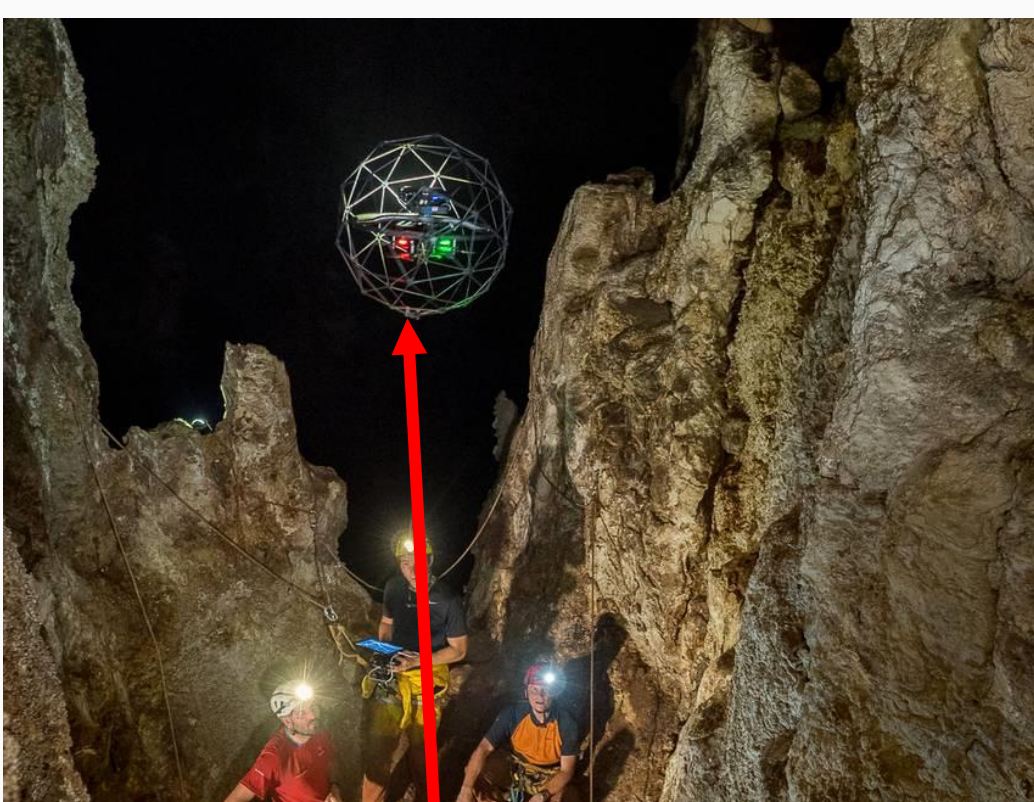


## MOTIVATION

- The increased usage of propeller driven UAVs in closed space raises some interesting questions:
- Will the R/C propeller performance change in close proximity to ground and ceiling?
  - Is there any difference between the effect of non-traditional ground with uneven surface and traditional flat ground on propeller performance?
  - Does the placement of the propeller on drones affect the overall performance of the propeller?
  - Can we predict the propeller performance in partial ground effect?

Drone in Cave

Drone in Tunnel



Heavy Cover to Avoid Crash

Close Proximity to the Ceiling

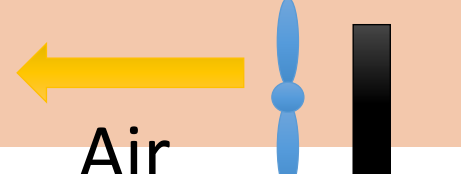
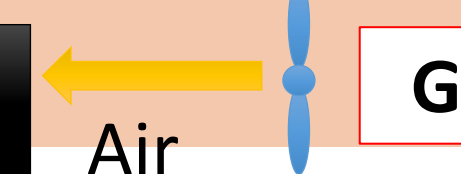
## OBJECTIVES

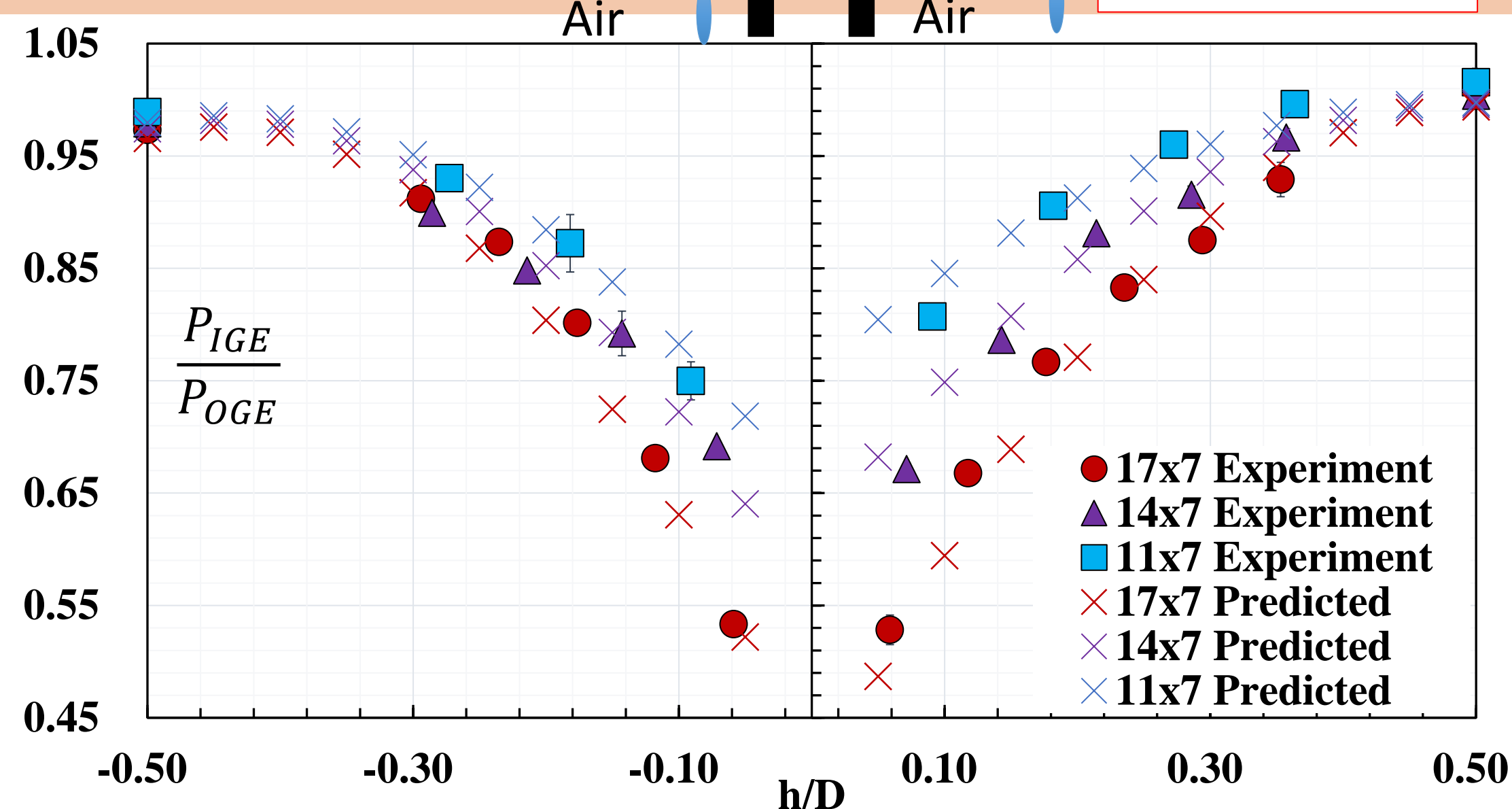
- To characterize the changes in propeller performance due to partial ground effect
- To understand the effect of propeller placement on drones
- To algebraically predict the changes of propeller performance in partial ground effect.

## Prior Work

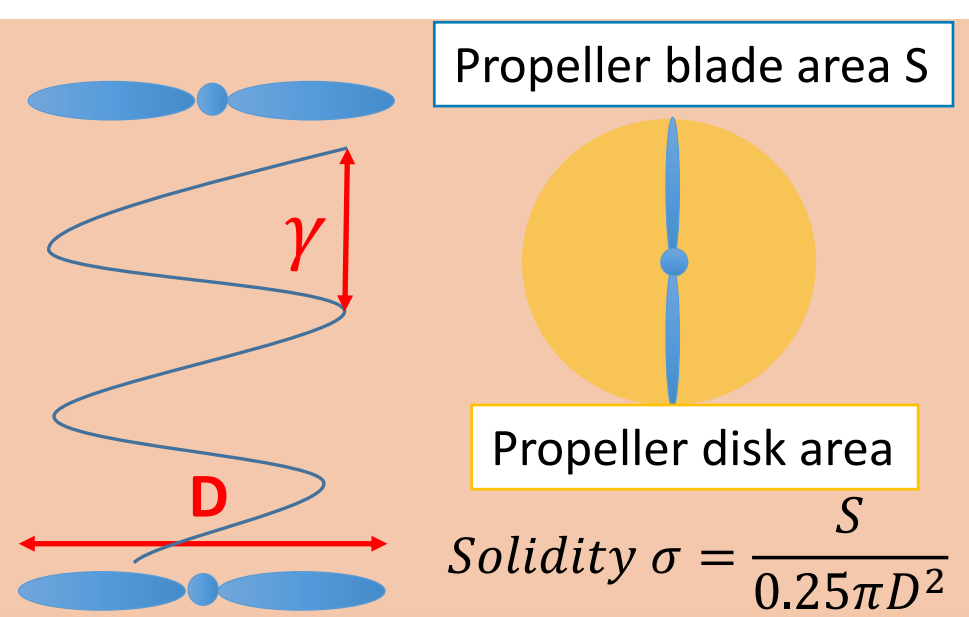
### Ground Effect Prediction (Infinite Ground)

$$\frac{P_{IGE}}{P_{OGE}} = \begin{cases} 1 - \left(1 - \frac{P_c}{P_{OGE}}\right) * \sigma * 100 / \left(\frac{Y}{D}\right)^2 & (0 \leq \frac{h}{D} \leq 0.5) \\ 1 - \left(1 - \frac{P_c}{P_{OGE}}\right) * \sigma * 100 / \left(\frac{Y}{D}\right)^1 & (-0.5 \leq \frac{h}{D} \leq 0) \end{cases}$$

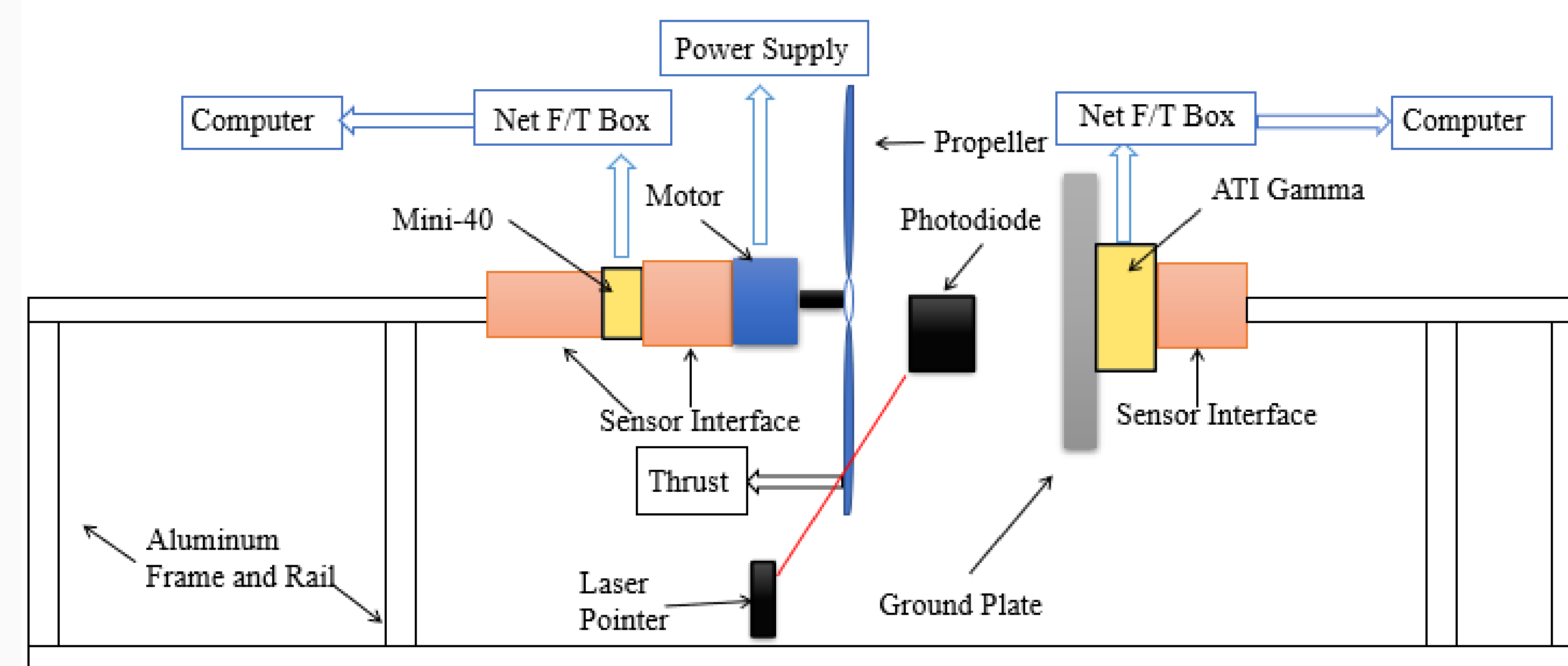
Ceiling Effect  Air  Ground Effect



- Lower Pitch to Diameter Ratio
- Higher Solidity
- Stronger Ground Effect

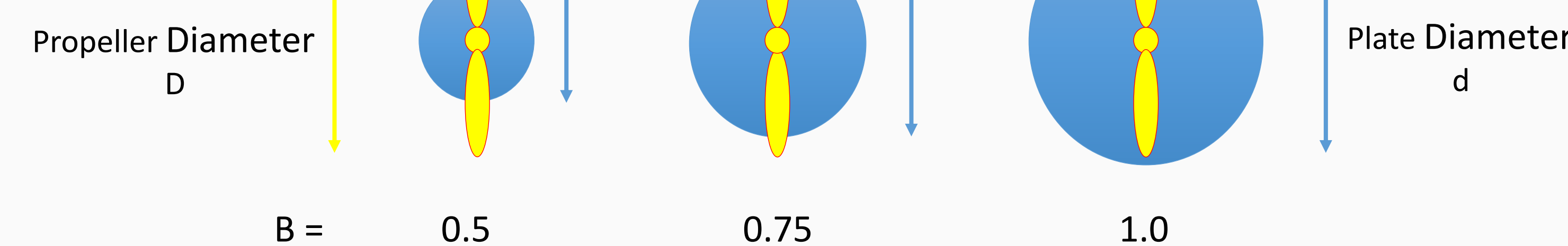


## EXPERIMENTAL SETUP AT UD-LSWT

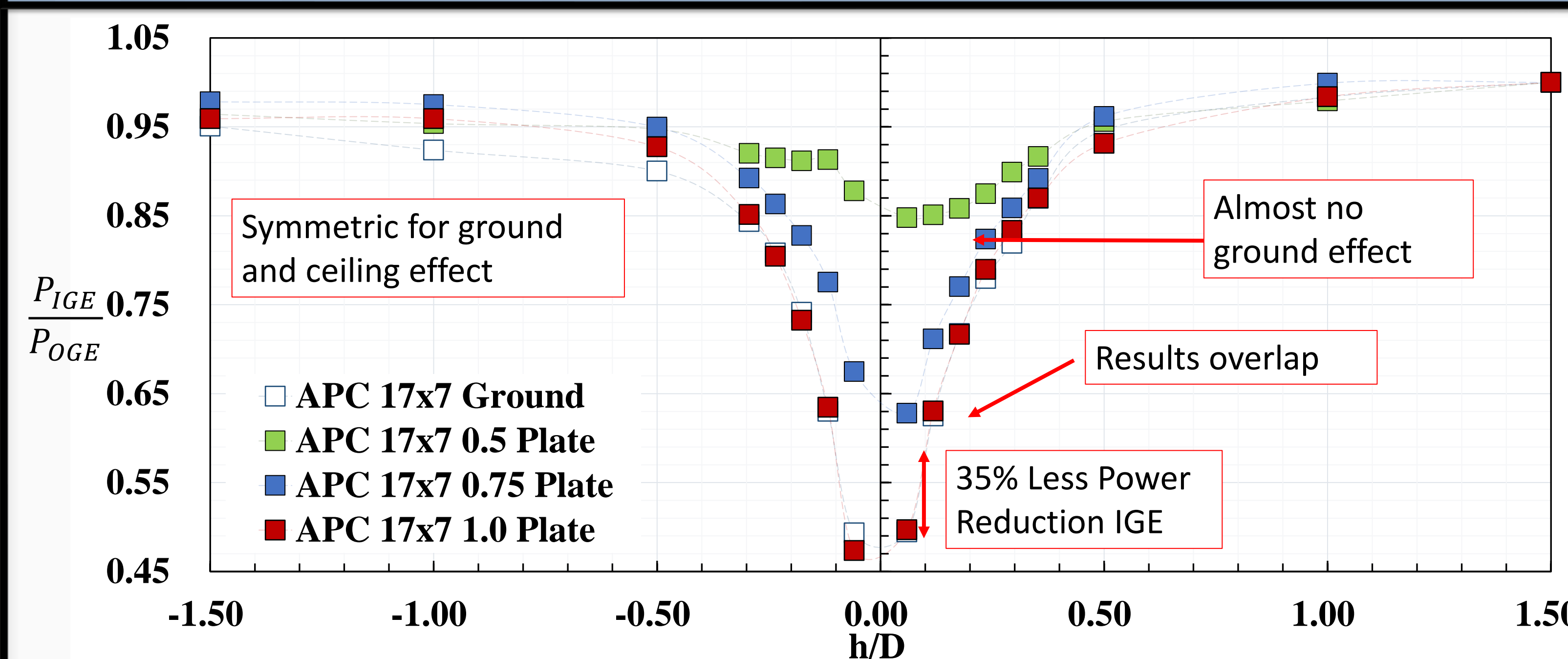


Propeller Properties			
Propeller (D x γ)	Pitch (γ) / Diameter (D)	Solidity (σ)	Peak Reynolds Number
17x12	0.705	0.0179	145,000
17x10	0.588	0.0188	160,000
17x7	0.412	0.0211	190,000

$$Blockage B = \frac{d_{plate}}{D_{propeller}}$$

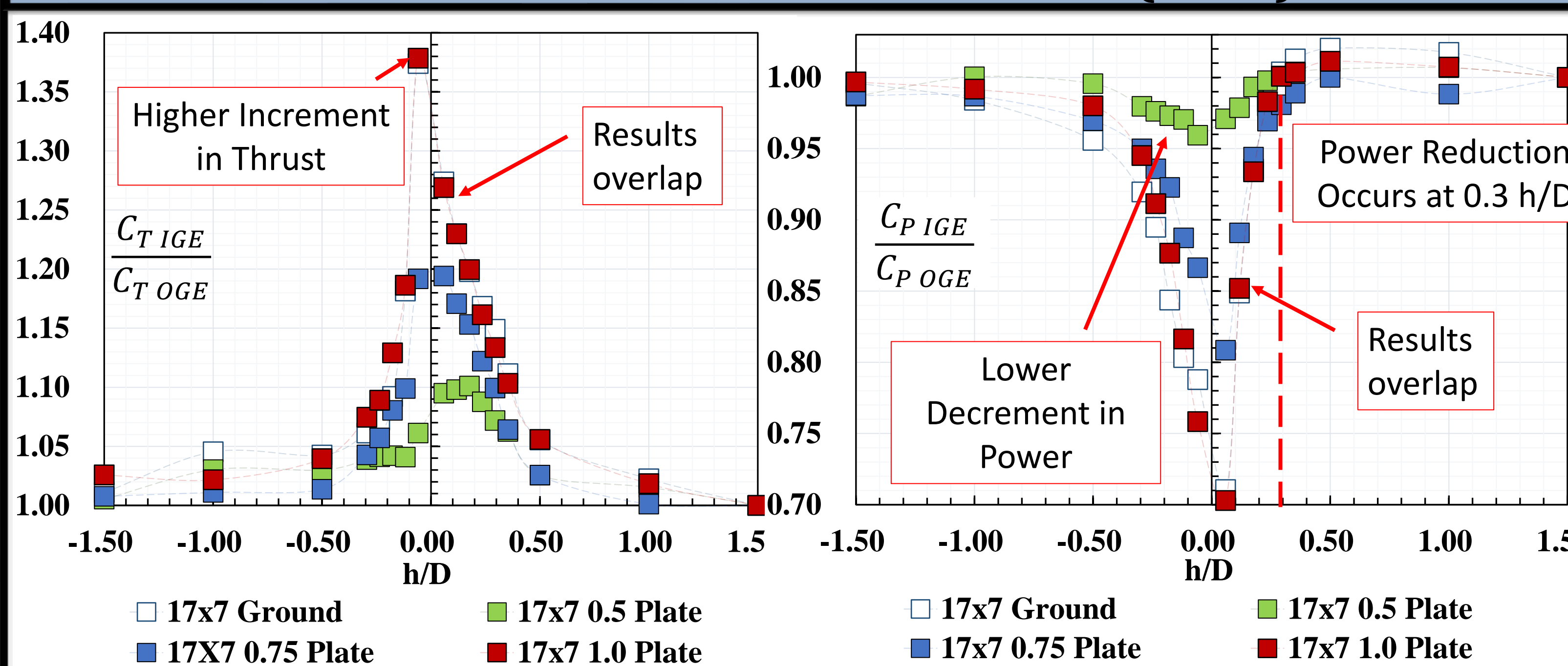


### Power Required at Constant Thrust (17x7)



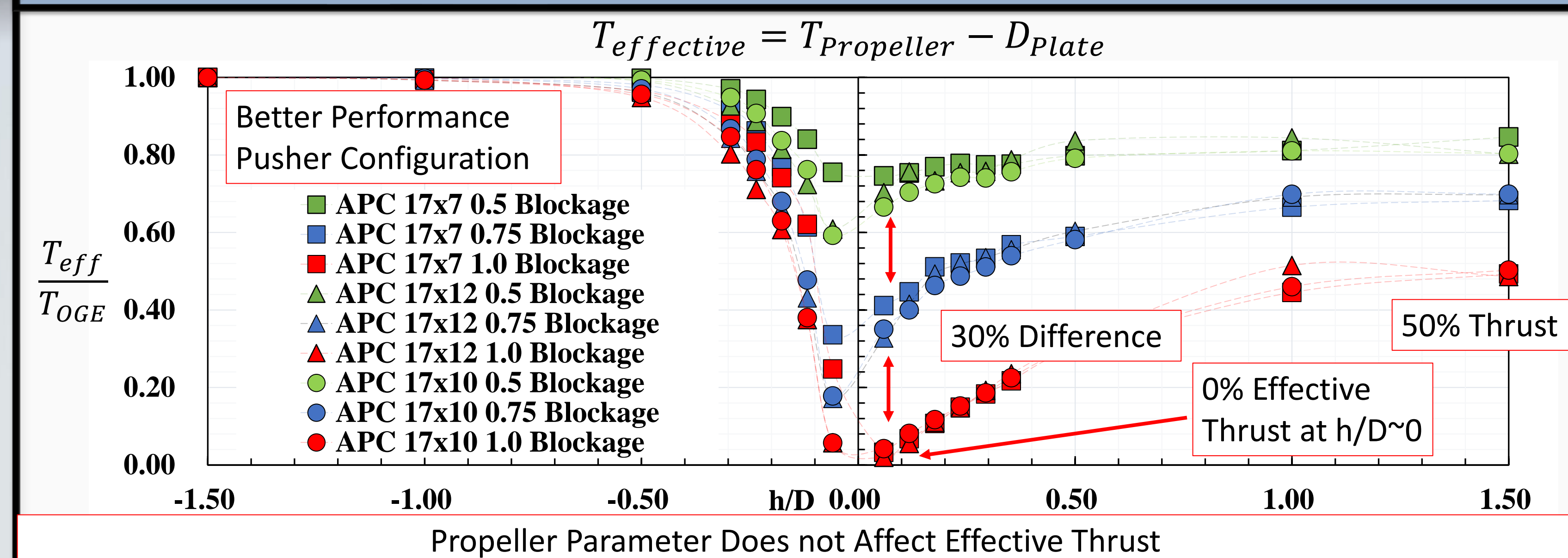
Smaller Blockage Ratio, Less Ground Effect  
Blockage Ratio of 1.0 can be considered as 'Infinite' Ground

### Thrust and Power Coefficient (17x7)

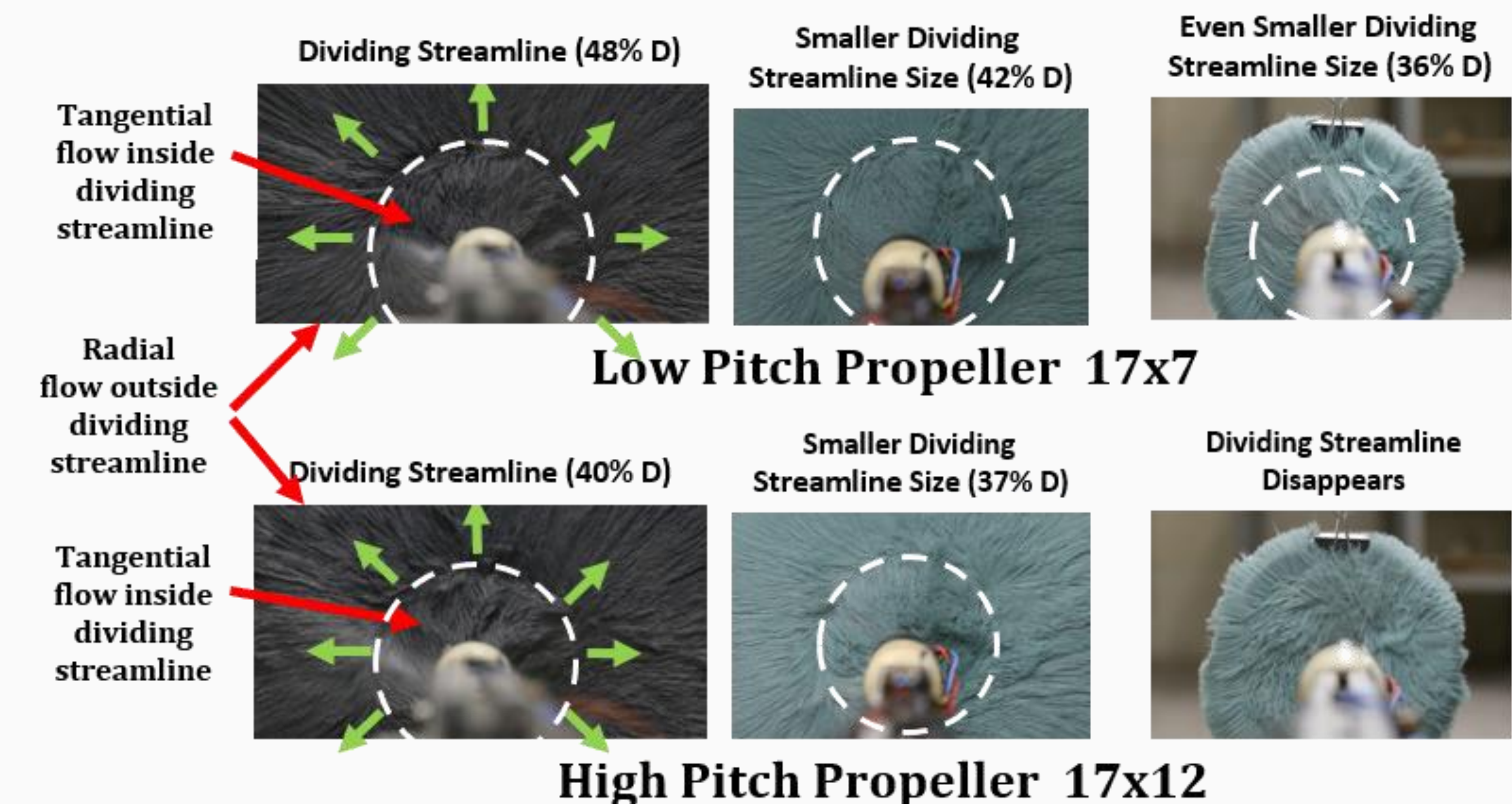


## RESULTS

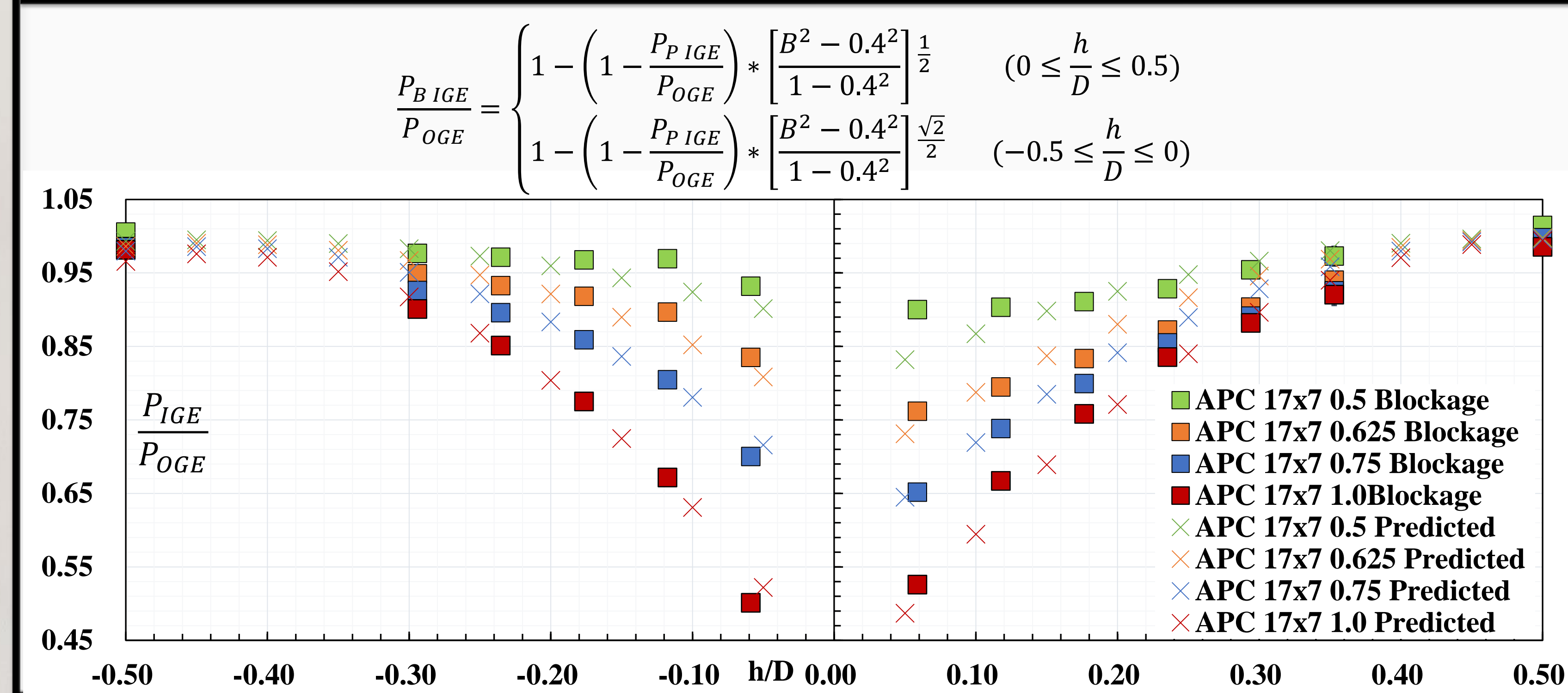
### Propeller Effective Thrust (17x12, 17x10, 17x7)



### Surface Tuft Flow Visualization



### Power Prediction with Algebraic Equation



## CONCLUSIONS

- A disk of blockage ratio of 1.0 was found to be sufficient enough as "classical" case of infinite ground-plate.
- Propeller effective thrust is independent of pitch to diameter ratio.
- The lower pitch to diameter ratio propeller leads to a bigger dividing streamline and stronger ground effect.
- The partial ground effect is also predictable.