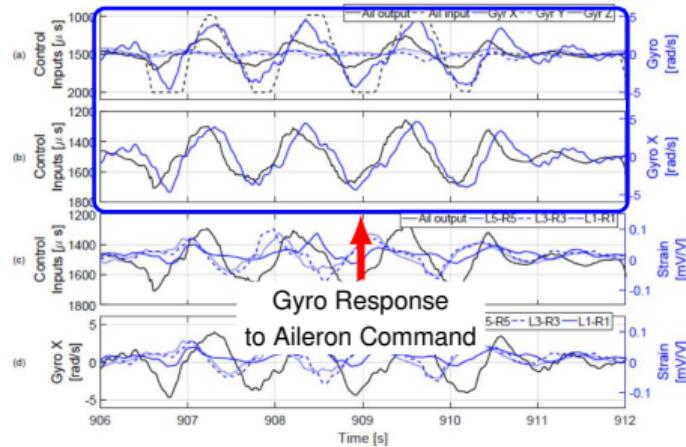
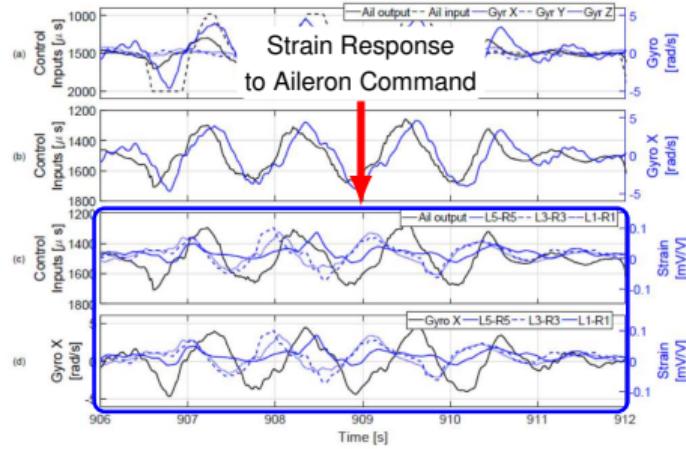


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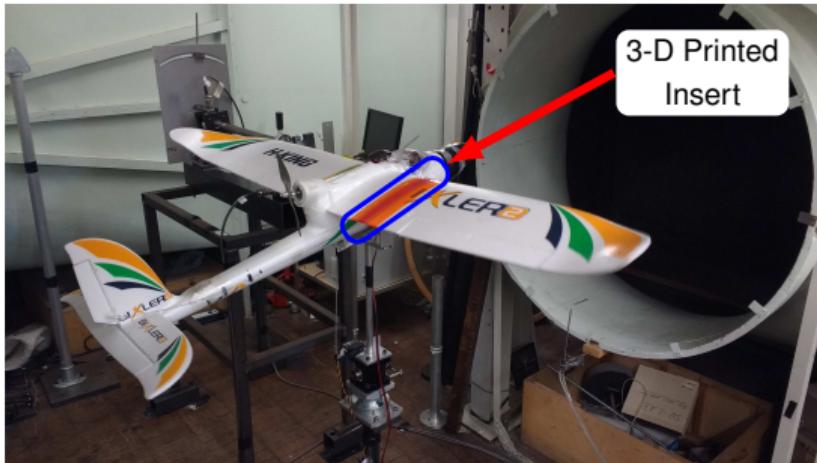


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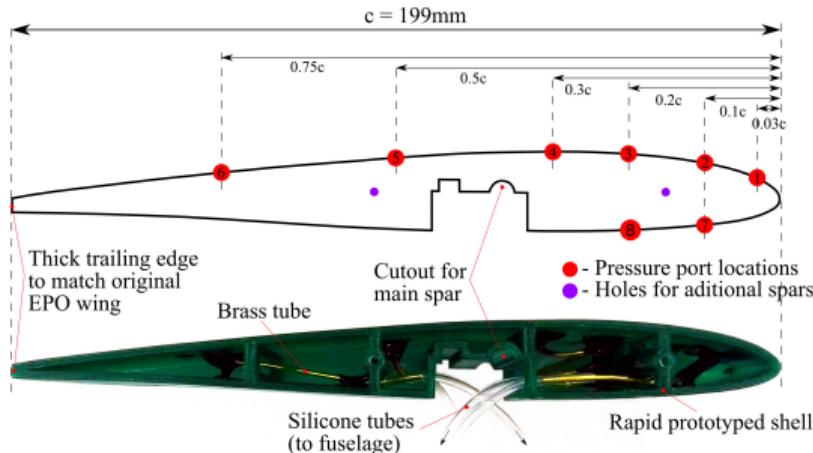


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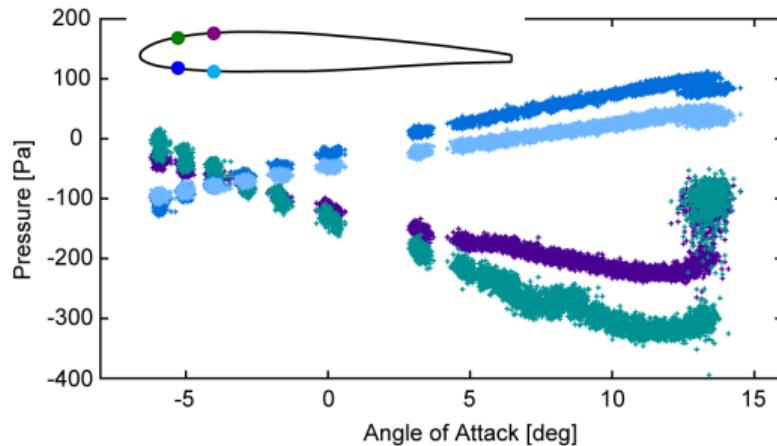


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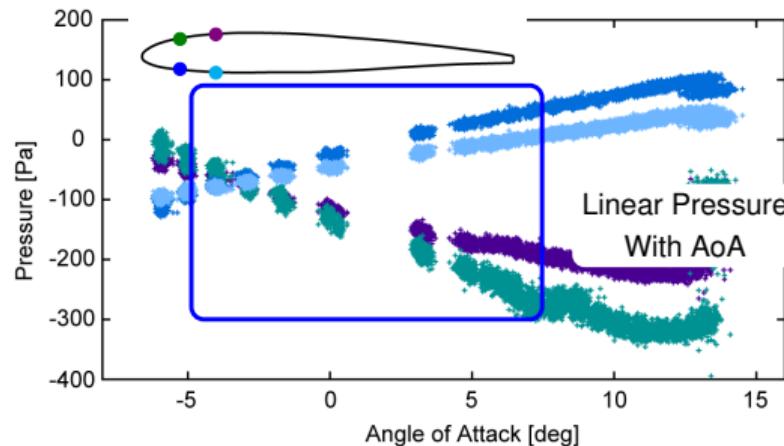


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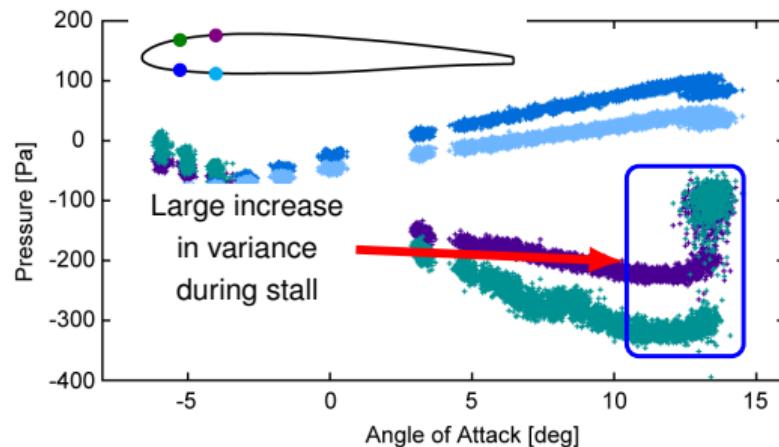


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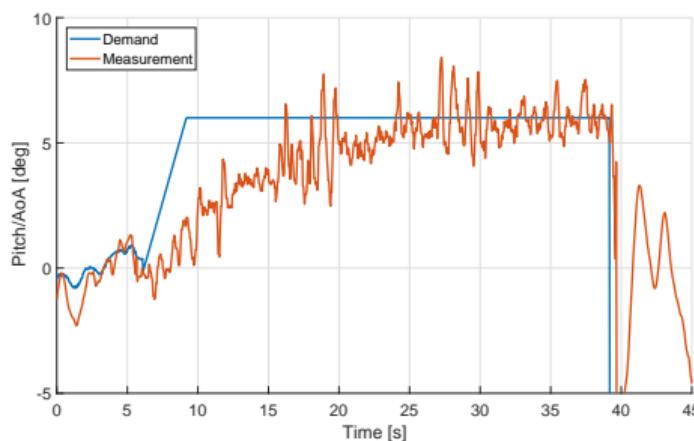


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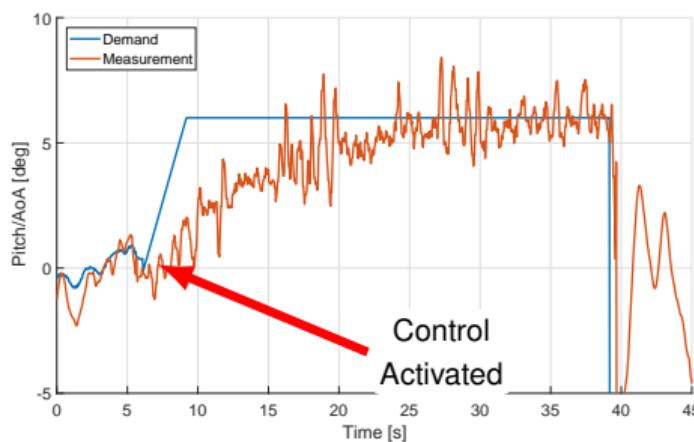


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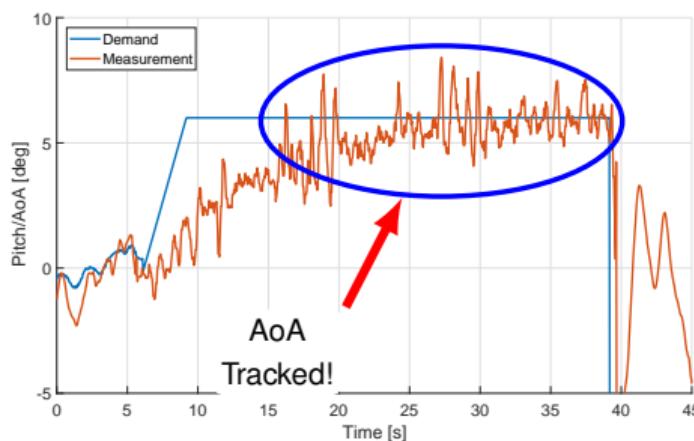


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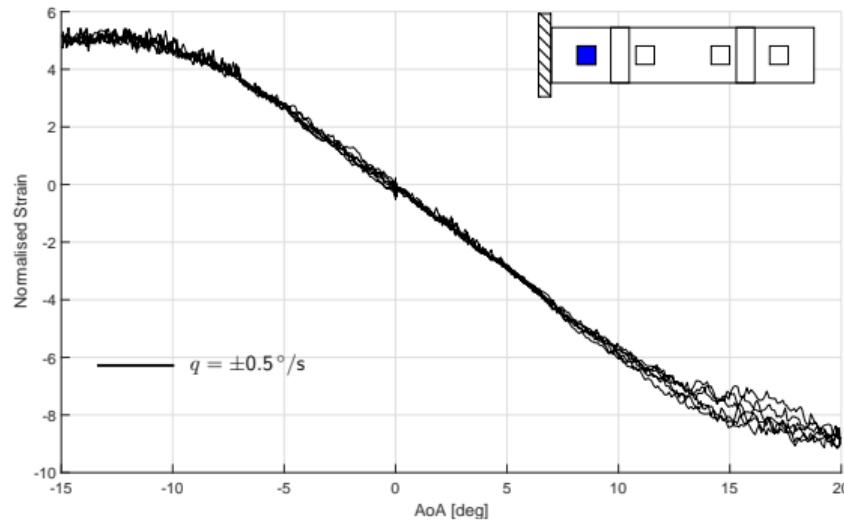


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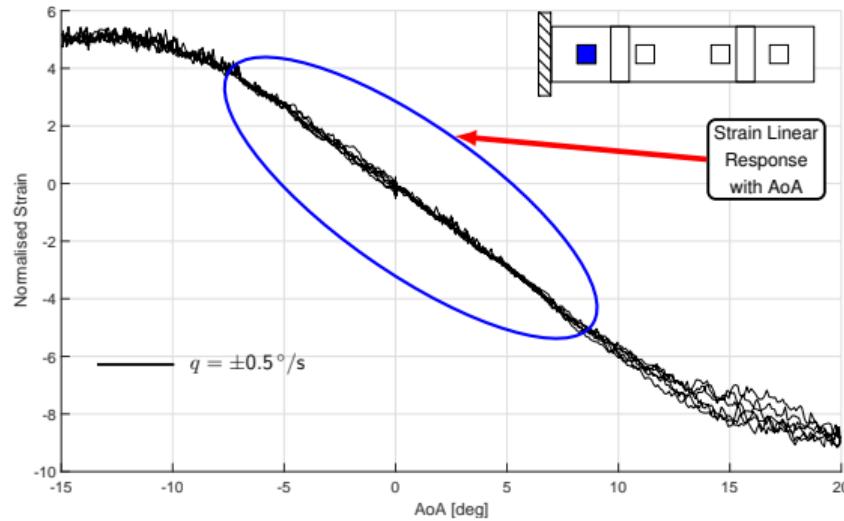


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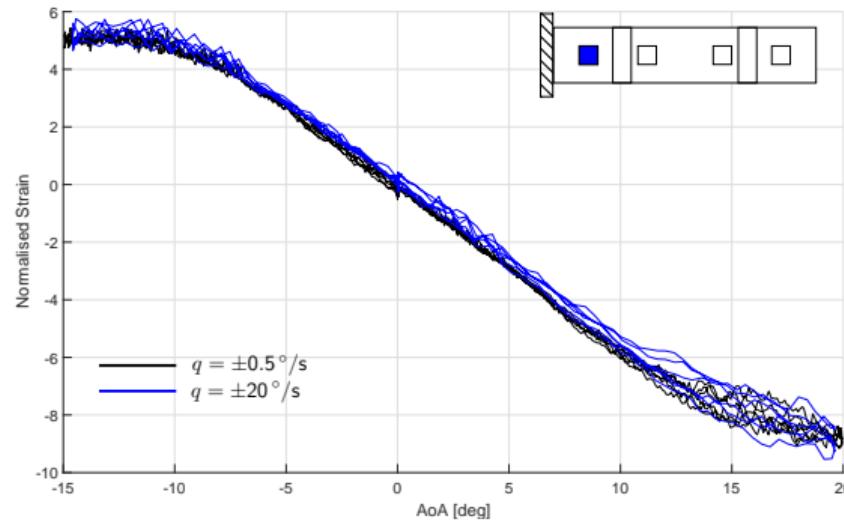


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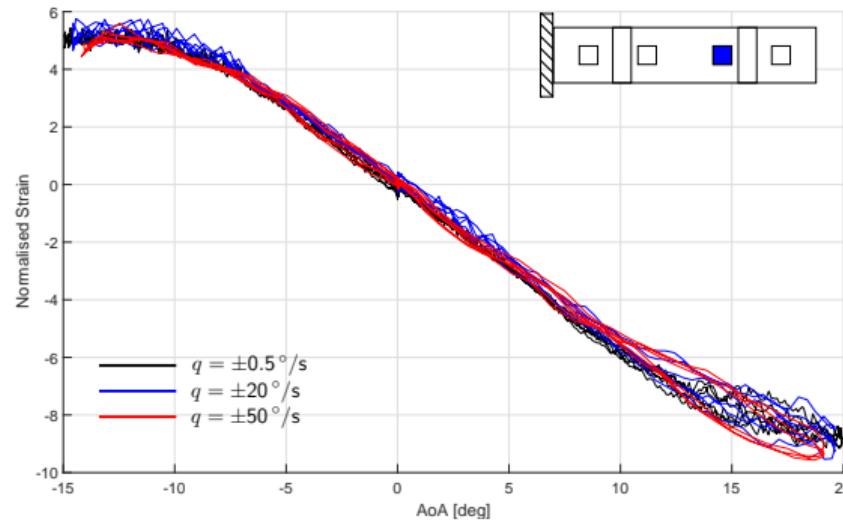


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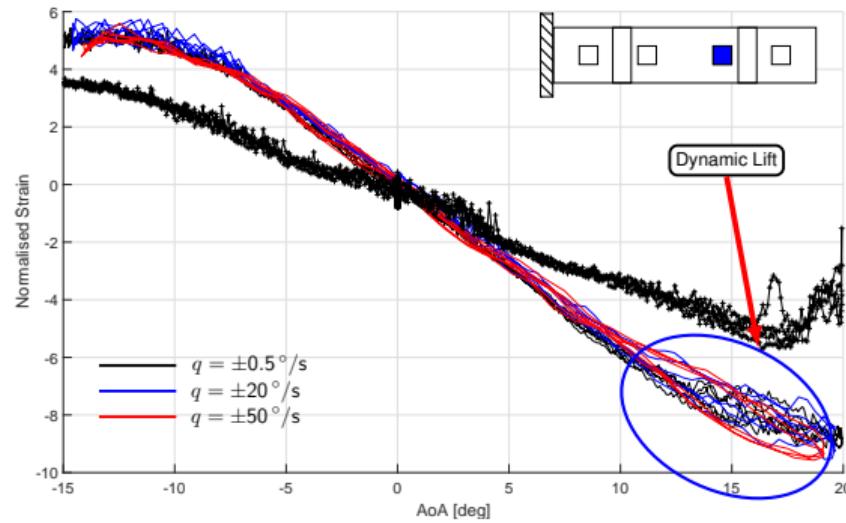


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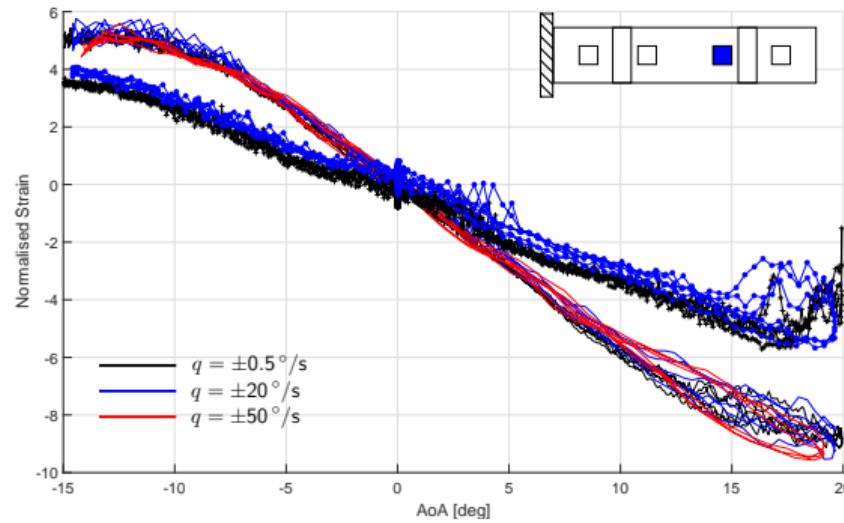


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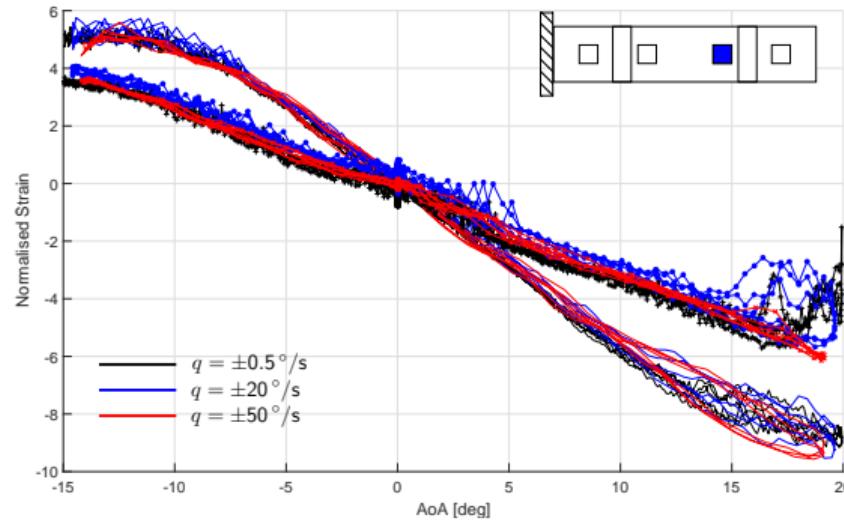


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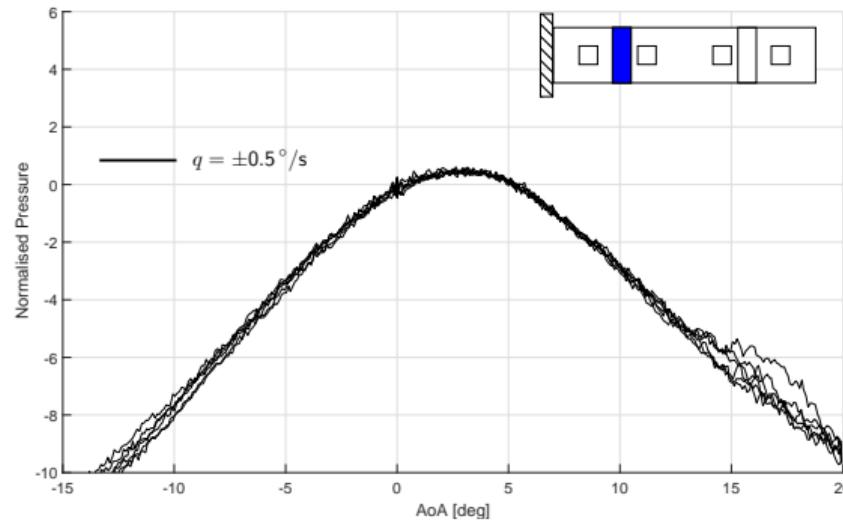


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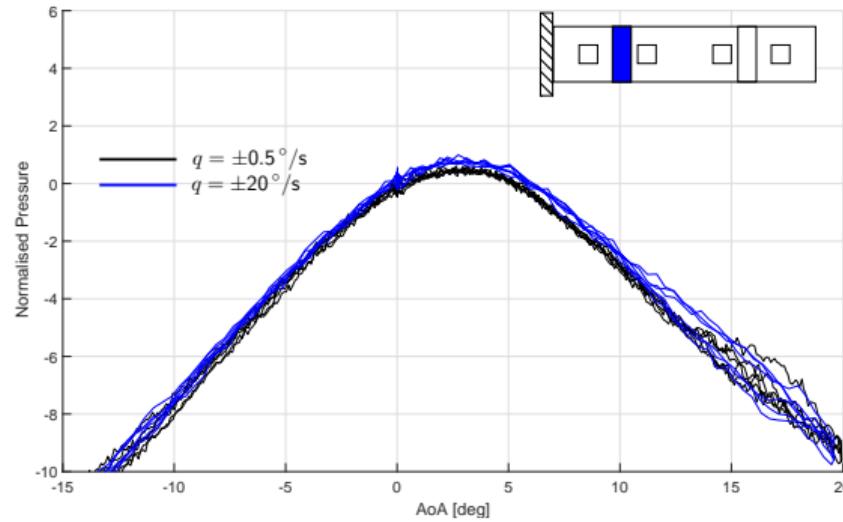


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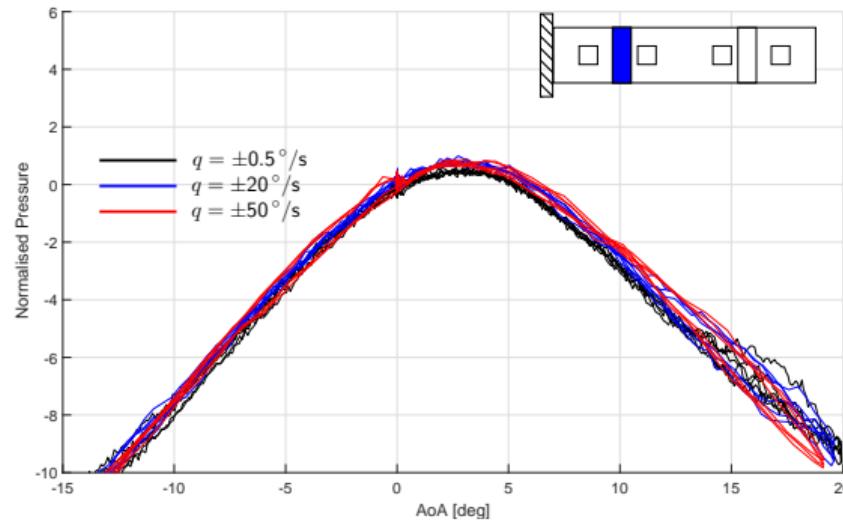


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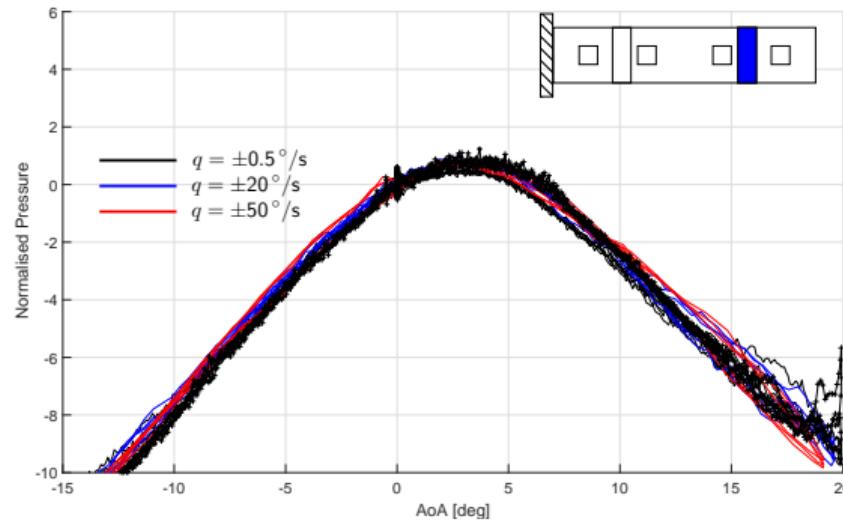


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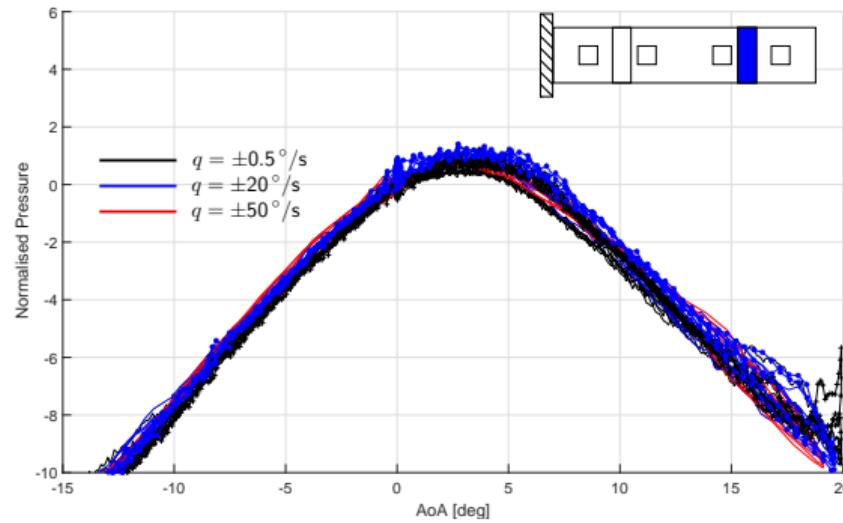


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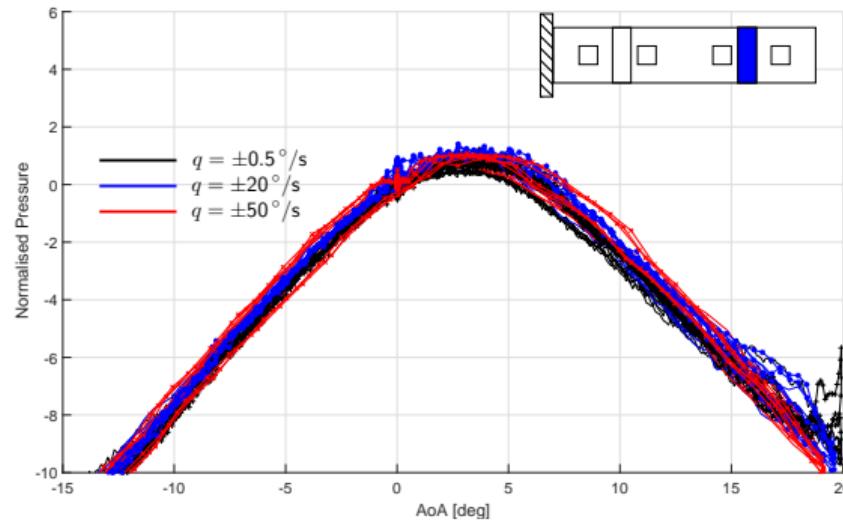


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