SOME OBSERVATIONS ON DEEP STALL LANDING

WITH APPLICATION TO SMALL UNMANNED AIRCRAFT

ICAS PAPER 2026_1091

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Three takeaways to carry through the talk

WHY
constrained landing

HOW
propeller-assisted deep stall

WHAT WE TEST
PIV over wing + tail

SO WHAT
control authority retained

1 Propeller flow is the mechanism

The research question is not just “can a UAV stall?” but whether the slipstream can keep useful local dynamic pressure over the wing and tail.

2 Deep stall can be trimmed

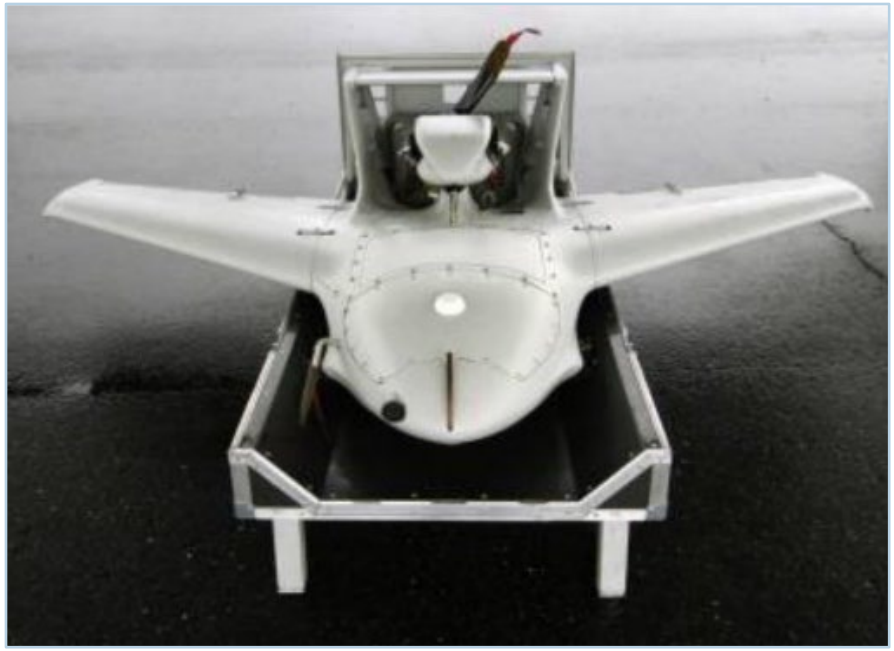
Aditya’s analysis treats deep stall as a family of high-α equilibrium states rather than a purely transient event.

3 Experiments test the premise

The ICAS water-tunnel campaign directly checks whether local flow remains energetic over the empennage and wing at high α.



Why Deep-Stall Landing?



Neptune RQ-15 inspired configuration

Problem

Fixed-wing UAVs are efficient, but conventional landings landings require runway or recovery space. Constrained Constrained sites demand steep, low-speed approach approach paths.

Deep-stall opportunity

Post-stall flight increases drag and reduces horizontal horizontal speed, but it also weakens aerodynamic damping and control authority.

Research question: can propeller-assisted flow keep the wing and tail aerodynamically useful during deep-stall flight?

WHY DEEP-STALL LANDING MATTERS

Fixed-wing UAVs are efficient, but landing space often limits deployment.

High α produces separated flow and low damping
Tail and control surfaces can sit inside the low-momentum wake
Ambient gusts become comparable to the low nominal flight speed

Runway / approach constraint

Deep stall entry high α + high drag

Steep descent low horizontal speed

The challenge is not only losing speed; it is keeping enough control authority after separation begins.

Based on ICAS 2026 paper: Introduction and motivation; AFM22/AFM23 problem framing.



Instead of keeping the whole aircraft attached, the design protects selected surfaces.

Low freestream post-stall wake → **Propeller adds local velocity** → **Tail + wing see higher qlocal** → **Control authority retained**

$$q_{local} = \tfrac{1}{2}\rho V_{local}^2$$

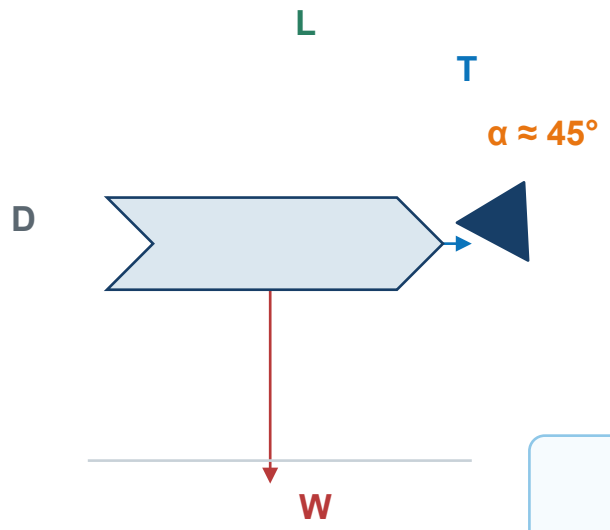
Slipstream raises local dynamic pressure
Horizontal tail can still produce pitching moment
Wing / fuselage can retain useful loading

Design hypothesis: propeller placement controls whether deep stall is controllable



1. Physics of Steady Deep-Stall Flight

ASSUMPTIONS High angle of attack $\alpha \approx 45°$ • shallow/level limiting case $\gamma \approx 0$ • post-stall forces $L \approx D$



Free-body view at high α

Steady point-mass balance

$$T \cos \alpha = D + W \sin \gamma$$

$$T \sin \alpha + L = W \cos \gamma$$

Deep-stall simplification

$$L \approx D$$

$$\alpha \approx 45°, \quad \gamma \approx 0$$

$$L \approx W/2$$

lift supports half the weight

$$T \approx 0.71\,W$$

thrust-to-weight below unity

Not a hover: lift + vertical thrust share weight support

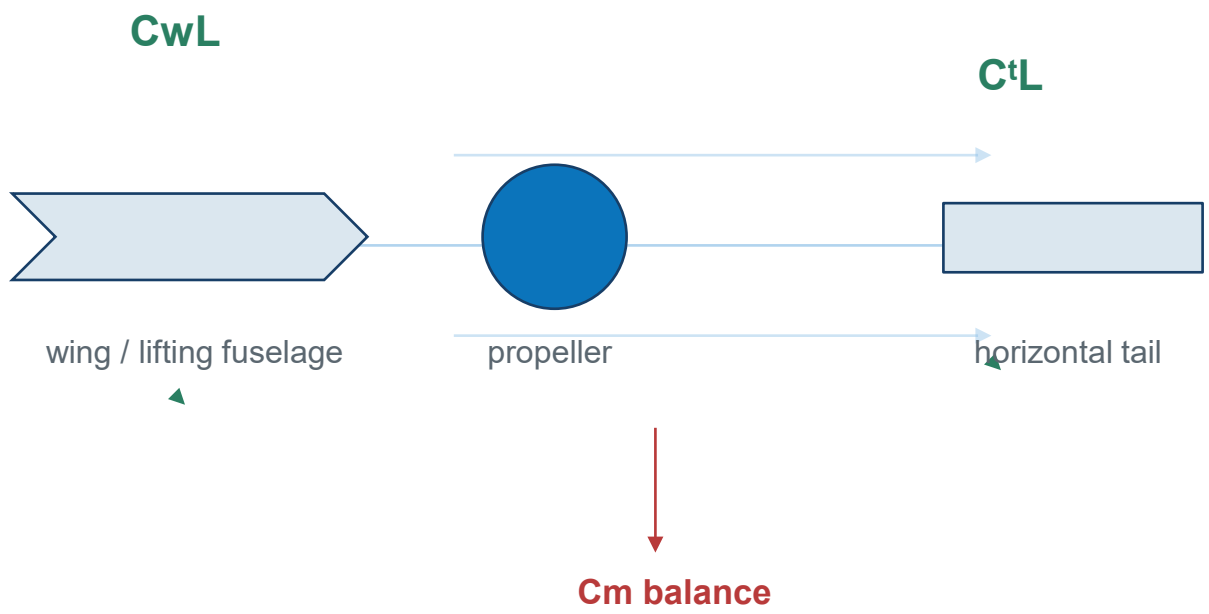
Takeaway: steady deep stall can be feasible without T/W > 1, but only if the airframe can still trim at high α.



2. Wing–Tail Trim Requirement

MODEL USED FOR DESIGN

Aircraft treated as wing/lifting fuselage + horizontal tail; propeller slipstream modifies local flow over lifting surfaces.



Lift split between wing and tail

$$C_L^w + \frac{S_t}{S} C_L^t = C_L$$

Pitching-moment balance

$$C_{m_0} + \frac{x_{ac}}{c} C_L^w = \frac{S_t l_t}{Sc} C_L^t - \frac{2T z_T}{\rho V^2 Sc}$$

where zT/c represents propeller vertical position

Need enough total lift

Need enough tail force

Need propwash over tail

Design implication: placing the horizontal tail in an energetic slipstream is what makes useful elevator authority possible in deep stall.



A steady deep-stall trim is possible when thrust, lift and pitch moment balance at high α.

At α ≈ 45°

T/W ≈ 0.71

L ≈ W/2

1 Tail must see propeller flow

Low speed requires the horizontal tail to stay aerodynamically useful; wing-only slipstream is not enough.

2 Propeller–tail distance matters

Placing the propeller ahead of the tail and minimizing vertical separation improves slipstream coverage.

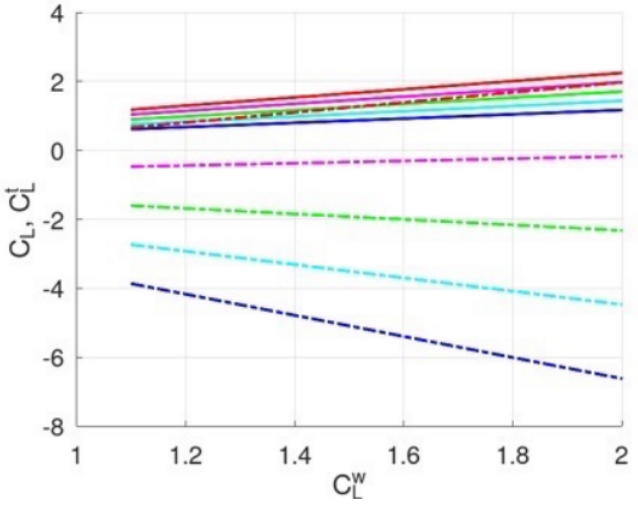


Figure 2 – Coefficients of lift of the aircraft (solid lines) and the horizontal tail (dashed lines) as functions of that of the wing for various propellor locations for $C_{m_0} = -0.1$. Blue and red curves correspond to the propellor placed below and above the wing, respectively.

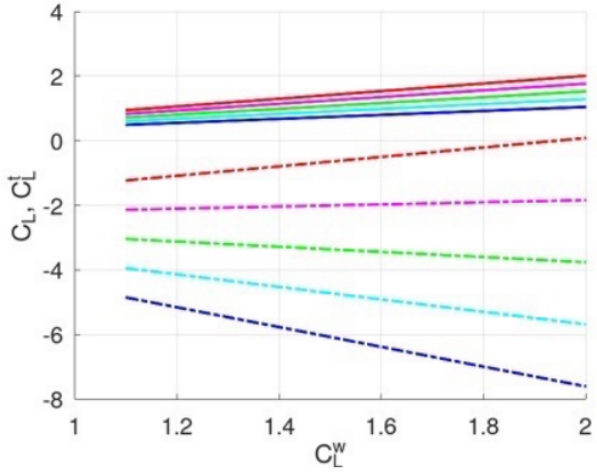


Figure 3 – Coefficients of lift of the aircraft (solid lines) and the horizontal tail (dashed lines) as functions of that of the wing for various propellor locations for $C_{m_0} = -0.3$. Blue and red curves correspond to the propellor placed below and above the wing, respectively.

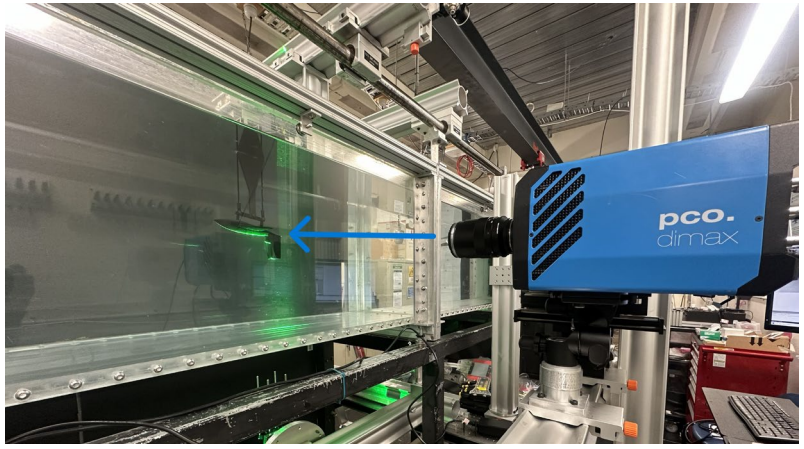
Sources: Paranjape AIAA SciTech 2022 design considerations; ICAS 2026 design calculation figures.



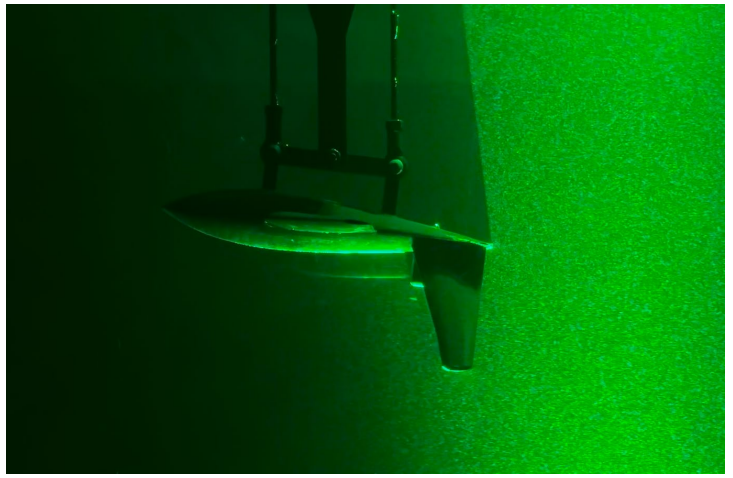
Question: does the propeller actually preserve energetic flow over the tail and wing at high angle of attack?



scaled Neptune-type model



PCO Dimax + 400 Hz laser



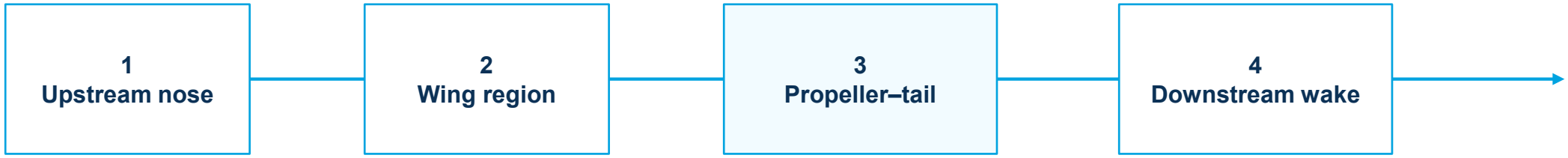
PIV field-of-view

Key setup details

b = 0.20 m • wing-tip chord = 0.015 m • dihedral = 4° • 60 mm propeller upstream of empennage

Source: ICAS 2026 experimental setup and PIV system.

The test matrix follows the flow from upstream → wing → propeller/tail → wake.



Spanwise stations



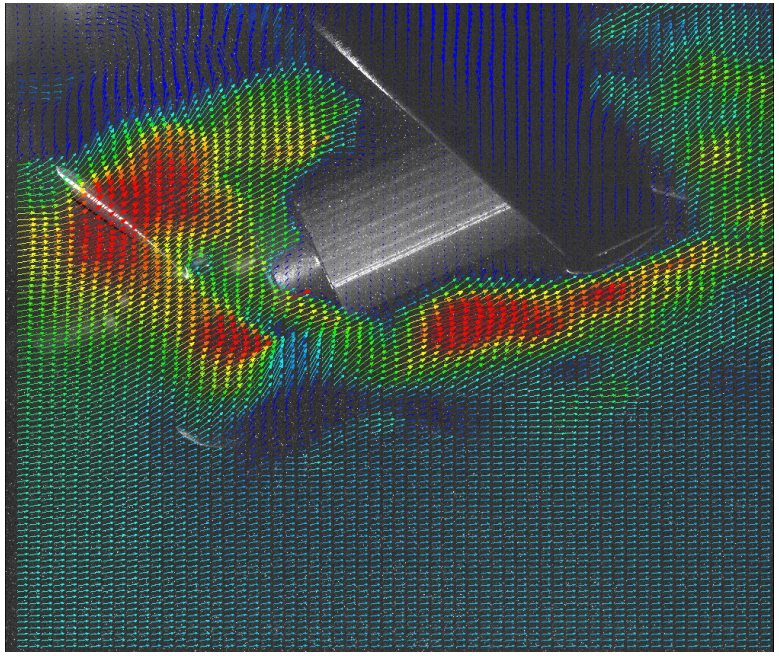
Angle-of-attack sweep 0° 10° 20° 30° 40° 50° 60°

propeller OFF / ON

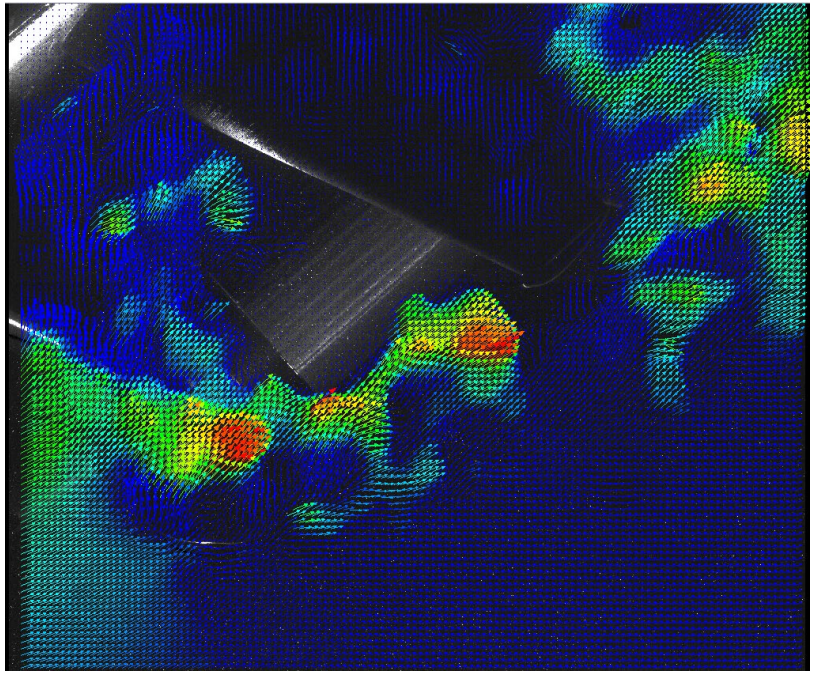
Source: ICAS 2026 PIV measurement locations and test matrix.



The tail remains inside a coherent, high-energy slipstream even at deep-stall angles.



α = 30°: slipstream attached over empennage



α = 50°: coherent local flow still visible

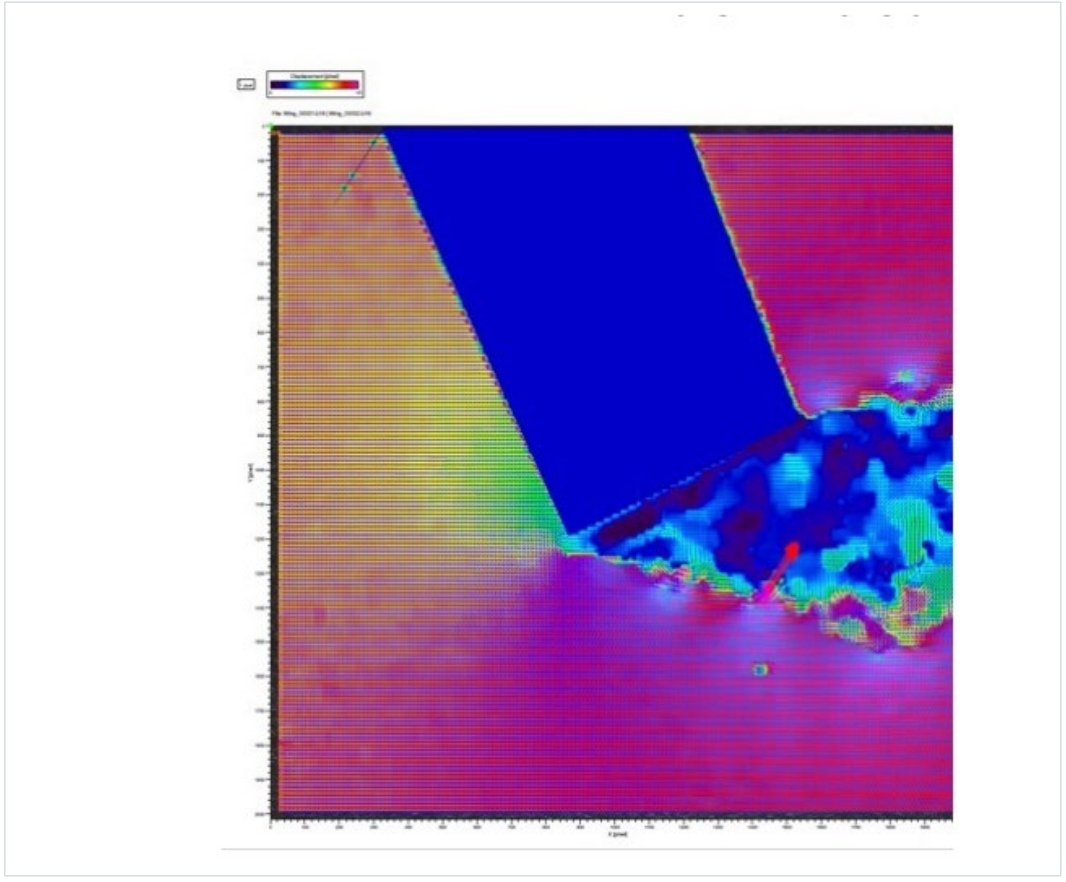
Why this matters

Tail dynamic pressure supports elevator effectiveness and pitching-moment balance when the surrounding aircraft flow is separated.

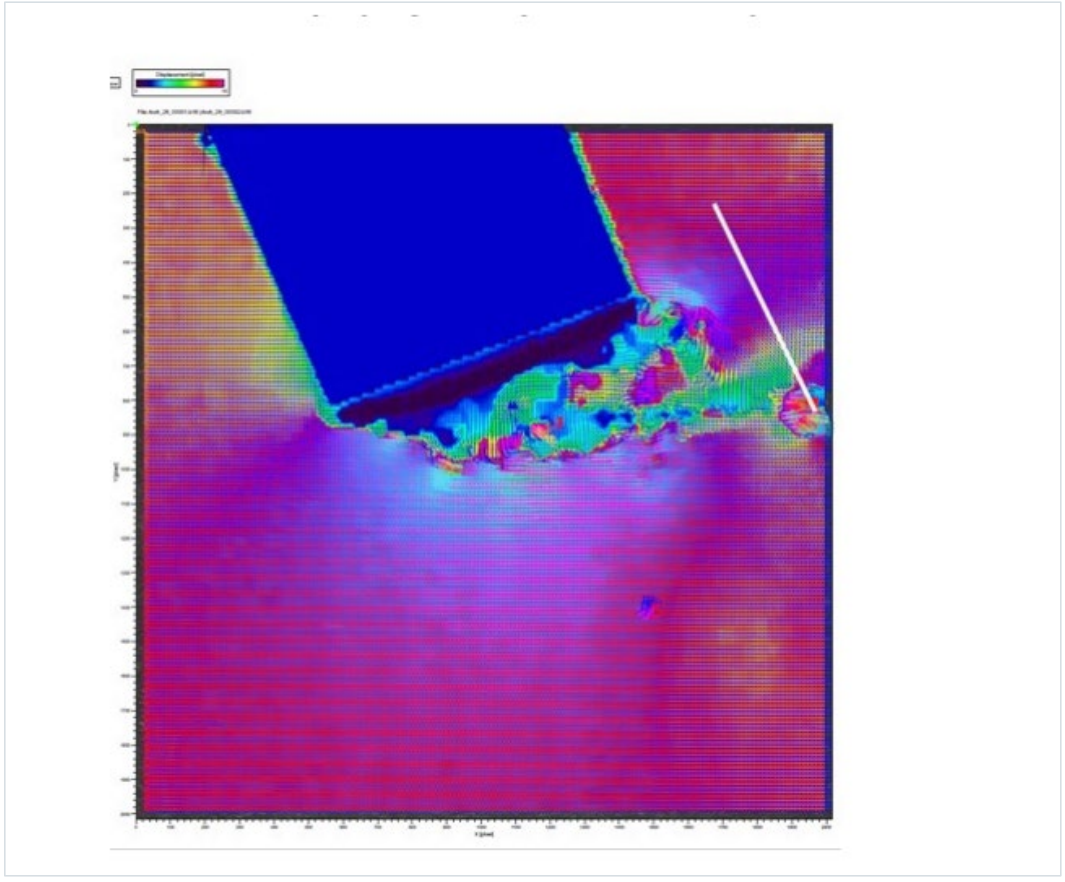
Source: ICAS 2026 preliminary tail-region PIV fields.

RESULT 2: PROPELLER FLOW REDUCES WING-REGION SEPARATION

Propeller-on flow is more energetic and better aligned near the wing.



propeller OFF: broad separated low-momentum region



propeller ON: energized flow closer to the wing

Source: ICAS 2026 wing-region PIV/displacement fields at α = 25°.



The ICAS observations provide experimental support for the aerodynamic assumption used in the 2022–2023 framework.

AFM22
Design + trim

AFM23
Guidance + control

ICAS26
Water-tunnel PIV

1 Prediction

Propeller flow over the wing and horizontal tail can enable high-α trim and maintain control authority.

2 Control use

Trim maps can translate desired path angle/speed into throttle and α commands; dihedral handles lateral-directional motion.

3 Experimental support

PIV shows more energetic, coherent local flow with propeller on, especially over the empennage and wing.

Current limitation: the comparison is qualitative; force/moment measurements are needed to close the loop quantitatively.

Sources: AFM22/AFM23 analytical framework and ICAS 2026 PIV observations.



Propwash is a useful mechanism, but practical deep-stall landing requires aerodynamic quantification and closed-loop control.

1 Quantify loading

Convert qualitative PIV observations into velocity metrics, separation measures, and force/moment coefficients.

2 Expand test envelope

Extend angle-of-attack coverage, propeller speeds, and prop-on/off cases to strengthen the aerodynamic database.

3 Close the control loop

Coordinate throttle, elevator and lateral-directional control to maintain high-α operation without climb or departure.

4 Validate design choices

Refine propeller placement, tail volume, and slipstream coverage using wind-tunnel forces and model-based trim calculations.

Sources: ICAS 2026 future work; AFM23 simulation and trajectory results.



Main message

Propeller-assisted flow can make deep-stall landing more controllable by retaining local aerodynamic authority over the wing and tail.

1 **Analysis**

Force/moment balance and bifurcation analysis predict high-α trim branches with thrust-to-weight below unity.

2 **Control**

A trim-based guidance architecture can use motion primitives and asymmetric dihedral to approach a touchdown zone.

3 **Experiment**

Water-tunnel PIV shows propeller-on flow is more energetic and less separated over the wing and empennage.

4 **Next step**

Quantitative force/moment data are needed to verify the aerodynamic coefficients used in the model.

Synthesis of ICAS 2026, AFM22 and AFM23 papers.



Thank you

Questions?

Some Observations on Deep Stall Landing, with Application to Small Unmanned Aircraft

