XuGong Foldable

BUILD GUIDE

Preliminary: v0.2 - 14 Jan 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, General

- 2mm Hex driver, for installation of the motor mounting screws, and T-Nut screws
- Small Phillips screwdriver (watchmaker's size, for Hitec self-tapping servo screws)
- Battery, HobbyKing Zippy Compact 4s4000 recommended for most builds. See the section 'Battery Choices' for more details.
- 3M VHB (or similar) double-sided tape for ESC mounting
- M3 x 8mm screws for motor mounting (low profile head, 2mm or less)
- Flight Controller, OpenPilot, or DJI Naza recommended (see below for a DJI-specific build)
- 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)
- Extender cables to connect the motors to the ESCs, length depends upon motors and ESCs used.
- XT60, or Deans connector according to the battery used
- 4mm single-sided self-adhesive foam for camera mounting
- Tilt servo, HS-65MG highly recommended
- FPV Camera, FatShark CMOS highly recommended

Pre-requisites, Build using DJI Components

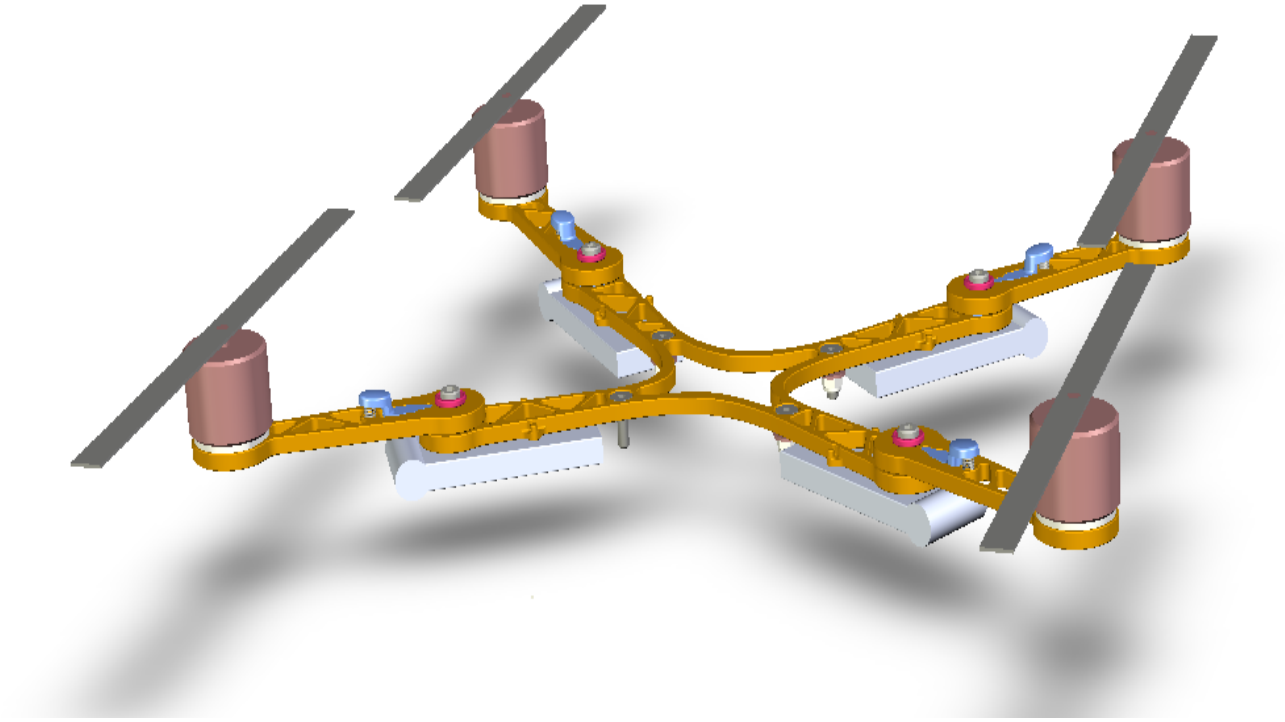
- DJI Naza-Lite, or Naza-M V2 *(smaller BEC from the Lite is preferred for most builds)*
- 4 x DJI 2212/920kV motors, or similar
- 8" DJI Phantom props (small arm version), or DJI 1038 props (new style) for the long arm version

The Anatomy of a XuGong

The Foldable Arms, Motor Mounts, and Motors

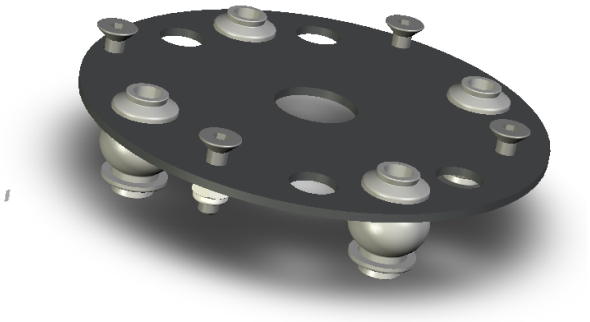
The foldable arms, milled out of a solid plate of 5mm Aluminium, allow the XuGong to collapse to a size which fits easily into the average Shoe Box/Hand Bag/Back Pack, etc.

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

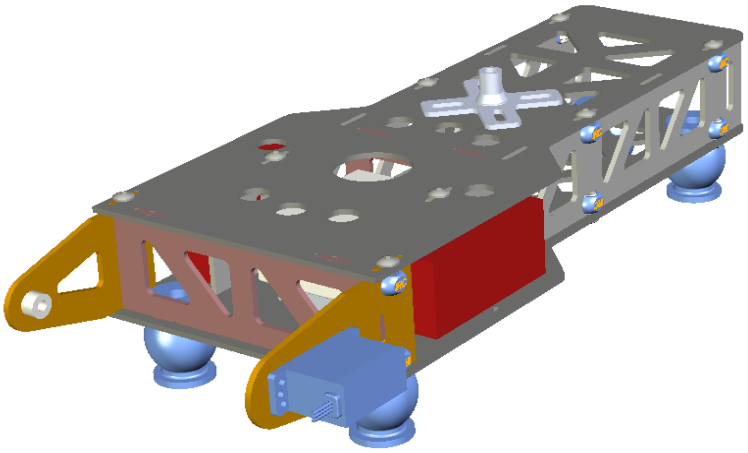
The Anti-Jello plate consists of an FR4 plate, laid out with PCB traces, which route the power between the battery, and the four ESCs.
It includes a selection of holes for silicone dampers, the number of which, and the durometer (hardness) of which, determine the tradeoff between video quality, and aerobatic flight characteristics.
Two kinds of dampers are available, the black ones included with the product, which are good for slow-flying photo/video work, and some harder red dampers, for more aggressive flying.
The red dampers have a slightly different tooling, to leave more material in the center.



The Frame Assembly

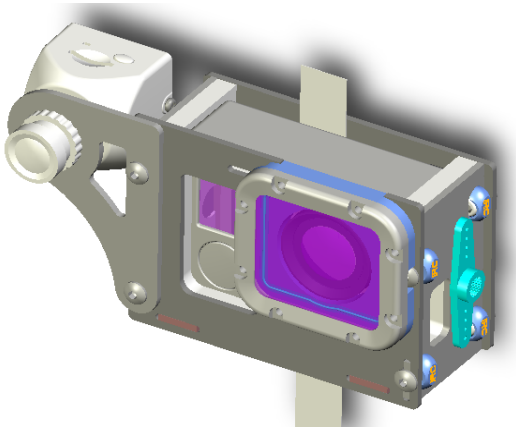
The Frame, constructed mainly of a very sturdy black FR4 material, holds (and protects) the battery, and all of the electronics. The flight controller sits in a protected box in the center of the frame. The A/V Tx, and UHF Rx can optionally be placed in the recesses each side of the frame, keeping them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

An alternative frame assembly will be made available in early January 2014, which will be made of carbon fibre, with lightweight anodized aluminium nuts and screws.
This version works well for two types of Quad flyers, the long range fanatic, who wants to shed every gram from the weight of the quad, and the poser :-), who just wants a quad to look fantastic.



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 standard version of the XuGong, a simple tilt-only gimbal using a Hitec HS65MG servo (or similar) is supported. This is a fairly robust mechanism, which works well for a quad which will be crammed into a backpack during travel.
The ‘HB’ version of this servo works also, but the gears are a bit fragile for this application.

A brushless gimbal is under development for the XuGong, and will be available in early 2014. Several 3rd-party brushless gimbals have been successfully used on the XuGong, including the Tarot, which with a few simple modifications can be mounted on the XuGong’s front bulkhead.

Building the XuGong... Component Selection:

There are a huge number of different components available to build multicopters these days. The

cost of these components, along with their quality, and compatibility, varies widely.
The component selections below are based upon our experience to date, and will result in a successful foldable quadcopter build.

Flight Controller

Most of the XuGong prototypes built by the ImmersionRC team have used various versions of the DJI Naza Flight controller.
This experience will be reflected in this build log, it will be the flight controller used during the build.

The Naza-M Lite is, in some ways, more suitable than the newer V2, due to its much smaller (and thus easier to mount) LED/Power unit.

Of course, any flight controller designed to fly quads, assuming reasonable physical size, will do just fine as a replacement for the Naza.
For use with the OpenPilot, and similar FCs, a standard pattern of 4 holes is provided on the bottom plate of the frame.

Motors

As for the flight controller, most of the XuGong prototypes have used the stock DJI motors (DJI 2212/920kV). These are generally priced fairly reasonably, and fit the frame arms nicely.
They are also compatible with either the 8” DJI props used on the smaller version of the XuGong, the XuGong-8, and the 10” (1038) props used on the XuGong-10.

Props

One of the most common causes for crashing during the XuGong development was due to props breaking in flight. The earlier 8” DJI props were generally the culprit.
Graupner 8” carbon fibre props do work as reasonable replacements, but require a small amount of drilling/filing to allow them to fit on the shafts of the stock DJI motors.

For the 10” version of the XuGong, the newer 1038 props from DJI work very nicely, and are yet to fail for us in flight.

Tip: Even though the XuGong is designed to reduce the transmission of vibration to the camera, well balanced props are still a good idea.

Battery

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. In addition, a nose-heavy XuGong can be balanced by sliding the battery rearwards in the battery bay, and padding the front of it with a small block of foam.

For pure flight-time, the Zippy Compact 4000, 4s, 25C, is a good choice (Hobby King Part Number ZC.4000.4S.25). This pack is used on most of the ImmersionRC prototype XuGongs.

A/V Transmitter

This will be a little predictable, but we do highly recommend an ImmersionRC product for the A/V transmitter. For license-free use, on 5.8GHz, the 25mW 5.8GHz Tx is a good choice, and will comply with CE standards for use in Europe.
For longer-ranage use, or where a radio license is available, the popular 600mW 5.8GHz transmitter is also a very good choice.
The top and bottom frame plates for the stock XuGong are designed to fit the transmitter between them, protecting it from damage caused by most ‘hard langings’.
A small piece of 3M VHB tape keeps the transmitter firmly attached to the side of the quad.

A/V Transmitter Antenna

The bottom plate of the XuGong has a ‘hook’ designed to mount one of our 5.8GHz SpiroNET omnidirectional antennas. This is positioned so as to keep the antenna below the craft, in clear view of the ground-based receiver, and the correct distance from the A/V Tx for the standard cable length.

FPV Camera

Even though the video output of the gimbal-mounted GoPro may be used as an FPV camera, it

is not really recommended. GoPro cameras have been known to shut down, losing their video feed, for several reasons (too hot, too cold, dead battery, .. just because it is the third Sunday of the month…).
To avoid the stress of having to use the Flight Controller's 'Return Home' function to recover a 'blind' quadcoper, a secondary FPV camera is highly recommended.
The gimbal was designed for use with the FatShark CMOS camera. Lightweight, and with very good performance in difficult lighting situations.
A wide-angle lense is recommended in order to let the CMOS camera see the same (or similar) FPV as the GoPro. This makes framing shots while filming with the GoPro much easier.

Radio Control system

Continuing on the predictable theme, we highly recommend the ImmersionRC EzUHF receivers for use in the control of the XuGong. These can be easily programmed to emit a PPM stream from one of the servo outputs, which is compatible with the PPM mode of the Naza controller. This greatly simplifies wiring, and enables even the 4 channel EzUHF receiver to supply the 5 channels required to fly the quad, plus additional channels for gimbal (and other) control.
Any of the EzUHF receivers, can be used with the XuGong, this list currently includes the 4 channel, 8 channel 'lite', and 8 channel diversity.

At the other end of the radio link, there are several radios compatible with the EzUHF. Our current favourite is the FrSKY Taranis, with our new JR EzUHF Module plugged in the back.

With the EzUHF, even with the 4 channel unit, radio control range will exceed the range achievable by the quad itself.

For the EzUHF Rx Antenna, a full ½ wave dipole is highly recommended if range of more than a few kilometers is required.
This antenna 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.

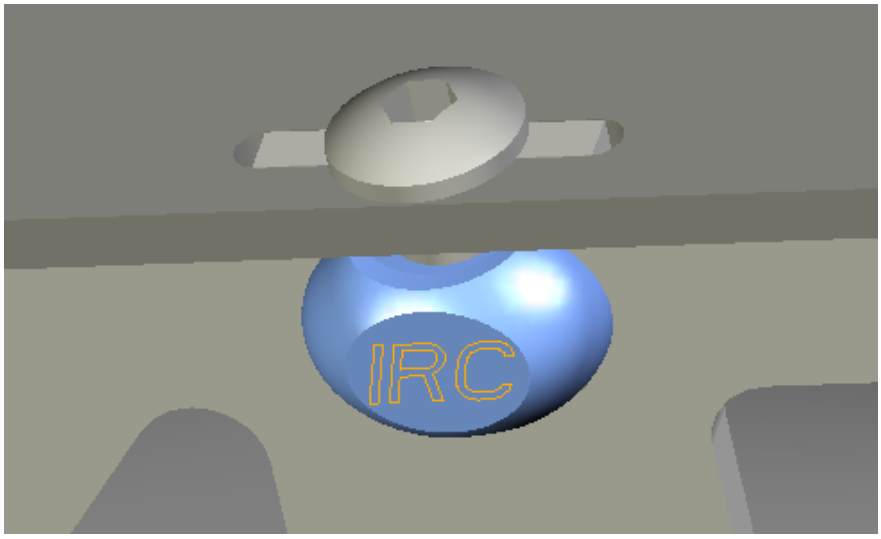
Mount the receiver on the back of the quadcopter, near the 'tail', with the dipole mounted vertically behind it.

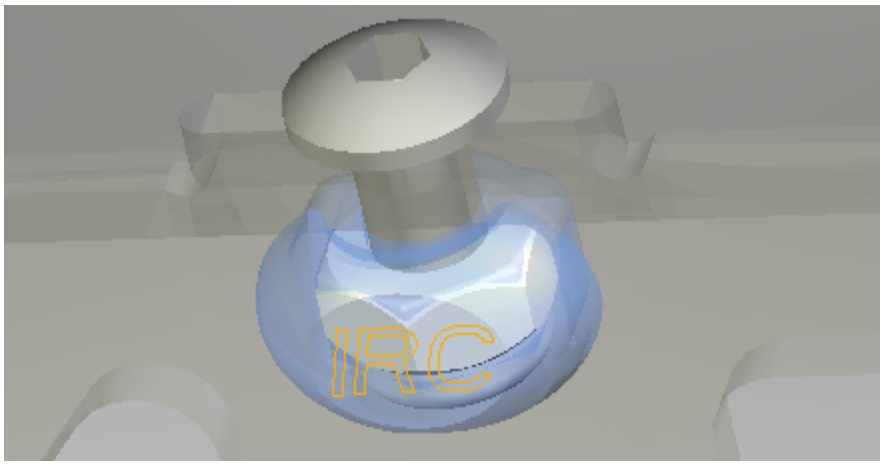
Building the XuGong... Basic Concepts:

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.

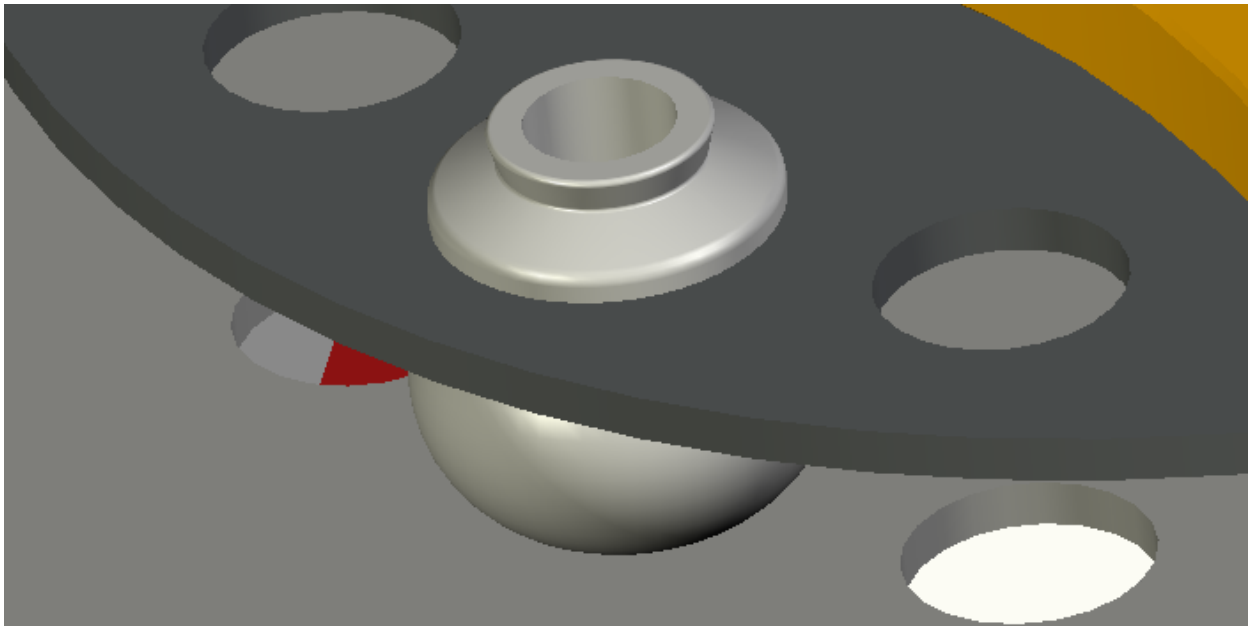




Concept #2: Anti-Jello Dampers

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:

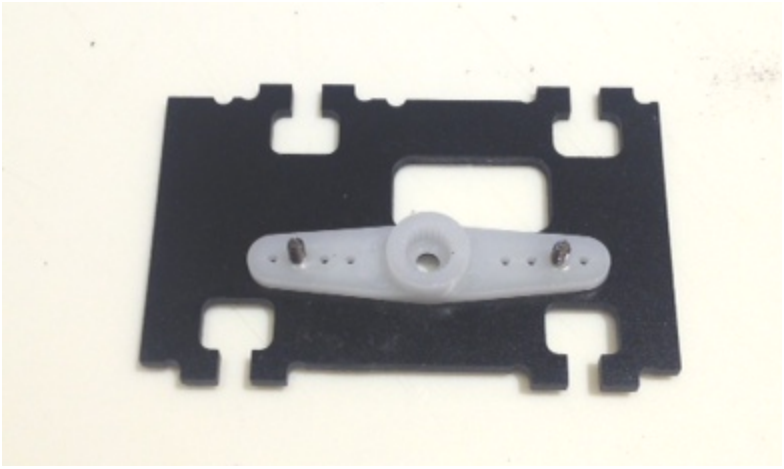
Step 1: GoPro mount

a) Servo mount: HS65MG

Using two of the self-tapping screws supplied with the HS65MG 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.

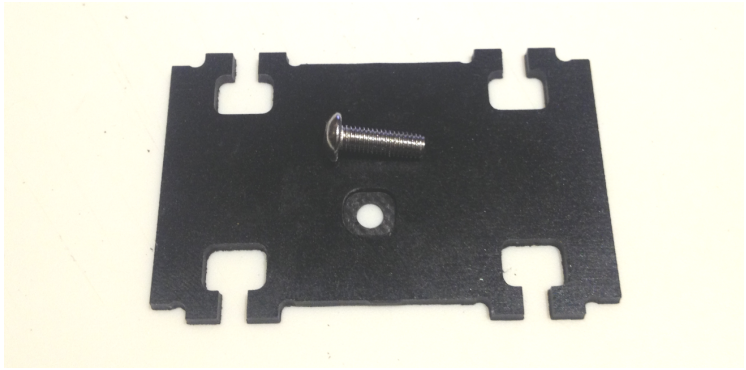
b) Servo Horn

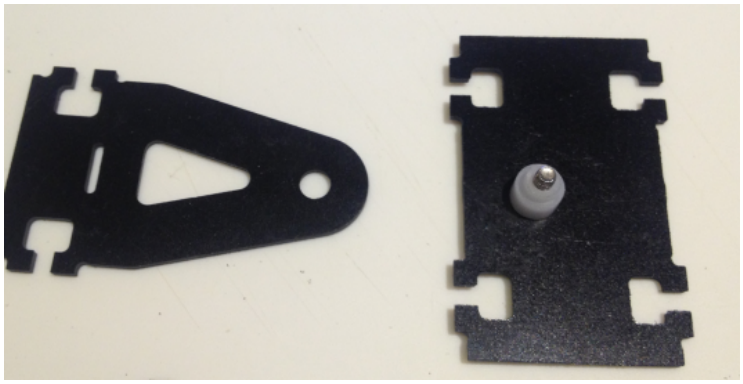
Using the second pair of self-tapping screws supplied with the HS-65HB servo, screw the servo horn onto the left-side GoPro mounting plate, as shown below:

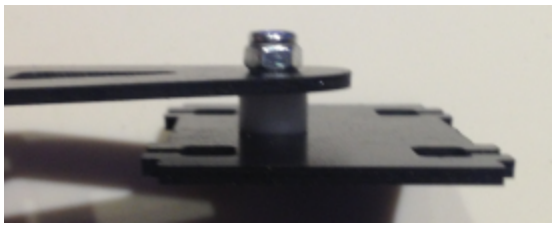


c) Right-side GoPro bearing

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.

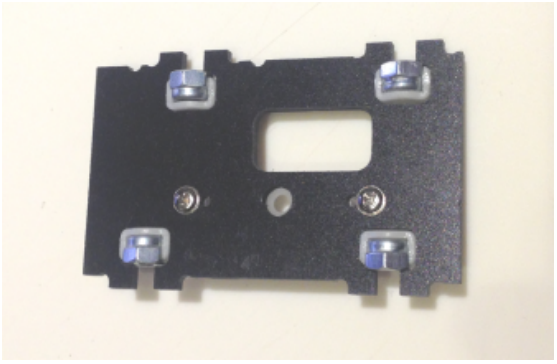


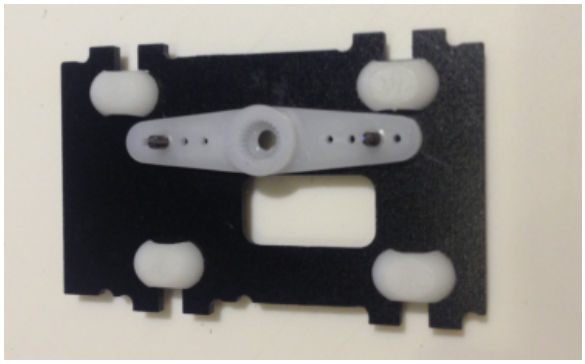




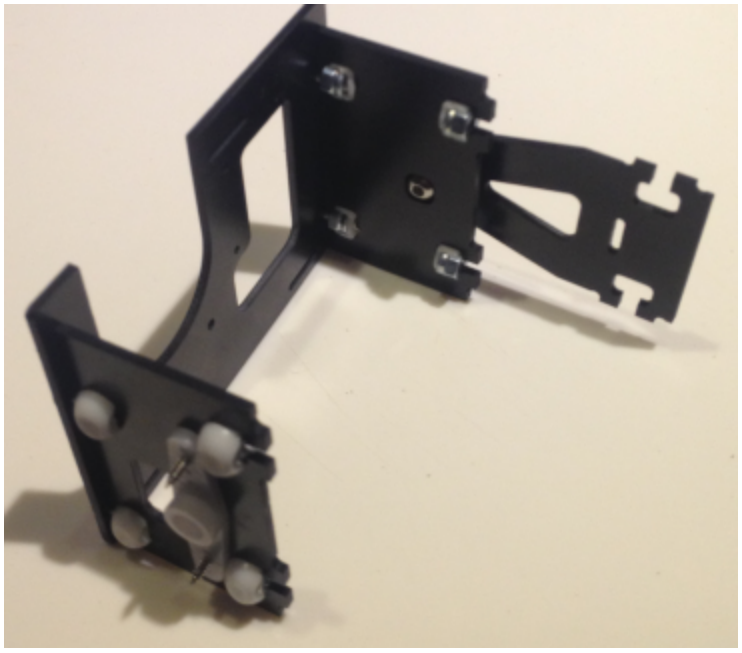
d) T-Nut installation, Finalize GoPro Assembly

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

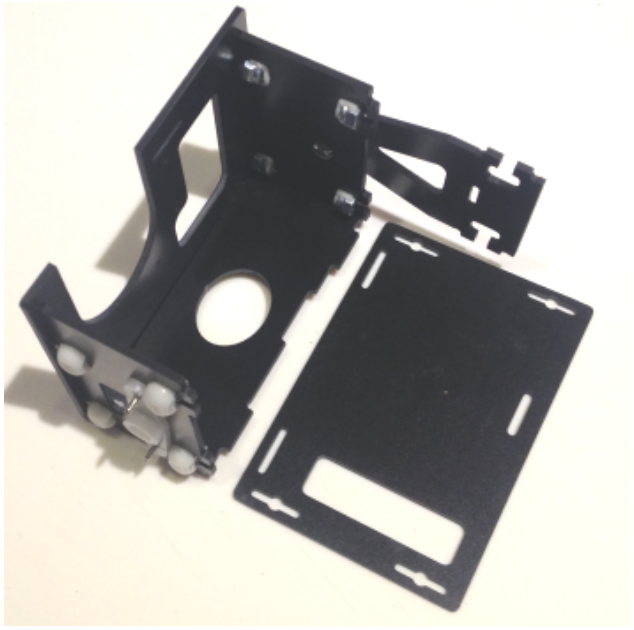




Mount the two plates to the GoPro front-plate:

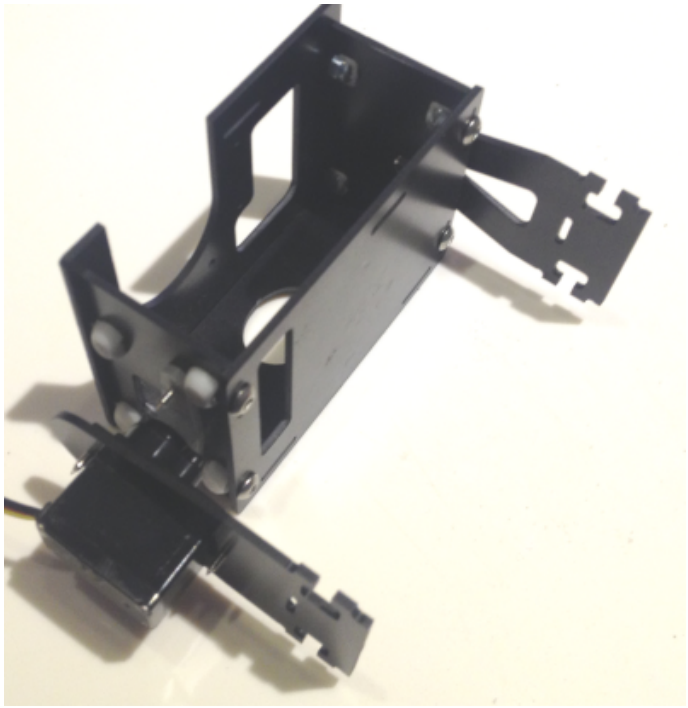


Mount the lower and back plates. Note the position of the slot in the back plate, and the corresponding slot in the lower plate.



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 tha when the mount is level, the servo is at it's mid-point.

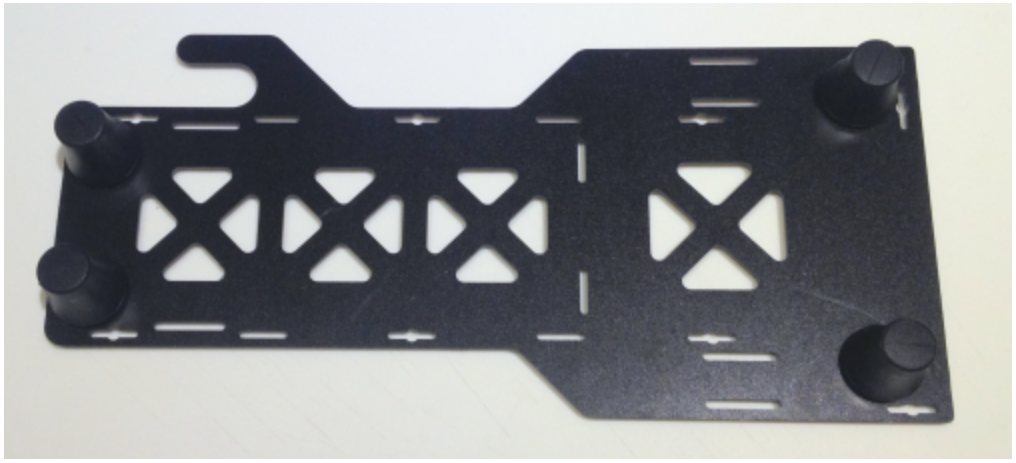


Step 2: The Frame

a) Silicone Feet installation

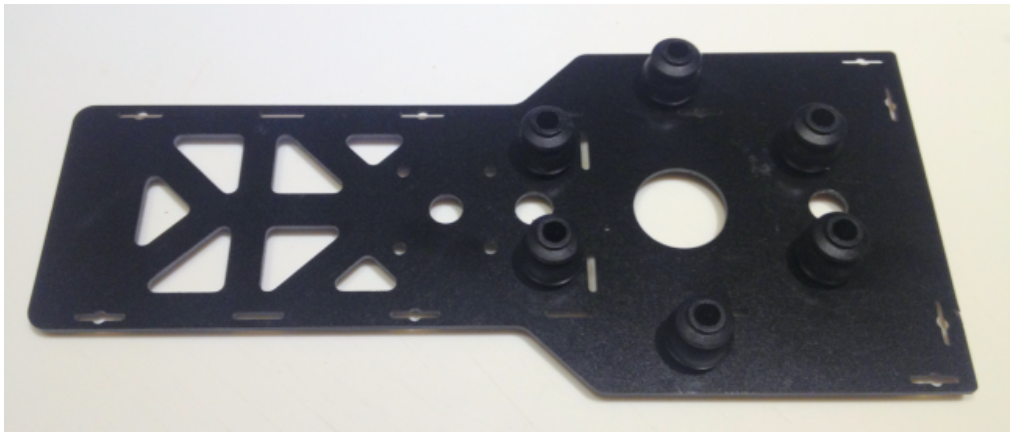
First step in building the frame is to install the rubber feet. Don't leave this until the end, since they are difficult to install once the frame is assembled.

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.



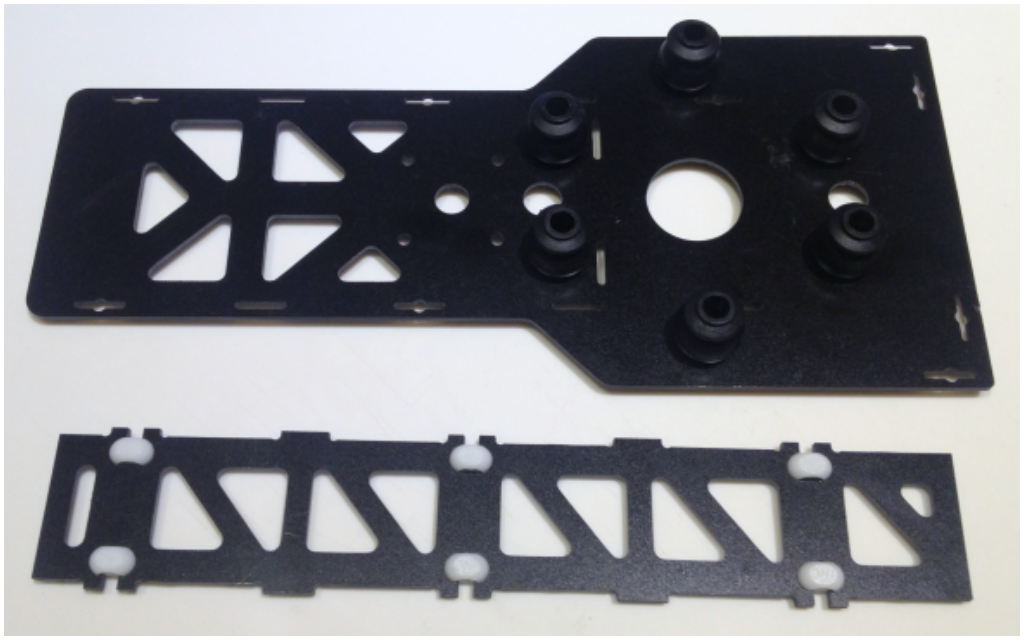
b) Anti-Jello Damper installation

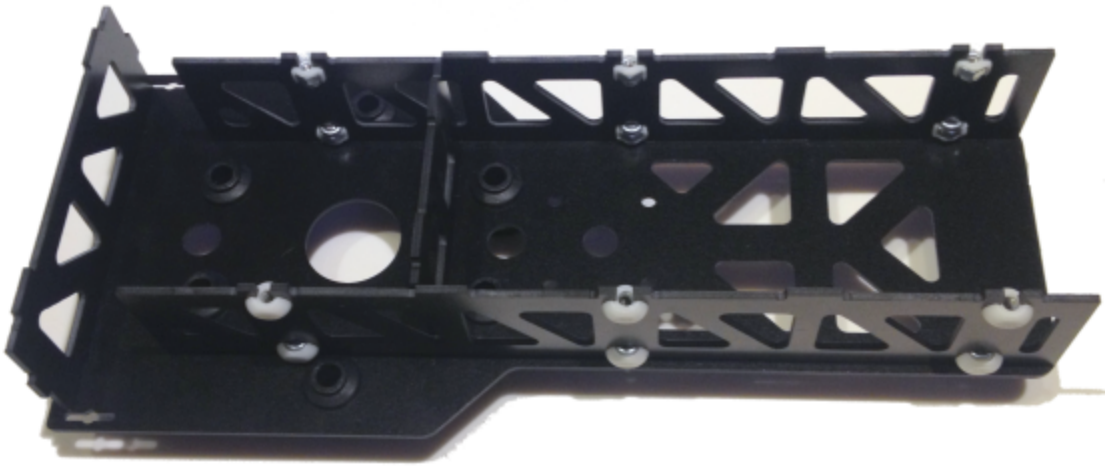
The anti-jello dampers should be installed next, as shown below. Again, don't leave these until later in the installation procedure, since they are difficult to install later.



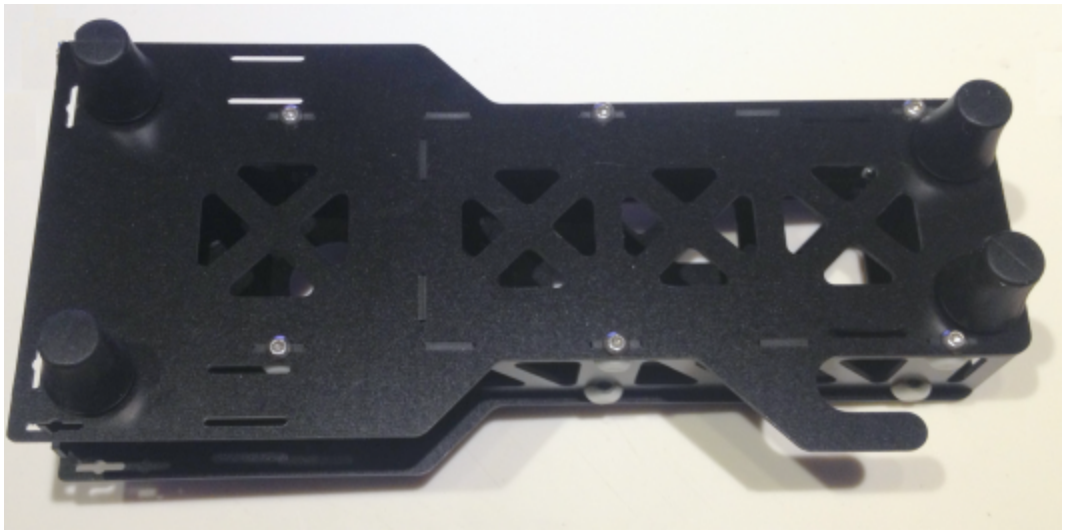
c) Frame Side-plate Install

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:

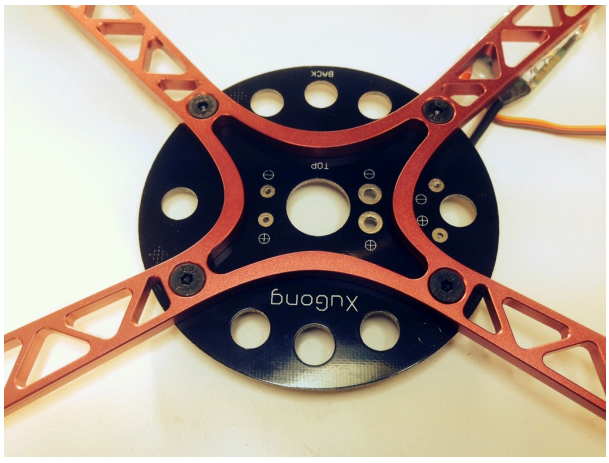


Don’t close it just now, as you’ll still need access to the inside to fix the controller and the GPS mount.

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:



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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 3M VHB double-sided tape. Avoid mounting them with tie-wraps, or anything else that wraps around the center spider, since that will impede the ability to fold the copter.

Tip: If possible, try to avoid 'peel & stick' type thicker foam tapes, the adhesive on these will last for a short while, but eventually will give way (this was recommended in previous versions of the build log)

Tip: 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.

Warning: Do not get these wires backwards… ESCs are not very forgiving if wired to a LiPo backwards!. Check, and double-check!

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 to 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.

Warning: 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.

Tip: For builds using the standard DJI motors, and standard DJI ESCs, it should be obvious a this point that the motor wires are too short, and won't reach the ESCs.

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. On the other hand, ensure that there is not too much cable 'dangling' under the arms, and possibly getting wrapped around the props.

Another alternative is to eliminate the bullet connectors altogether, and directly solder the motors to the ESCs. For a very robust installation, eliminating as many connectors as possible is a good thing.

Mounting the GPS/Compass

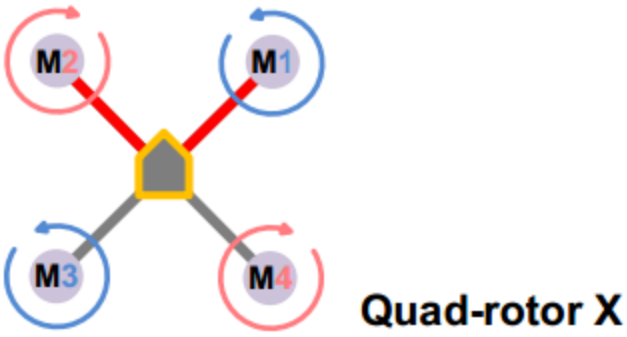
Holes in the top plate are provided for the standard DJI GPS/Compass. Even though it is tempting to stick the GPS directly onto the back of the upper plate of the frame, it is highly recommended to use the standard DJI ‘stalk’ supplied with the GPS.

Mount them with the nuts on the exterior part and the screw head in the inside, otherwise the battery won’t fit in the compartment (and more seriously, the end of the screw shafts will tear the battery housing, and potentially cause a fire).

The recommended height of the GPS above the top of the props is approx. 10mm. This requires trimming 10mm from the standard GPS Carbon Fibre ‘stalk’.

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



As with any quad build, take great care to make sure that the props are rotating in the correct direction, have the correct CW/CCW prop on each motor, and are correctly wired to the Naza. One you are sure that they are wired/attached correctly, check again!

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.
Alternatively a short extension cable ships in recent XuGong boxes, use this to extend the GPS cable.

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

Warning: 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 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.

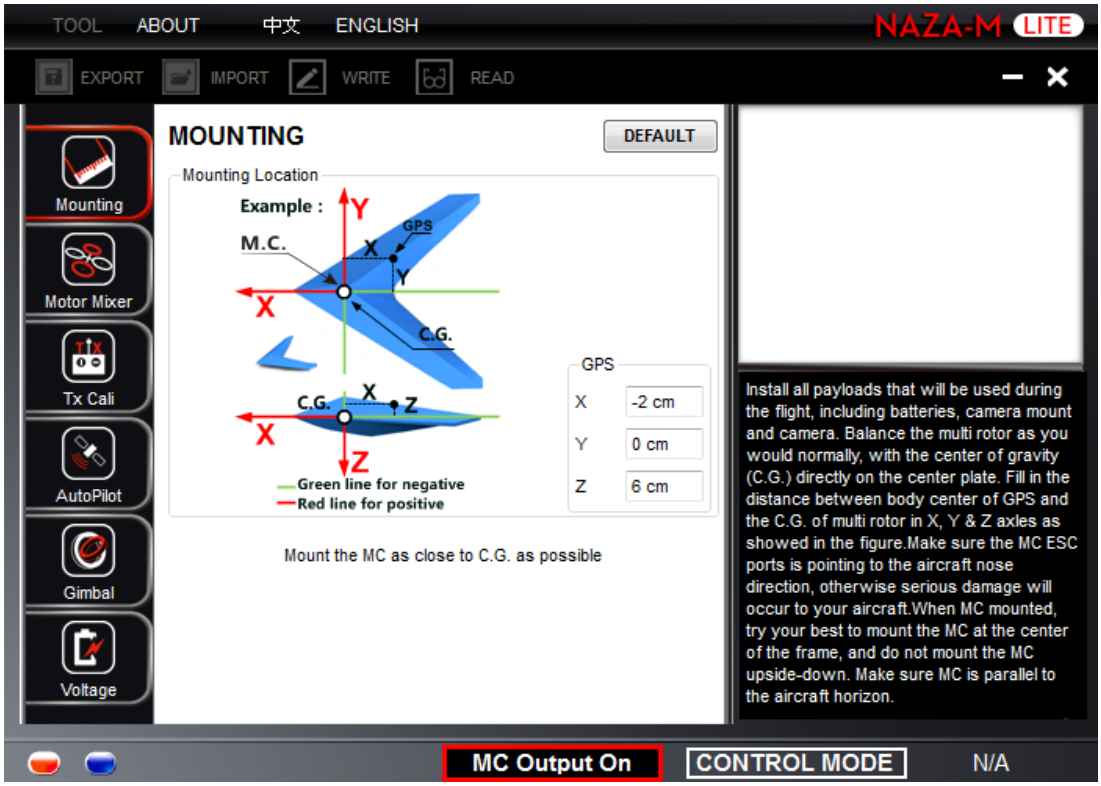
When correctly bound, the LED on the Rx should be ‘breathing’, indicating normal operation.

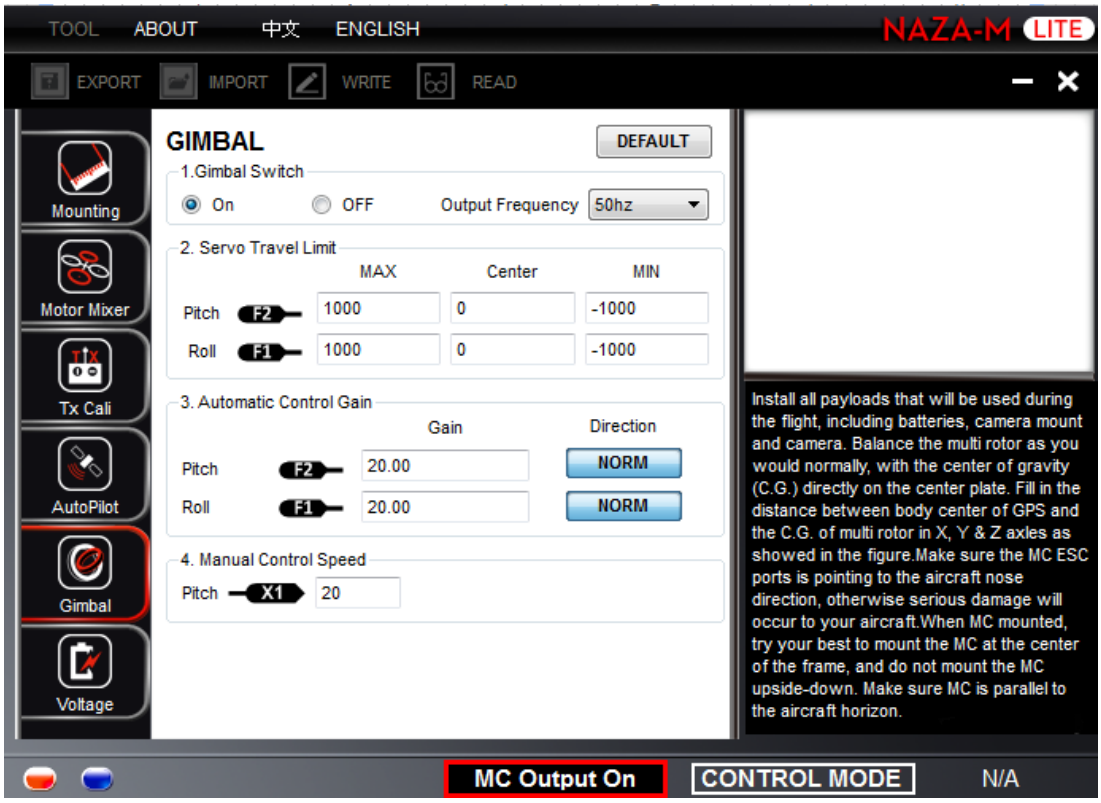
The only cable hookup to the EzUHF should be a single servo cable, between connector X2 on the NAZA, and CH1 of the EzUHF receiver.

2) Setting up the Naza

Naza gain settings depend heavily upon the configuration of the XuGong.
Default settings are generally a good place to start from, and then fine tuning can be performed following one of the multiple guides available with a quick google search.

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





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.

> Warning: the easiest way to lose a naza-equipped quad is not to follow carefully the GPS/Compass mounting instructions!

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.

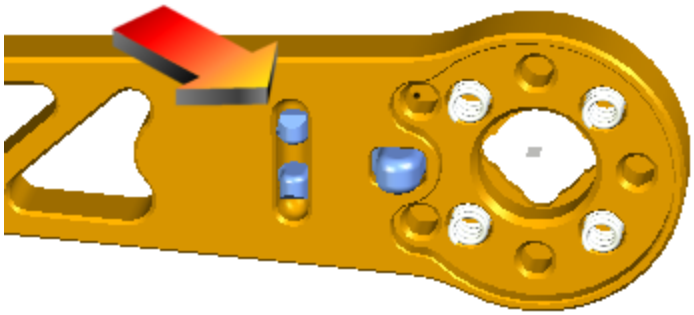
In practice, during approx. 1 year of testing before the XuGong was announced, we experienced several serious crashes. The most common was DJI props (1st generation 8" props) breaking while several 10s of meters in the air. In every case, the repair was as simple as bending the arms gently back into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

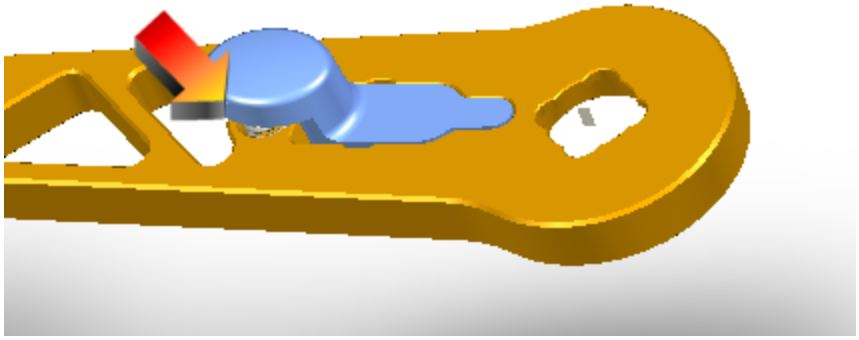
Lastly, several head-on crashes took place, generally while fence-hopping (forgetting to hop). In these cases the small white arm release would snap off, but is easy to replace in the field.

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.



Warning: 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!



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.

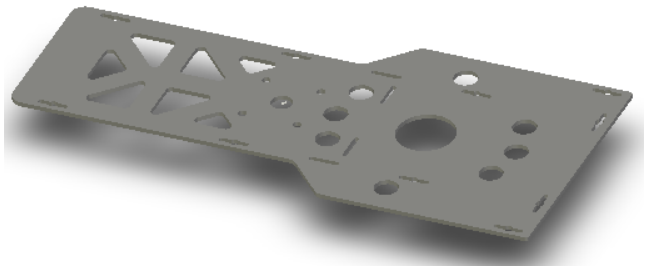
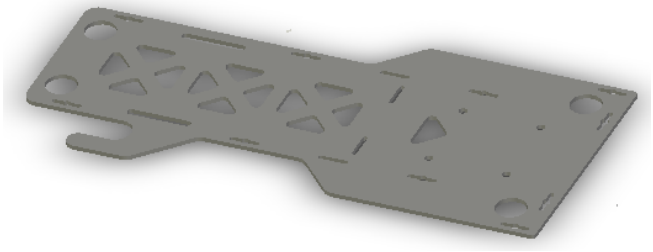
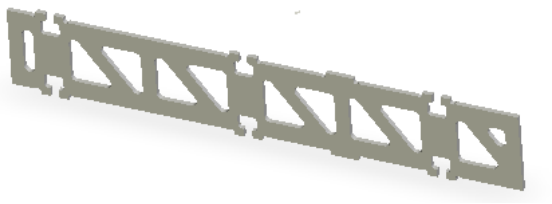
(This system was used for one of the XuGong promotional videos here: https://vimeo.com/78925542)

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

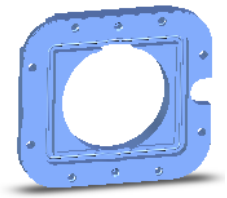
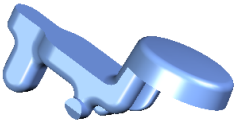
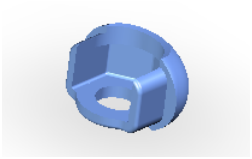
FR4 pieces, Main body

Top Plate, FR4	x1	
Bottom Plate, FR4	x1	
Side Plate, FR4	x2	
Front Bulkhead, FR4	x1	
Battery Bulkhead, FR4	x1	

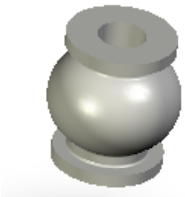
FR4 pieces, GoPro Mount

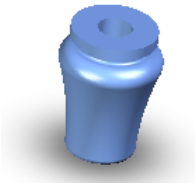
Right camera mount, FR4	x1	
Left camera mount, FR4	x1	
Camera box front, FR4	x1	
Camera box back, FR4	x1	
Camera box right, FR4	x1	
Camera box left, FR4	x1	
Camera box bottom, FR4	x1	
FPV Camera mount, FR4	x1	

Plastic parts

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

Silicone Rubber Parts

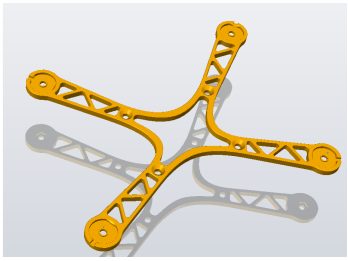
Damper Rubbers, Std	x8	

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. 8” Version	x1	
Outer Arms, Std. 10” Version	x1