Golden Skies R/C

Electric Powered Aircraft

Design - Selection Process & Considerations

The Basics

Presented by

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Copies of this presentation may be obtained on the website

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What we will accomplish

1. De-mystify the Terminology
2. Determine how much Power "Watts" you need.
3. Select a Motor
4. Establish the Size and Type of Battery you will be using
    1. The "S" and "P" of the battery pack
5. Choose a Speed Controller.

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Terminology

Series (S)	Parallel (P)	KV
Horse Power (hp)	Power	Watts
Volts	Current	Resistance
Energy	**m**illi-**A**mps (mA)	**m**illl-**A**mp-**H**ours (mAh)
Efficiency	Internal Resistance	Max Voltage
Capacity (C)	Burst Rating	Multiple “C” Rating

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Terminology

Fortunately, for all practical purposes, we only need to use a few selected parameter to properly select the Motor, Battery & Speed Controller:

Series (S)	Parallel (P)	KV
Horse Power (hp)	Power	Watts
Volts	Current	Resistance
Energy	**m**illi-**A**mps (mA)	**m**illl-**A**mp-**H**ours (mAh)
Efficiency	Internal Resistance	Max Voltage
Capacity (C)	Burst Rating	Multiple “C” Rating

Red – Battery Related Blue – Motor Related

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Term	Definition	Correlation
Volts	Force	The Nitro in Fuel
mAh (*)	Flight Time	Gas in Tank
KV	Motor rpm/volt	Propeller Speed
Capacity (*)	# of mAh in Bat	Size of Fuel Tank
Series (S)	# of Batteries in row	Determines Voltage
Parallel (P)	# of Batteries in row	Determines Flight Time

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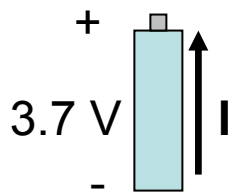
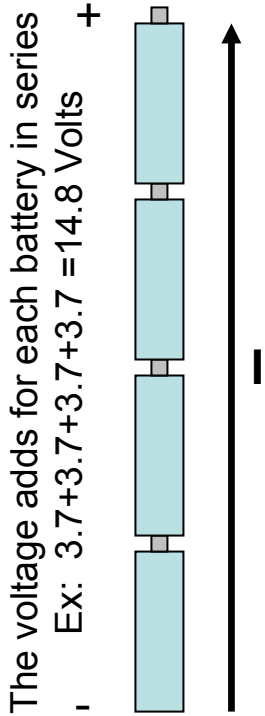
Appendix A: Series and Parallel Battery Configurations

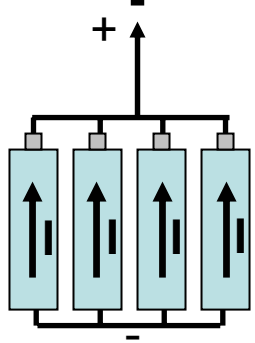
Cell Voltage Based upon Typical LiPo Cells.



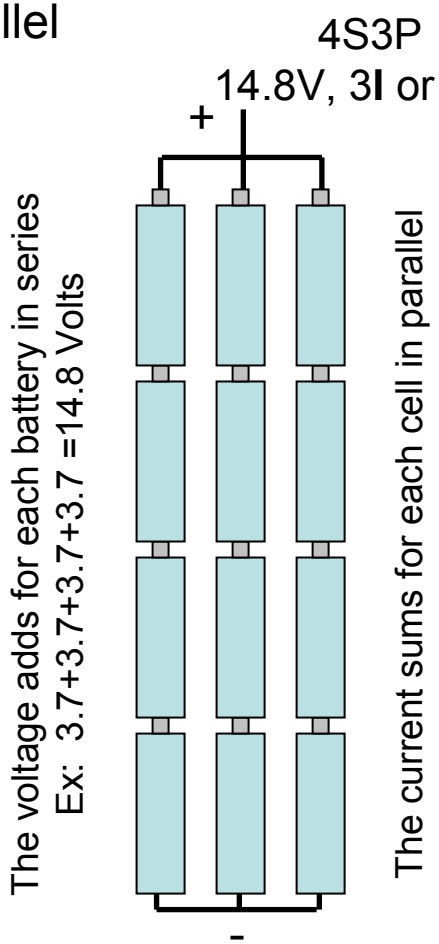
A Single Cell Battery



Four batteries In Series or "4S"



Four batteries in Parallel or "4P"



12 batteries: 4 Series 3 parallel or 4S3P

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Terminology

The Tribal Knowledge of Fuel Engines Planes *relative* to Electric Powered Aircraft.

General:

Volt: The potential ("Force") to get work done. (V)

- Think of the battery voltage as the Nitro-content of glow fuel.

mAh: milli-Amp-hours (mAh)

- Think of this as the amount of Fuel you have in your tank

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Terminology

Common Terms and Terminology in Electric Powered Aircraft

Motors: 1. **KV** or engine rpm per Volt applied.

2. ~~Efficiency~~ or ratio of output vs. input power = Po/Pi

Batteries: 1. "C" **C**apacity of a single battery cell (in mAh)

The Total (typical) Battery Current "**I**" **over time**,

(note do not confuse with Amps)

2. "S" **S**eries (the number of battery cells in a row)

o Increases Voltage or "potential"

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Terminology

Batteries Continued

3. "P" **P**arallel (The number of battery cells or row of cells in parallel

   o Increases the Overall 'mAh" or Capacity

   (Note: Do not confuse with Capacity of a single cell, but rather Multiples of C

4. "mAh" (The total current over time in each cell of battery pack)
   Sometimes thought of as "*ENERGY*" but is Capacity.

5. Rating: (The multiples of "C" , in current "**I**" that can be continuously drawn out of the battery.

   This is not Amp-hours but Amps!

6. Burst: The SHORT TERM blast of current that the battery is compatible of delivering. Short term may or may not be defined by the battery manufacturer.

For a Review of Series and Parallel Battery Configurations, see Appendix A

The Basic Equations

Electronic Physical Laws & Definitions

1. **V** = I*R V = Volts, I = Current, R = Resistance, (Ohm's Law)
2. **P** = V*I V = Volts, I = Current, P = Power (measured in Watts)
3. **E** = P*t E = Energy, P = power, t = time (watt-seconds = Joules)

(E = V*I*t or E = V * mAh)

➢ Horse-Power "hp": 1hp = 745.7 Watts

QUESTIONS ?

Is everybody OK and with us so far?

The Component Selection Process

1. Determine Flying Style and Plane Weight
2. From Power-Requirement Chart, obtain total wattage needed: **P**
3. Select motor based on prop rpm and Motor "KV" (rpm/volt): **V**
4. Calculate number of LiPo cells as: **V** / 3.7 = # of Cells in Series
5. Calculate maximum current (I) to satisfy power requirement: **I** = **P** / **V**
6. Choose Motor based upon max current **I**
7. Select Batteries parallel cells: (Flight-time * **I**) / **C** (mAh) = P' # of Cells in Parallel
8. Select Electronic Speed Controller (ESP) based on **I** and "features, BEC, etc.

Let' Get Started

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Let's get Started and use the GSRC CrossFire 320E as an example and convert it to an Electric Powered Aircraft.

The CrossFire's Flight Parameters are;

1. Engine: YS-110 FZ
2. Prop: APC 15x8
3. rpm ~9,500 – 10,000
4. Weight: 7.5 - 8.5 lbs
5. Flying Style: Aggressive 3D and Free-style
6. Fuel Tank: 16 oz (15-20 minute flights)
7. 4-ch, 5-servos.
8. Span: 64" Wing Area: 779 in ^{2}

The Design Process or How do I get from here into the Air

Step 1. Determine the Flight Power Requirements

The Process:

1. Decide how you want to fly the plane!
   a. Trainer, Sport-Aerobatic, Advanced Aerobatic, 3-D Free-Style
2. Determine the final flying weight of the Plane (8.5lbs)
3. Use Power-chart to determine the total POWER (Watts) needed for your flying style and plane's weight.

Power (in watts/pound)

Required to perform the Four Flying Styles

Trainer	Sport Aerobatic	Advanced Sport Aerobatic	3-D & Free Style
50 watts/lb	80 Watts/lb	100 Watts/lb	150 Watts/lb

Where do these numbers come from?
(See Chart on Slide 11)

NOTE: In a more pure aerodynamic sense, one should develop the power requirements from propeller THRUST DATA, but that is beyond the scope of this presentation.

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Flight Power Requirements for Model Aircraft.

General Assumptions

These are "Tried and True" Assumptions based upon empirical and experimental data over the years.

General Assumptions:					
1:	0.25	hp per pound (total Plane weight) for Sport Aerobatic Performance			
2:	0.31	hp per pound (total Plane weight) for 3-D & Free Style Performance			
3:	745.7	watts per Horse-Power (hp)			
4:	Trainer	Sport Aerobatic	Advanced Aerobatics	3-D & Free Style	
	50	**80**	**100**	**150**	**Watts per pound Required for the four Flying Performance Styles**
5:	100%	Motor Conversion Efficiency = Watts in / Watts out			

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	Electric Aircraft Input Power Requirements (watts)			
Plane Weight (lbs)	Trainer	Sport Aerobatic	Advanced Aerobatics	3-D & Free Style
1	50	80	100	150
1.5	75	120	150	225
2	100	160	200	300
2.5	125	200	250	375
3	150	240	300	450
3.5	175	280	350	525
4	200	320	400	600
4.5	225	360	450	675
5	250	400	500	750
5.5	275	440	550	825
6	300	480	600	900
6.5	325	520	650	975
7	350	560	700	1050
7.5	375	600	750	1125
8	400	640	800	1200
8.5	425	680	850	1275

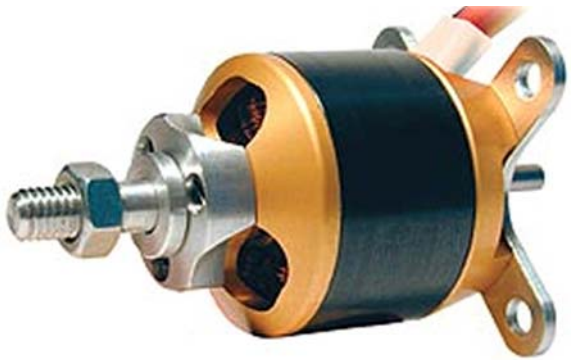
Complete Chart available on Golden Skies R/C Website

www.goldenskiesrc.com

Step 2: Determine the Motor type

The Process:

1. Determine the Prop rpm:
   - Based on the plane's size, weight, profile, etc. and the typical fuel engine, prop size establish the prop rpm you would need to fly. (ex: 10,000 rpm)



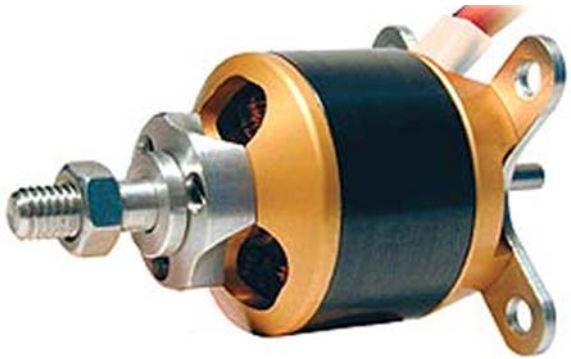
AXI 4130-16

Let's pause and look at a

Typical Motor Specification Sheet

Typical Motor Specification Sheet

AXI 4130-16®



No. of Cells	16-24 Ni-CAD 5-8 Li-Poly
KV (rpm/V)	390
Max. Efficiency	88%
Efficient Current (max)	18-40 Amps
Current Capacity	60A / 50sec
Dimensions (OD, L)	49.8 x 65.5 mm
Shaft Diameter	6 mm
Weight (w/cables)	409g (14.4 oz)
Recommended Gear Box	None

2. Calculate the Battery Voltage Required to deliver the rpm:

   a. Using the motors specifications, select an appropriate motor:

   b. Start with the KV or rpm / volt

      - Ex: If you want to run a 15 x 8 prop at 10,000 rpm
        choose a KV parameter to realistically get 10,000 rpm
        within the confines of the battery parameters and
        power requirements…… here's how ….
        For an AXI 4130-16, where **KV = 390 rpm/volt**

   c. Calculate the Battery Voltage:

      •Divide the rpm by the KV

      10,000 rpm / 390rpm/v = 25.6 Volts that the battery must supply*

      (* not considering motor efficiency)

d. Calculate the number Cells or "S" to deliver the Required Voltage:
   - Divide the Required Voltage by the Lipo Voltage per cell
     - A LiPo cell has ~ 3.7 Volts (under load)
   - 25.6 V / 3.7 V/cell = 6.9 cells

e. We will round 6.9 cells off to 7 cells or 25.9 Volts (7 * 3.7V)

3. Determine the Current needed to deliver 1275 watts with a battery voltage of 25.9 Volts ….. Refer to slide 12

   P = VI or I = P/V

   I = 1275 / 25.9 = 49.2 Amps (max)

   I = 49 Amps (rounded off)

4. Check the current requirements against the motor current rating

   AXI 4130-16 efficient current rating is 18 – 40 Amps

   OK?

5. Check the current requirements against the batteries' current rating specification. The battery on, slide 18, is rated at 12C where C = 4000 mAh, or 4 Ah, and 12C = 48 Amps.

   OK? ….. Let's see

Typical Battery Specifications & Terminology

TP4000-3S2P

4000 mAh, 11.1V (charge as 3 cells), 13G wire, 4-pin balancer connector
Rating: 12C(48A) continuous, 20C(80A) burst
Dimension: 50mm x 185mm x 17mm
Weight: 255gm

Note: 1 LiPo cell = ~ 3.7 Volts

6. Determine the “C” of the Battery by desired flight time

Well, now how long can we, or do we, want to Fly?

This is determined by the mAh rating of the battery.

Assumptions:

a. What will be the average throttle setting for the flight?

- 65-70% based on “average” flying

therefore 65% times 48 Amps = 31.2 Amp (average)

b. Say we want to fly for fifteen (15) minutes

- To determine the Amp-hour capacity of the battery

15 min * 31.2 Amps = 468 Am = 7.8 Ah (468Am/60min/hr = 7.8 Ah)

If the battery = 4 Ah then 7.8/4 = 1.92 cells in parallel

OK? …… Maybe

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- We will round the number of parallel cells up from 1.92 to 2
- 2 is the "**P**" part of the battery pack specification.

- Now we have determined the Battery Pack configuration as
  - **7S2P**

8. Should we consider a different battery, one with a higher mAh rating or Capacity?

   First Consider the 65% average current draw assumption.

   In a 3D hover, at what power setting does one hover?

   ans: ~ 1/3 power level, or 15.4 Amps

   so the 65% assumption should be OK.

Step 4: Select an Electronic Speed Controller:

1. Select for the maximum current to be drawn.

   - ~ 49 Amp (slide 17)

   - Add a 10 – 15% safety margin

     o 1.15 * 49 = 56.4 Amps

b. A Castle Creation “Phoenix-60” ® would be adequate.

c. Finally, consider the Battery Eliminator Circuit” (BEC” option)

® *Registered Trademark of Castle Creation*

Step 5: Wire gage Considerations:

Current Capacity of Copper Wire

AWG Size	Single Copper Wire (Amps)	3-Wire Cable (Amps)
16	n/a	n/a
14	25	20
12	30	25
10	40	30
8	60	40
6	80	55
4	100	70

Results

Motor: AXI 4130-16 ©

Battery: 25.9 Volts, ~ 7.8 Ah (approx. 7S2P)

ESC: Phoenix-60 ™

BEC: Switch (lightest, w/ 1.5 A capacity in the BEC power line)

Wire Gage: 10 AWG, single conductor

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Summary

1. Determine Flying Style and Plane Weight
2. From Power-Requirement Chart, obtain total wattage needed: **P**
3. Select motor based on prop rpm and Motor "KV" (rpm/volt): **V**
4. Calculate number of LiPo cells as: **V** / 3.7 = # of Cells in Series
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Good Flying

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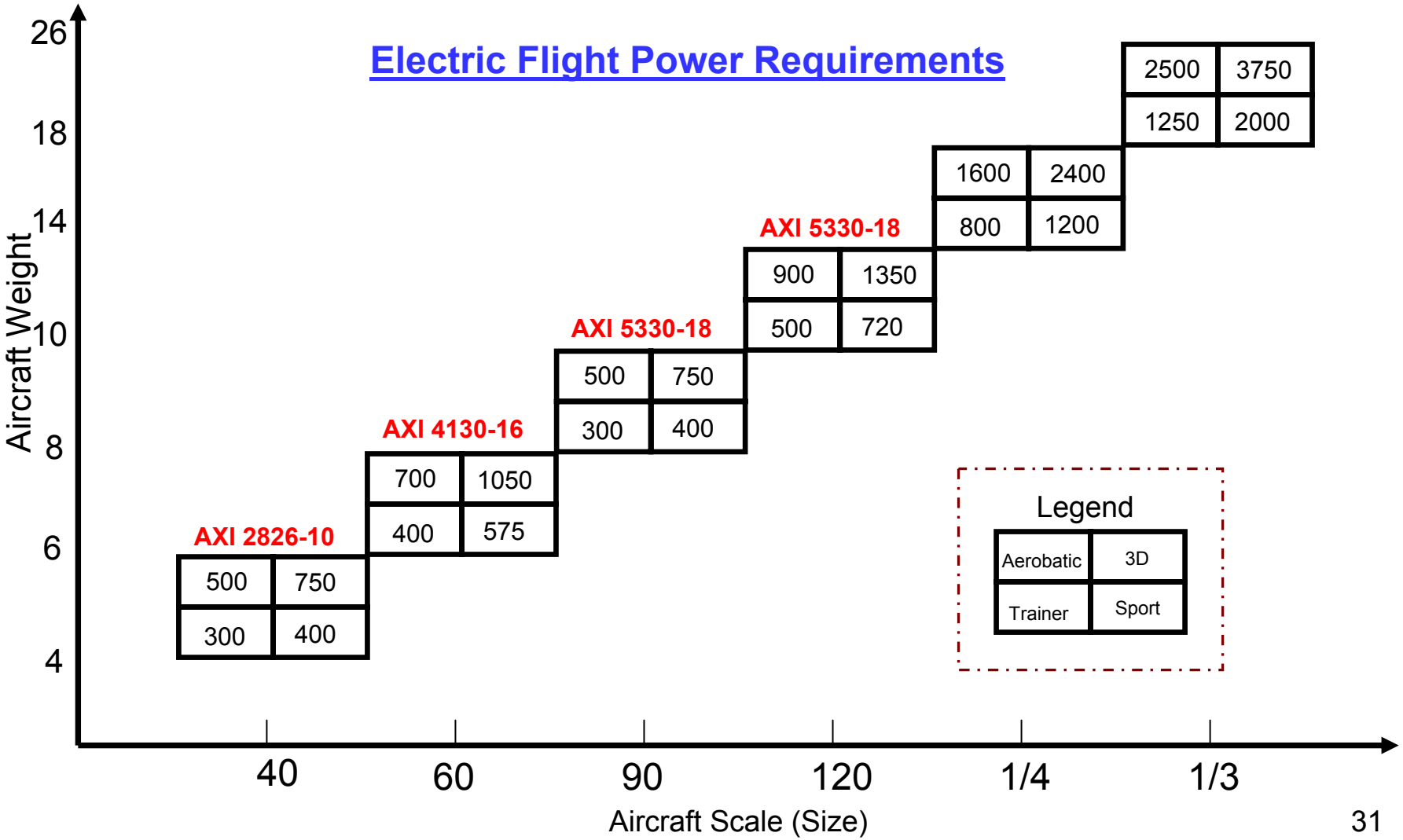
Electric Flight Power Requirements



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GSRC Aircraft ready for Electric Flight

Type: Precision, Sport Aerobatic & 3D Capable

Span: 64 inches; Wing Area: 779 in ^{2}

Length: 60 inches

Weight: 6.5 to 8 lbs

Engine: AXI 4130-16, Battery 7SxP 4000 mAh

Type: 3D – Free Style, & Stable Sport Aerobatic

Span: 64” Wing Area: 936 in ^{2}

Length: 60-1/2 inches

Weight: ~ 7.5 lbs

Engine: AXI 4130-16, Battery 7S3P, 5000 – 7000 mAh

Motor and Battery Mounting Considerations

- Cooling
- Motor Mount Methods
- Battery Access
- Weight Distribution (Pitch C/G)
- Charging
- Safety

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Appendix B: "Typical" Circuit Diagram

Bampf 3D Extreme

CrossFire 320E

1 Consideration must be given to the main battery potential failure or a Low Voltage situation and thus not being able to provide power to the receiver and thus control of the aircraft. Many choose to use a separate battery to power the receiver.

2 Some motors and/or speed controllers may not be able to "tolerate" the imbalance that may be created by the "Safety-Fuse-Switch".

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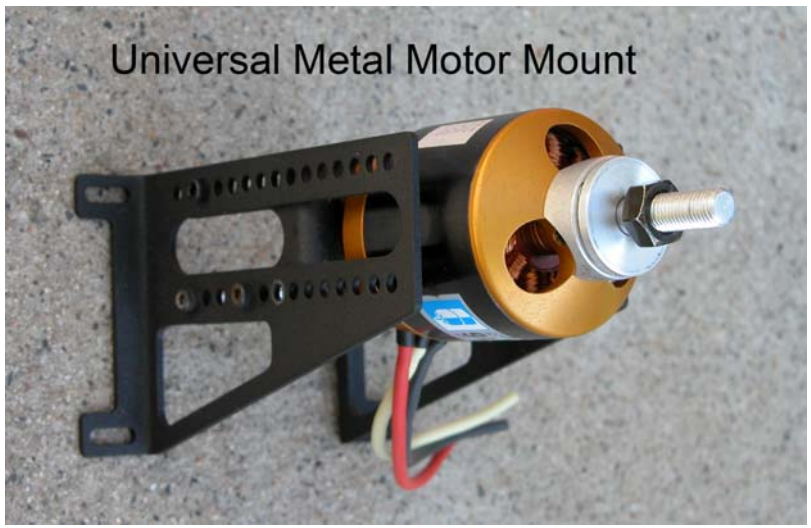
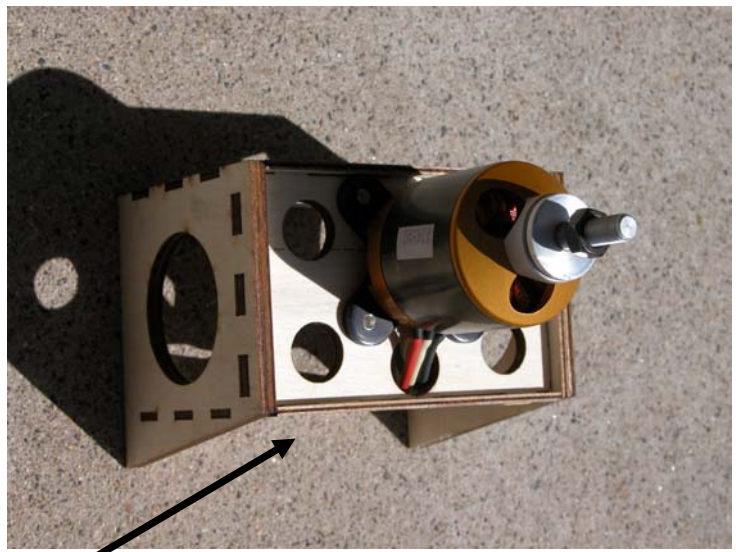
Motor Mounting





GS R/C provides custom motor and battery mounts for each of our ARFs
With cooling considerations designed in.

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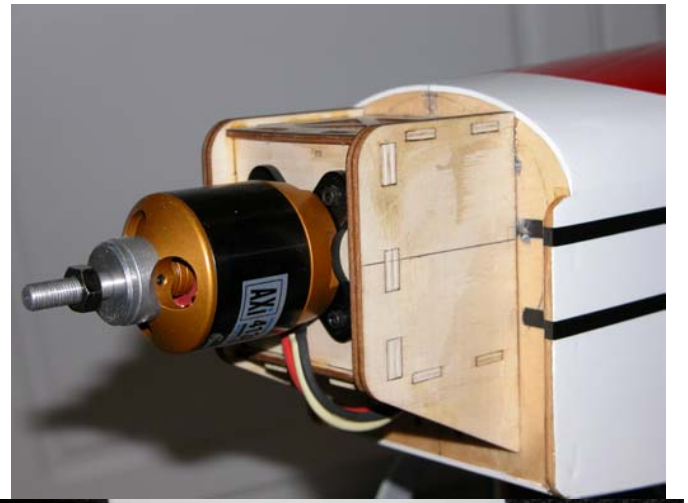
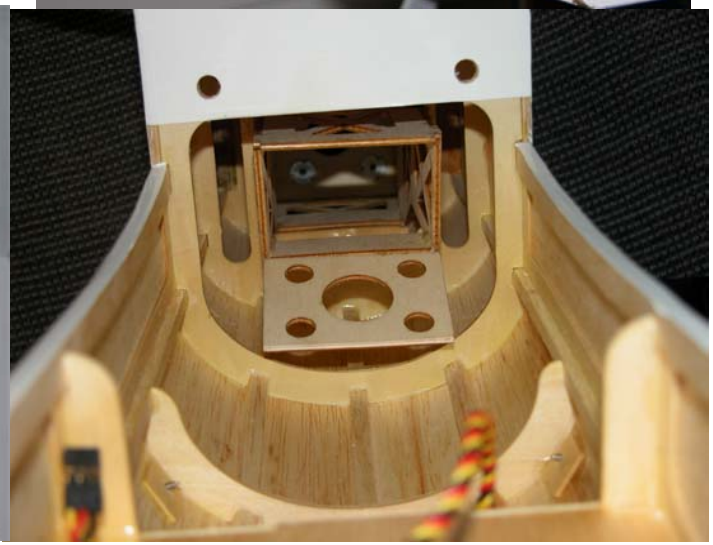
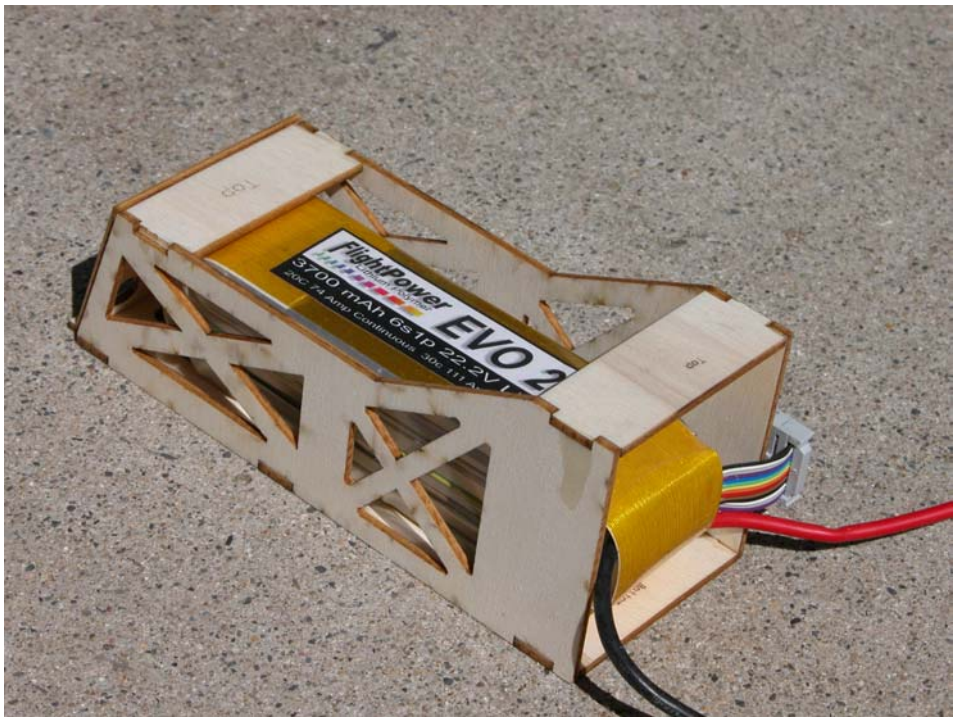




Battery Box



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Battery Box and Motor Mount on the CS R/C CrossFire 320E

Battery Box Mounted in Firewall cut out
Battery is accessible through wing saddle

Motor mount Slips over Battery box and
Secures to battery box and Firewall

Thrust offsets are preserved by Design

Thank You For Attending
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Electric Flight Basics