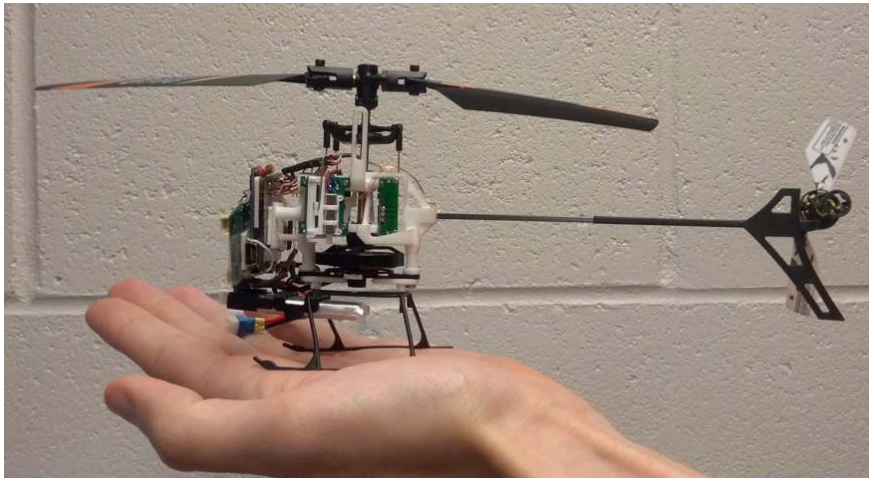
Introduction to Motor and Propeller Testing and Selection for Quadcopters Designers

Objective

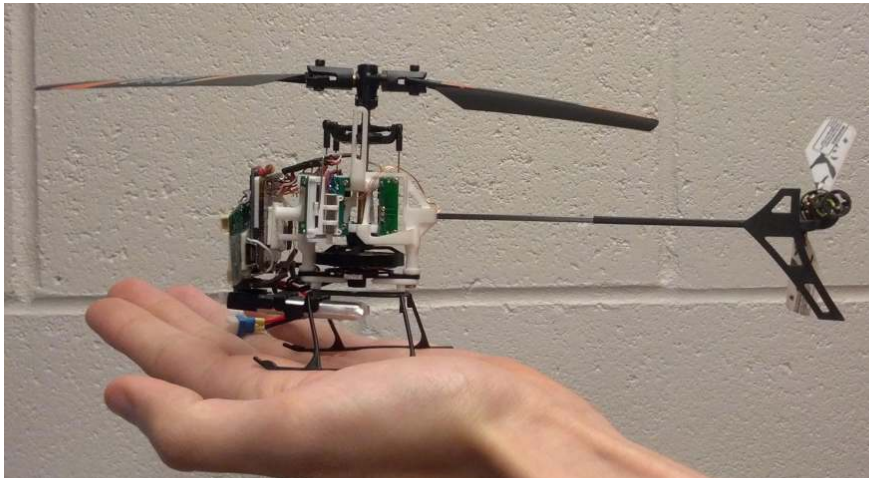
Problem

- Low flight time
- <30% Efficiency



Objective

- Understand
  - Basic motor and propeller theory
  - Motors and propeller testing
- Improve
  - Performance
  - Range
  - Flight time in your design

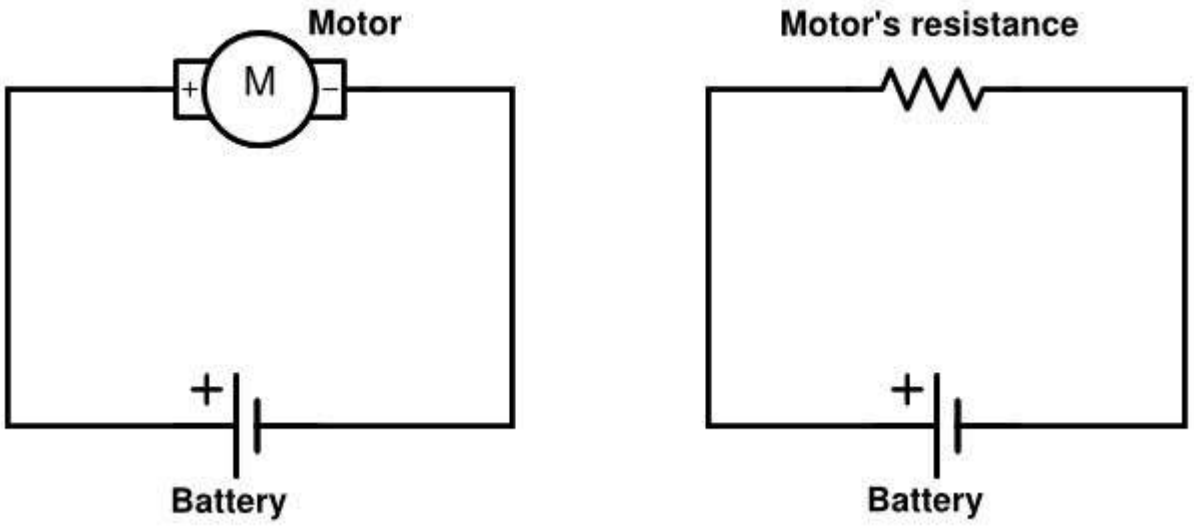


Coil and magnet model

Stall motor model

Voltage and power relationship

$$V = RI$$



Stall motor model

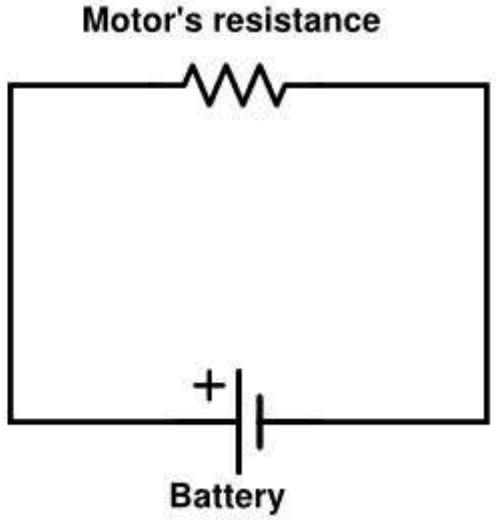
Power loss (heat)

$$P = RI^2$$

Example

11.4V battery with 0.3116Ohms

36.5A and 417W.

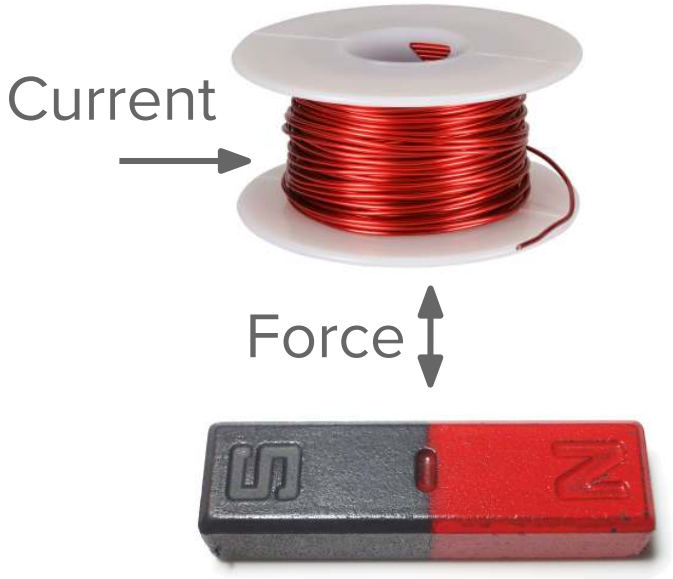


Model with electromagnetism

Force is proportional to current I and number of turns on coil N_c

$$\text{Force} \propto \text{Current} * N_c$$

$$\text{Torque} = \text{Current} * K_T$$



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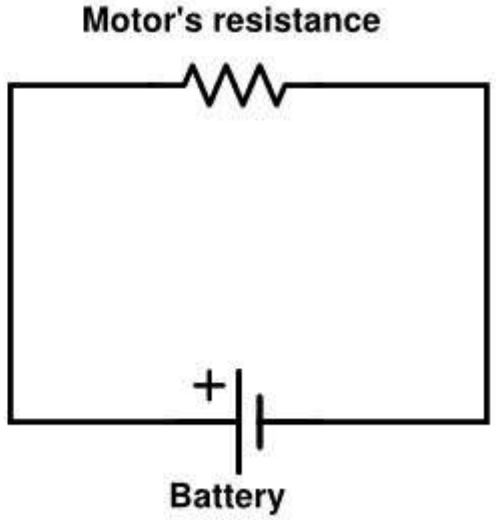
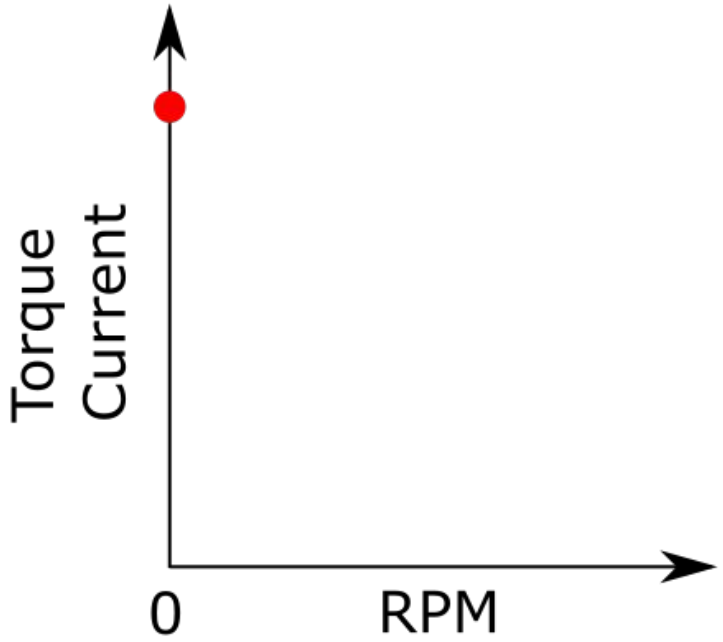


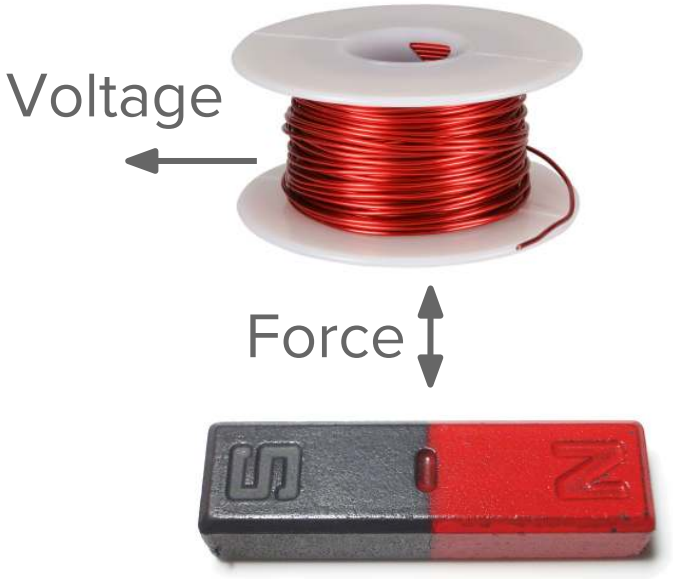
Torque-RPM graph

Current * K_t = Torque



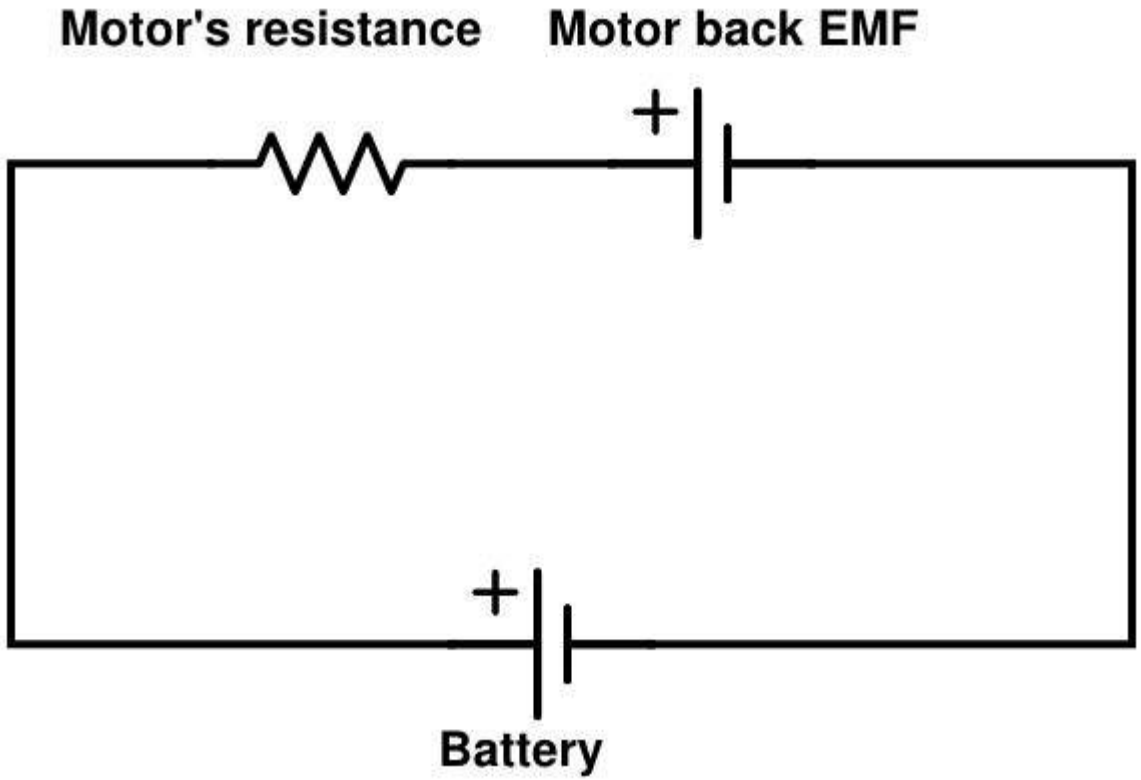
Back EMF

A magnet moving close to the coil will generate a voltage



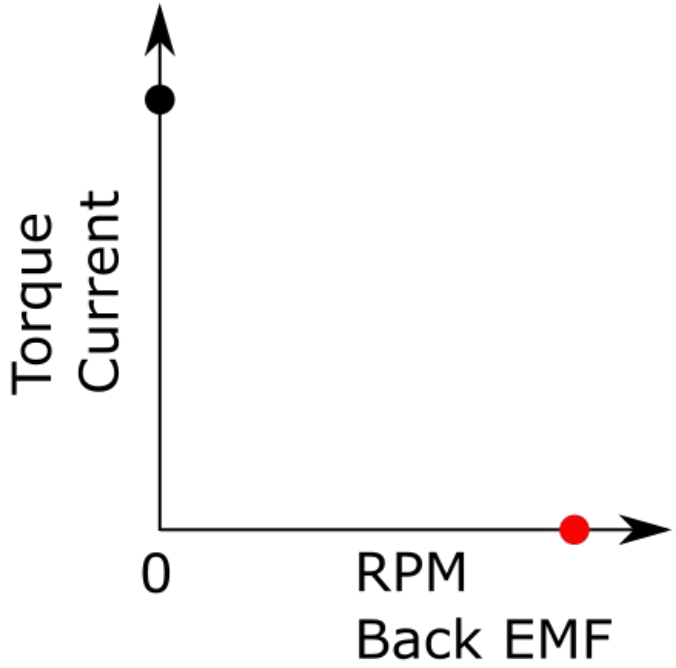
Motor with back EMF

RPM $\propto$ Back EMF

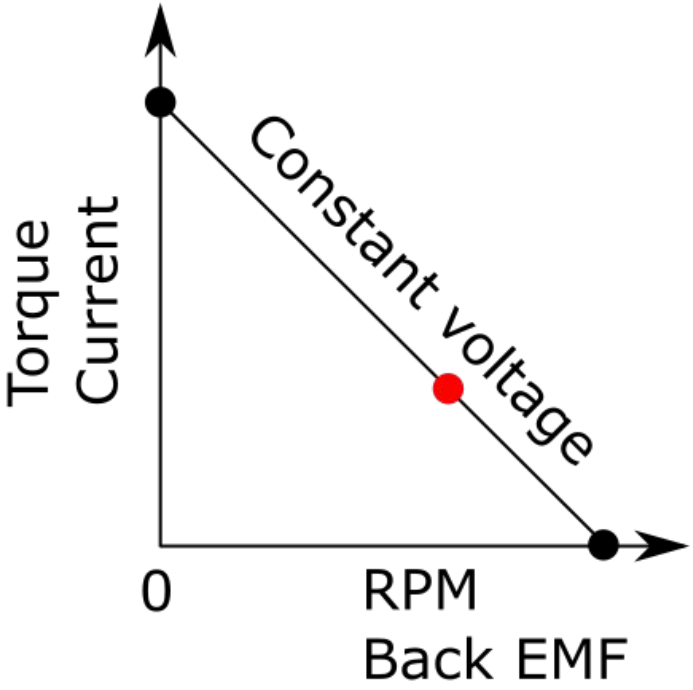


No load motor

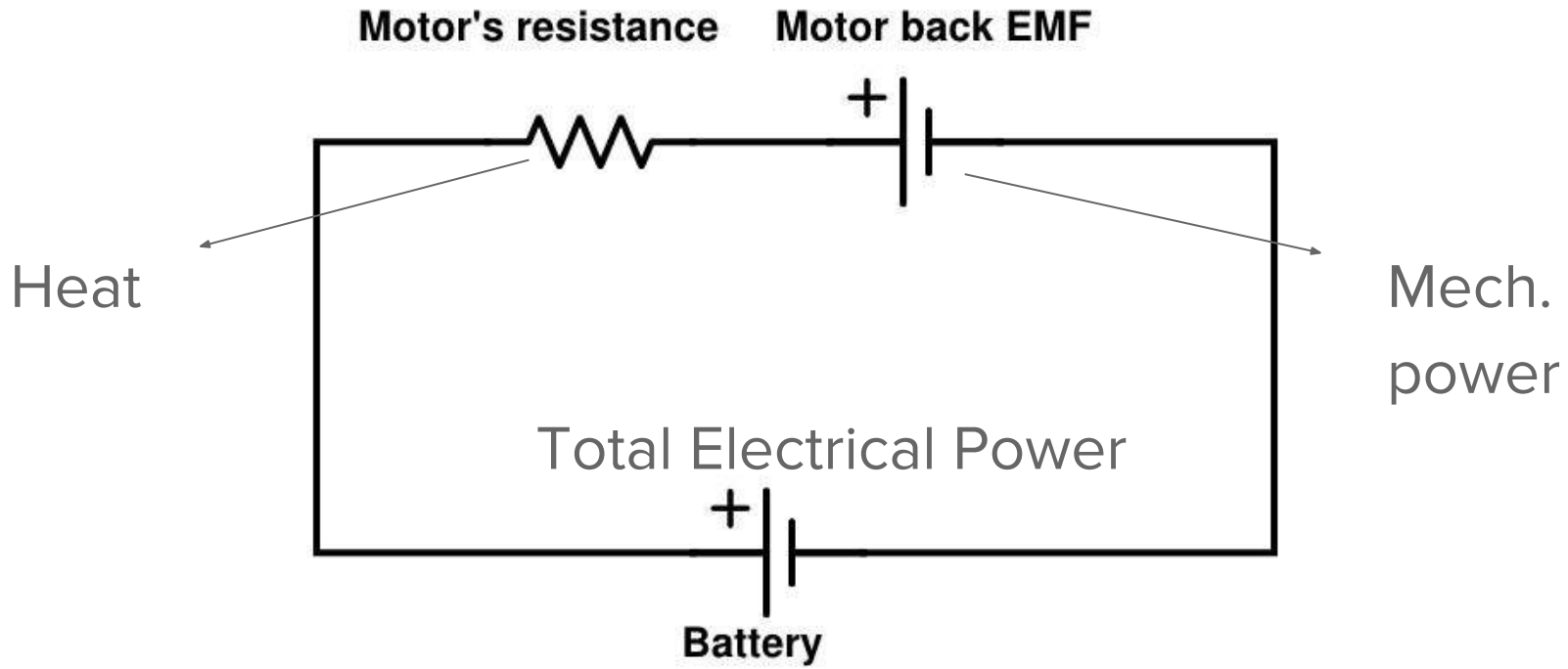
$K_V * V_{batt}$ = No load RPM



Constant Voltage - ESC input



Power


Motor's resistance
Motor back EMF
+
Heat
Mech.
power
Total Electrical Power
+
Battery

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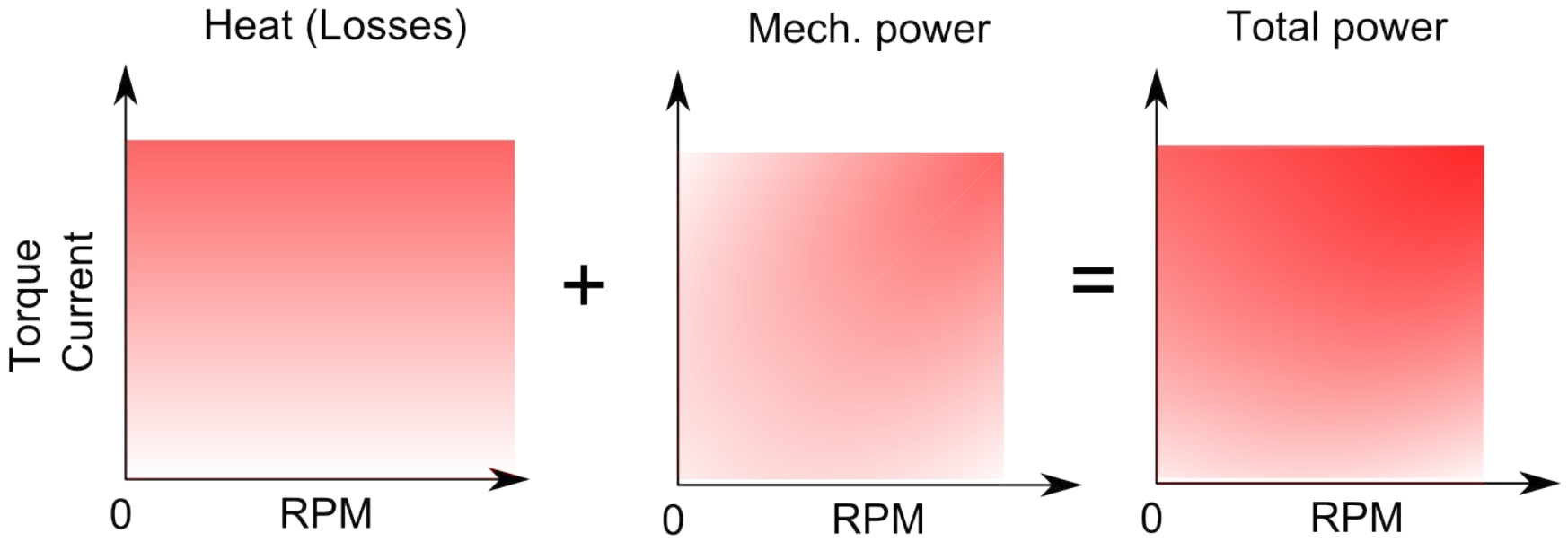
Energy distribution in motor



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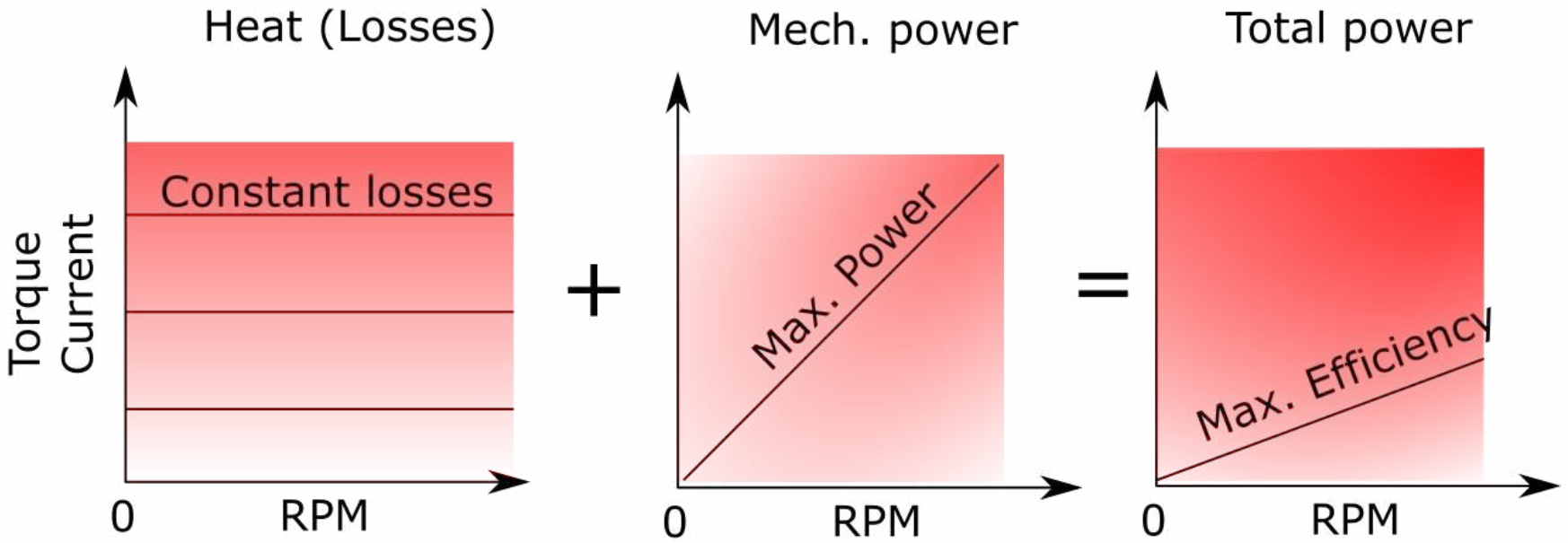
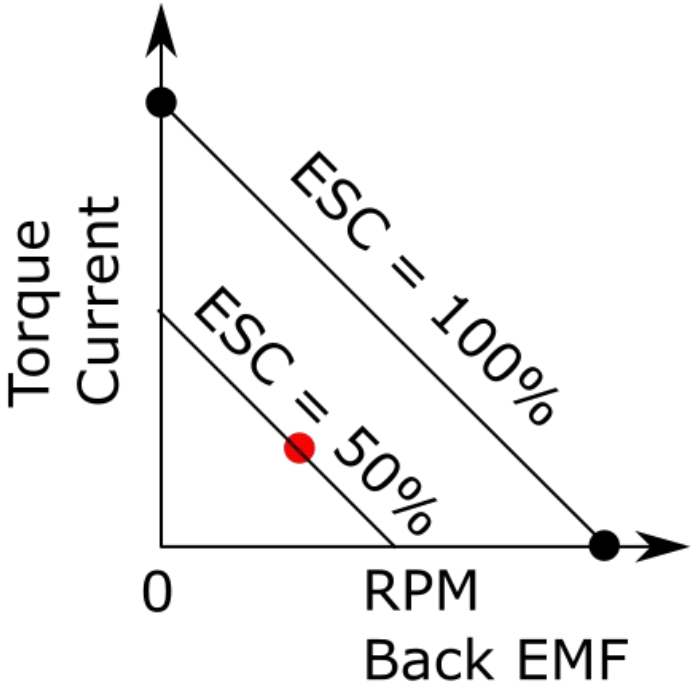
Energy distribution in motor



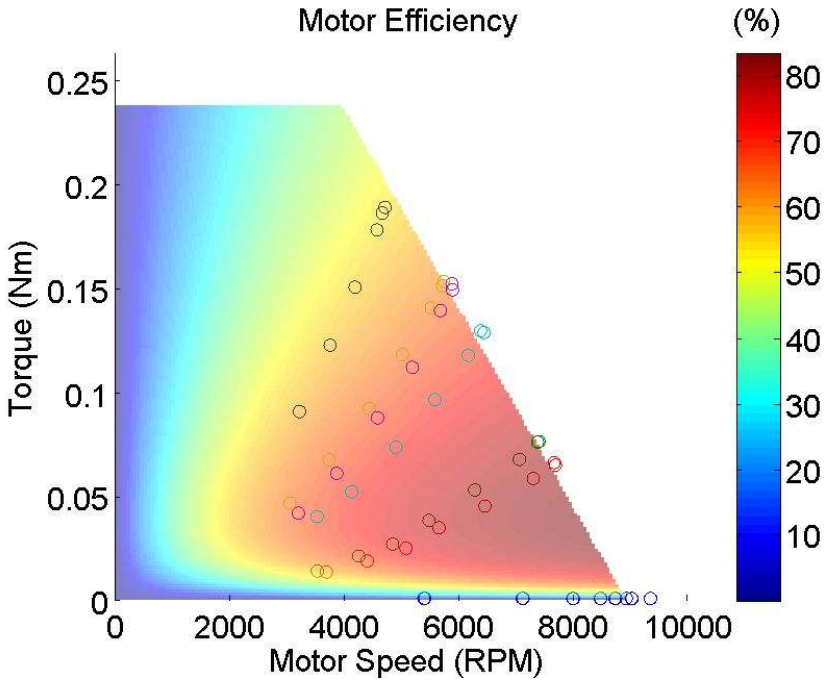
Varying voltage



Motor Efficiency

Efficiency =

$$\frac{\text{Mechanical power}}{\text{Electrical power}}$$



Anatomy of an outrunner

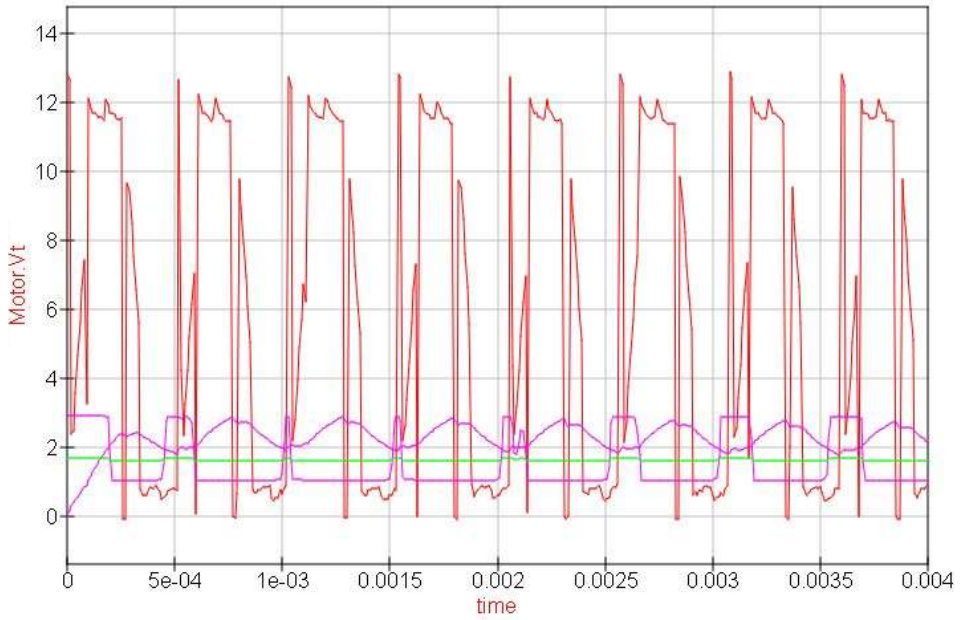
Rotor

Stator

3 Phases, 10 poles, 12 coils

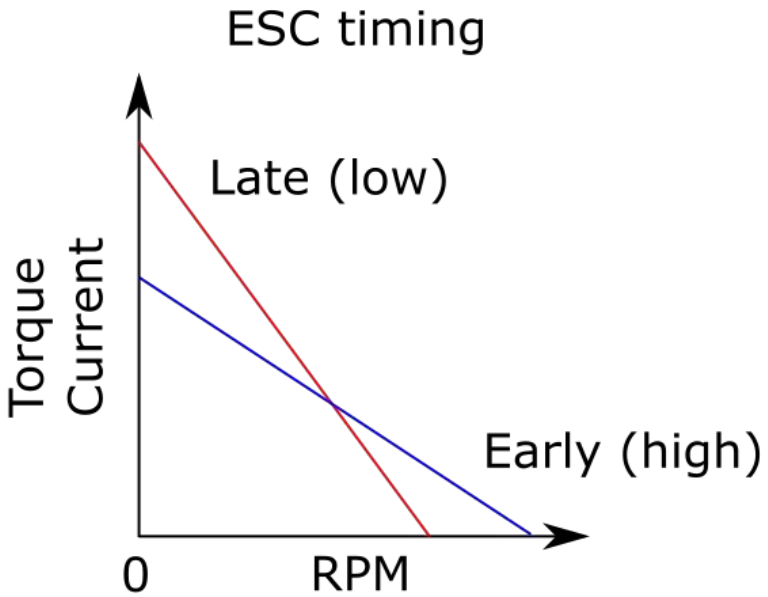
Note on ESC and phases

- Half sine wave or triangular wave.
- Generated by rapid switching of transistors.



Timing

- Phase timing changes Kv
- Dynamic timing can maximize power or efficiency.



Other effects

Bearing friction

No-load current

ESC settings

Thermal limitation

Propeller definition

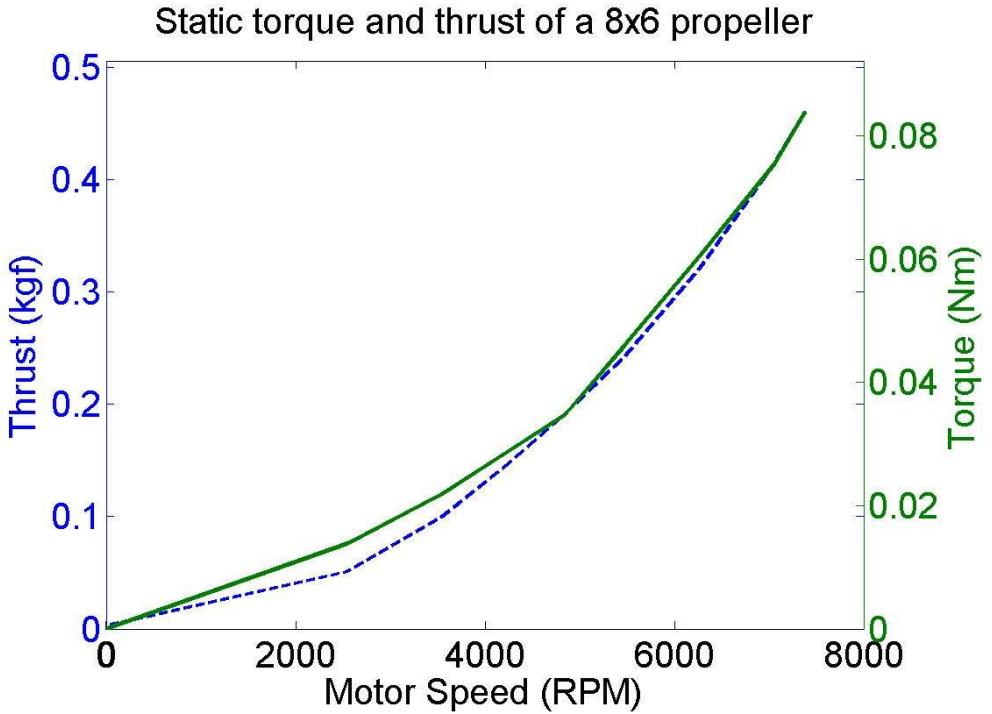
Diameter: usually in inches.

Pitch: How much the propeller would move forward in one turn in a gel like medium.

Static thrust

Thrust = C_T * speed^2

Torque = C_R * speed^2



Dynamic thrust

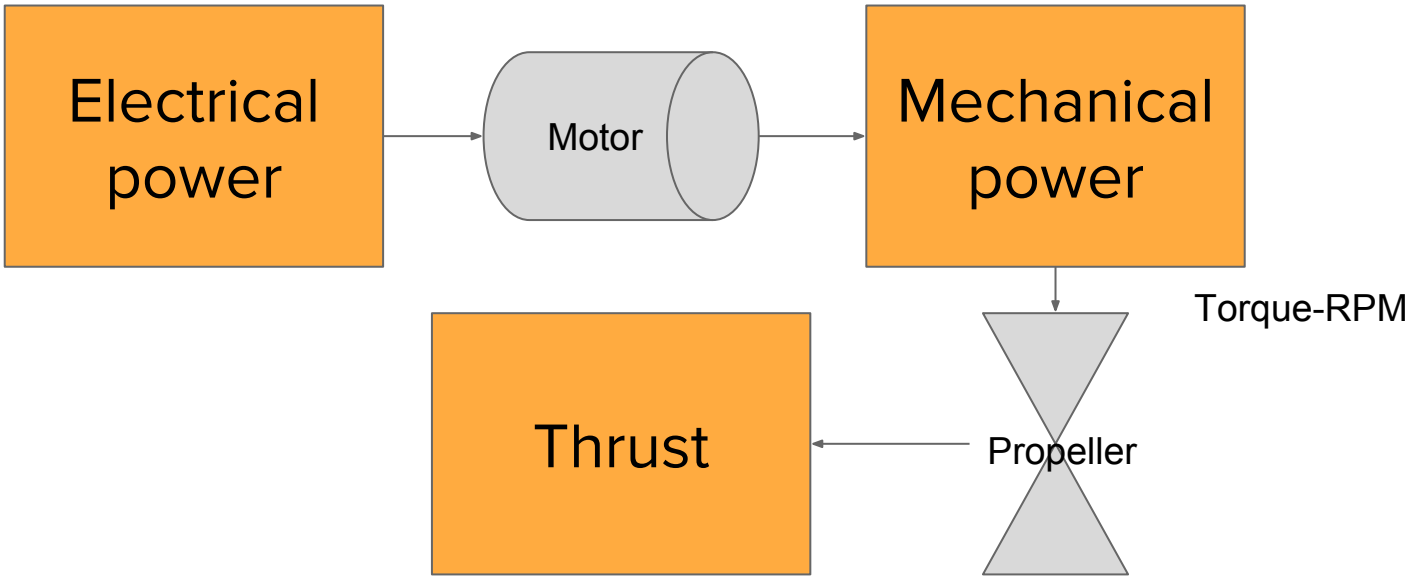
Higher airspeed: Use high pitch

Low airspeed: Use low pitch

Use equations to correct for airspeed.

Testing Efficiency

Motor efficiency * Propeller Efficiency = Overall efficiency



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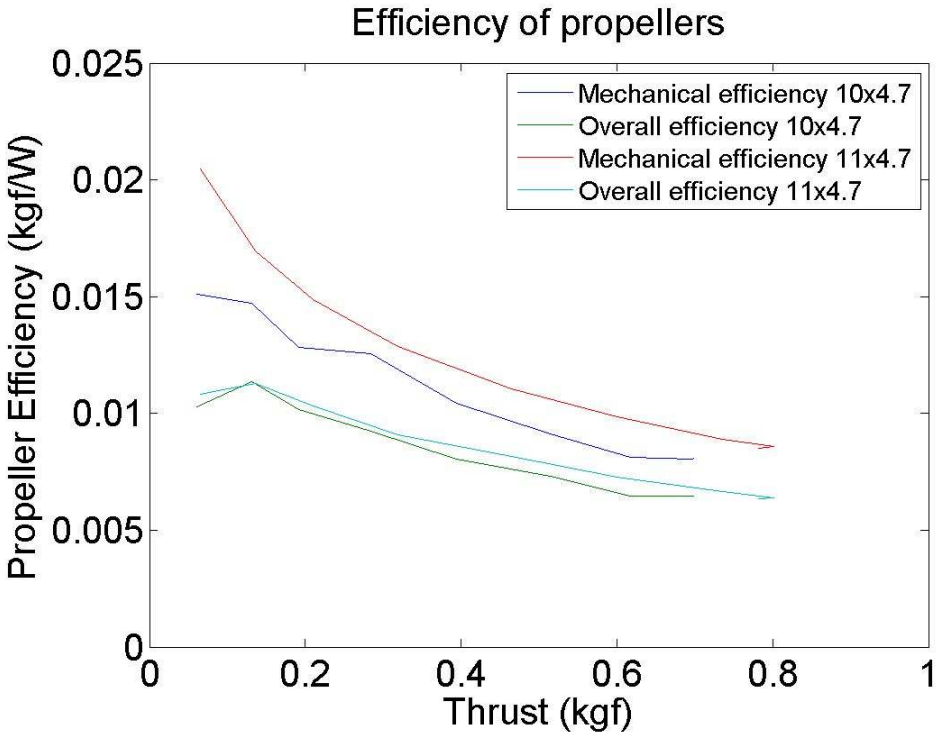
Propeller efficiency

Propeller Efficiency =

$$\frac{\text{Thrust}}{\text{Mechanical power}} =$$

Overall Efficiency =

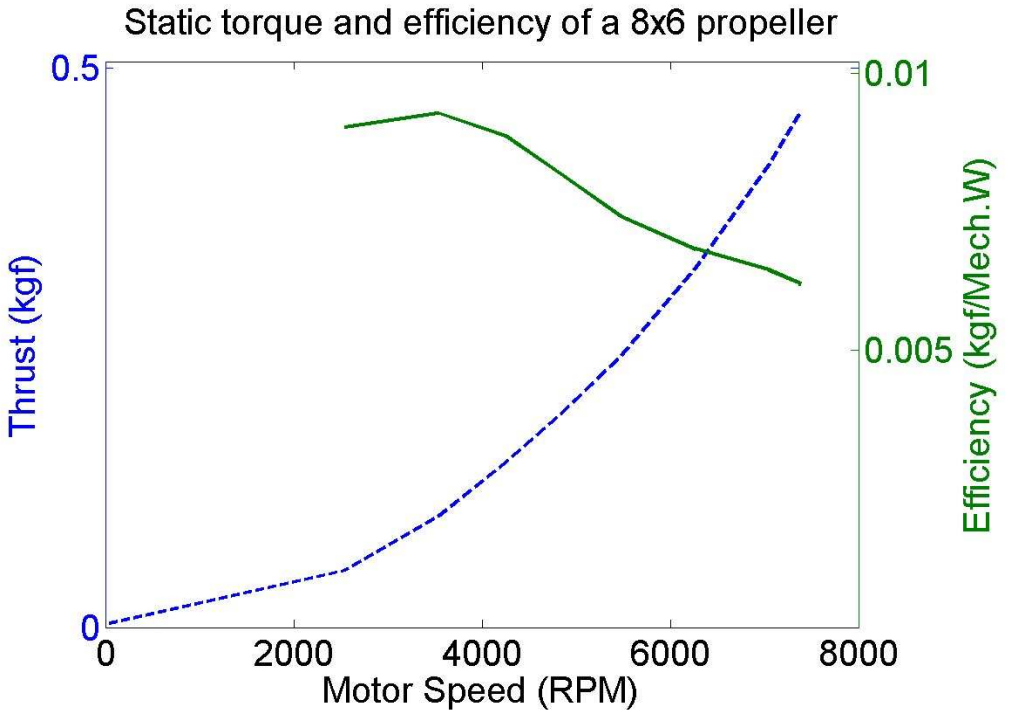
$$\frac{\text{Thrust}}{\text{Electrical power}} =$$



Propeller testing

Increase propeller efficiency with:

- Large propeller
- Slow propeller



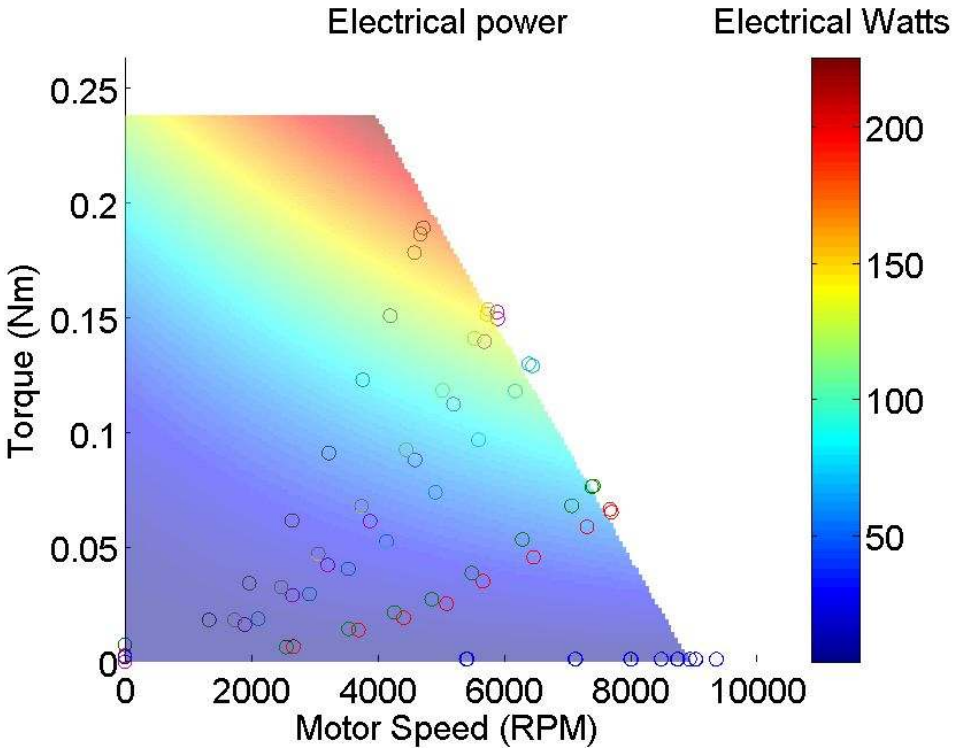
Motor testing

Objective:

Test multiple torque-RPM combinaison

Loading:

Load with propellers



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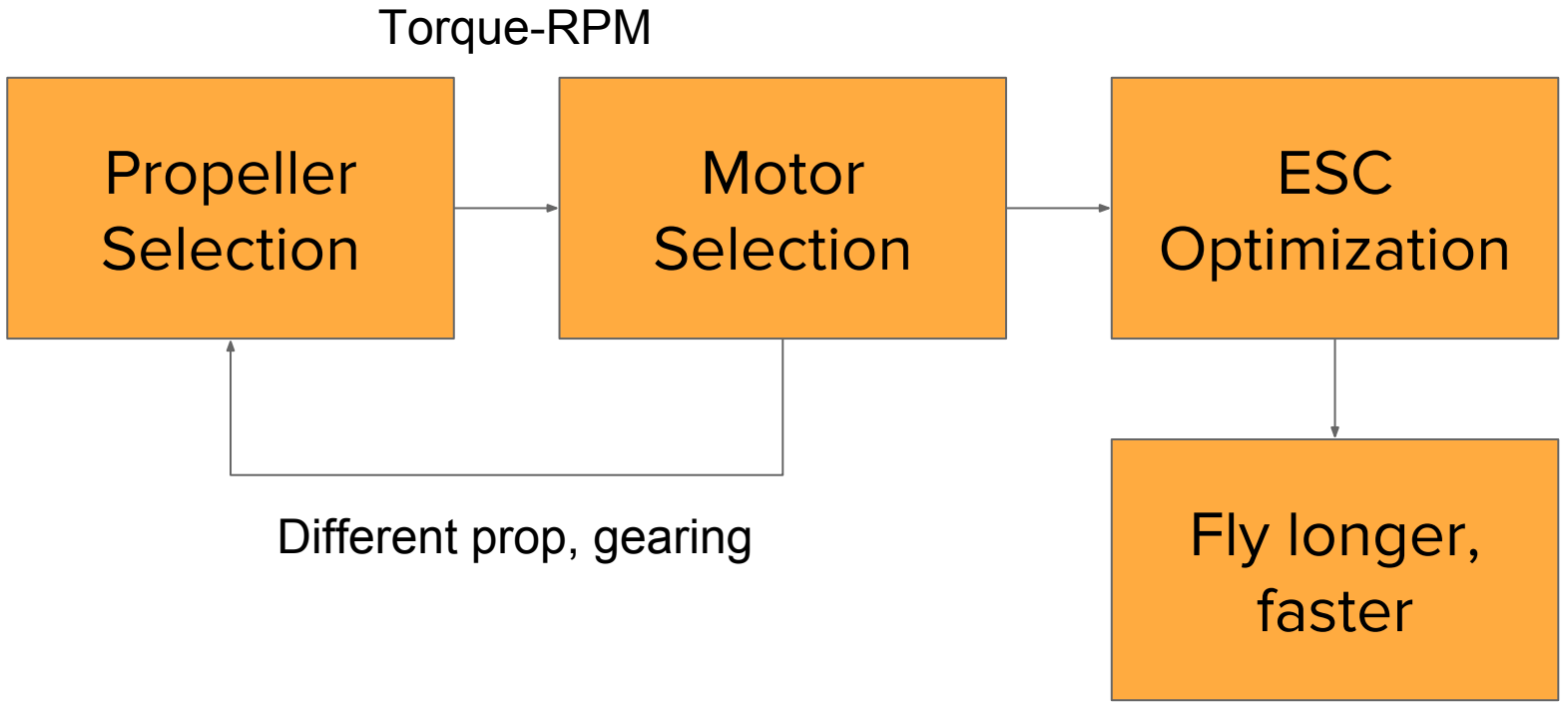
Selection of motor/propeller



RCbenchmark overview

- Thrust
- Torque
- RPM
- Voltage
- Current
- Mechanical power
- Electrical power
- Motor efficiency

- Propeller efficiency
- Overall efficiency
- Coil resistance

RCbenchmark overview

- Manual tests
- Automated tests
- Scripting

Questions?