Electric Motors And Batteries

Flightline Hobby, October 2018

This Year's Theme: Old vs New

Brushed vs Brushless

Rubber vs Electric

NiMH vs LiPO

Brushed Motor Physics

Brushed:

- Magnetic fields switched mechanically. Timing is fixed.
- Outrunners with stationary windings (surrounded by magnets) impractical.
- Brushed motors typically require gears to lower RPM for aircraft.

Brushed Motor Size Lingo

380, 390, 540, 550 etc. the number is *approximately* the length of the can (x10)

540 motor can is ~54 mm.

Aircraft cobalt: Graupner **“Speed 400” (~380). “Speed 600” (~560).**

380 class common for 1/18 scale cars (80 to 160 watts)* most > 30k RPM

540 class common for 1/10 scale cars (80 to 250+ watts)* most > 14k RPM

390 is a longer (upgrade) 380. 550 is a longer (upgrade) 540.

*Output ~ 50% of input

Brushed Motor Lingo

Turns: (Typically specified in any spec. racing class)

More turns = more wire in magnetic field, more torque, slower RPM

Few turns = less wire in magnetic field, more current, faster RPM

27 T motor typical for stock cars and trucks and geared cobalt airplane motors.

12 to 15 turn motors for fast / powerful cars and trucks.

More than 27 turns common for slow trucks and crawlers.

Changing from 27T to 13T will increase current draw! May need heat sink.

Brushed Motor Advantages

Titan 550 $15.99

Inexpensive.

Inexpensive speed controller.

Mechanical resistor or switch can control motor.

Mechanical timing provides precise low speed control. Motor of choice for crawlers.

Old school cool.

Brushed Motor Disadvantages

Brushes wear out.

All are “inrunners”, no load speeds 15k to 50k RPM.

Gear reduction typically required.

Efficiency ~ 50%

Brushless Motor Advantages

No brushes to wear, power remains constant with use.**

**Power will drop if magnets get hot.

**Magnetic resistance to temperature = $$

Outrunners possible, RPMs < 12k RPM.

Gear reduction not required for aircraft.

Higher efficiency possible (~85%). Greater run time.

540 Car Brushless Motor Upgrade

Tazer Twin ESC and BL motor upgrade for 1/10 scale cars

3000 Kv 2S lipo (8.4v) 45 amp max. **That's 375 watts!**

3000 Kv at 8.4v = 25,000 rpm no load

$89.99

Eflite & Rimfire Brushless Motor Sizes

“Park” 180 to 480 designations ***approximate*** brushed motor power (not size)

- 480 approximately 200 watts

“Power” .10, .15, .25 on up ***approximate*** glow engine power.

- Power .10 approximately 450 watts

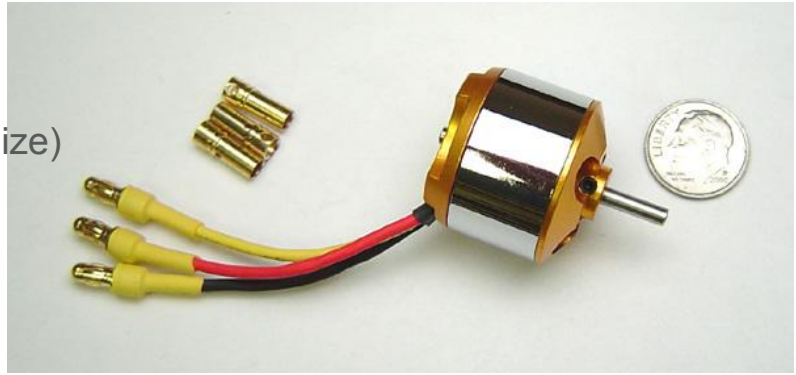
However, torque and RPM don’t always translate. **What matters is watts.**

100 to 125 watts / lbs for sport flying

200 watts / lbs for 3D flying

Cheetah Brushless Motor Sizes

- A2212-15
  - 22 mm case diameter
  - 12 mm case length
  - 15 turn (if omitted, only one configuration in that size)
- Bigger case = more power
- More turns = more torque = lower kV rating



kV x voltage = no load RPM.

For A2212-15 133W 12A max motor, kV = 930.

On 3S (~12 V) no load speed = 930 * 12 = 1160 RPM

Electric Motors in a Nutshell

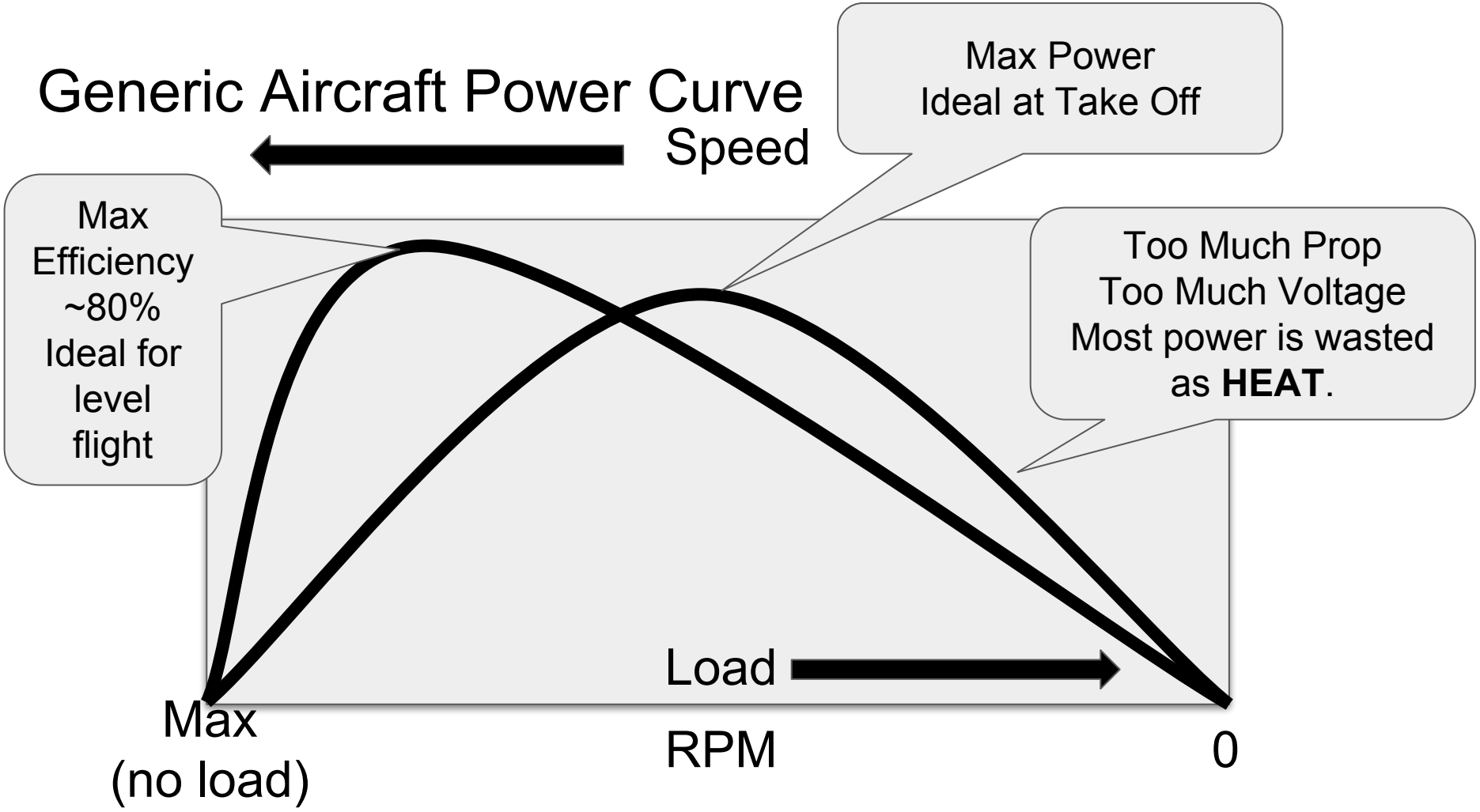
Voltage ~ RPM

Amperage ~ Load

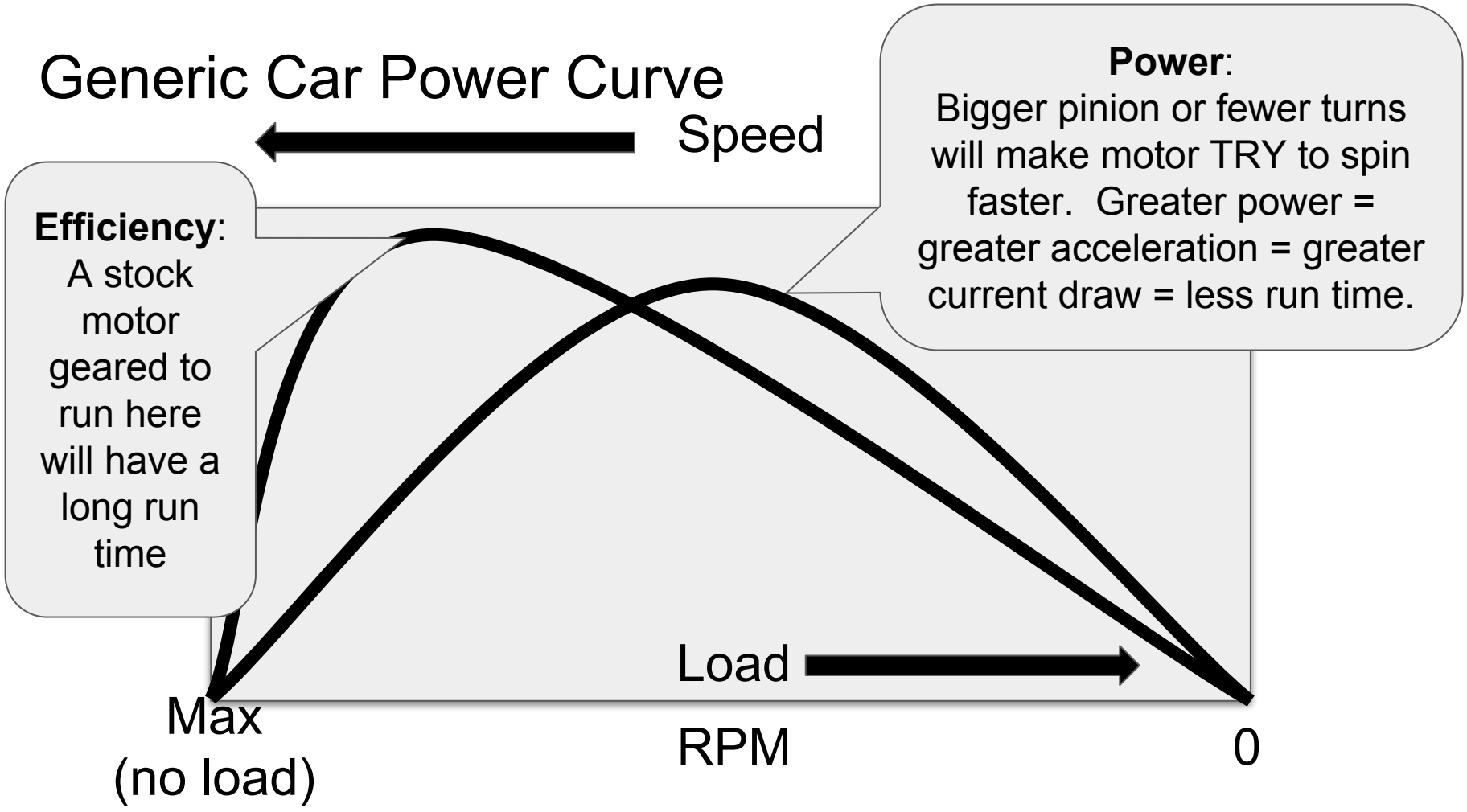
Larger pinion and/or smaller spur gear = more load!

Larger diameter and/or greater pitch = more load!

More voltage = more RPM = more load!


Generic Aircraft Power Curve
Speed
Max Power
Ideal at Take Off
Max
Efficiency
~80%
Ideal for
level
flight
Too Much Prop
Too Much Voltage
Most power is wasted
as **HEAT**.
Load
Max
(no load)
RPM
0

Generic Car Power Curve



For Aircraft, First Priority is Power

70 to 100 watts / lb: Scale Flying

100 to 130 watts / lb: Sport Flying

> 180 watts / lb: 3D Flying

Speed

- At 10,500 RPM:
  - Pitch Speed (mph) = Pitch (inches) * 10
  - For example: 10 x 7 prop - 70 mph
- No load Motor RPM = voltage * kV
  - For Example 12 volts * 980 kV = 11,760 RPM
  - Approx. 80% or 9,400 RPM with prop drag.

Common Design Solutions

- UMX Waco (2S 240 mah)
- 3.5 oz, ~17 watts*
- ~80 watts/lb
- 5.75” x 2.5” prop
- 3000 kV * 8 volts = 24,000 RPM
- Tip speed ~ 67% SS
- Pitch Speed ~ 45 mph

*Watts estimated, no specifications found.

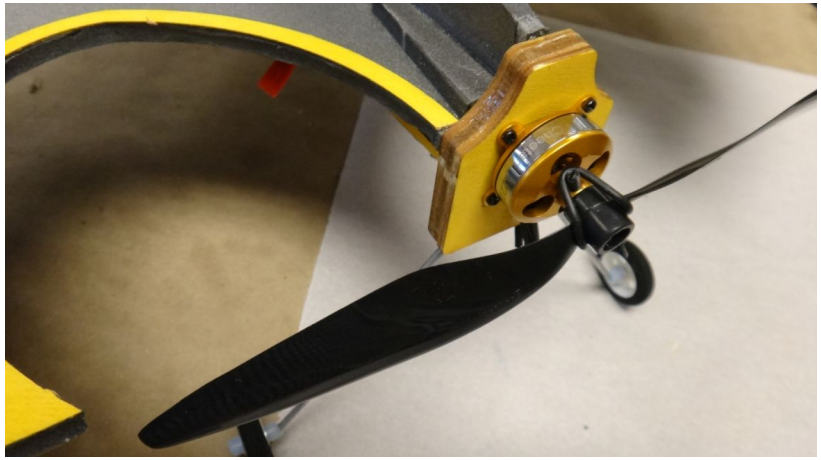
Approximate Rubber Comparison

- 8 strands, 30” long, 1.36 oz.*
- 10 oz-in 800 turns ~ 70 N.mm x 5,000 radians
- ~350 joules, assuming a motor run of 30 sec.:
- 350/30 = 12 watts!
- Power similar to UMX, but run times less and mass 2 x UMX battery mass.

*William F. McCombs “Flying and Improving Scale Model Aircraft”

Common Design Solutions

- Foamie (2S 450 mah)
- 7 oz, ~46 watts
- ~105 watts/lb
- 8” x 4.3” prop
- 1400 kV * 8 volts = 11,200 RPM
- Tip speed ~ 44% SS (slow flyer)
- Pitch Speed ~ 37 mph



Common Design Solutions

- PT-17 (3S 2200 mah)
- 51 oz, ~450 watts*
- ~141 watts/lb
- 11” x 7” prop
- 880 kV * 12 volts = 10,560 RPM
- Tip speed ~ 57% SS
- Pitch Speed ~ 56 mph

*Watts estimated, no specifications found.

Common Design Solutions

- 25e Super Cub (4S 3200 mah)
- 6 lbs, 600 watts
- 100 watts/lb
- 14” x 7” prop
- 870 kV * 12 volts = 10,440 RPM
- Tip speed = 72% SS
- Pitch Speed ~ 56 mph

What is Consistent in a Balanced System

- ~ 100 watts / lb
- Tip speed ~ 2/3 the speed of sound
- Pitch speed of 35 to 55 mph
- RPM similar to glow engines
  - .049 turned > 20,000 RPM
  - Larger glow - 8,000 to 9,000 RPM on bench, ~10,000 to 11,000 RPM in the air.

NiMH vs LiPO Batteries

- NiMH heavier than LiPO batteries
- In cars with run times > 15 min (< 4 C) NiMH batteries provide durable effective power.
- In cars and airplanes with run times of ~ 6 min (~ 10 C) LiPO batteries more capable of delivering peak current (~ 20 C peaks)

Battery Letter Designations

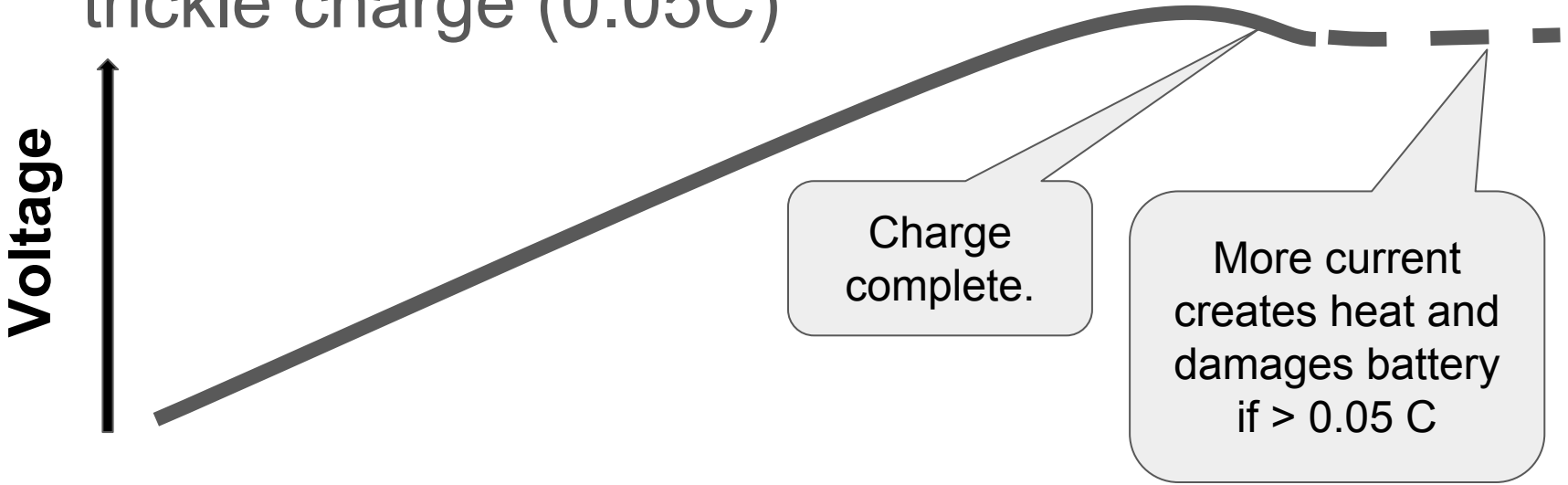
- **S - “Series”** i.e. 3S (3 cells in series)
  - Voltage adds.
    - 3S LiPO max voltage = 3 x 4.2 = 12.6v
    - 3S LiPO min voltage ~ 3 x 3.7 = 11.1v
- **P - “Parallel”** i.e. 3P (3 cells in parallel)
  - Voltage same as 1 cell, capacity increases
- **C - Charge (and Discharge) Rate**

Battery Charging Rates

- “Fast” charge at 1C **with proper charger**
  - Fastest recommended for NiMH
  - Conservative for LiPO
    - Ensures they remain cool and balanced
    - Helps extend life
- i.e. for a 2300 mAh battery:
  - 1C = 2300 mA (for one hour) = **2.3 amps**

NiMH Battery Charging Physics

- Constant current until voltage sags (1C) or trickle charge (0.05C)

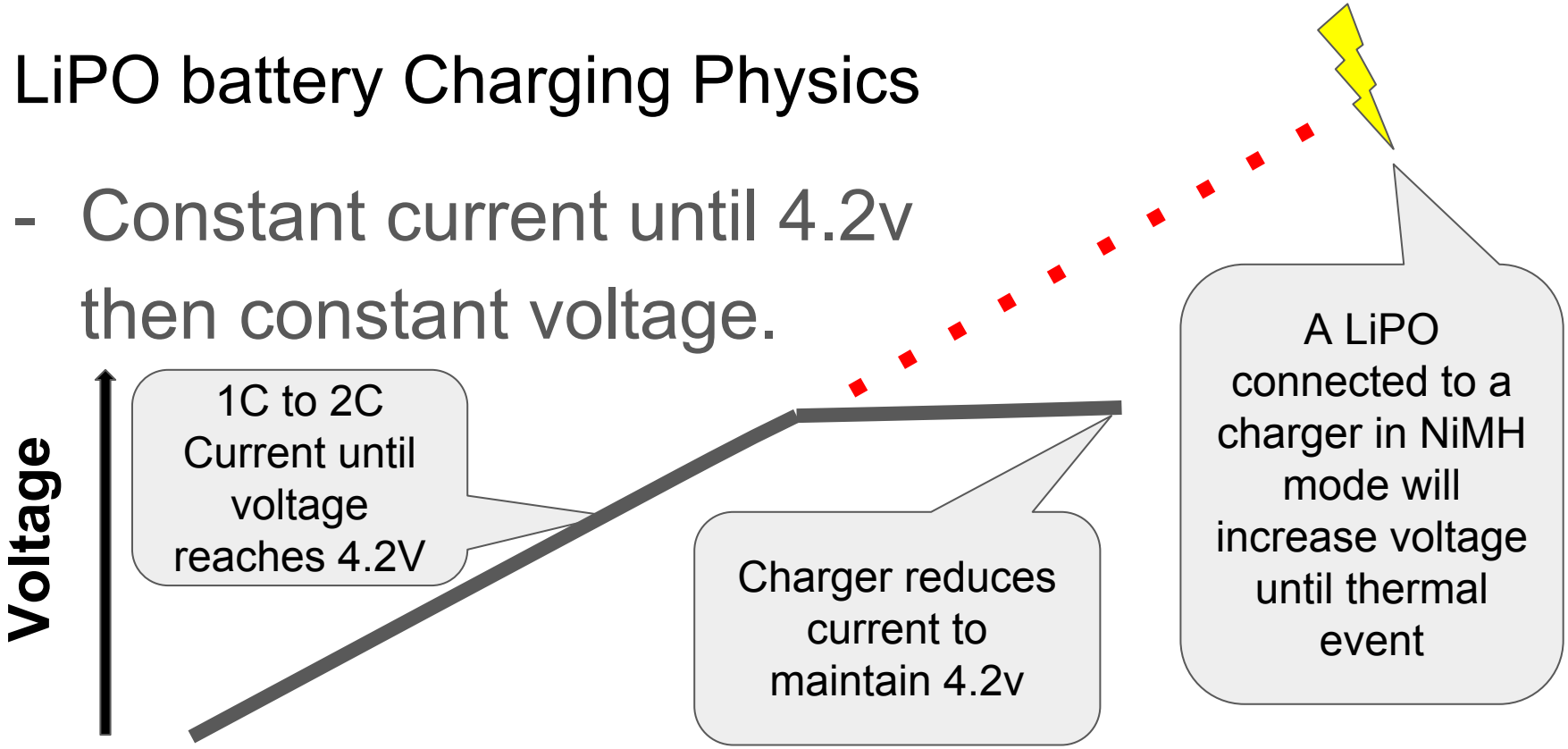


Battery Charging Physics

- NiMH: Constant current until voltage sags (1C) or trickle charge (0.05C)
  - For a 2200 mAh battery:
    - 1C = 2.2 amps
    - 0.05C = C/20 = 0.11 ~.1 amps

LiPO battery Charging Physics

- Constant current until 4.2v then constant voltage.



Battery Storage

- NiMH
  - Will lose charge
  - Periodically recharge / trickle charge (1/20C)
- LiPO
  - Will hold charge, but may puff if stored full
  - Best storage voltage around 3.80 to 3.85v
  - Never below 3.74v per cell for max life

Flightline Chargers

- Entry level charger - Prophet Sport Mini 50W
  - AC powered, 50W
  - Up to 4A, less for 4S, 4S max
  - Indicator lights
  - $24.99

Flightline Chargers

- Mid level charger - Traxxas Peak ID charger
  - AC powered
  - ID function with Traxxas batteries ensures proper charger setting
  - $49.99

Flightline Chargers

- AC/DC power charger - RDX Pro 1
  - AC/DC powered 100 watt
  - Up to 10 amps
  - **6S pack at 4 amps**
    - (i.e. 6S 4000 mAh at 1C)
  - $69.99

Flightline Chargers

- UMX charger - Ultra Micro 4
  - AC /DC powered 4 x 9 watt
  - Charges 1S and 2S batteries for UMX planes, helis and quads
  - Four ports
  - $54.99