



# Rotor Wing Interaction at Low Reynolds Numbers

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## ABSTRACT

The increasing interest in micro air vehicles (MAVs) due to the development of small microcontrollers, batteries and sensors has led to unique MAV designs incorporating aspects of fixed-wing, flapping-wing and multi-rotor systems capable of hovering and forward flight. Of interest in this research are tilt-wing and tilt-rotor designs. Although research has been conducted on large vehicles with these capabilities, little research has been performed on the MAV counterparts ( $Re \sim 100,000$  and disk loading  $< 100 \text{ N/m}^2$ ). The objective of this research project was to build a test stand and measure the rotor-wing interaction of a dual-rotor configuration in hover above a flat plate representing a simple wing. Rotor-wing height and rotor-rotor separation can be set as well as rotor rpm. Surface pressures, motor thrust and motor torque are measured. The equipment was controlled and data was acquired using an in-house LabVIEW code. Results will quantify the ground effect and potential loss of lifting force in hover for different rotor configurations. In future studies, these results will be used to validate computational models.

## INTRODUCTION



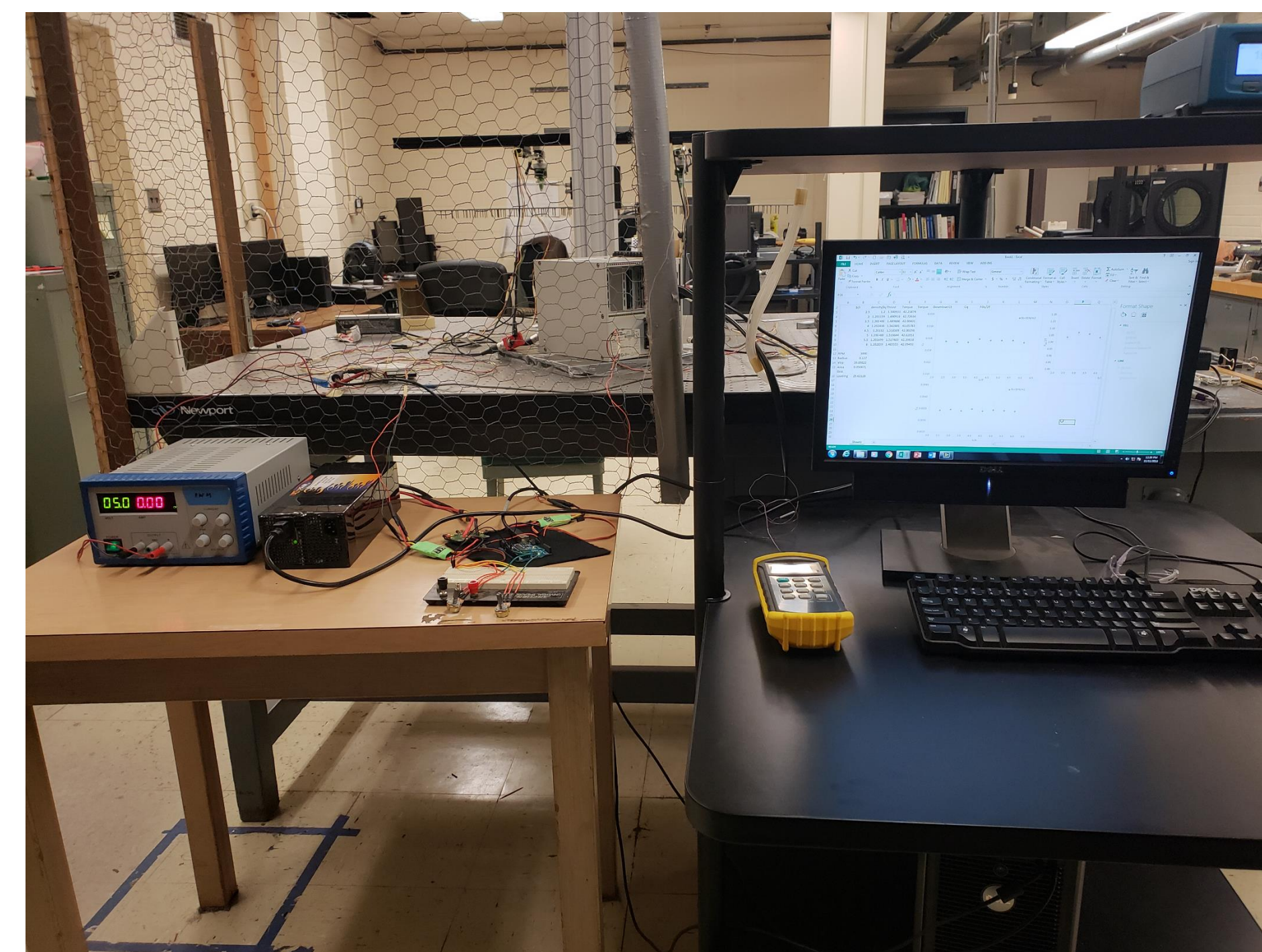
### Micro Aerial Vehicles (MAVs)

- Origin: 1996 DARPA proposed micro air vehicles
- Vehicles are the size of birds
- MAVs are low cost
- MAVs should have extended endurance
- Three core MAV designs: fixed-wing, flapping-wing, an multi-rotor systems

### Ground Effect

- Thrust increases as the height-to-radius ratio decreases between the rotor and the ground
- Increase in thrust production could allow for larger payloads if the net download force on the wing is not adversely affected

## METHODS & RESULTS

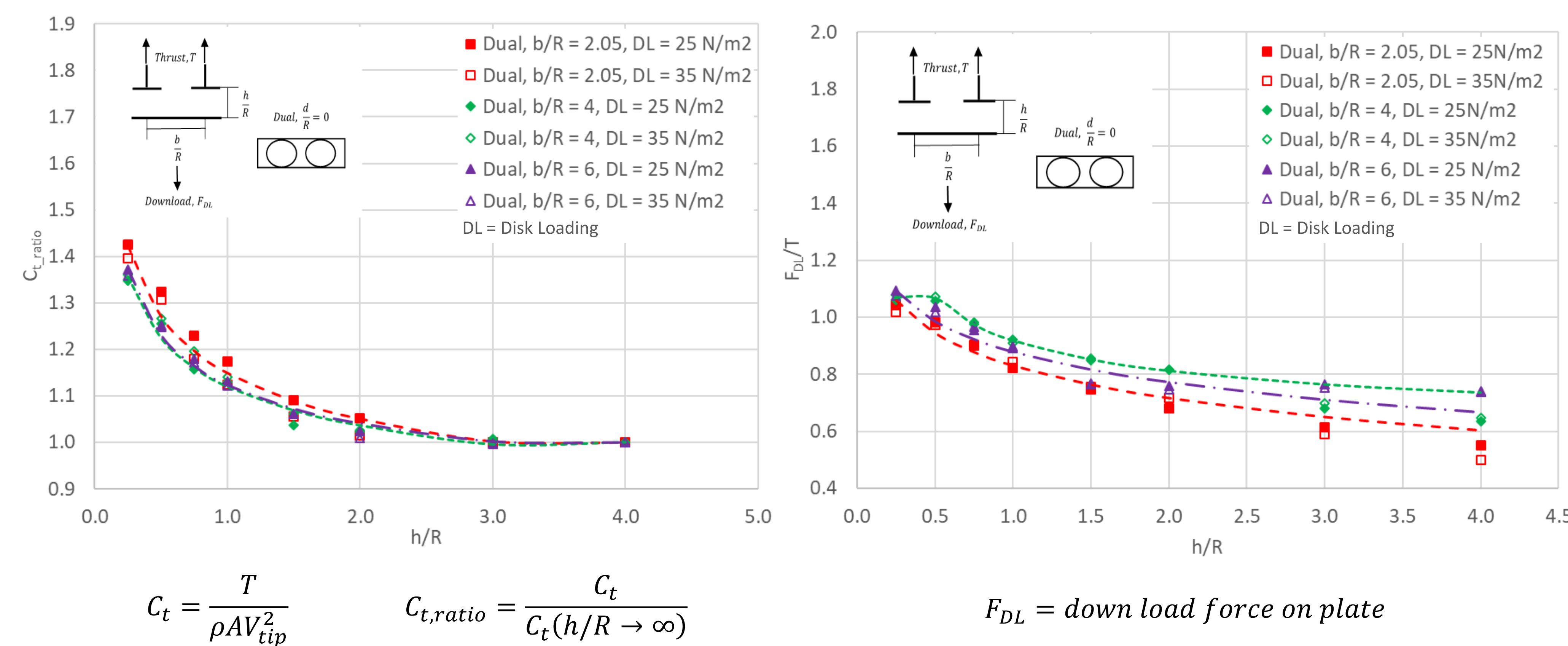


Computer and data acquisition equipment setup



Test stand with two rotors mounted above flat plate

- Two rotors are suspended above a flat plate (simplified wing) and moved horizontally and vertically with respect to the plate
  - Photosensors next to the rotors measure frequency
    - Arduino Uno sets the rotor RPM
  - ATI Mini40 measures the downwash on the plate
  - ATI Nano17 measures the thrust generated by the rotor
  - PSI 9116 measures surface pressure (future work)
  - LabVIEW codes record frequency, pressure and forces



## CONCLUSIONS

- Decreasing the distance between the wing and the rotors increases rotor thrust but also increases wing down load force
- Decreasing the distance between rotors enhances the ground effect relative to rotor thrust but decreases the ground effect relative to wing down load

## FUTURE DIRECTIONS

- Measure surface pressures beneath rotors
- Measure wake diameter via flow visualization techniques
- Develop computational models and validate with experimental data

## REFERENCES

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