XuGong Foldable

BUILD LOG

Preliminary: v0.1 - 28 Nov 2013

ImmersionRC Real Virtuality

Important Note:

This build log is currently a work in progress that can really benefit from input from anyone using it. Please send any suggestions/updates to info@immersionrc.com and we will be delighted to incorporate them in the manual.
A video build log is in progress and will be released shortly.

Pre-requisites

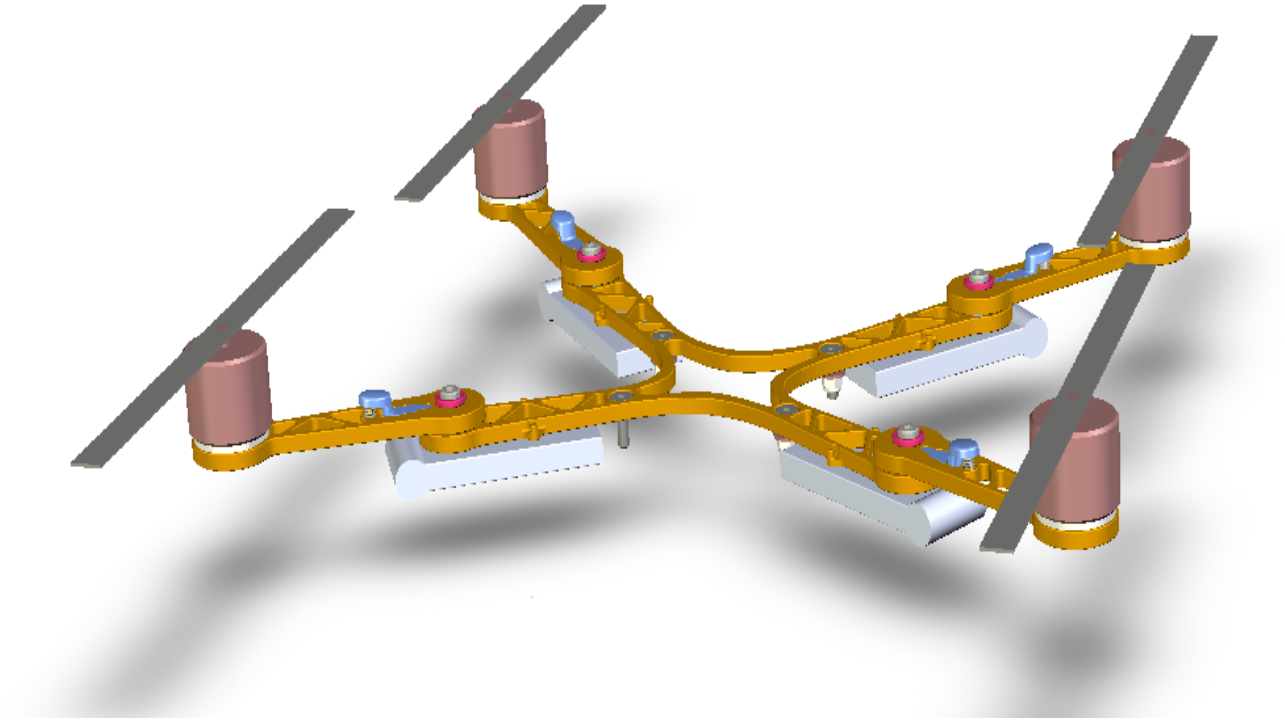
- #?? Hex driver, for installation of the T-Nuts
- Small philips screwdriver (watchmaker's size, for Hitec servo screws)
- Battery, HobbyKing Zippy Compact 4s4000 recommended. See the section 'Battery Choices' for more details.
- 4mm 'peel-n-stick' foam for ESC mounting
- M3 x 8 screws for motor mounting.
- Flight Controller, OpenPilot, or DJI Naza recommended
- 4 x DJI 2212/920kV motors
- 8" DJI props (small arm version), or DJI 1038 props (new style) for the long arm version
- Two lengths of ~AWG14 wire, red and black, approx. 10cm long (Battery hookup)
- Two lengths of ~AWG20 wire, red and black, approx. 20cm long (Naza hookup)
- XT60, or Deans connector according to the battery used
- 4mm single-sided self-adhesive foam for camera mounting

The Anatomy of a XuGong

The Foldable Arms, Motor Mounts, and Motors

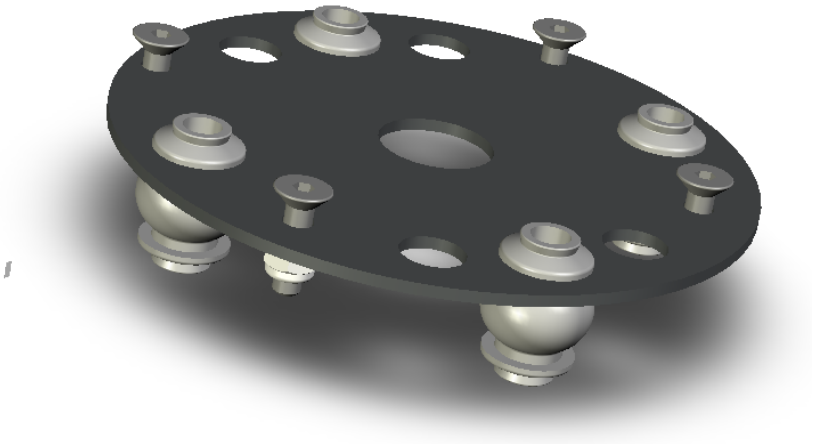
The foldable arms, milled out of a solid plate of 5mm Aluminium, allow the XuGong to collapse to a size which fits easily into the average Shoe Box/Hand Bag/Back Pack, etc.

Whether the long, or short-arm version is built, the pivot points allow the four motors to pivot into the center of the frame for storage and transport. While in this position, the prop blades are much easier to protect from damage than they are on a more traditional quadcopter.



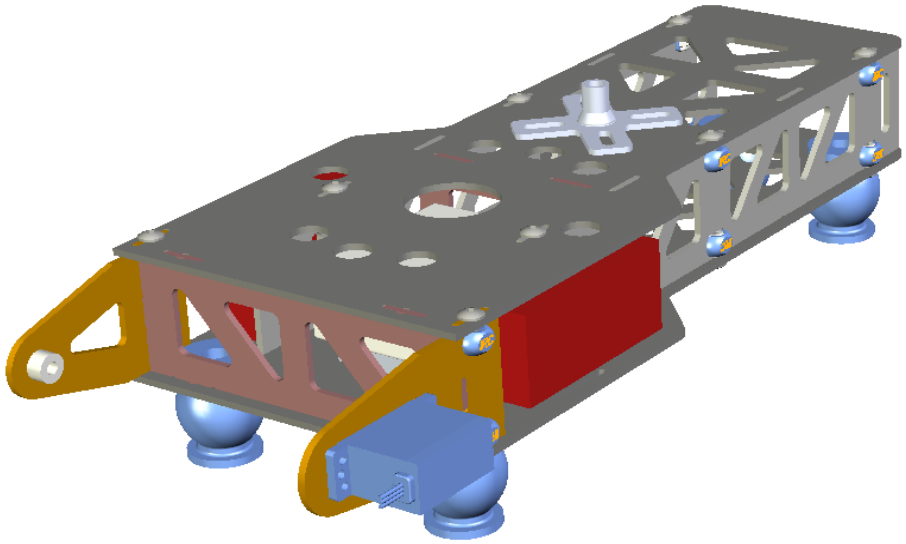
The Anti-Jello Plate

The Anti-Jello plate consists of an FR4 plate, laid out with PCB traces, which route the power between the battery, and the four ESCs.
It includes a selection of holes for silicone dampers, the number of which, and the durometer (hardness) of which, determine the tradeoff between video quality, and aerobatic flight characteristics.



The Frame Assembly

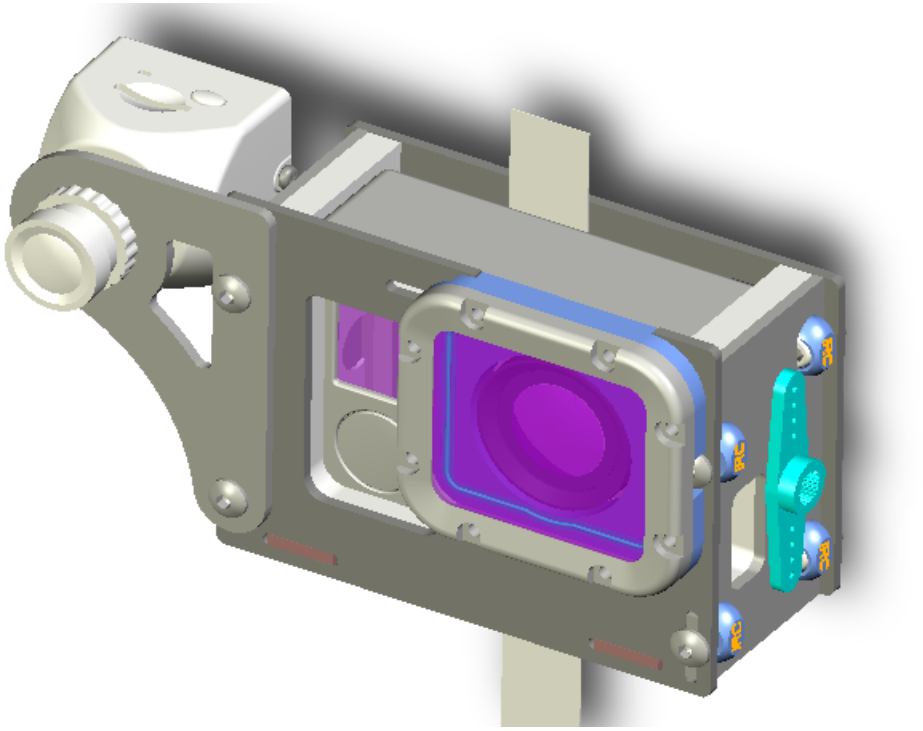
The Frame, constructed mainly of a very sturdy black FR4 material, holds (and protects) the battery, and all of the electronics. The flight controller sits in a protected box in the center of the frame. The A/V Tx, and UHF Rx can optionally be placed in the recesses each side of the frame, keeping them protected against crash damage.



The GoPro Camera Assembly

The GoPro camera assembly includes a padded support for a GoPro 3 (any edition), an optional support for an SD camera (FatShark CMOS, with ‘GoPro equivalent’ Lens, highly reommended).

For the first version of the XuGong, a simple tilt pivot using a Hitec HS65HB servo (or similar) is supported. The follow-on version will replace this assembly with a brushless gimbal, for Tilt/Roll.

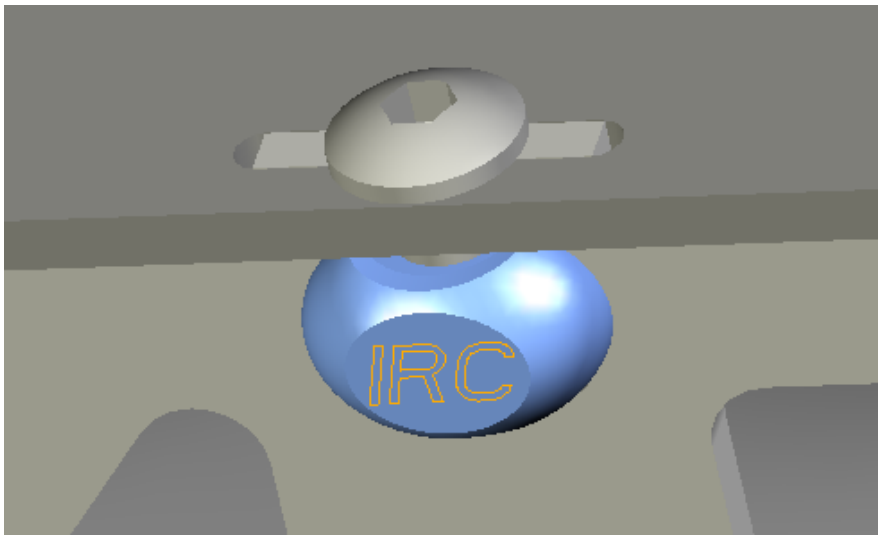


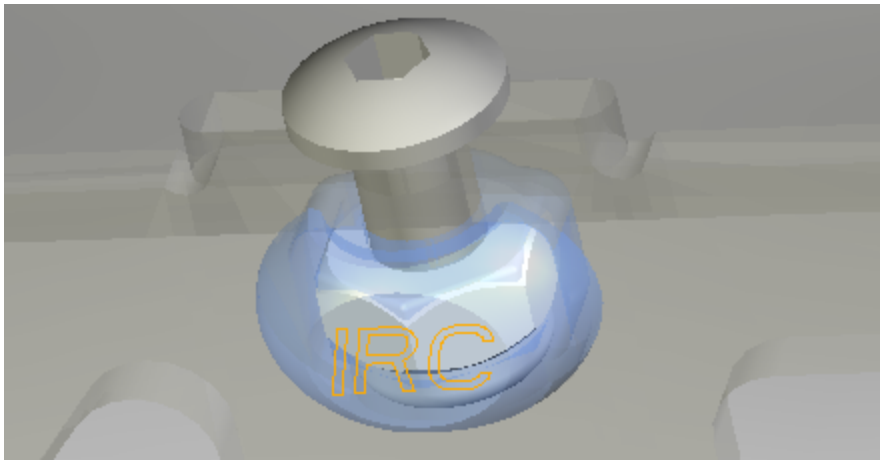
Building the XuGong... Basic Concepts:

Concept #1: Introducing the IRC T-Nut

The IRC T-Nut is a unique design which allows very strong joints between FR4 plates, while captivating the nyloc nut during assembly.

Using these is easy, just insert the nyloc nut into the plastic part, and push the two into the T-Slot. The parts will be retained to allow the second FR4 plate to be mated, and the screw inserted.

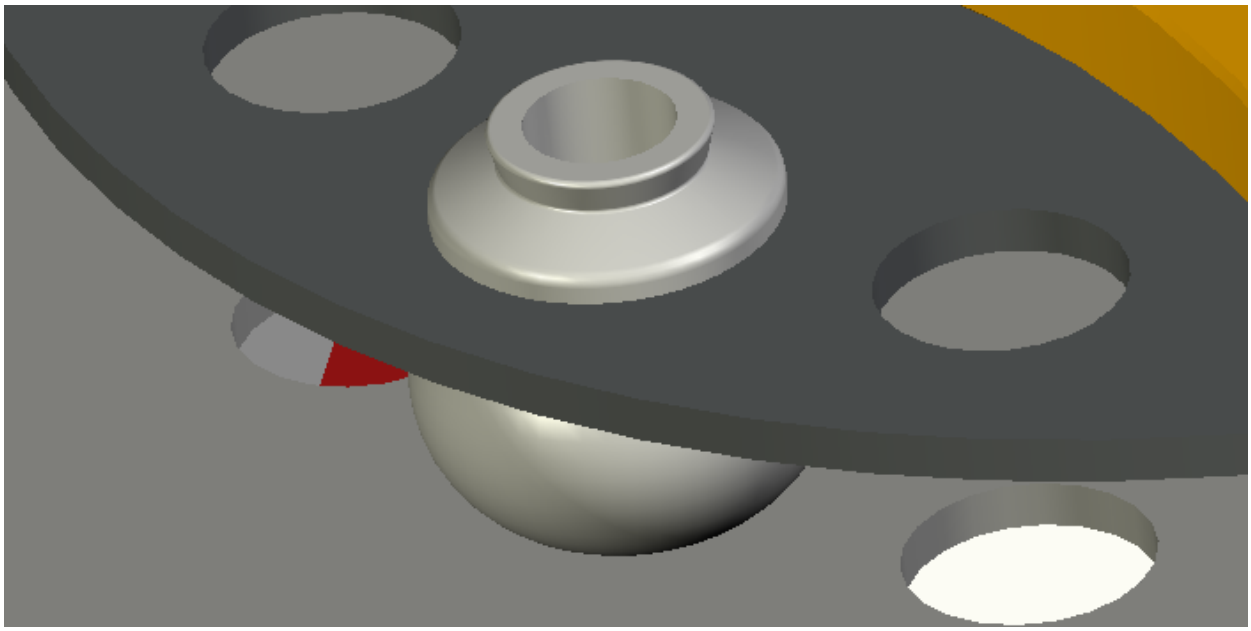




Concept #2: Anti-Jello Dampers

Jello (or rather Jelly as it is called in the UK), might be good to eat, but it is not appreciated in aerial video productions. The XuGong arm assembly is mounted to the frame using anti-vibration dampers, similar to those used on the DJI ZenMuse.

To install them, first push one side of each of them into the holes in the top of the frame plate. If they resist, a gentle rotation generally convinced them to drop into place.



Once the PCB containing the upper arm assembly is ready to mount (check and double check that all soldering has been completed before mounting it), press it lightly against the dampers, and one-by-one, tease the upper part of the dampers through the hole in the PCB.

A pair of tweezers, like the ones below, work a treat for teasing these in. Just close the tweezers, sneak them around the back of the damper, and use them to poke the upper rim into the hole.

Building the XuGong... Step-by-Step:

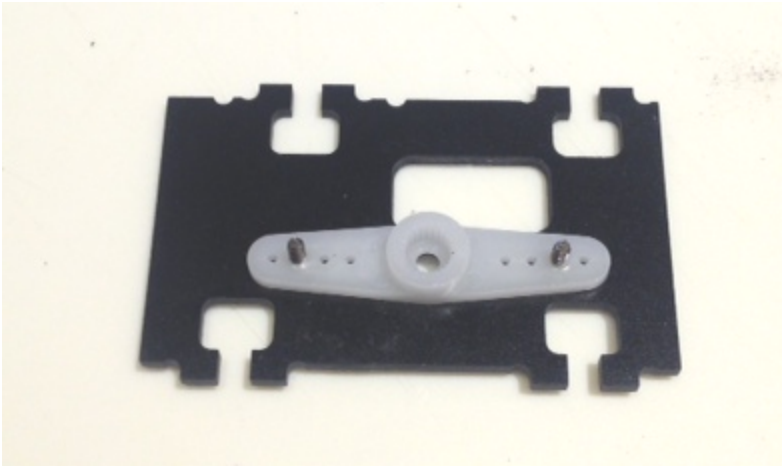
Step 1: GoPro mount

a) Servo mount: HS65HB

Using two of the self-tapping screws supplied with the HS65HB servo, mount the servo into one of the GoPro mounting arms, as shown below:
ERRATA: The servo actually goes in from the other side of this plate.

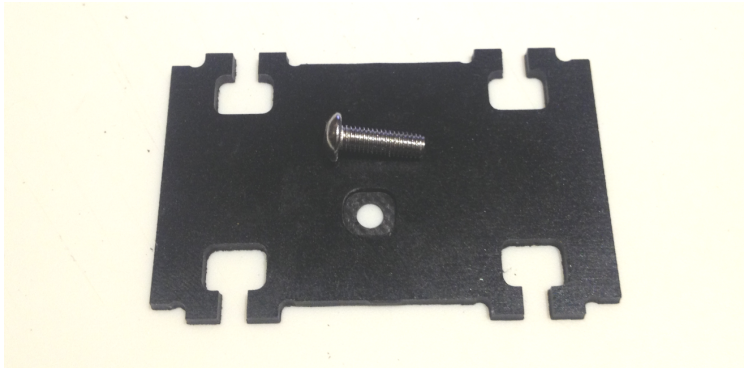
b) Servo Horn

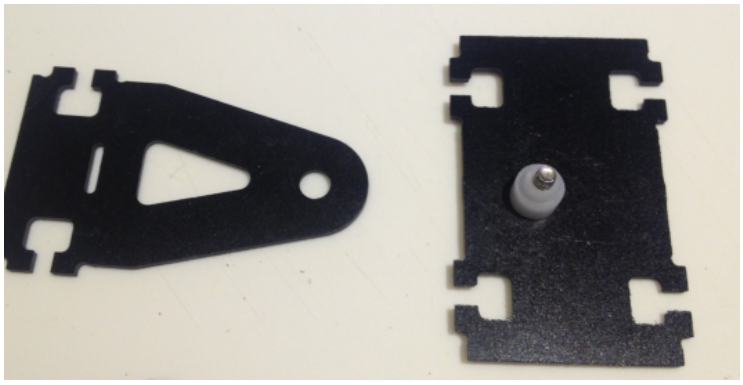
Using the second pair of self-tapping screws supplied with the HS-65HB servo, screw the servo horn onto the left-side GoPro mounting plate, as shown below:

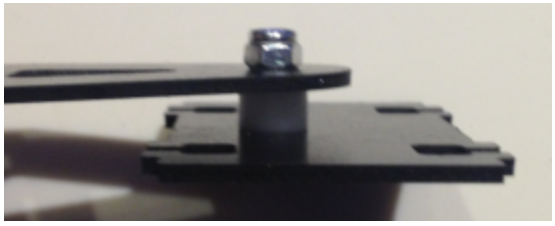


c) Right-side GoPro bearing

Take a M3 x 10mm screw, and pass it through the right-side GoPro mounting plate, so that the head of the screw sits in the milled recess in the plate. Mount the right-side mounting bracket, and secure with an M3 nyloc nut.

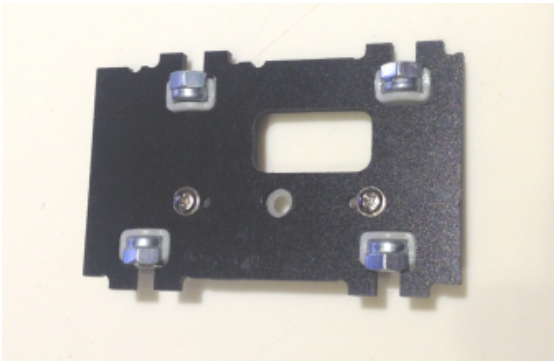


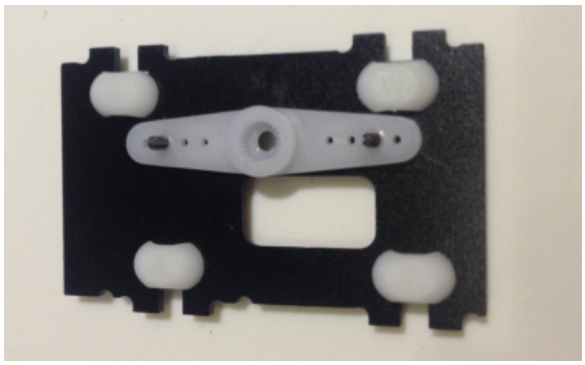




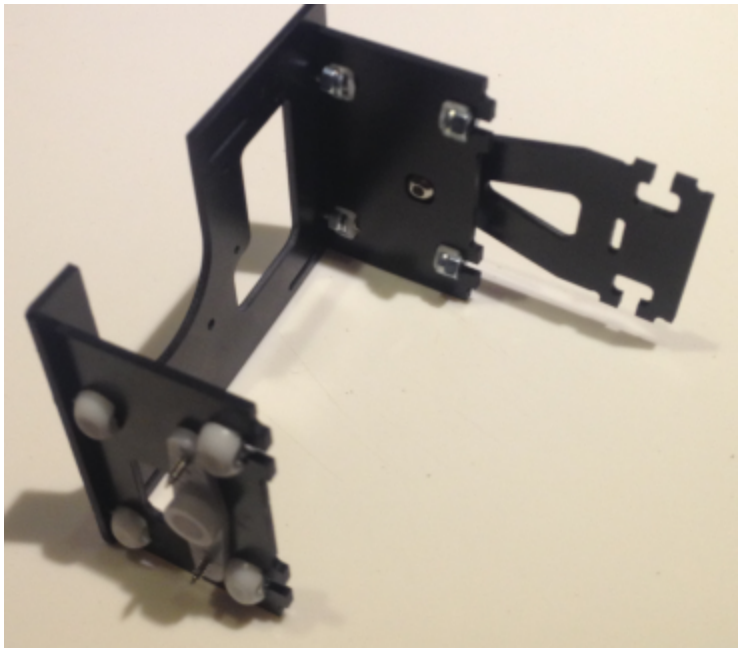
d) T-Nut installation, Finalize GoPro Assembly

Install the plastic nut holders into the two GoPro side-plates.

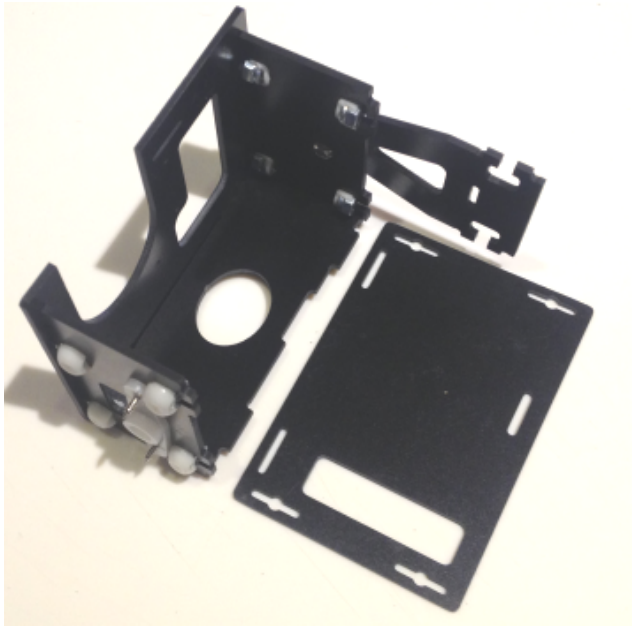




Mount the two plates to the GoPro front-plate:

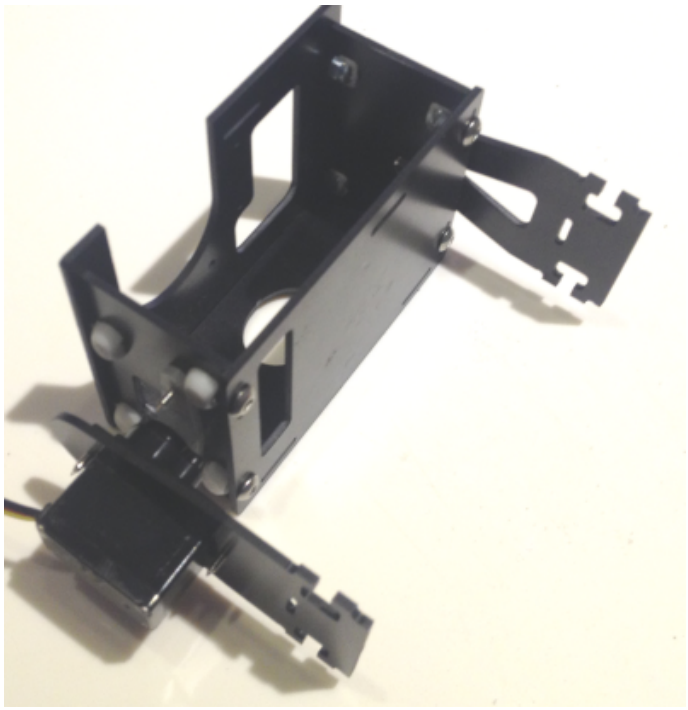


Mount the lower and back plates. Note the position of the slot in the back plate, and the corresponding slot in the lower plate.



Finally, screw the servo horn to the servo.

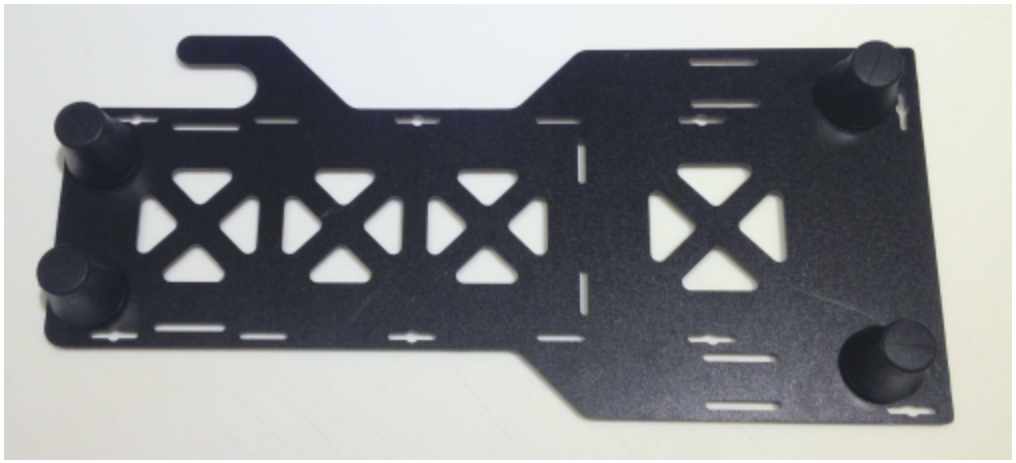
Tip: To avoid broken servo pinions later in the build, rotate the servo horn on the servo so that when the mount is level, the servo is at it's mid-point.



Step 2: The Frame

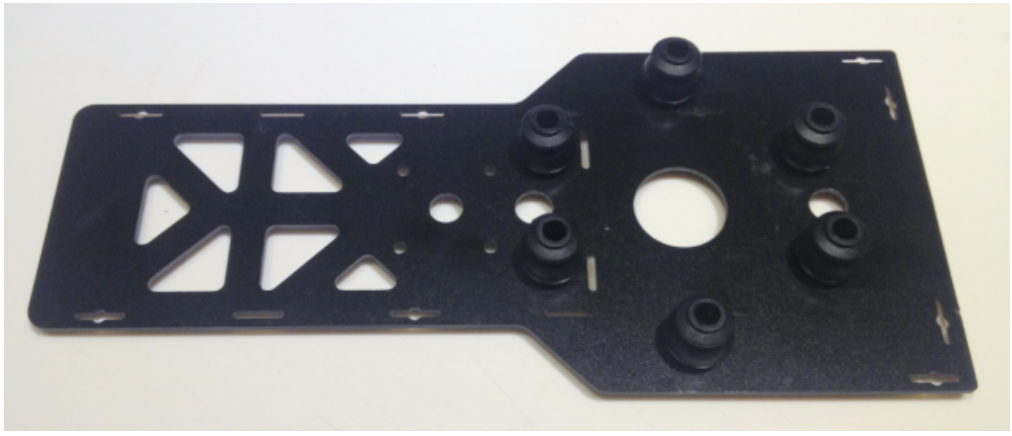
a) Silicone Feet installation

First step in building the frame is to install the rubber feet. Don't leave this until the end, since they are difficult to install once the frame is assembled.
Lay out the bottom frame plate as shown below, and tease the feet into place.
NOTE: The 'Hook' as it has been described, in the top-left of the photo here is for mounting the 5.8GHz SpiroNet Antenna. A small piece of 3M VHB tape holds the antenna securely on the bottom of the Quad.



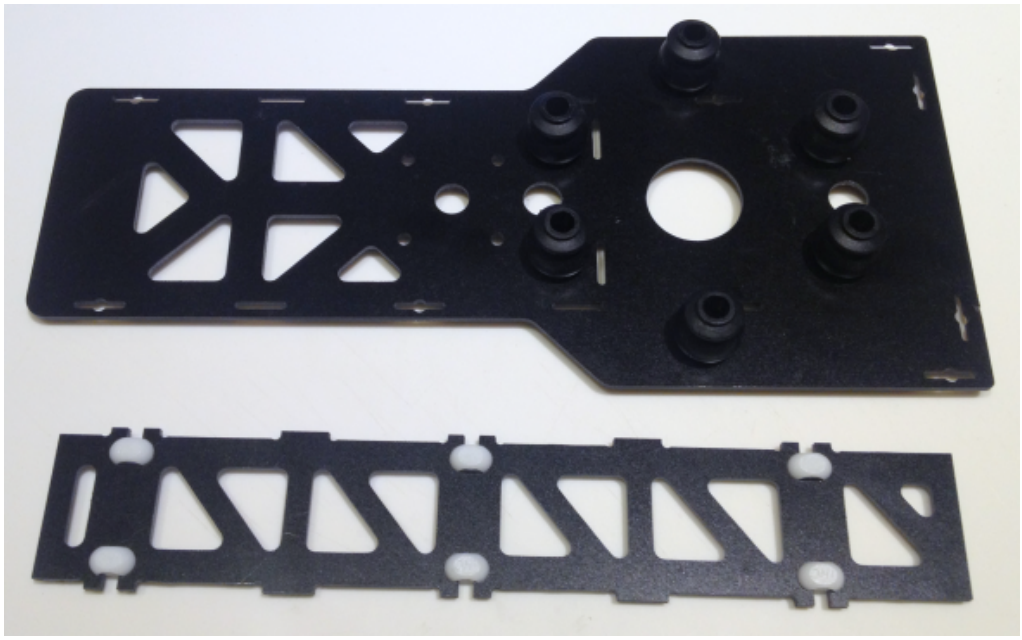
b) Anti-Jello Damper installation

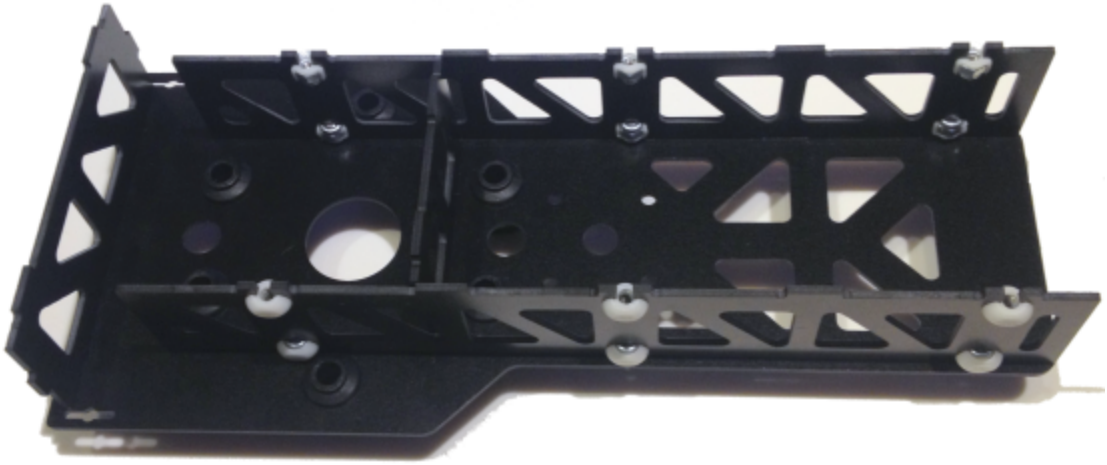
The anti-jello dampers should be installed next, as shown below. Again, don't leave these until later in the installation procedure, since they are difficult to install later.



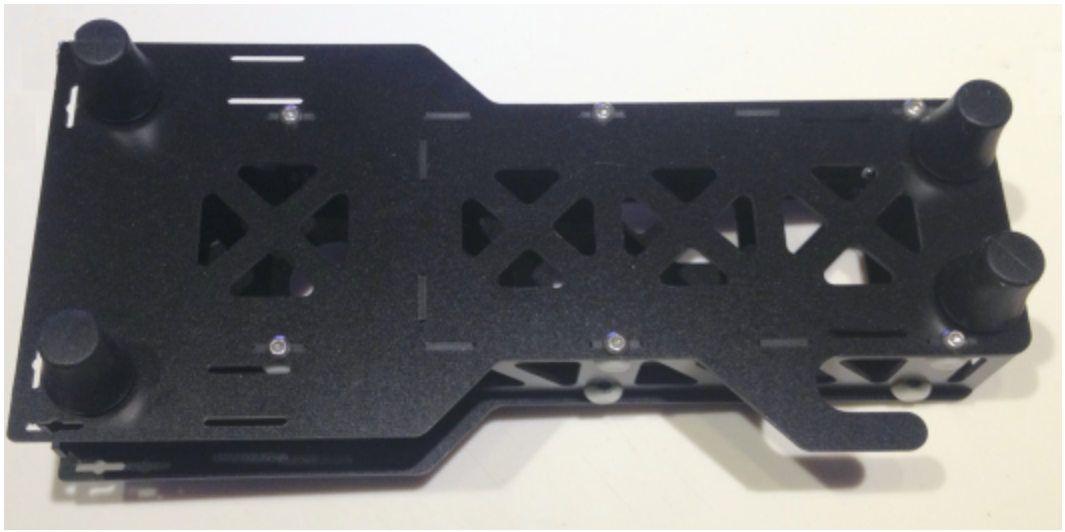
c) Frame Side-plate Install

Next step is to install the side plates. Use the pictures below as a guide, to install the T-Nut assemblies, and screw the frame together.
Don't forget the inner 'firewall', which protects the flight-controller from a runaway battery, in the event of a serious crash, and the front firewall.





Finally you should have something that looks like this, from below:



Step 3: The Foldable arms

Power Distribution Plate

First step on the foldable arms is to attach them to the round power distribution PCB.
Do this with the supplied M4 bolts, and nyloc screws.
Note that the PCB is mounted under the arms, as shown below:

Insert Photo

ESC Mounting

The ESCs sit below the center spider as shown below. On beta units the best way to mount them is with a piece of 4mm double-sided self-adhesive foam (Hobby King part number ST-FOAM-DB).

Production units will move the o-ring mounting points so that they will be the primary mounting method.

Note that the ESCs should not be mounted too close to the center plate, or the capacitor that is usually sticking out of the end of the ESC will become a great way to transmit vibration between the arm, and the frame.

Soldering Cables to the Power Distribution Plate

Now that the ESCs are installed, you can complete all of the soldering to the power distribution plate.
Starting with the ESCs, cut the ESC power wires to the correct length to allow them to be soldered directly onto the pads on the board. Note that for DJI ESCs, the positive and negative terminals are positioned correctly to line up directly with the power cables, without crossing wires. Ensure that with the ESCs used, the red ESC power wire is soldered to the + terminal, and the black ESC power wire is soldered to the - terminal.

Next, solder two lengths of 14 AWG (or similar) silicone-coated wire to the pads market BATT. To start with, use a length of approx 10cm, these can be cut down to the correct length later when the battery is selected and installed.

Next step is to solder two lengths of thinner silicone-coated wire to the pads marked NAZA. Start with a length of about 10cm, and as for the power cables above, these will be cut down to length later in the build. For both the power, and these cables, try to use color coded wire, red and black, to avoid any magic smoke later when they are hooked up backwards.

Final soldering step is the A/V Tx power cable. This should be approx 10cm long, and be soldered onto the pads marked NAZA, since they need to exit on the right side of the quad, nearest the antenna mount on the lower frame plate. The frame is designed for an ImmersionRC 600mW Tx, mounted in the recess in the right side of the frame, which protects it from impact from all sides.

Once all of the cables are soldered, to reduce spaghetti later, take a couple of nylon tie-wraps and bundle the 4 ESC cables together close to the power plate.

This assembly should look just like the photo below. Please double, and triple check the polarity of all of the wiring at this point. The plate is not easy to remove and reinstall later.

Insert Photo

Installation of the arm assembly on the frame

This is where your XuGong finally starts to take shape. Assuming that you mounted the rubber dampers on the upper frame plate earlier in this procedure, you can drop the arm assembly onto them, and start the process of pulling them through the plate.
Run the servo cable bundle, and the naza power cables, through the hole in the top frame for later hookup. The battery cables should be run through the gap between the top frame plate, and the power plate, at the rear of the assembly.

For the first time mounting this plate, there will almost definitely be some cursing, but trust us, it gets easier (our record is 60 seconds to get them all installed).

The easiest way to mount them is toto start at the front, apply downwards pressure on the top plate, while teasing the dampers through the holes in the power plate using a small screwdriver, or ideally a pair of angled tweezers. Once part of the damper is through the hole, it is possible to pull the rest through from the top.

Motor Installation

Mount the motors on the ends of the foldable arms using the spacer plates supplied, and M3x8mm screws. Ensure that the screws are not too long, and will touch the motor windings. This will destroy the motor, and will potentially create a short circuit between motors on the conductive aluminium arms.

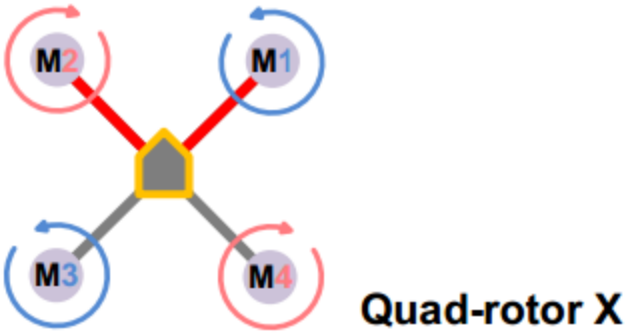
NOTE: For beta builds, or builds using standard DJI motors, it should be obvious at this point that the motor wires are too short, and won't reach the ESCs.
As soon as our custom motors are available, these will be offered with the correct cable lengths, to simplify construction.
For the shorter wires, the easiest way to extend them is to remove the heatshrink over the bullet connector, un-solder the bullet, and solder in a length of suitable silicone-coated wire before applying heat-shrink to the joint, and the bullet.
Be sure to carefully select the length of the wire carefully so that when installed, the arm can pivot correctly to fold the motors into the center of the frame.

Mounting the GPS/Compass

Holes in the top plate are provided for the standard DJI GPS/Compass. Even though it is tempting to stick the GPS directly onto the back of the upper plate of the frame, it is highly recommended to use the standard DJI 'stalk' supplied with the GPS.

Prop Installation

Props should be installed as shown in the picture below. The motor direction will be determined later once the Naza is fired up for the first time



Step 5: Flight Controller Hookup

Recent versions of the Naza GPS have a rather long strain relief on the connector that plugs into the Naza. This is a little too long to sit in the electronics compartment of the XuGong.
There are various ways to deal with this, the simplest is to very carefully cut back the strain relief plastic with a sharp knife, taking extreme care not to cut into the cables themselves.

Connect one of the 3-pin to 3-pin servo cables which ship with the Naza to connector X2

Connect the 3-pin servo connector from the LED module to X3

Connect the tilt gimbal servo to F2

IMPORTANT: Set Failsafe on the EzUHF BEFORE connecting to the Naza. If this is not done, the Naza calibration cannot be performed successfully.

Building the XuGong... Electronics Selection:

Battery Selection

Several batteries have been used successfully with the XuGong, depending upon the flight/duration characteristics desired, and the equipment installed.

A table containing some battery suggestions is located near the end of this build log.

Flight Controller

The XuGong was designed for use with any of the popular flight controllers, including the DJI Naza/Naza Lite series, and the controllers from OpenPilot.

For the OpenPilot boards, four mounting holes are included on the bottom of the lower frame plate to securely mount it.

For the Naza, the LED module fits under the quad, on the bottom frame, and is protected from impact by the four sturdy silicone feet. Mounting the module here allows easy access to the USB port for configuration of the Naza.

Control Uplink

For a robust, and long-range control uplink, the ImmersionRC EzUHF system is recommended. Any of the ImmersionRC EzUHF receivers may be used on the quad. These will easily provide several kilometers of reliable control range.

For the Rx Antenna, a full ½ wave dipole is highly recommended. This can be constructed using the monopole antennas which are shipped stock with the EzUHF Receivers. Take a length of the cable commonly used for bicycle brake cables, the same length as the monopole, and solder it to the side of the monopole SMA connector. The flexible nature of this cable will allow the antenna to deform during takeoff and landing, and fold out to create a solid dipole during flight.

Mount the receiver on the back of the quadcopter, near the ‘tail’, with the dipole mounted vertically behind it.

A/V Downlink

The XuGong frame has a convenient mounting point for an ImmersionRC 5.8GHz SpiroNET antenna. When coupled to a 600mW ImmersionRC 5.8GHz transmitter, several km of range are easily achievable even using a simple SpiroNet antenna on the headset.

For longer range, either use a patch antenna on the receiver, or instead use a 2.4GHz link.

Building the XuGong... Electronics Installation & Configuration:

1) Setting up the EzUHF Receiver

The EzUHF receiver should have its firmware upgraded to v1.48, or later before installing on the XuGong. A matching firmware revision should be installed in the EzUHF transmitter.

With this firmware revision, and v1.30 or later of the ImmersionRC tools, it is easy to configure CH1 of any model of EzUHF Rx to be a PPM stream containing all channels.

To switch to a PPM output, switch to the **Servo Mapping** tab of the Rx setup, and change the **CH1** servo output to **PPM Muxed**.

Bind the receiver to the transmitter, either using the button on the Rx, or the ImmersionRC tools, **Bind/RSSI** tab of the Rx setup page.

When correctly bound, the LED on the Rx should be ‘breathing’, indicating normal operation.

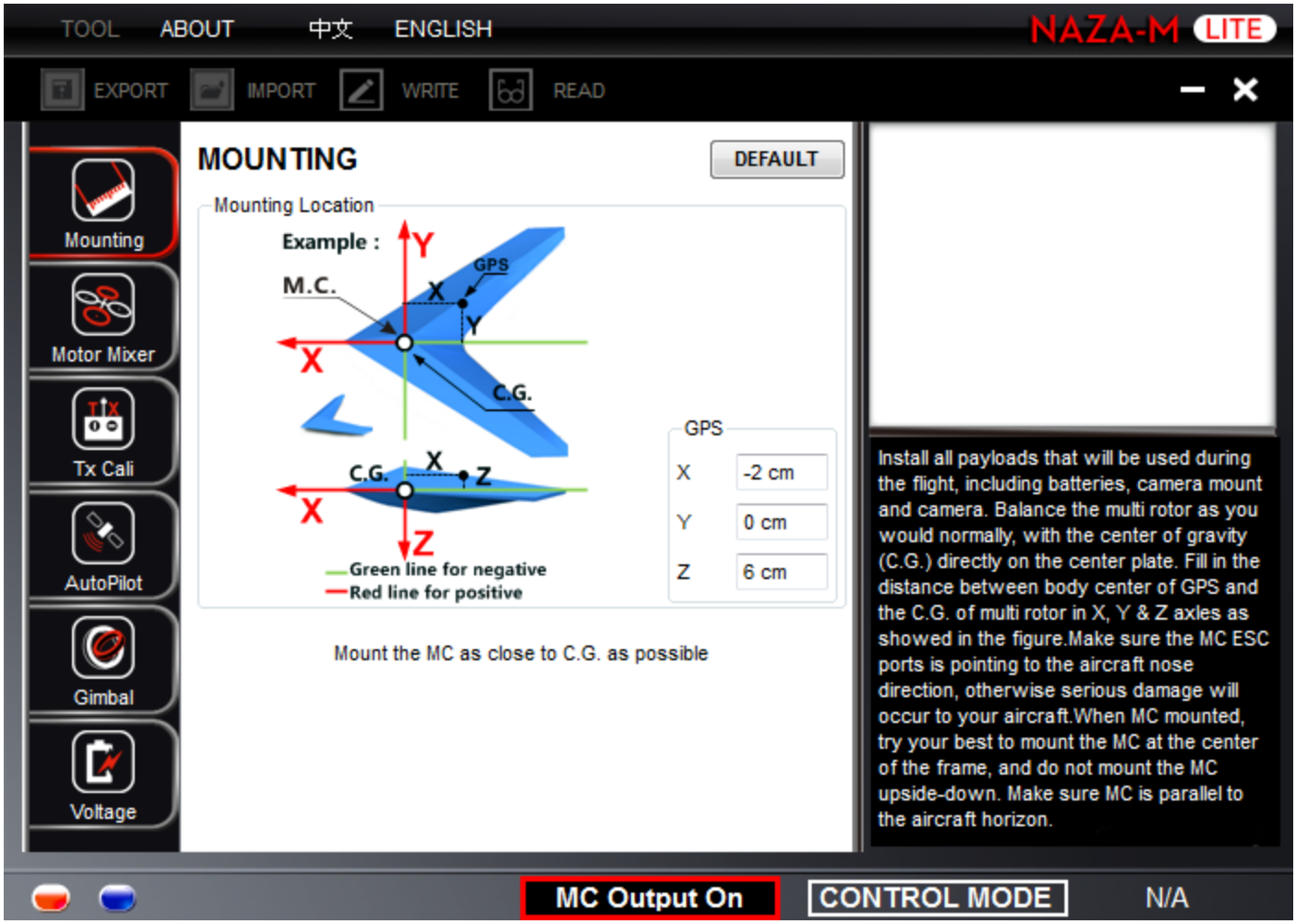
The only cable hookup to the EzUHF should be a single servo cable, between connector X2 on the NAZA, and CH1 of the EzUHF receiver.

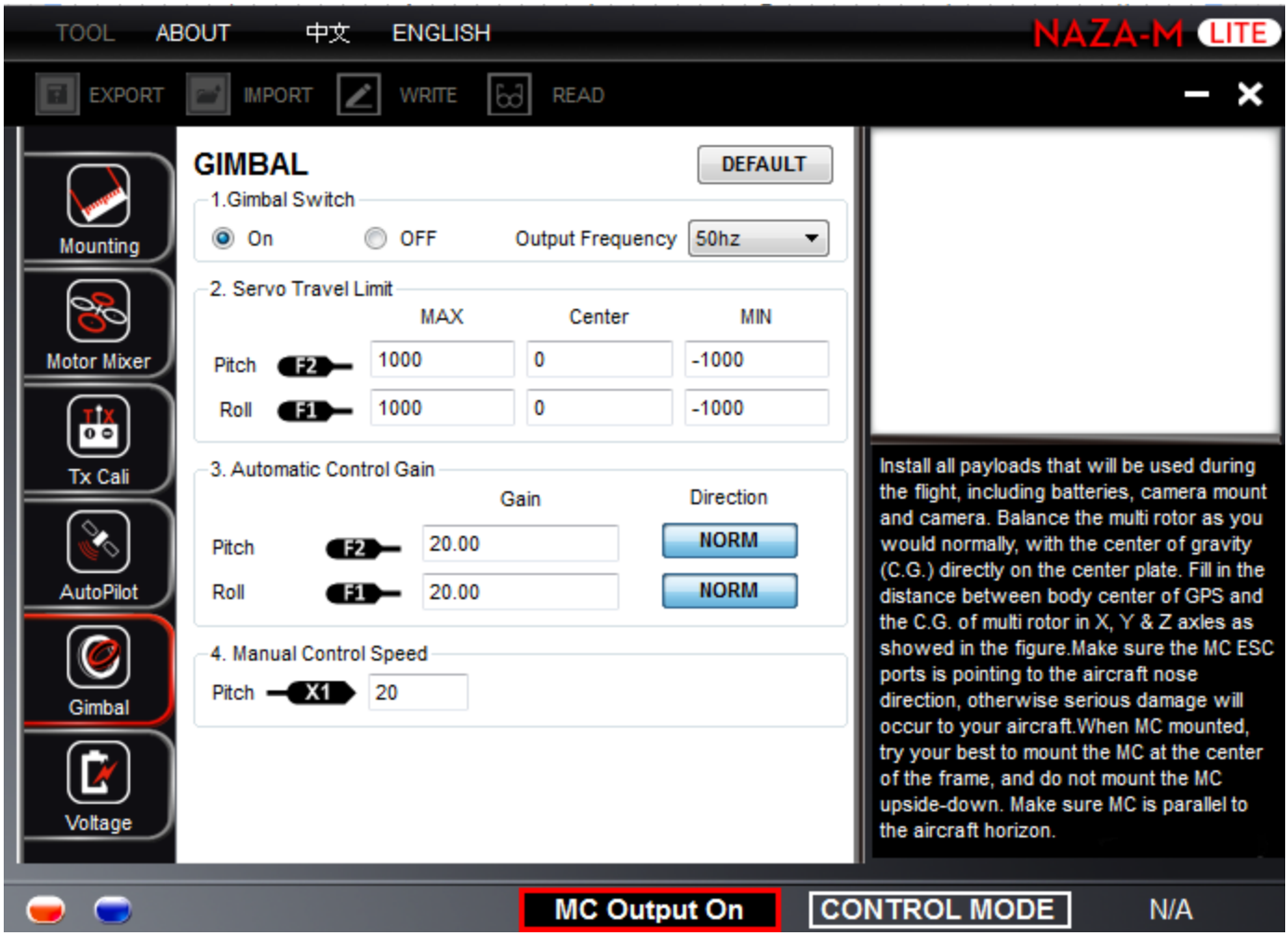
2) Setting up the Naza

The following settings should be programmed into the Naza for the long, and short arm variants of the XuGong.

To Be Determined

Note that it is extremely important to correctly setup the position of the IMU vs. the center of gravity of the Quad. The values below should be used.


TOOL
ABOUT
中文
ENGLISH
NAZA-M LITE
EXPORT
IMPORT
WRITE
READ
Mounting
Motor Mixer
Tx Cali
AutoPilot
Gimbal
Voltage
MOUNTING
DEFAULT
Mounting Location
Example :
M.C.
GPS
X
Y
C.G.
Z
Green line for negative
Red line for positive
GPS
X -2 cm
Y 0 cm
Z 6 cm
Mount the MC as close to C.G. as possible
Install all payloads that will be used during the flight, including batteries, camera mount and camera. Balance the multi rotor as you would normally, with the center of gravity (C.G.) directly on the center plate. Fill in the distance between body center of GPS and the C.G. of multi rotor in X, Y & Z axles as showed in the figure.Make sure the MC ESC ports is pointing to the aircraft nose direction, otherwise serious damage will occur to your aircraft.When MC mounted, try your best to mount the MC at the center of the frame, and do not mount the MC upside-down. Make sure MC is parallel to the aircraft horizon.
MC Output On
CONTROL MODE
N/A



Stuff To Watch Out For

Naza Compass Orientation

The Naza doesn't fly well with the gps/compass pointing any direction but towards the nose. Infact, when installed pointing towards the tail, the quad will likely fly uncontrollably in any direction but where the pilot requests... ask us how we know!.

Ensure that the gps/compass is securely mounted, and cannot spin around in its mount.

Crash Survival

The XuGong was designed to survive the occasional crash, without permanent damage. Nothing is more frustrating than launching from the perfect location, after a day of hiking, and breaking a plastic arm. Three fundamental survival techniques are inherent to the design:

1. The XuGong's CNC'd aluminium arms are designed to bend in a serious crash, and be bent back without tools.

2. The silicone rubber 'anti-jello' mount is designed to break loose in a crash, absorbing much of the shock that would normally go into destroying the quad.

3. The plastic 'pegs' on the arm locking mechanism are designed to break in a head-on crash, while protecting the rest of the quad. A few of these small plastic parts should be carried as spares.

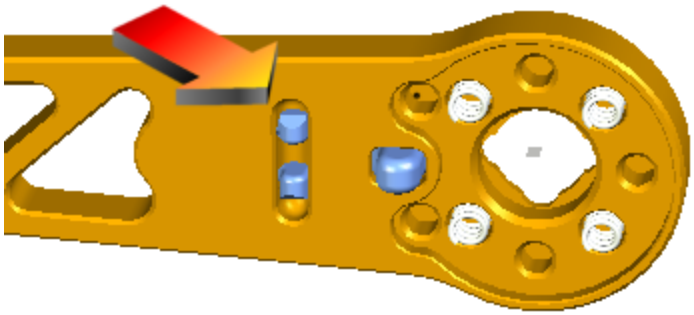
In practice, during approx. 1 year of testing before the XuGong was announced, we experienced several serious crashes. The most common was DJI props (1st generation 8" props) breaking while several 10s of meters in the air. In every case, the repair was as simple as bending the arms gently back into shape, replacing the prop, and relaunching.

During a particularly fun session at the beach, a XuGong with exhausted battery dropped about 50 meters onto the sand, landing belly-down. The arms bent down about 30 degrees. Upon changing the battery, and bending the arms back into shape, the quad was relaunched, and a few more hours of photo/video taking took place uneventfully.

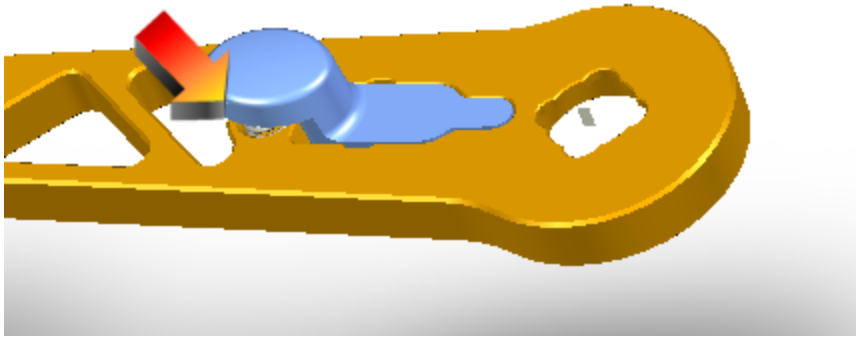
Lastly, several head-on crashes took place, generally while fence-hopping (forgetting to hop). In these cases the small white arm release would snap off, but is easy to replace in the field.

Replacing the plastic arm-locking parts

To replace the plastic locking part, take a sharp object, and press the black pegs which poke through the bottom of the arm.



IMPORTANT: When the part is released, ensure that the spring, which is sandwiched between the arm and the white plastic part, doesn't 'boing' into the middle of next week!
A few spare springs are included in your box, don't throw these away!



Battery Options

Several batteries are compatible with the XuGong, and should be selected based upon the kind of flight characteristics required. A battery box 30mm height, with 2.4mm required for the retaining ring of the rubber feet means that a 28mm tall battery fits comfortably, but nothing taller.

Battery	mAh	Height	Width	Length	Weight	Status/Time
NanoTech 3.3 25-50C	3300	28mm	44mm	135mm	327g	recommended
Lunenier 3.3, 4s, 35C	3300	27mm	44mm	135mm	330g	Good candiate, to be tested
Zippy Compact 25C, 2700	2700	21mm	44mm	138mm	278g	12 minute flight time
Zippy Compact 4000, 25C **PREFERRED**	4000	28mm	43mm	145mm	385g	210mAh/minute of flight w/1038 props
NanoTech 2.2 35-870C	2200	33mm	35mm	105mm	246g	too tall for betas

The battery box dimensions are: 30mm H x 48mm W x 125mm deep

Remember that the battery plays a big part in the determination of the Center of Gravity of the XuGong. A heavier camera, or a brushless camera gimbal, can be compensated for by a heavier battery.

For pure flight-time, the Zippy Compact 4000, 25C, is a good choice (Hobby King Part Number ZC.4000.4S.25). This pack is used on most of the ImmersionRC prototype XuGongs.

Flight Time vs. Battery Selection & Prop Choice

Example 1:

With a 4000mAh zippy compact pack, Stock DJI 2212 motors, DJI 1038 props, in forward flight the consumption is approx. 210mAh per minute of flight. This results in an approx. 17 minute flight time, enough for comfortable 5km out, 5km back, flights (10km total).

AUW is approx. 1400g with this configuration, with GoPro + battery installed.

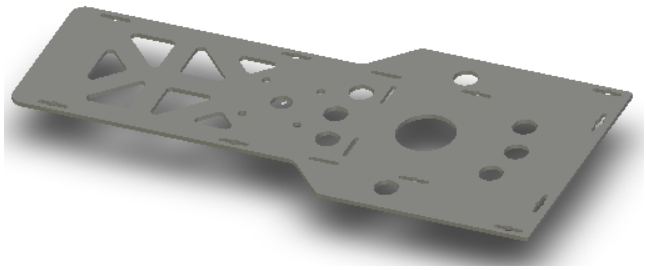
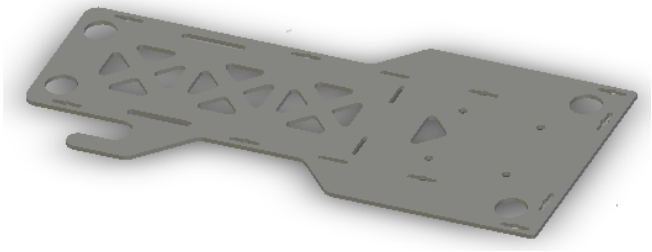
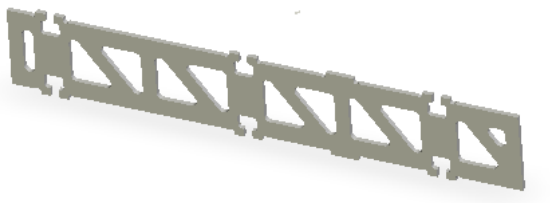
(This system was used for one of the XuGong promotional videos here: https://vimeo.com/78925542)

For those of you familiar with the 'ecalc' multicopter calculator, the following values get close to this setup:

General	Engine Cooling: medium	# Of rotor: 4	Model Weight: 508 g / 17.9 oz	Drive without			FieldElevation 500 m ASL / 1640 ft ASL	Air Temperature 25 °C / 77 °F	Pressure (QNH): 1013 hPa / 29.91 inHg
Cell Battery	Type (continuous / C max.) - Charge state: custom - full	Configuration: 4 S 1 P	Cell Capacity: 4000 mAh	Total Capacity: 4000 mAh	Resistance: 0.0056 Ohm	Voltage: 3.7 V	C rate: 25 C cont. / 35 C max.	Weight: 92 g / 3.2 oz	
Controller	Type: custom	cont. Curent: 20 A	max. Curent: 20 A		Resistance: 0.01 Ohm			Weight: 19 g / 0.7 oz	
Engine	Manufacturer - Type (Kv): AXI - custom	KV (w / o torque): 920 rpm / V	no-load current: 0.3 A @ 10 V	Limit (up to 15s): 30 A	Resistance: 0.135 Ohm	Case Length: 30 mm / 1.18 inch	# Likes. Poles: 14	Weight: 80 g / 2.8 oz	
Propeller	Type - yoke twist: custom - 0 °	Diameter: 11 inch	Pitch: 4.5 inch	# Blades: 2	Pconst: 1.3	Gear Ratio: 1 1		calculate	

Parts List

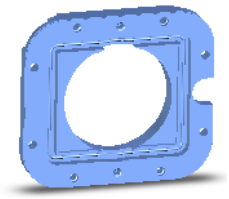
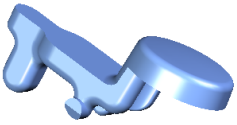
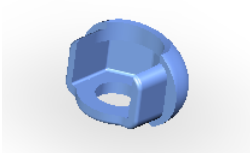
FR4 pieces, Main body

Top Plate	x1	
Bottom Plate	x1	
Side Plate	x2	
Front Bulkhead	x1	
Battery Bulkhead	x1	

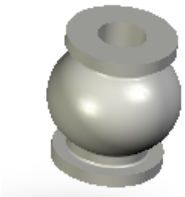
FR4 pieces, GoPro Mount

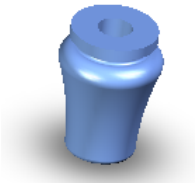
Right camera mount	x1	
Left camera mount	x1	
Camera box front	x1	
Camera box back	x1	
Camera box right	x1	
Camera box left	x1	
Camera box bottom	x1	
FPV Camera mount	x1	

Plastic parts

GoPro Lens Adapter	x1	
Camera bushing	x1	
Arm Locking Pivot	x4	
T-Nut Plug	x28	
Arm Pivot Washers	x4	

Silicone Rubber Parts

Damper Rubbers, std	x8	

Rubber Feet	x4	

Metal Parts

Ball bearing	x16	
Spring, large	x4	
Spring. small	x16	
Screws, M3x8	x28	
Screws, M4x16 *Arm pivot screws*	x4	

Aluminium Arms

Center Spider, Std. x1
Outer Arms, Std. x1