# Effects of Propeller-Wing Interference on M-Fly Aircraft Performance

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## Background and Motivation

The M-Fly Aero Design Team is pursuing dual wing-mounted propeller designs due to potential performance increases vs nose-mounted designs

- M-Fly wants to investigate the effects of wing-mounted propeller locations on wing aerodynamic characteristics
- Literature supports an increase in aerodynamic performance from propeller wing interference [1]
- M-Fly is uncertain on how this gain translates to its competition aircraft
- We are tasked with characterizing the sensitivity of this performance change relative to propulsor location

*M-Fly's MAT-3 with a dual-propeller configuration in 2020.*

## Criteria Rationale

Two criteria were used to judge propulsor configurations:

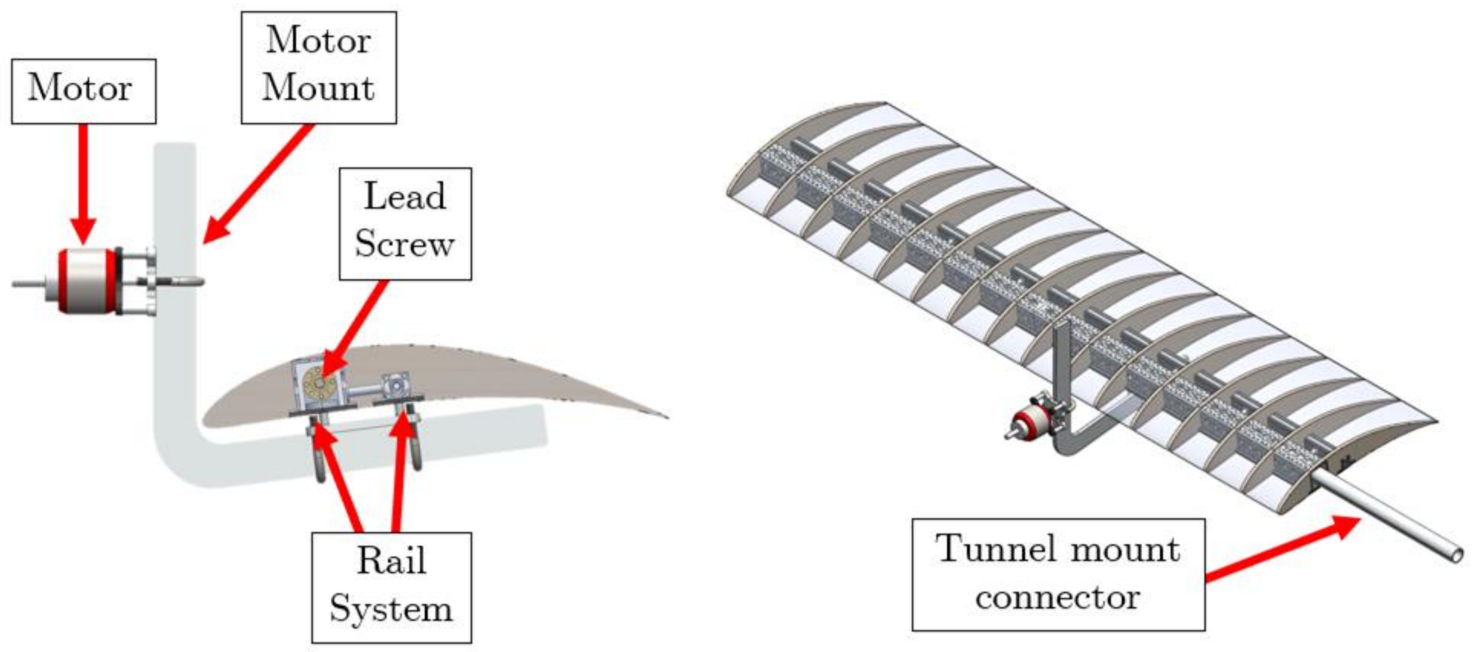
**Effectiveness:** For a design to be useful, it must offer an aerodynamic performance increase over the base wing. This is determined by plotting the drag polars of all configurations alongside the base wing and comparing their behavior.

**Practicality:** As the propellor is placed closer to the wingtip, the potential for damage from tip strikes increases in addition to structural mass. A good design:

- Must not decrease the existing tip-over angle of the aircraft
- Must not increase the wing's structural mass more than it increases the lift

## Test Wing Design and Construction

| Test Parameter | Value | Wing Parameter | Value |
|---|---|---|---|
| Advance ratio | 0.2 | Airfoil | CH10 |
| Reynolds number | 400,000 | Chord | 1.15 ft |
| Propeller | 14 x 8.5 | Half-span | 4 ft |

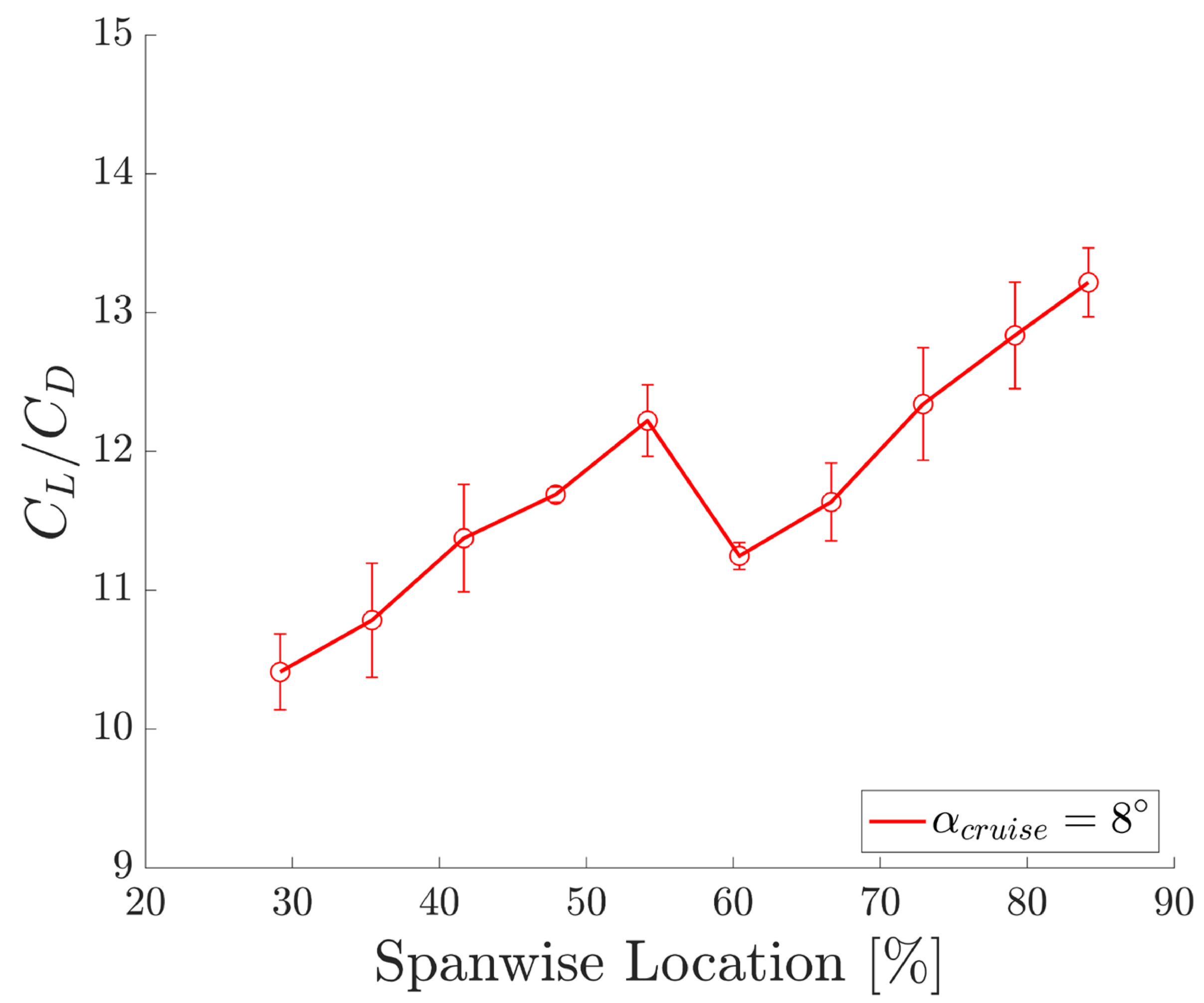



*Side profile and isometric view of test wing design*

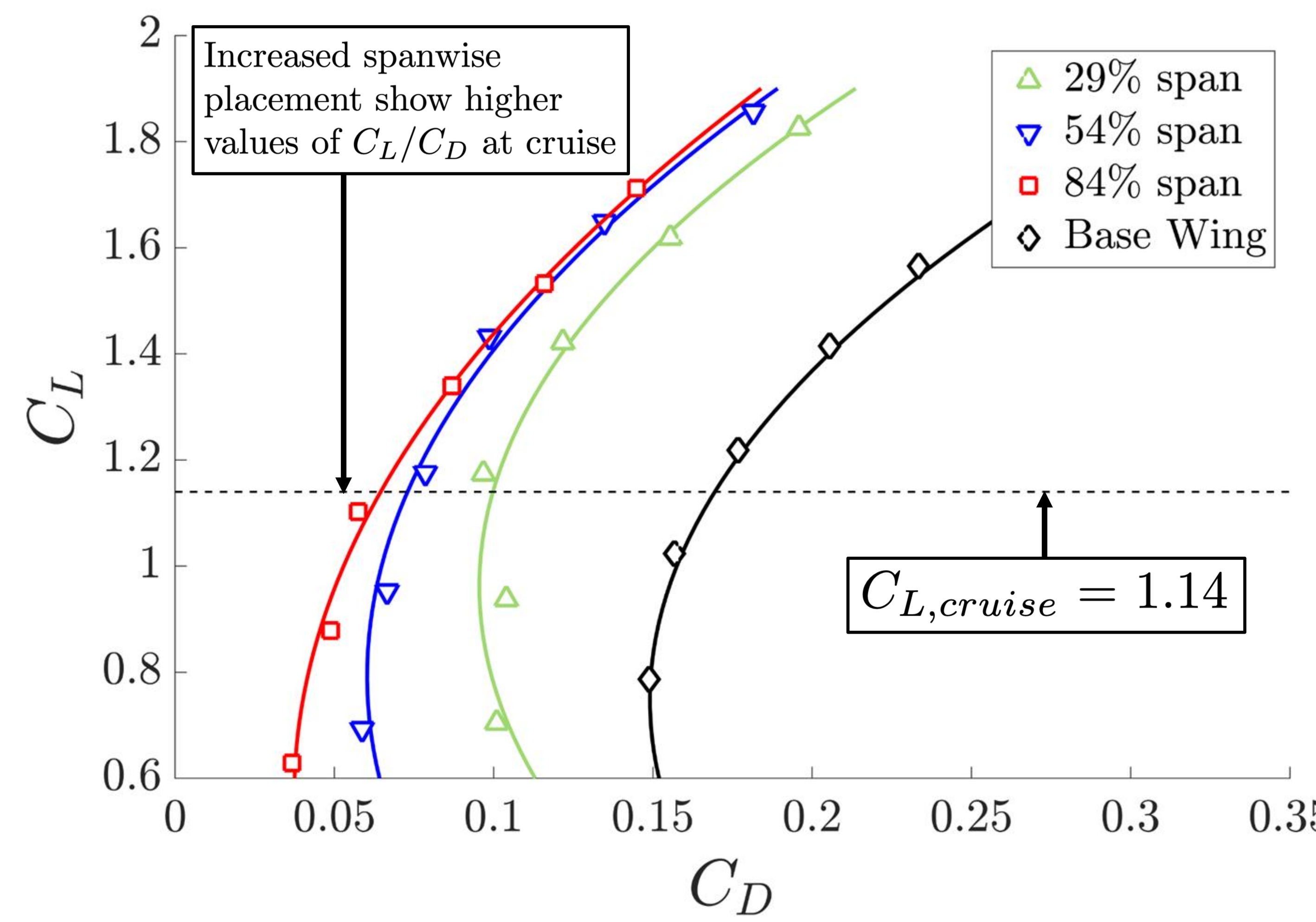
## Results and Analysis

The following actions were taken when analyzing the experimental data:

- Forces were non-dimensionalized to directly relate them to M-Fly flight conditions
- Dynamic thrust data was subtracted from experimental drag measurement to calculate the effective drag from the test wing
- Lift generated by the propeller at high values of α was subtracted from experimental measurements to calculate effective lift generated by test wing




*$C_L/C_D$ at α = 8° shows upward trend as spanwise location increases, indicating better performance*




*Drag polars for 3 spanwise locations, starting at 29% to 84% of the wingspan from the left tip. α from 0° to 10°.*

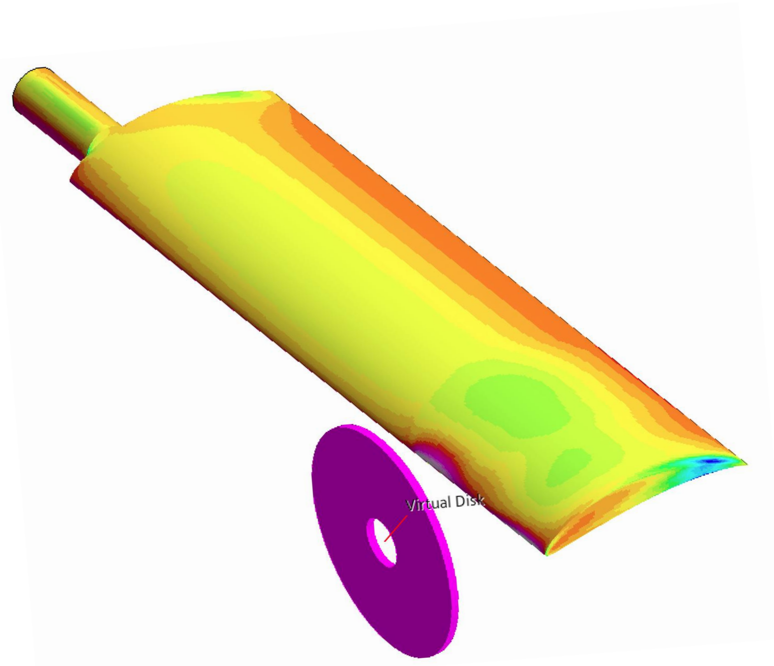
- Clear leftward trend as spanwise location increases. This indicates that the wing experiences less drag for a given $C_L$ as the propeller is closer towards the right wingtip.
- At the M-Fly cruise $C_L$, there is a significant decrease in drag as the motor moves to increased spanwise locations
- Increased $C_L/C_D$ at higher spanwise % indicates better wing performance

## Experimental Methodology

We conducted a series of experiments using physical test articles and computer simulations to properly evaluate the effects of propeller location along a wing.

**Wind Tunnel Testing:** We characterized the effect of varying spanwise propeller location in the University's 5- by 7-foot wind tunnel and varied the wing's angle of attack with each propeller location to generate a wing drag polar. We adjusted our wind tunnel results with the propeller dynamic characterization from 2- by 2-foot wind tunnel testing.

**Simulations:** We modeled our propeller-wing setup in computational fluid dynamics (CFD) software using a virtual disk method in Star-CCM+. The University's 5- by 7-foot test section was re-created to compare our simulations to experimental results.



*(**Top**) CFD pressure distribution with virtual disk at 84% span.*

*(**Left**) Full size wing and propeller rig in the University's 5- by 7-foot wind tunnel.*

## Conclusions and Recommendations

We tested ten spanwise propeller locations and a base wing configuration, and have made the following conclusions and recommendations for M-Fly:

- All wing-mounted propeller configurations far outperform the base wing
- Aerodynamic performance improves as the propeller spanwise location approaches the wingtip
- M-Fly should place the propulsor as far out on the wing as possible such that it is still compatible with intended tip-strike angles
- Structural considerations are less necessary because M-Fly typically utilizes a wingbox as the main structural component of the wing

## Future Work

Our team was unable to test all the variables that we had identified initially in the time frame of this project. As such, we recommend that future teams interested in this subject investigate the following:

- Vertical and streamwise propeller positions
- Propeller positions over and behind the wing
- Fuselage wall effect for nearby propeller positions
- Additionally, we recommend recreating our results with increased test fidelity, and performing additional CFD to better align with our current experimental results.

# References

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