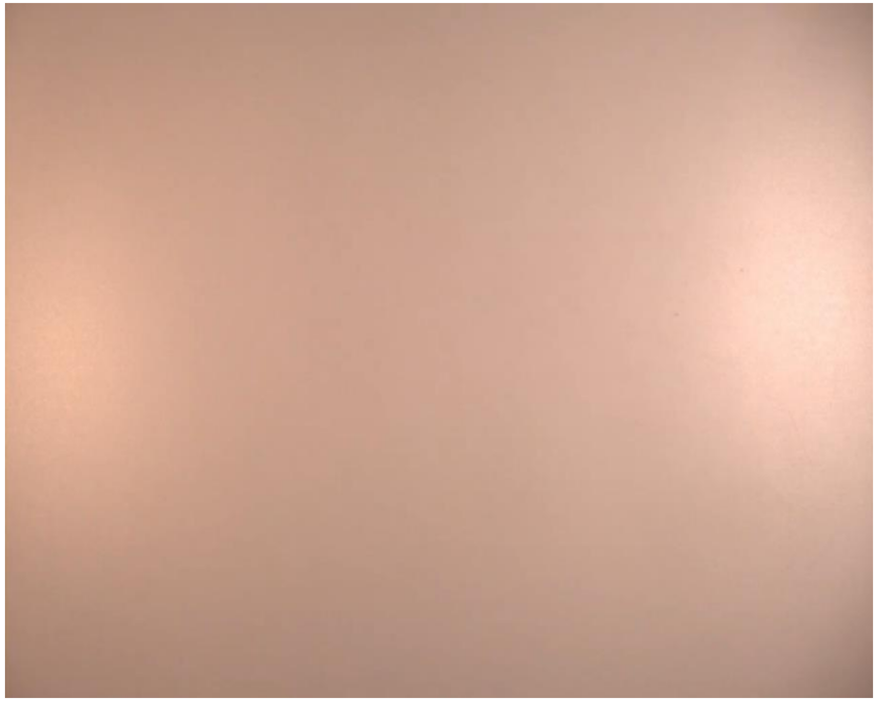
Escaping helicopters

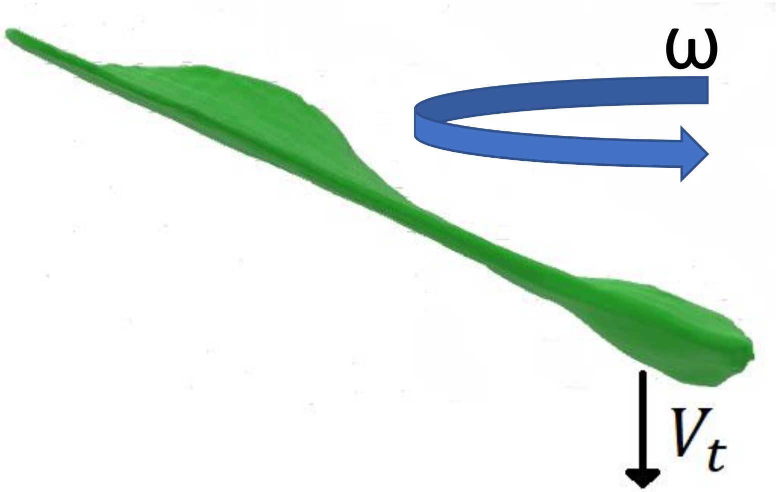
Certain species of trees produce a type of dry fruit known as a samara. It has a winged structure that allows the seeds to be carried by the wind over large distances. How does the terminal speed of a samara depend on the relevant parameters? Is it more efficient than a parachute?

Joachim Marco Hermansen, Danish Team

Description of the fall:

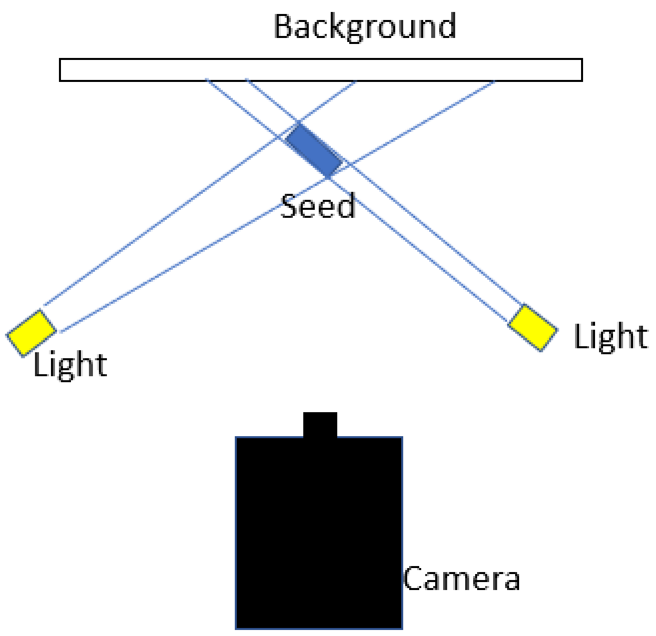
When the seed is droped it falls in a chaotic way. Then the drag on the seed makes a touqe on it, causing it to spin. The spin in a sweeping motion creates lift like a plane wing.



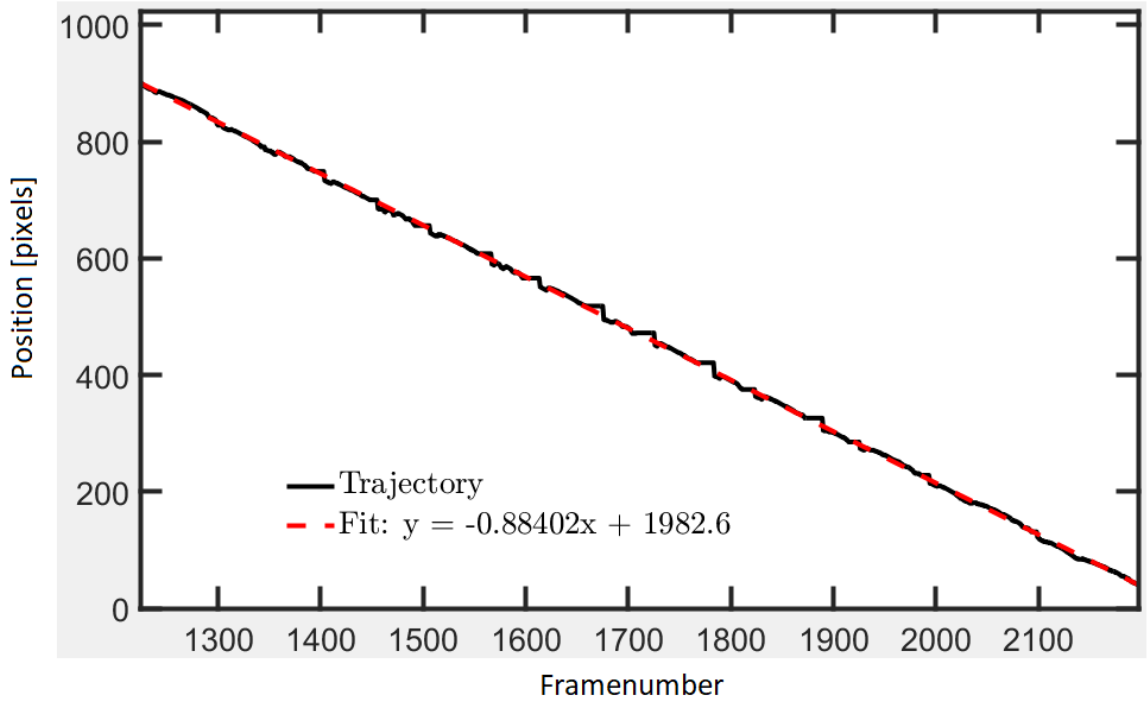


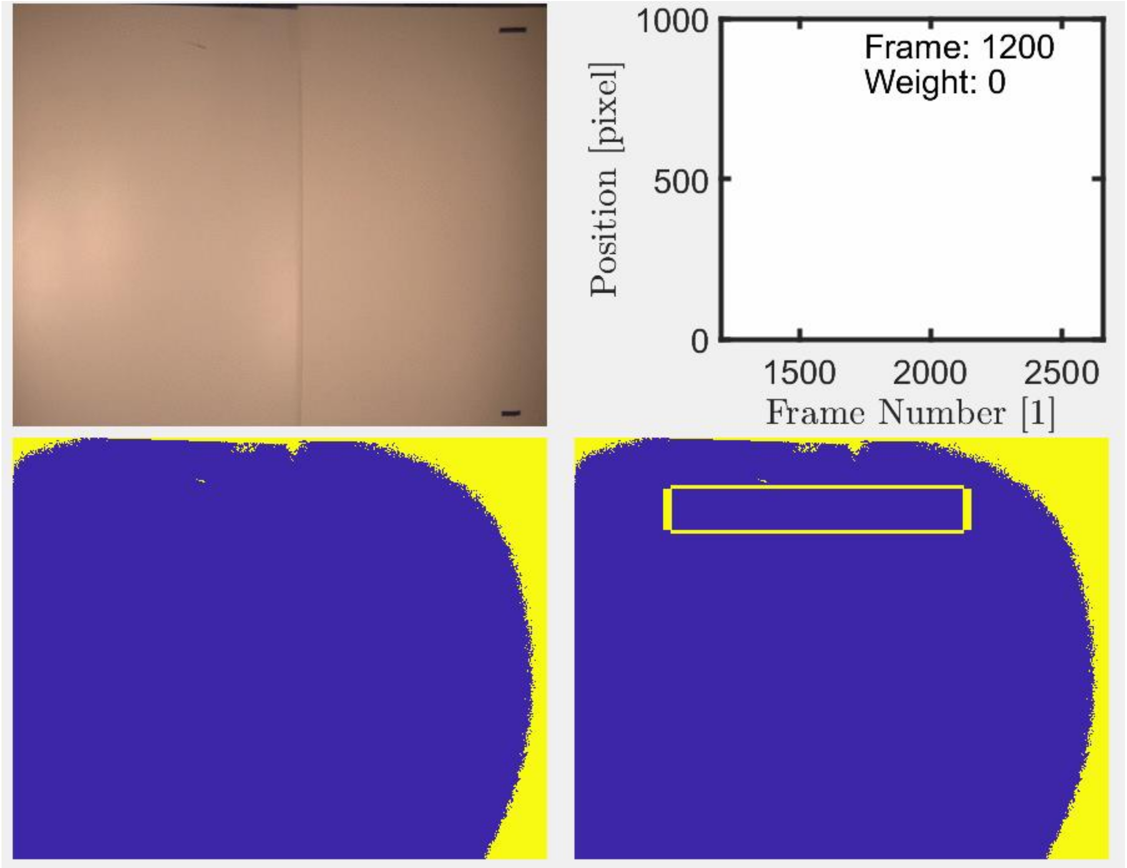
Droping different seeds

- Setup:
  - A white background.
  - A high speed camera
- The procedure:
  - Drop the seed
  - Measure length, width and mass
- Results:
  - Terminal velocity

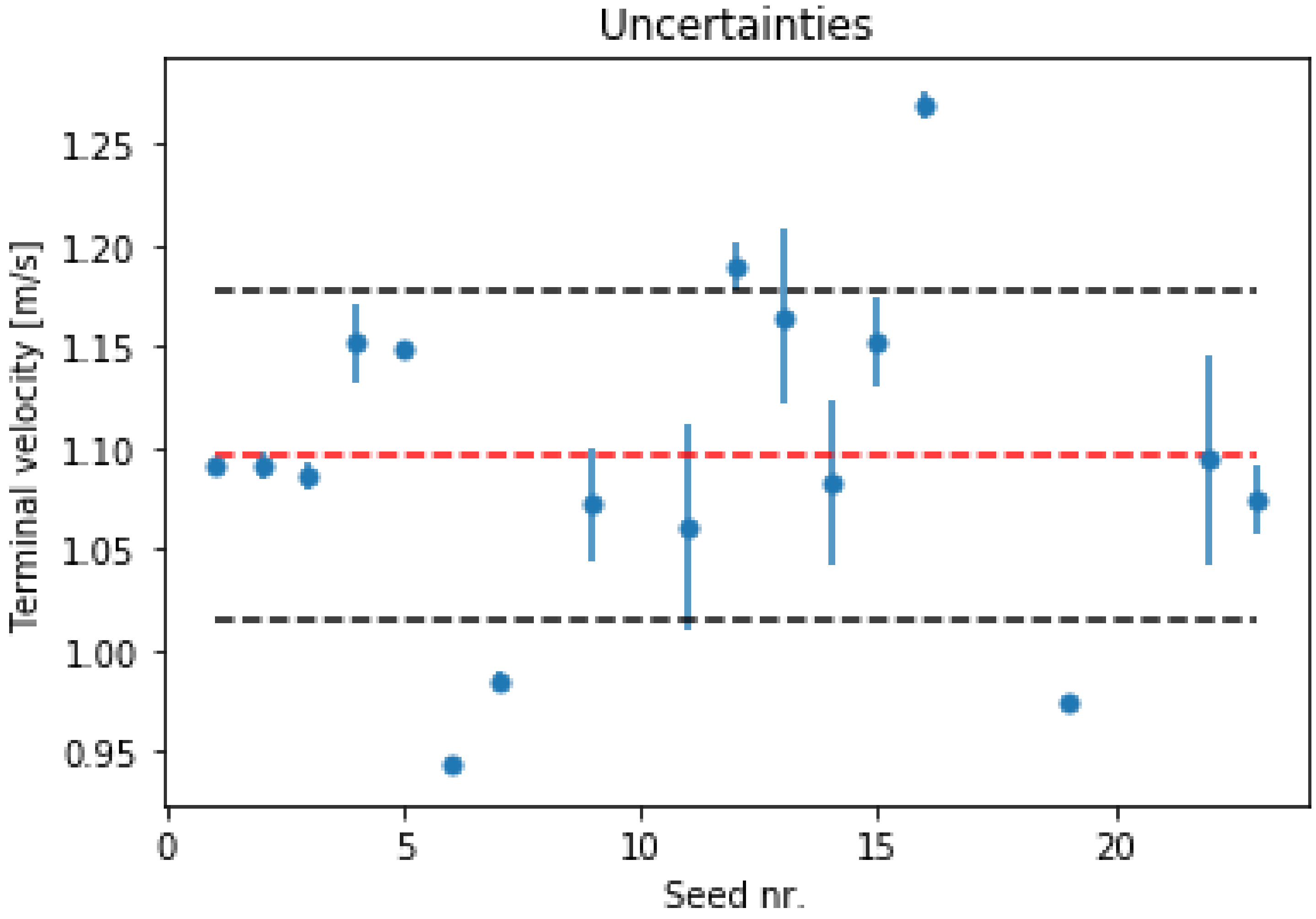


Analizing data

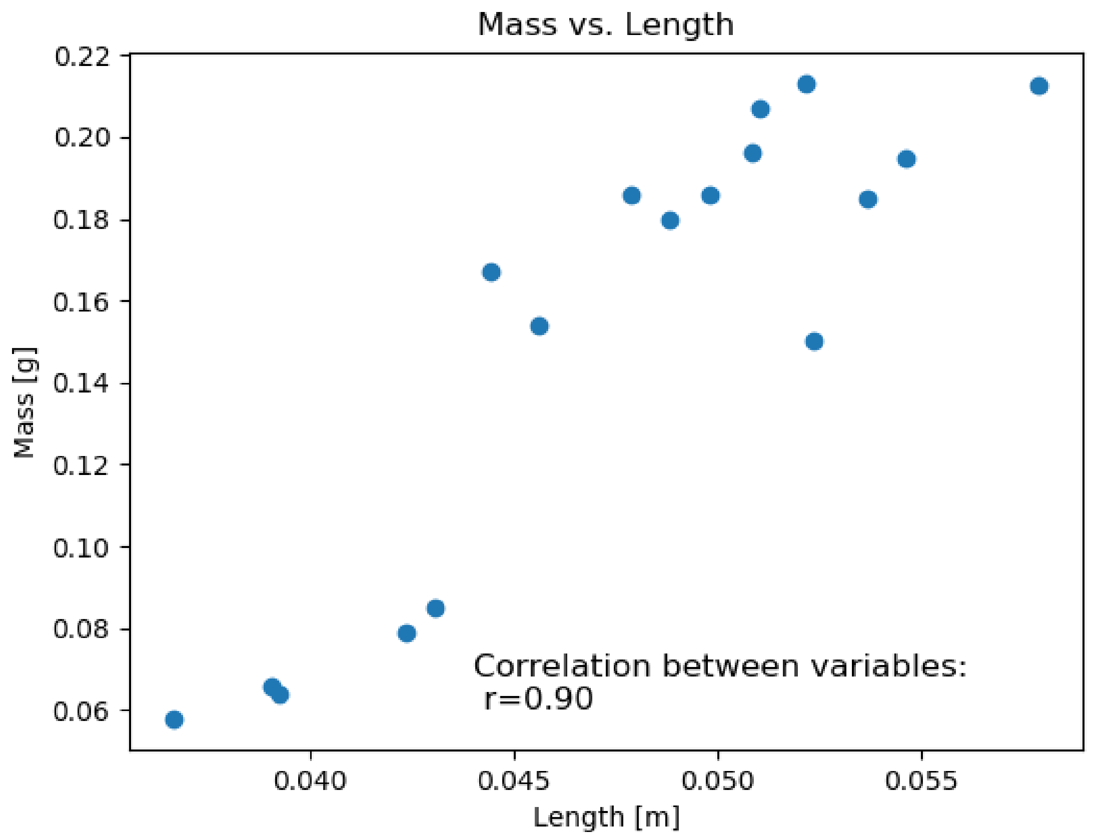




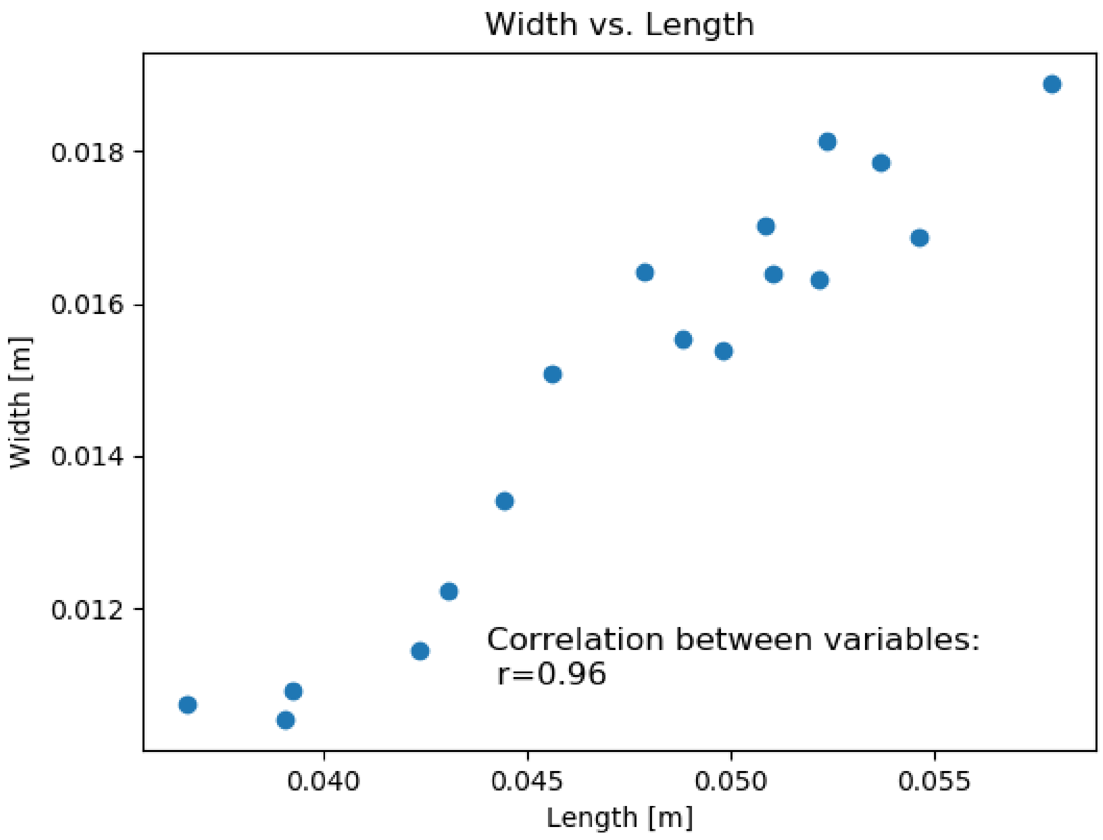
Results


Uncertainties
Terminal velocity [m/s]
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0
5
10
15
20
Seed nr.

Results

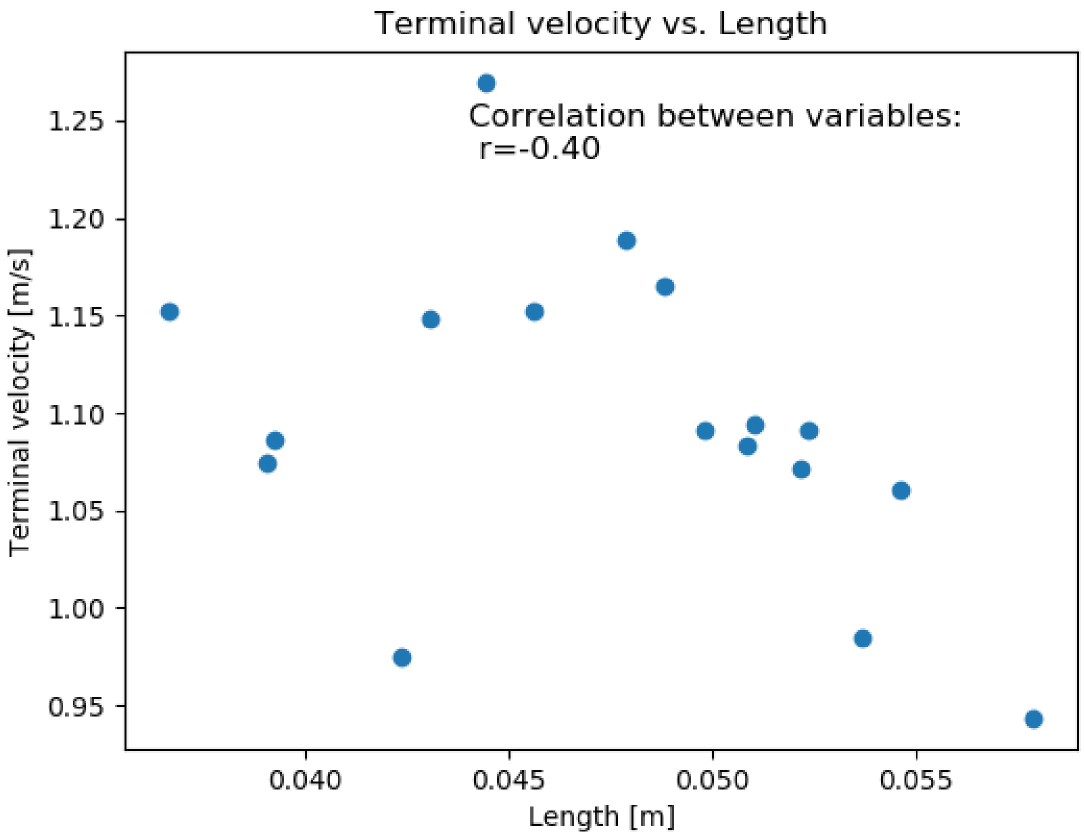


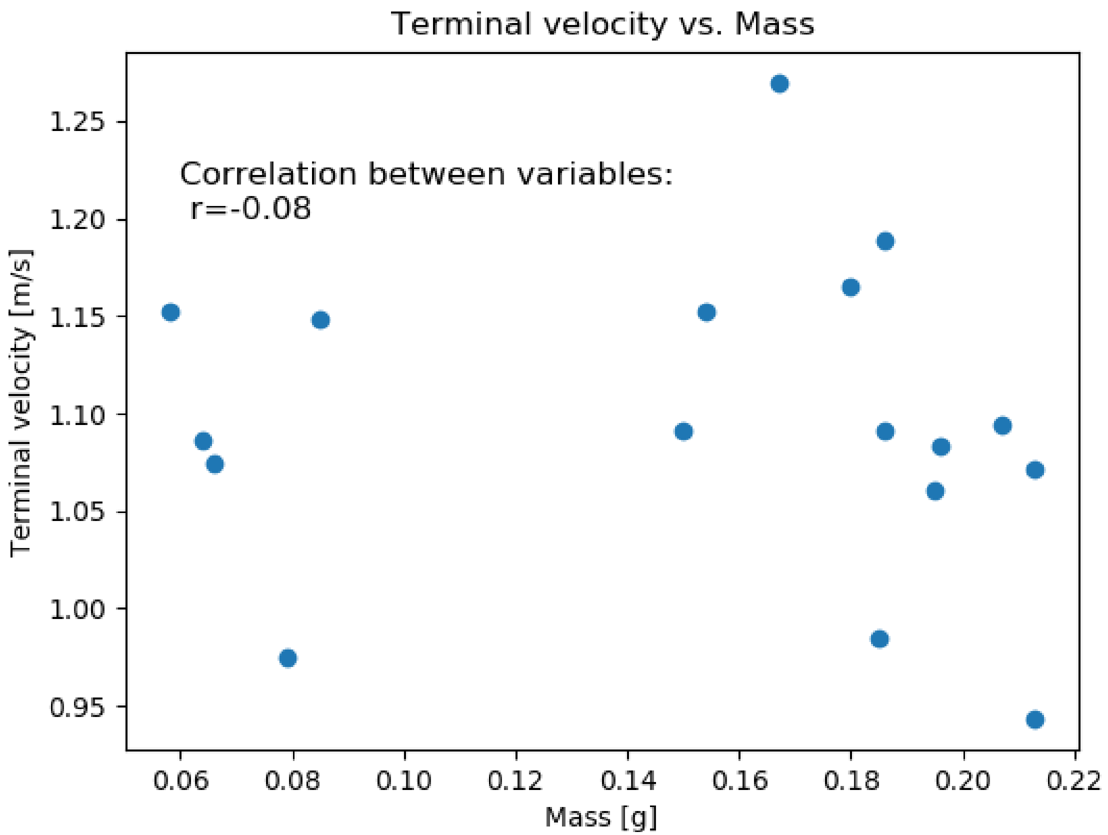
Mass vs. Length
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
Mass [g]
0.040
0.045
0.050
0.055
Length [m]
Correlation between variables:
r=0.90



Width vs. Length
0.018
0.016
0.014
0.012
Width [m]
0.040
0.045
0.050
0.055
Length [m]
Correlation between variables:
r=0.96

Results


Terminal velocity vs. Length
Correlation between variables:
r=-0.40
Terminal velocity [m/s]
Length [m]
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.040
0.045
0.050
0.055


Terminal velocity vs. Mass
Correlation between variables:
r=-0.08
Terminal velocity [m/s]
Mass [g]
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22

What can we learn from this

- Correlation between data -> new method must be used
- The seeds balence out their weight with increased lenght and width.

Forces

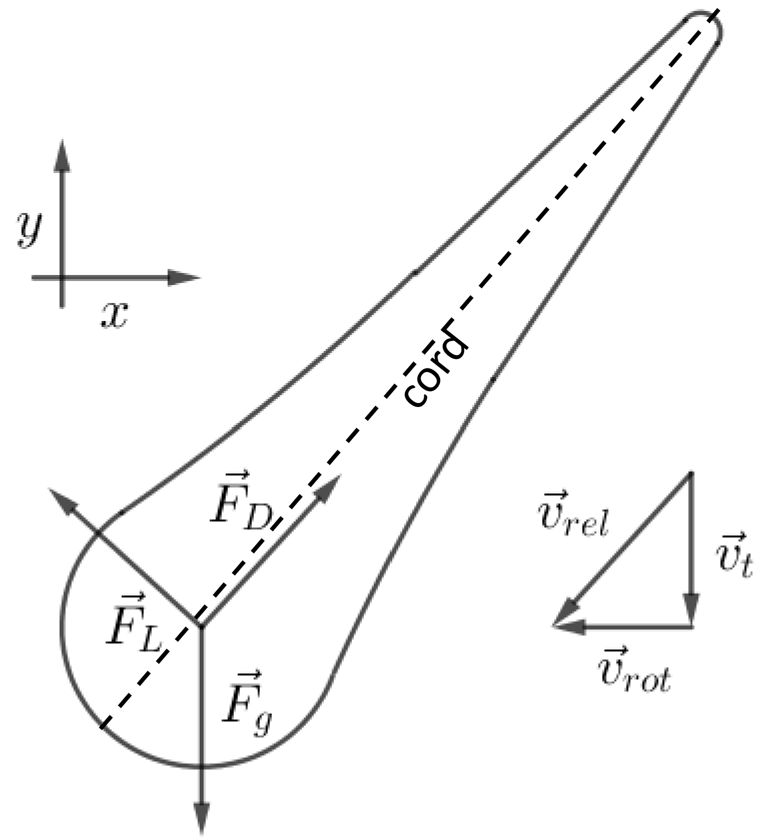
The forces on the seed is:

$$\vec{F}_L = \frac{1}{2}\rho A C_L V_{rel}^2 \vec{n}_{rel} \qquad \vec{F}_D = \frac{1}{2}\rho A C_D V_{rel}^2 \vec{e}_{rel}$$

$$\vec{F}_g = -mg\vec{e}_x$$

In steady state the sum of forces are zero:

$$0 = \vec{F}_L + \vec{F}_D + \vec{F}_g$$



Blade element momentum theory

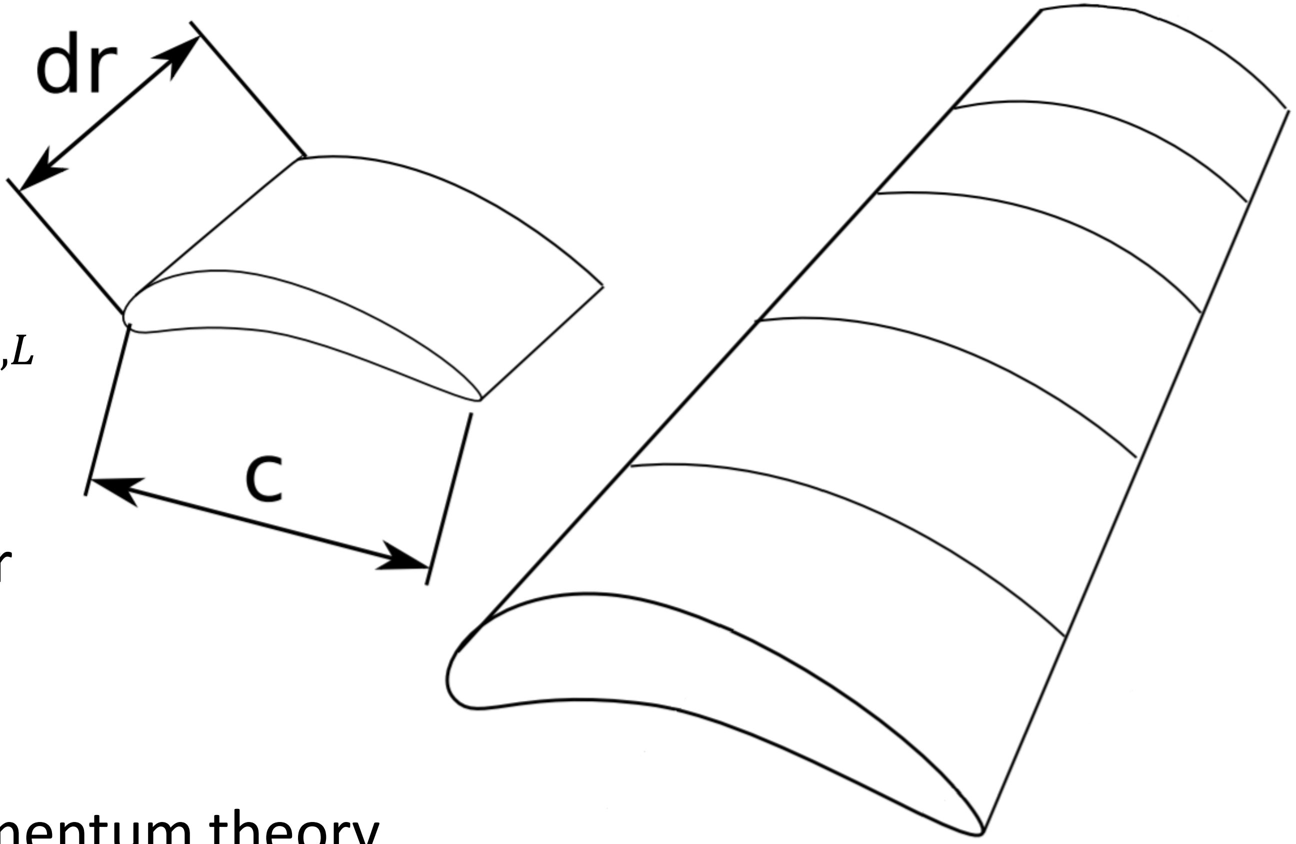
$$\vec{F}_{D,L} = \frac{1}{2}\rho\, A\, C_{D,L}\, (V_t^2 + V_{rot}^2)\, \vec{e}_{D,L}$$

The blade is divided into smaller parts:

$$d\vec{F}_{D,L} = \frac{1}{2}\rho\, c(r)dr\, C_{D,L}(r)(V_t^2 + \omega^2 r^2)\vec{e}_{D,L}$$

The force on the center of mass:

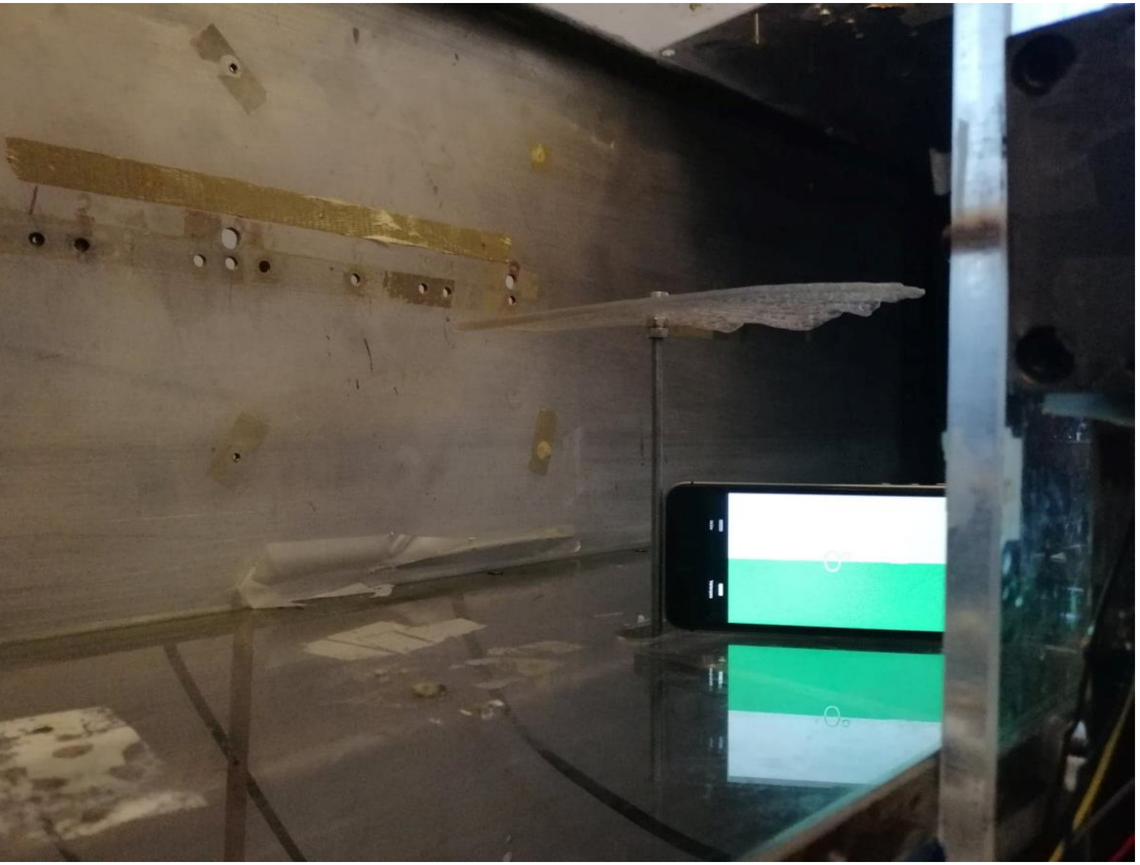
$$\int dF_{D,L} = \int_0^L \frac{1}{2}\rho\, c(r)\, C_{D,L}(r)(V_t^2 + \omega^2 r^2)\mathrm{dr}$$

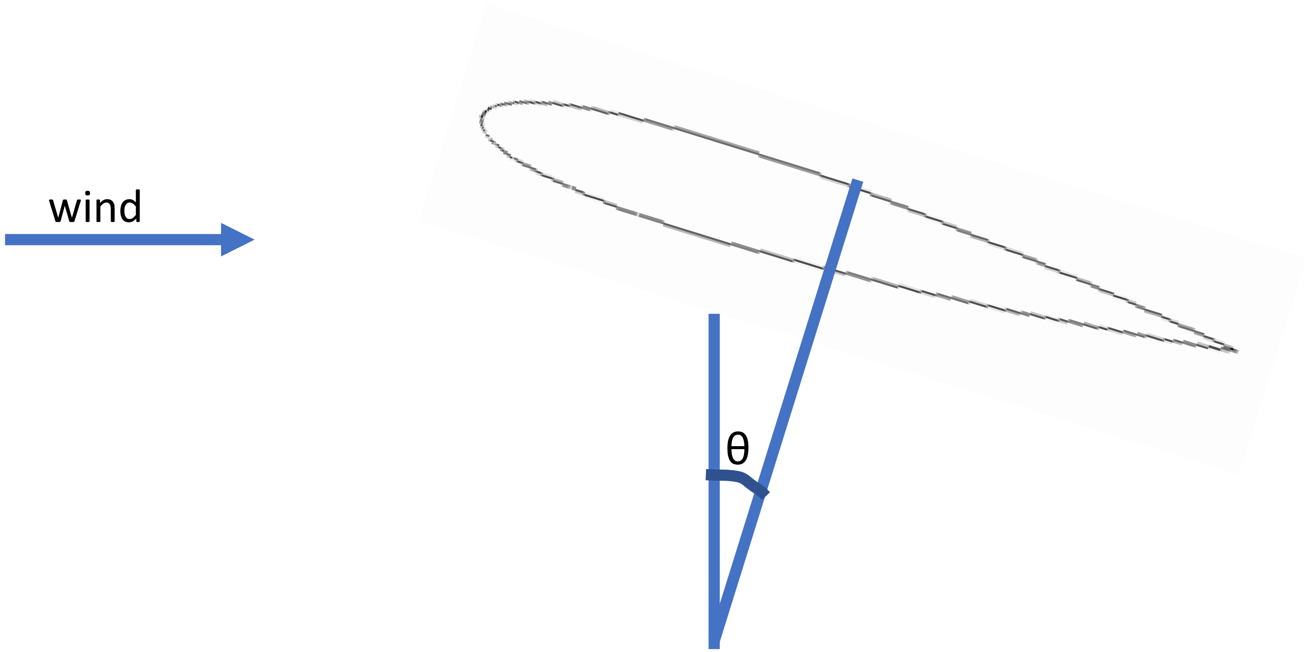


Blade element momentum theory

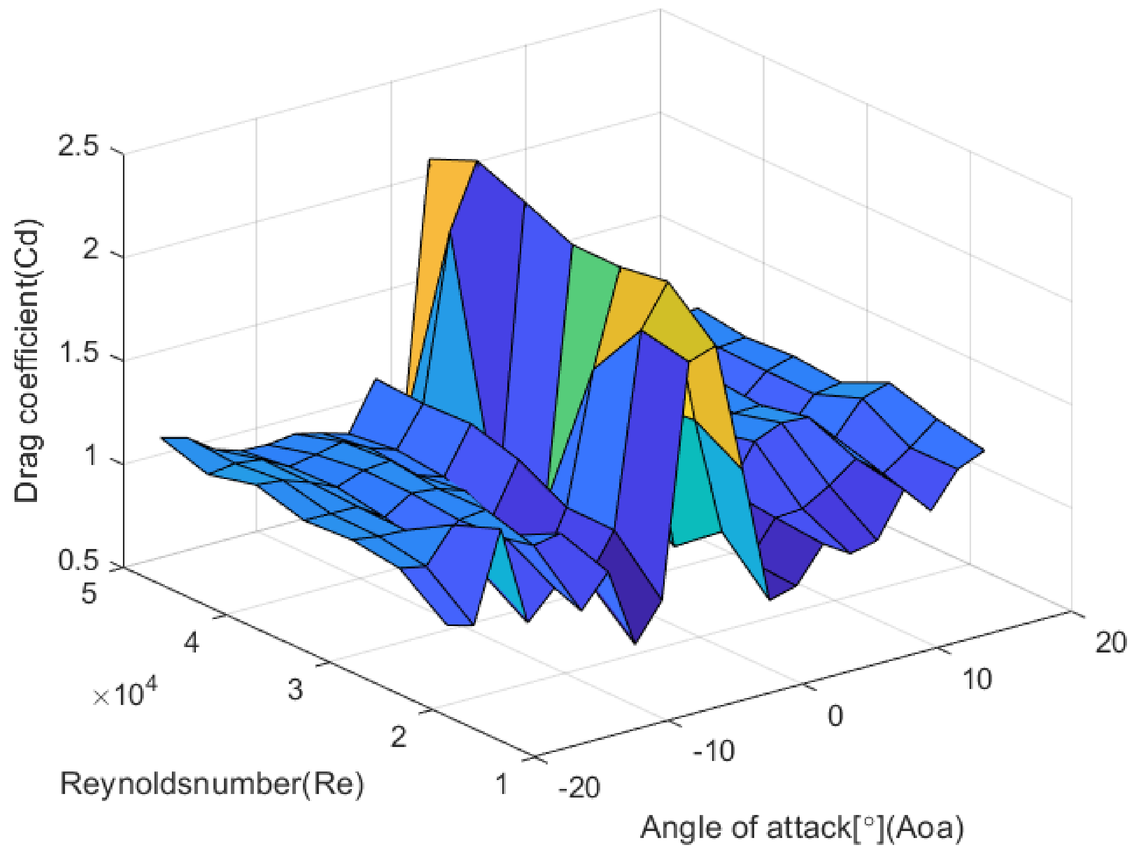
G. Ingram, "Wind Turbine Blade Analysis using the Blade Element Momentum Method. Version 1.1", School of Engineering, Durham University, Durham, USA, 2005.

Wind tunnel

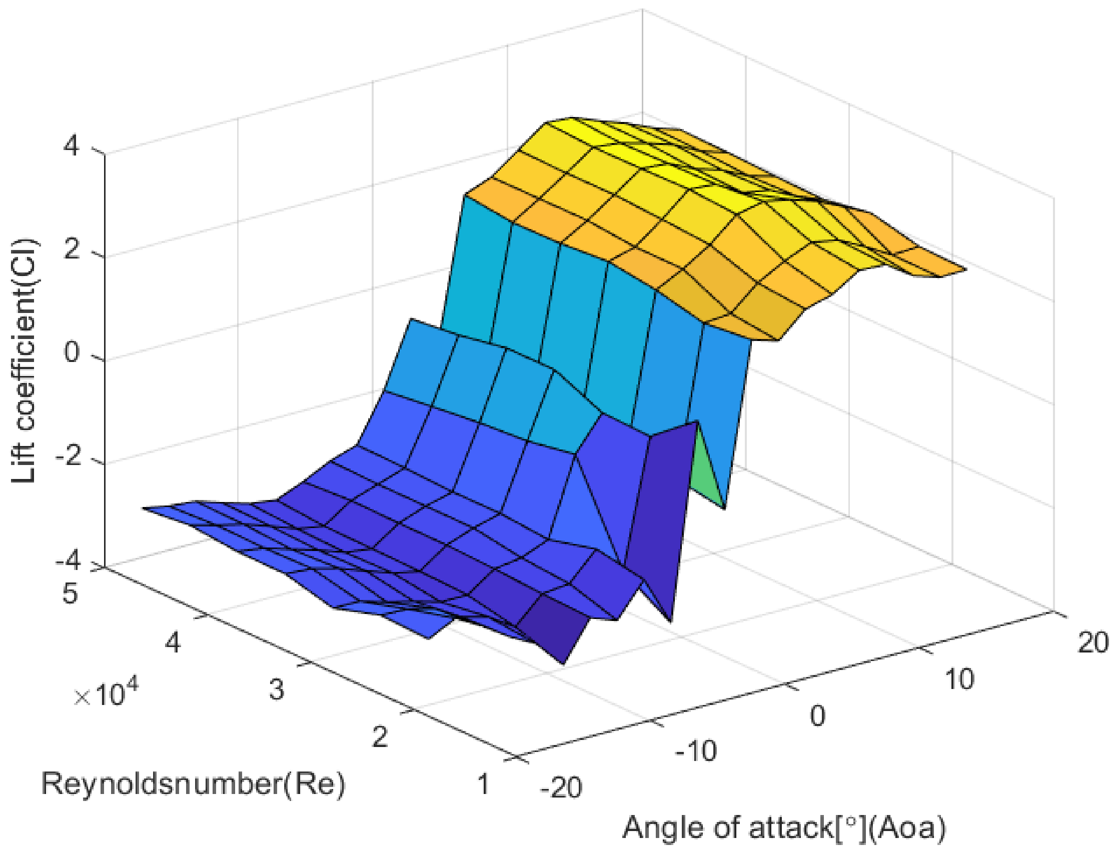




Wind tunnel



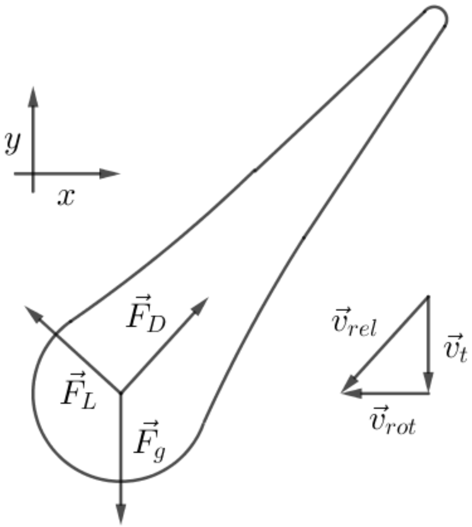
Drag coefficient(Cd)
2.5
2
1.5
1
0.5
5
4
3
2
1
×10^4
Reynoldsnumber(Re)
-20
-10
0
10
20
Angle of attack[°](Aoa)

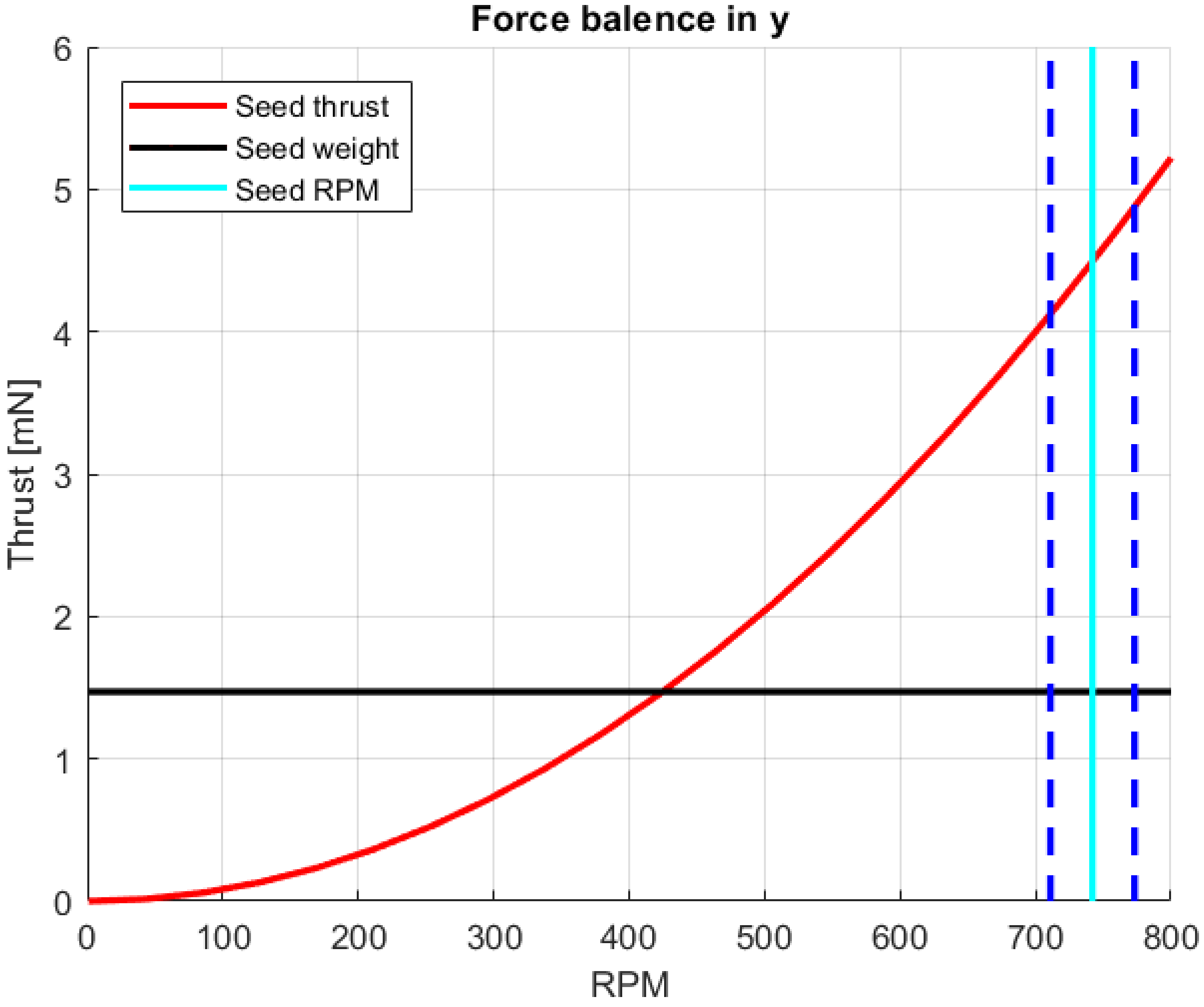


Lift coefficient(Cl)
4
2
0
-2
-4
5
4
3
2
1
×10^4
Reynoldsnumber(Re)
-20
-10
0
10
20
Angle of attack[°](Aoa)

Wind tunnel

3D-scaned and printed maple seed maple seed

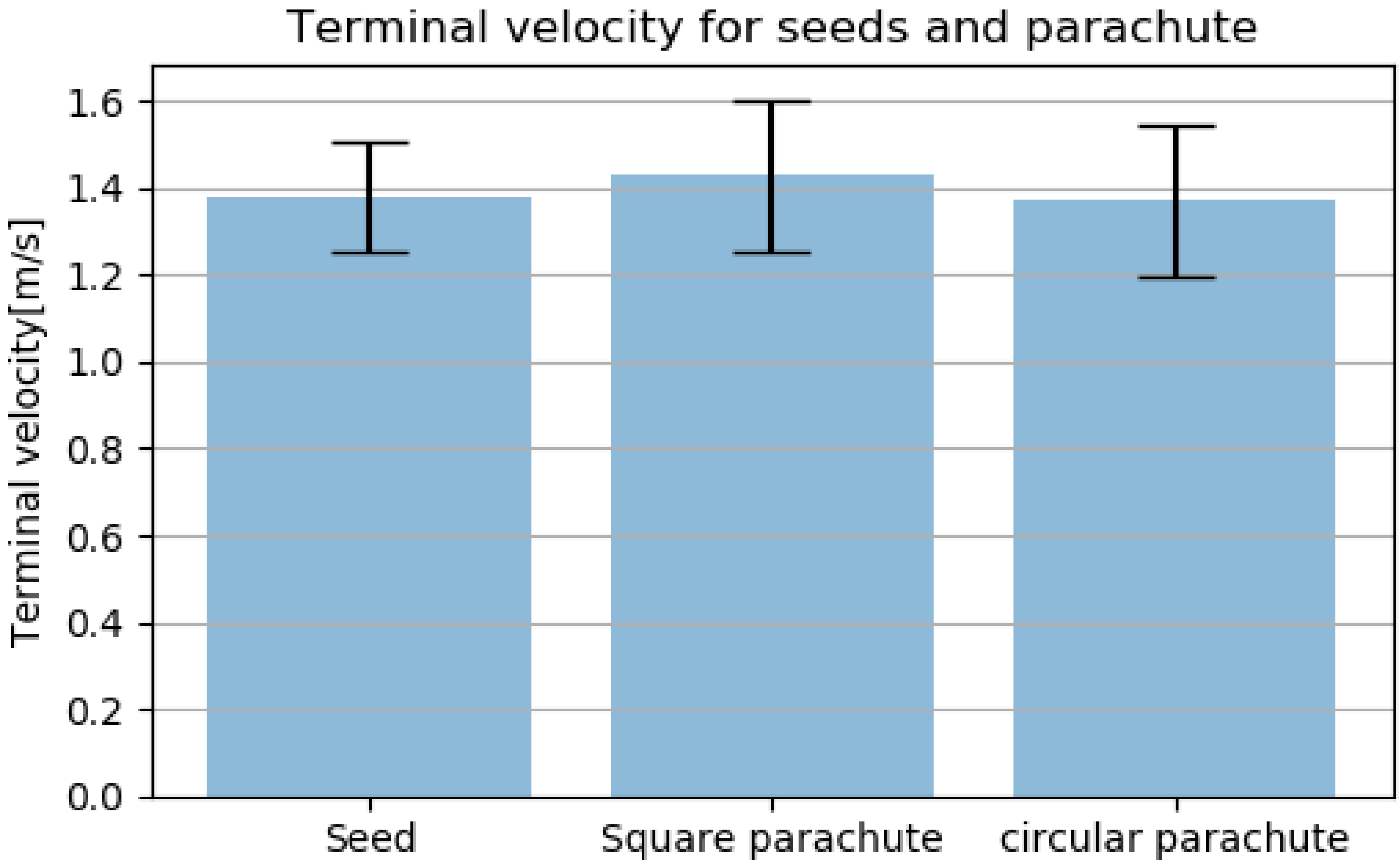




Parachute vs Seed

	Seed	Square parachute	Circle Parachute
Area wing	$4.7cm^2 \pm 0.1cm^2$	$32cm^2 \pm 1cm^2$	$32cm^2 \pm 1cm^2$
Weight seed	152mg±1mg	150mg±5mg	150mg±5mg
Weight wing	36mg±1mg	40mg±5mg	40mg±5mg
Weight rope		0.01±2mg	0.01±2mg

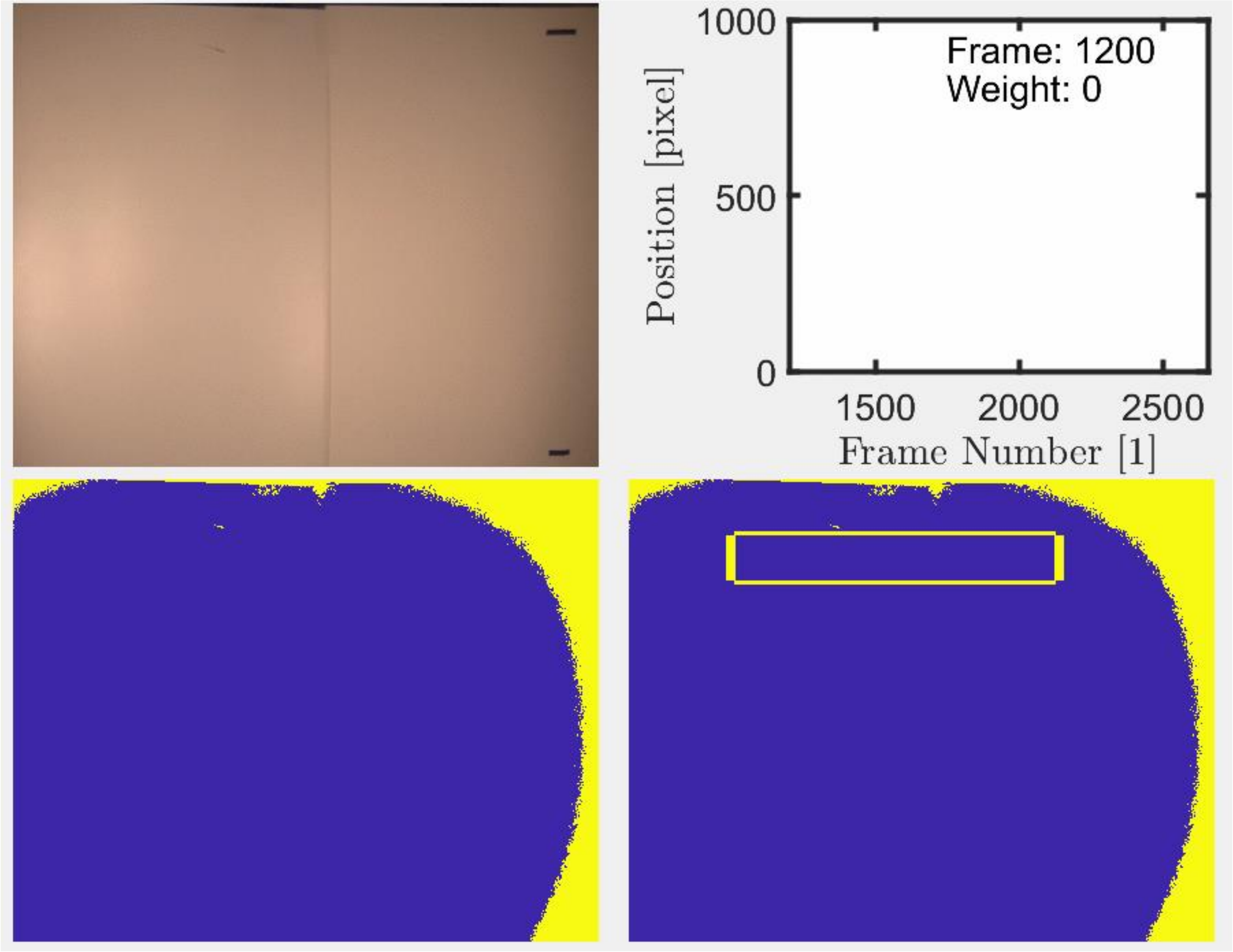
Parachute vs Seed



Conclusion

- The parachute and the seed are about the same, efficiency wise.
- The seed is more robust but requires that the seed has a certain mass distribution.
- The parachute is easy to upscale, but it requires lighter/thinner fabric.
- Our experiments show that the terminal velocity of the maple seed is independent mass,lenght and width.

The end



Frame: 1200
Weight: 0
Position [pixel]
1000
500
0
1500
2000
2500
Frame Number [1]