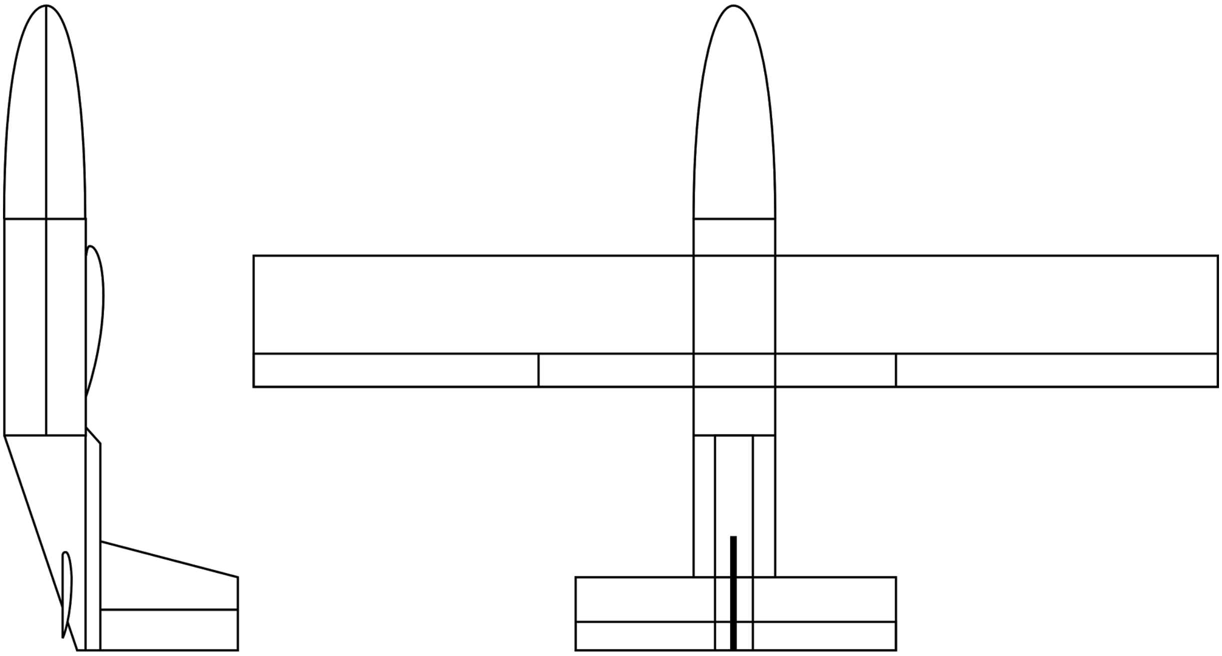
RESEARCHDRONES
DISCOVERING NEW PERSPECTIVES

Maja D Operator Manual



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Introduction

The Maja UAV is a fully autonomous, small unmanned aerial vehicle commonly referred to as UAV or Drone. It is designed to be operated in small spaces. 100 * 100 meter of open and rather flat area should be large enough for automatic takeoffs and landings. By design, the aircraft flies relatively slow (cruise speed is 12 m/s) to be able to map areas at low altitude and high resolution.

Because of the low flying altitudes, this aircraft is usually operated in unregulated airspace (usually Class G) and in line of sight. In most countries around the world an aircraft can be operated without special permission and certification from authorities.

This manual explains the various aspects of the Maja UAV.

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DISCOVERING NEW PERSPECTIVES

Table of contents

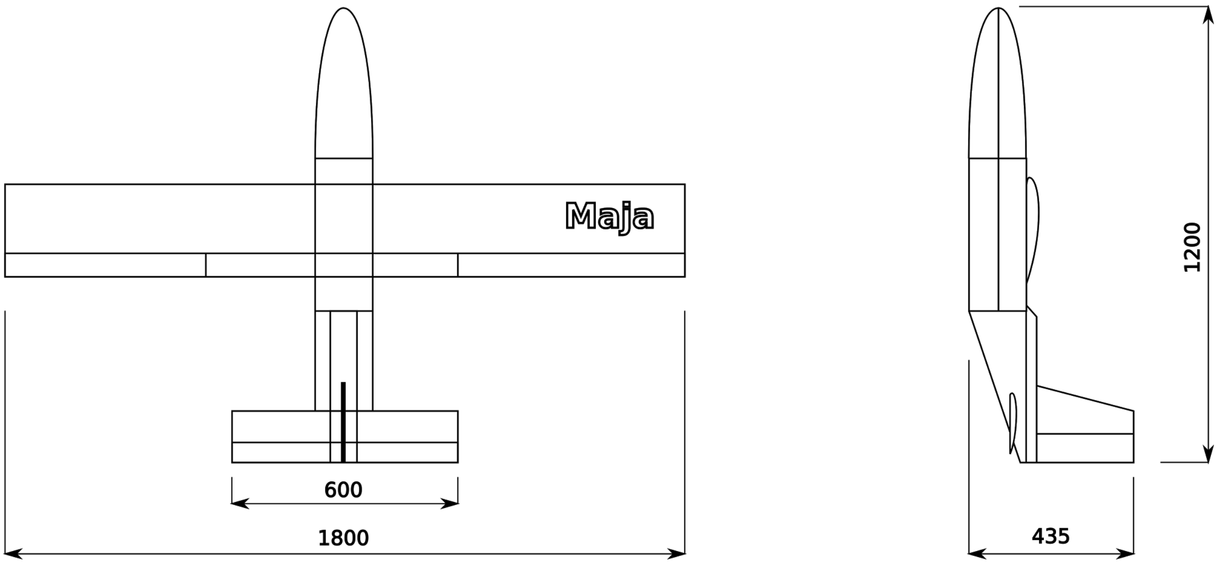
Maja D

The Maja D is a fully autonomous unmanned aerial vehicle (UAV). It is equipped with a downward looking high resolution photo camera for mapping landscapes. Depending on the setup it may also carry a forward looking high definition video camera.

The airframe offers easy access to batteries and payload. It's flight characteristics are optimized for hand launch, flying mapping missions at 100m above ground (and higher) as well as landing rough terrain.

Technical Data

		Remarks
Length	1200 mm	
Wingspan	1800 mm	
Max take-off weight (MTOW)	3000 g	
Empty weight	1200 g	
Payload capacity	1000 g	
Battery weight	800 g	With 2*5000 mAh batteries
Endurance	1 h	Depending on mission and wind
Range	40 km	Depending on mission and wind

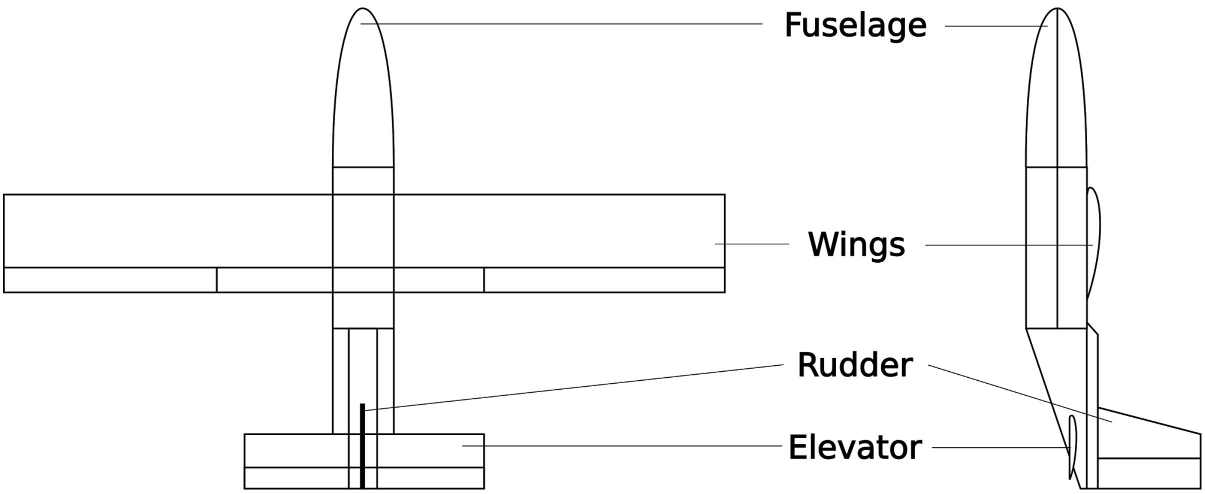


Airframe

Parts

The airframe consists of the following parts

- fuselage
- wings
- elevator
- rudder (tail fin)



Moving surfaces

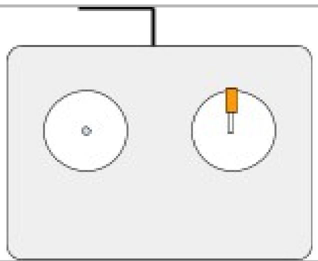
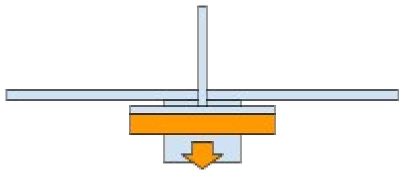
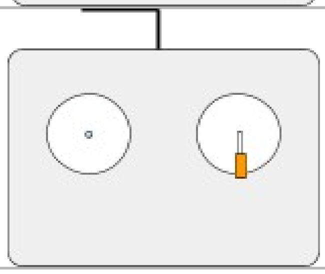
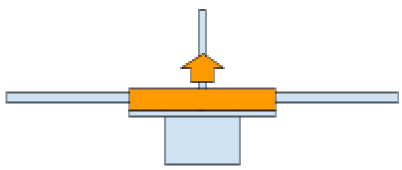
Manual input

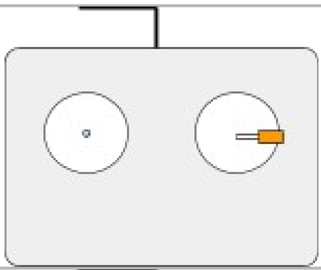
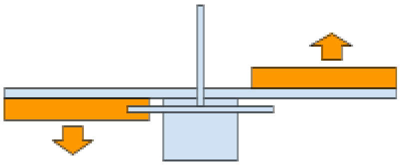
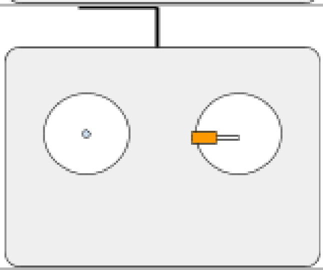
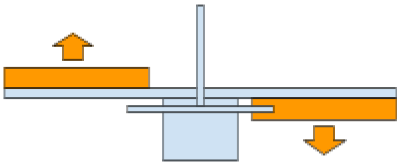
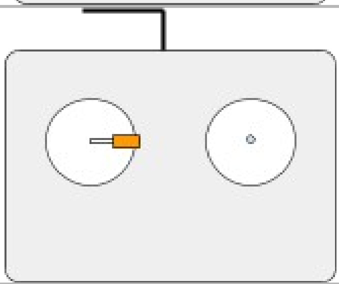
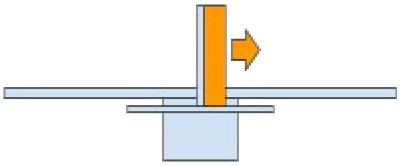
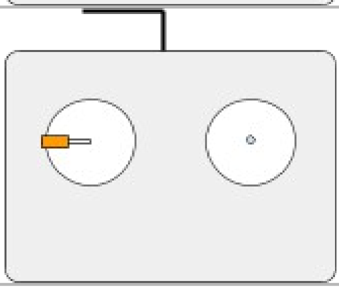
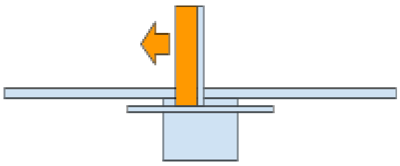
It is important to make sure the transmitter and autopilot are configured to move all moving surfaces into the right direction. Check this before every flight. The illustrations below show in which direction each moving surface should point when moving the stick.

Autopilot input

Banking the aircraft in stabilize/Fly-By-Wire mode should produce the opposite result. In these modes the autopilot will try bring the aircraft into a level flight attitude again. When the aircraft is banked to the right, the autopilot should move the surfaces so that the aircraft banks back to the left until the aircraft is level again.

The orange surfaces show in which direction the stick input will move the surface. All images are shown from **behind the aircraft**.

Transmitter	Surfaces (from behind)	Direction
		Nose down
		Nose up

		Roll right
		Roll left
		Yaw right
		Yaw left

Payload

The Maja airframe allows easy access to it’s payload. The payload consist of a still camera and a high definition Video camera. The payload has to be configured and setup before take-off. Data can be obtained after landing via USB cable and/or SD card reader.

Still Camera

The MAJA D comes with a Canon SX260HS pre-configured and pre-loaded with custom firmware.

Power

The camera’s battery lasts for approximately 1.5h and should be recharged before every flight with the supplied battery charger.

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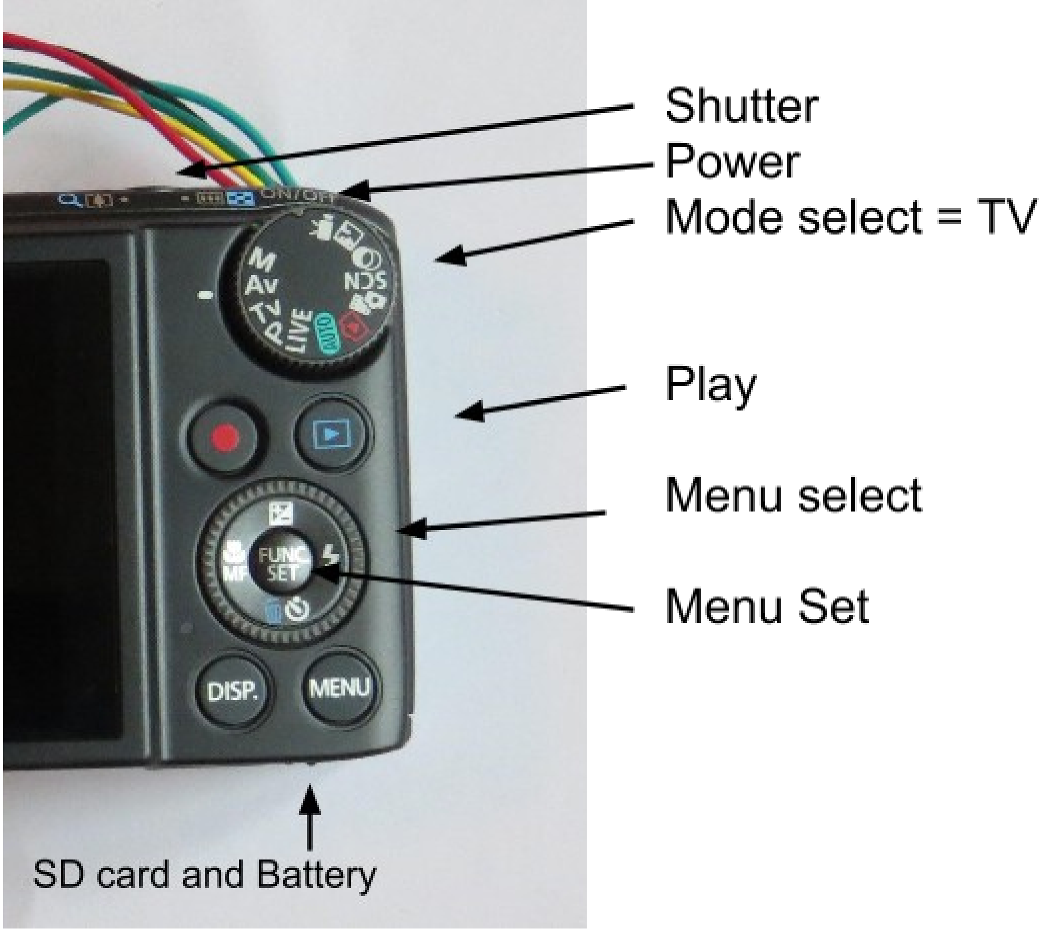
Buttons



The Mode select button should always be set to TV. The play button is used to turn the camera on and start the intervalometer script. Menu select and Menu set are used to change the camera's interval and duration settings. The power button is used to turn the camera off.

Camera Configuration

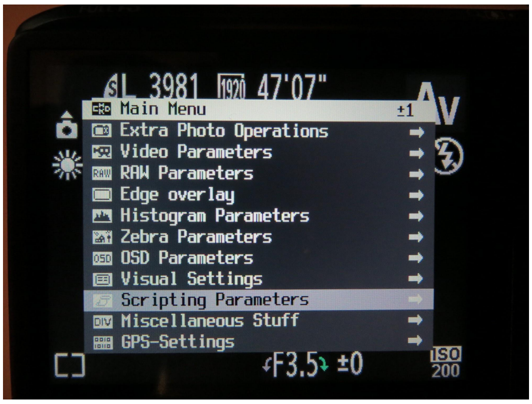
It is possible to change 4 parameters of the cameras interval settings:

- Start delay [s] (default: 5)

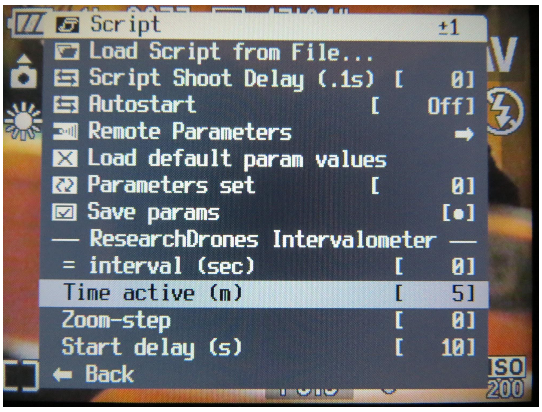
- Interval [sec] (default: 0)
- Zoom-Step (default: 0)
- Time active [m] (default: 5)

Usually there is only a need to change the “Time active” value. This should be set to the planned mission time. Once the time active is reached, the camera will shut down and the lens will close. It is important that the lens is close before landing, that way the lens is protected from dust and dirt during the landing. To change these values, do the following:

1. Turn the camera on via power button.
2. wait a couple of seconds and stop the script via shutter button
3. click the play button and then the menu button, you should see the following menu:



4. Select “Scripting Parameters”
5. At the bottom of the scripting parameters menue you can now change the values of the 4 parameters. Use the “menu set” button to toggle a value for change. Use the “menu select” dial to change the value.



6. When done, hit the “Shutter” button to save the changes.
7. Start the script by hitting the “Shutter” button

More information on camera settings can be found in the Appendix.

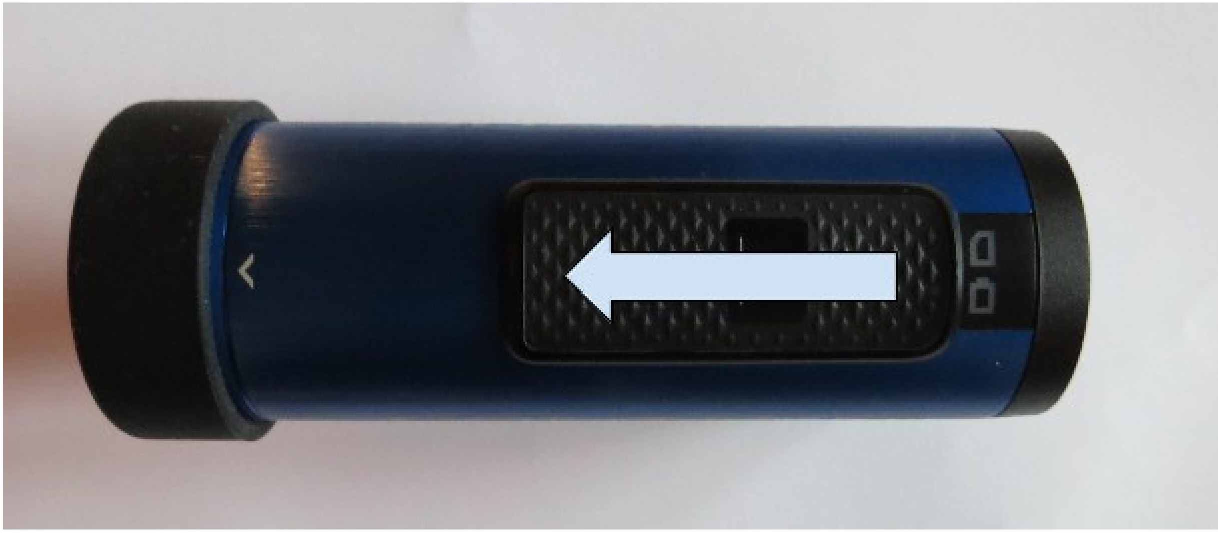
Video Camera

The video camera is mounted on or in the nose. Recharging can be done through USB from a laptop/PC or with an external USB charger (12V inverter or 220/110V).

The microSD card and the USB port are accessible behind the lid at the end of the camera. lift the lid up and the camera opens.

Accessing the SD card

Turning the camera on and off



Check that the red light is on. If the icon on the top is red, there is a problem with the SD card

- the SD card might be full
- the SD card might be unformatted
- SD card not inserted

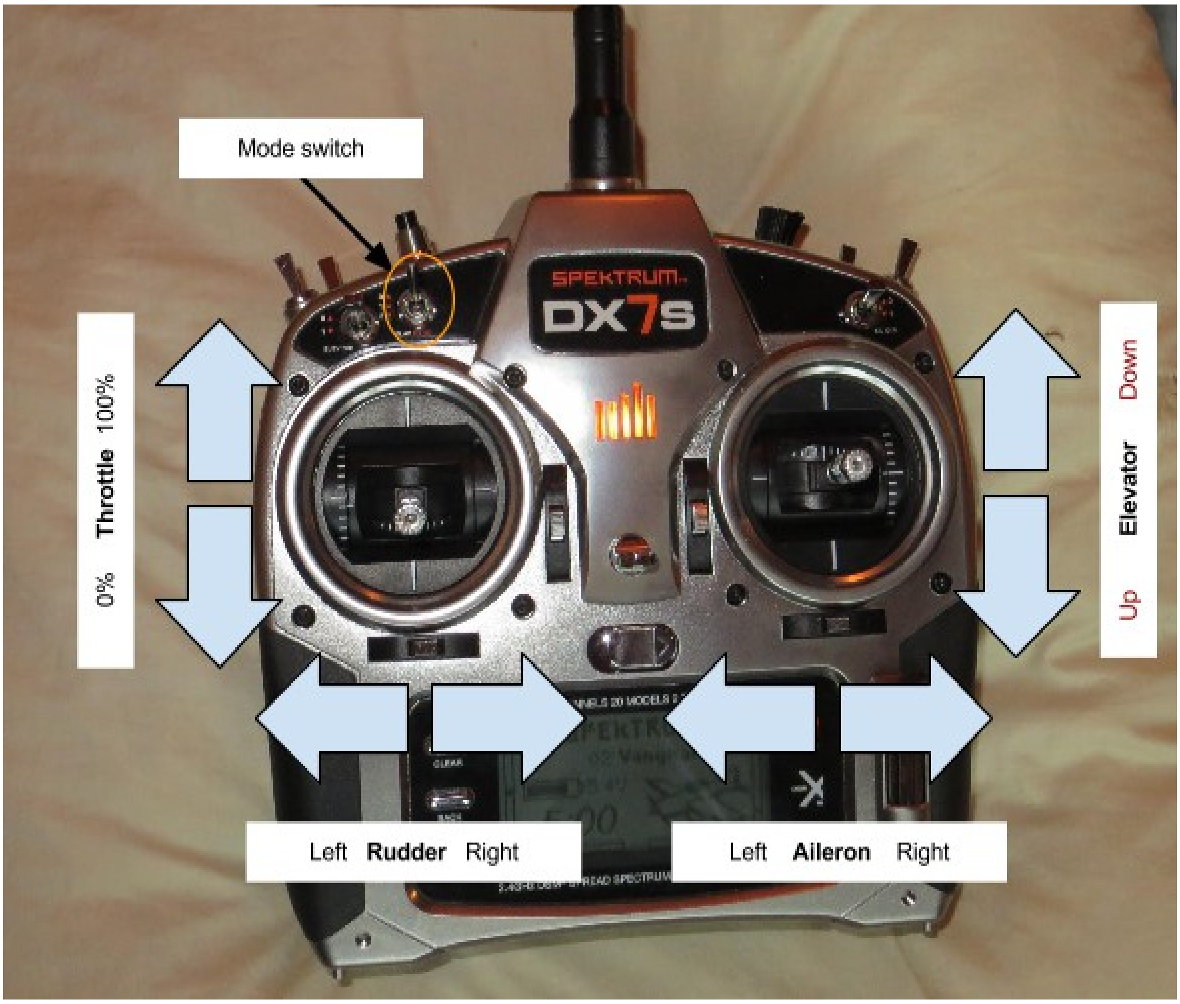
The battery icon changes color from green to orange to red to indicate the battery status. Green indicates that the battery is fully charged.

Hardware

Transmitter

The transmitter is primarily used by the operator to select the flight modes and for small corrections during auto landings. Advanced operators might also use the transmitter for manual control of the UAV while in line of sight. From experience we know that at least 40-60 hours experience of flying r/c planes is required to safely fly the aircraft in manual mode.

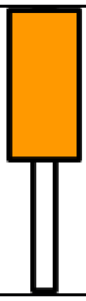
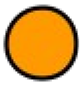
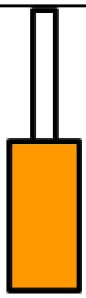
This is a description of the used buttons and levers on the Maja D UAV:



See “moving surfaces” on a detailed explanation of what effect the 2 joysticks have. See “Mode switch” for a more detailed explanation of the modes and function of this switch.

Mode switch

The mode switch on the transmitter is used to set the different modes the autopilot should execute.

	**Manual Mode** This mode gives control to the pilot. It is used for initialisation test and ground handling. Make sure to always have the **throttle stick to 0%** before moving into manual mode while on ground.
	**RTL (Return To Launch)** The RTL mode is used to command the aircraft back to it's initialisation position which is usually where it took off. The altitude for RTL is set in mission planner. The default altitude is used.
	**Auto** This mode is used to fly a mission. Once enabled, the engine will start. Be very careful, do this only shortly before take-off.In auto mode, as long as a valid mission is planned, the UAV will take-off, fly it's mission and land without intervention of the operator. However, Joystick inputs are active and may disturb the autopilots flight path, do not move the joysticks unless you really intend to change the flight path (for example during a landing to correct drift caused by wind).

Telemetry link

Although the MAJA UAV is able to fly a fully autonomous mission, it is possible to change commands and flight paths via telemetry link. this is the preferred method of controlling the UAV because it does not require any knowledge of lying an aircraft. New commands are planned on a laptop or tablet and sent up via telemetry link to the aircraft.

The telemetry link is primarily used as control channel to visualize the state of the flying UAV on a laptop/tablet. All known autopilot parameters are constantly sent down to the computer where they are visualized and logged. If a mission does not work out as planned the telemetry logs are very valuable for analyzing the systems parameters at any time of the flight.

The telemetry link has a limited range, depending on a country's regulation, ground antennas, terrain and type.

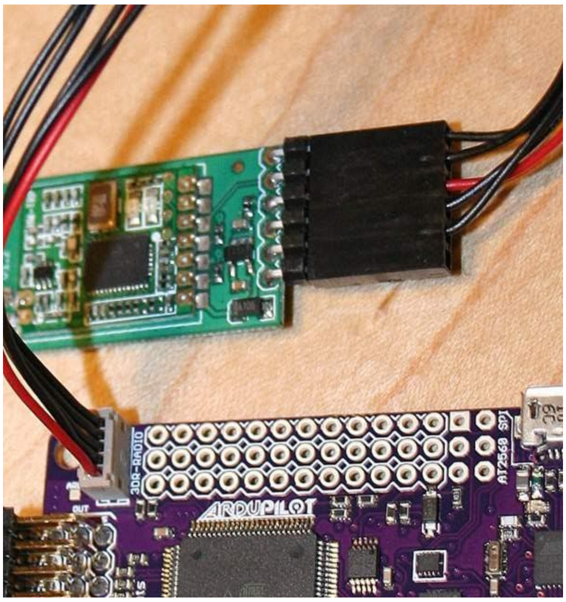
Short range Telemetry

The short range telemetry has a range of up to 1km (with rubber duck antennas). It is available at 2 frequencies:

- 433 MHz
- 900 MHz

433MHz is mostly recommended for use in Europe, Australia and Brazil. 900 Mhz in the rest of the world. Be aware, that mobile networks (mostly 900 MHz) often are in the 900 MHz range, so make sure you do not get interference from mobile towers.

The telemetry modems are connected via special telemetry cable to the autopilot and with a standard FTDI 3.3V cable to the computer/tablet (OTG cable required for tablet).



Long range Telemetry

The RDF900 long range modem gives a range of up to 3km (with line of sight and rubber duck antenna). If high gain antenna is used on the ground side (for example a patch or yagi antenna).

Telemetry frequencies

Region	Radio Model	Settings	Standard
USA	3DR 900 / RFD900	MIN_FREQ=902000 MAX_FREQ=928000 NUM_CHANNELS=50	FCC 15.247
Canada	3DR 900 / RFD900	MIN_FREQ=902000 MAX_FREQ=928000 NUM_CHANNELS=50	RSS-210 Annex 8.1
Australia	3DR 900 / RFD900	MIN_FREQ=915000 MAX_FREQ=928000 NUM_CHANNELS>=20	LIPD-2000 item 52
Australia	3DR 433	MIN_FREQ=433050 MAX_FREQ=434790 TXPOWER<=14	LIPD-2000 item 17
Europe (most countries)	3DR 433	MIN_FREQ=434040 MAX_FREQ=434790 TXPOWER<=8 NUM_CHANNELS>=30	ETSI EN300 220 7.2.3
Europe (most countries)	3DR 433	MIN_FREQ=433050 MAX_FREQ=434790 TXPOWER<=8 DUTY_CYCLE=10	ETSI EN300 220 7.2.3
United Kingdom	3DR 433	MIN_FREQ=433050 MAX_FREQ=434790 TXPOWER<=8 DUTY_CYCLE=10	IR2030/1/10
New Zealand	3DR 900 / RFD900	MIN_FREQ=921000 MAX_FREQ=928000	Notice 2007, Schedule 1
New Zealand	3DR 433	MIN_FREQ=433050 MAX_FREQ=434790	Notice 2007, Schedule 1
Brazil	3DR 433	MIN_FREQ=433000 MAX_FREQ=435000 TXPOWER<=8	Resolução ANATEL nº506/2008
Brazil	3DR 900 / RFD900	MIN_FREQ=902000 MAX_FREQ=907500 NUM_CHANNELS>=11	Resolução ANATEL nº506/2008
Brazil	3DR 900 / RFD900	MIN_FREQ=915000 MAX_FREQ=928000 NUM_CHANNELS>=26	Resolução ANATEL nº506/2008
Argentina	3DR 900 / RFD900	MIN_FREQ=902000 MAX_FREQ=928000	Comisión Nacional de Comunicaciones

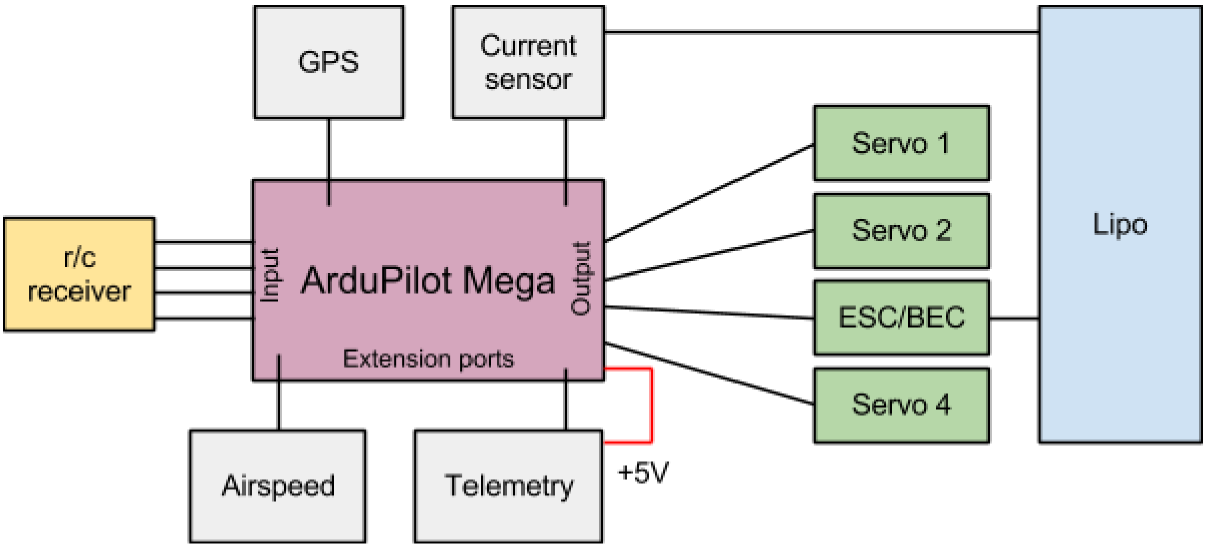
South Africa	3DR 433	MIN_FREQ=433050 MAX_FREQ=434790 TXPOWER<=10mW	2008 RR 5.138, Government Gazette No 31127, Notice No 713 of 2008 and Government Gazette No 31290, Notice No 926 of 2008 refer

Wiring

This is a schematic description of the wiring of all components that make up the auto pilot system. A detailed pin description can be found in the drawing which describes the ArduPilot Mega's connectors in detail ("Appendix A").

All connectors are also labelled on the ArduPilot case and board. Most of the connectors do not have a protective measures to prevent you from plugging them in the wrong way. Be careful, we recommend to double check connectors before powering up the system the first time after maintenance work or re-wiring.

A wrong connected component will most probably damage parts or all of the system.



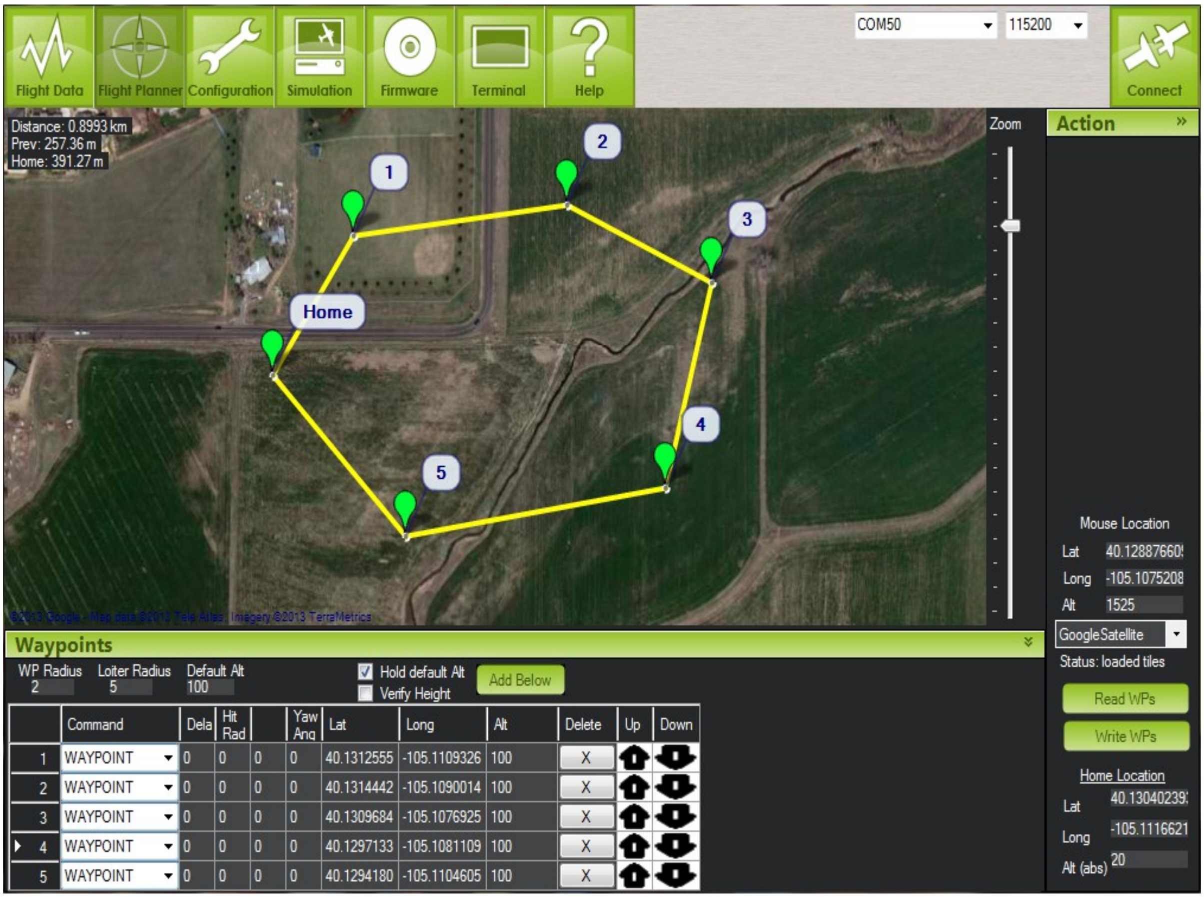
NOTE: The RDF900 telemetry modem needs to be powered from the output rail.

Groundstation software

There are several programs that can be used as groundstation software. The groundstation software is used for:

- Mission planning
- Real time telemetry data display
- UAV control
- analysing log data

Windows[1]



The Mission Planner, created by Michael Oborne, does a lot more than its name. Here are some of the features:

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1 Windows XP and 7 are supported at the time of this writing. Windows 8 is not yet fully supported but there are work arounds: http://diydrones.com/profiles/blogs/windows-8-and-how-to-get-your-apm2-working-on-it

- Point-and-click waypoint entry, using Google Maps.
- Select mission commands from drop-down menus
- Download mission log files and analyze them
- Configure APM settings for your airframe
- Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.
- See the output from APM's serial terminal

Set up the software

If you haven't done so already, download the Mission Planner here[2] (it will be called APM !Mission Planner x.x.xx.msi).

It requires a Windows machine running .net Framework 3.5+. This is shipped as part of Windows Vista and Windows 7, so if you're using them you don't need to load anything more. If you're using Windows XP you will have to download it yourself here[3]).

The Mission Planner will open a task bar at the top of your screen, and open with the Planner window. In the Options menu on the task bar, select the Com port assigned to your APM board or telemetry link (115200 baud for APM, 57600 baud for Telemetry).

The main Mission Planner function is represented by a tab in the top row of every screen.

2 http://ardupilot.com/downloads/?category=4
3 http://www.microsoft.com/net/download.aspx

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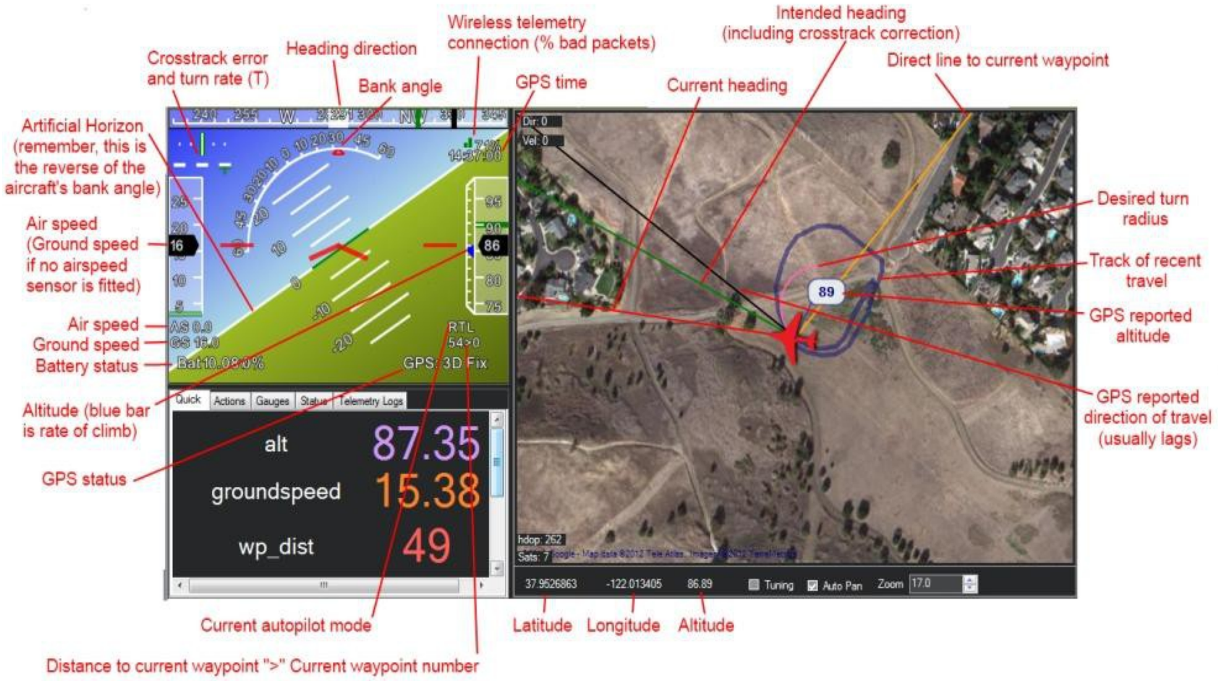
Using mission planner

GUI components



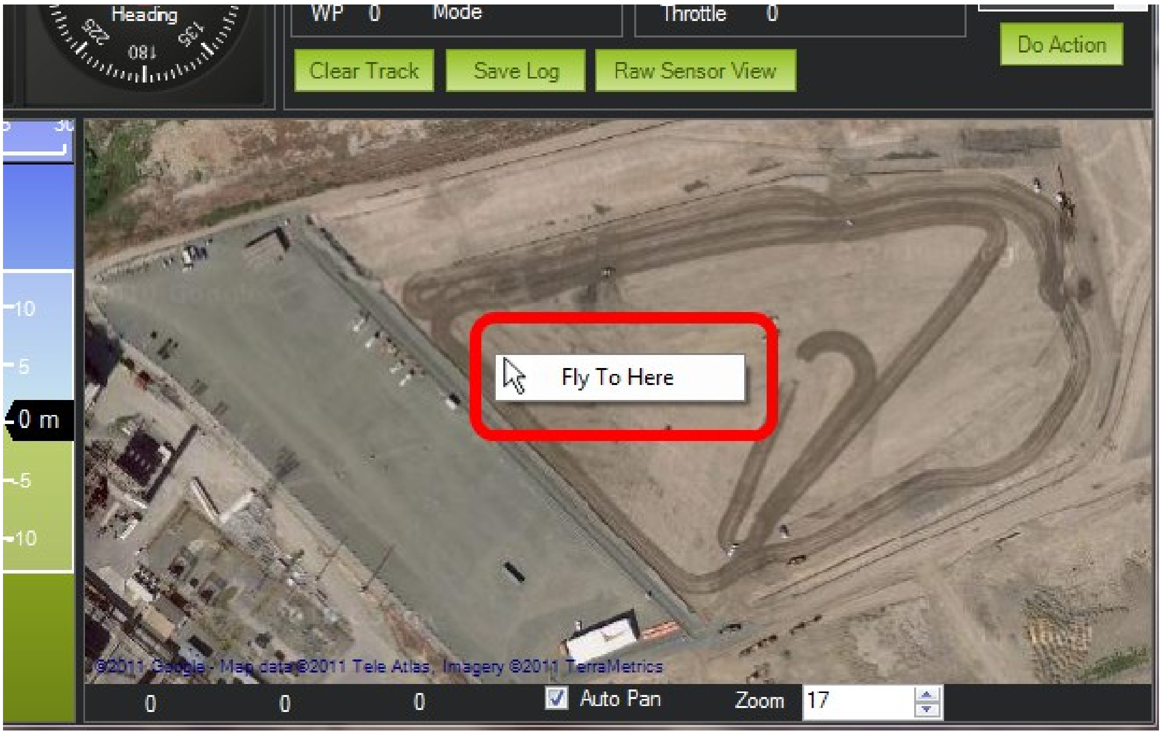
The above is the main Ground Station view of the Mission Planner, showing the Heads-up Display (HUD). Once you have connected via MAVLink over USB or wireless telemetry the dials and position on this screen will display the telemetry sent by APM.

A few tips:

- The map will only show current position when you have GPS lock or are using a flight simulator
- Remember how artificial horizons work: when the aircraft tilts to the right, the horizon tilts to the left. (Just tilt your head and you'll see what I mean). This is normal! Please don't tell us it's reversed ;-)
- You can issues mode changes and other action commands in the air with the Mission Planner and other GCSs, but note that you must be under autopilot control for them to take effect. When your RC toggle switch is in the Manual position, you are no longer under autopilot control and no commands will take effect. You must be in one of the other positions (Stabilize, Fly-by-Wire, Auto or any other autopilot-controlled mode) for MAVlink commands to take effect.

- You can change the voice used in the speech synthesis in the Ease of Access center in Windows Control Panel. Go to the "Text to Speech" options.
- If you double-click the HUD it will popout, allowing you to run the hud full screen on a second screen.
- If you double-click on the Speed Guage you can modify the max scale you want to display.
- If you enable the Tuning checkbox and double-click tuning you can graph any data that is available in the status tab. This means you can have alt, attitude, or many other options in real time.
- You can use custom imagery instead of Google Maps. Press control-F. This allows you to upload your own orthophotos. Use will require Globalmapper, as this is currently one of the key steps in exporting in the required format for use in the planner.

Guided Mode



One of the most commonly-used features in pro UAVs is point-and-click mission control in real time. Rather than just pre-planned missions or manually flying the UAV, operators can just click on a map and say "go here now".

On the GCS map, you can right-click on the map and just select "Fly To Here". The UAV will fly there and loiter until you give it another command. We call this "Guided Mode". There are more commands coming in this mode soon, but the functionality is now built-in.

Note: Guided is a separate flight mode. If you enter it you will remain in it until you do something to change modes. So if you tell it to "go here now", once it arrives there it will loiter at the Guided waypoint till you tell it to do something else. Something else could either be going to another Guided waypoint (staying in Guided mode) or changing to some other flight mode. If you change to Auto your mission will resume where it left off.

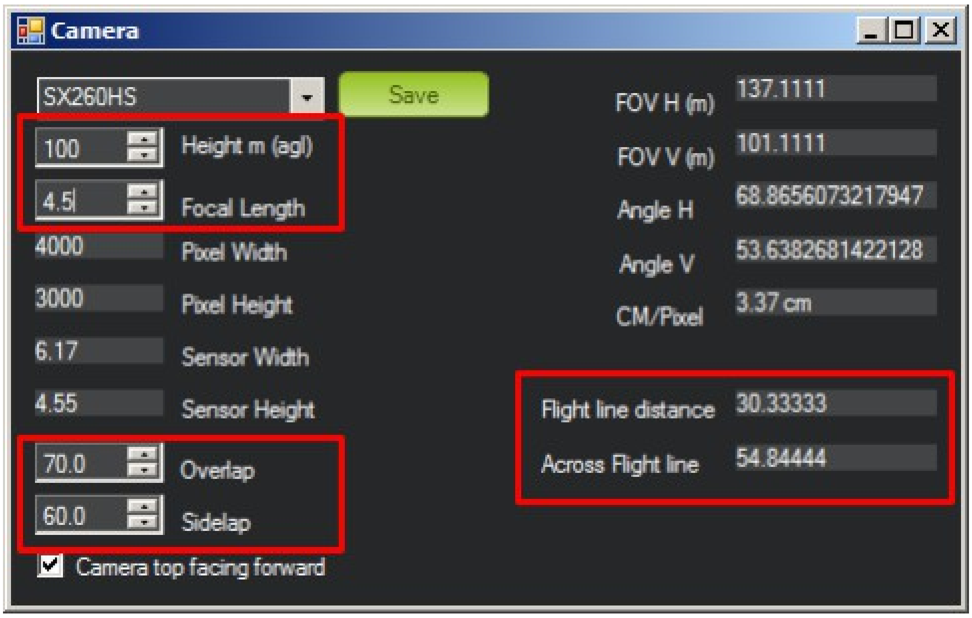
Camera settings calculator

Mission planner offers a tool to calculate the field of view of a camera from a certain altitude. for mapping missions it is important to have enough overlap of your images (depending on the post processing method used).

We recommend to have at least 60% overlap in both directions. I case one image is not sharp enough it can be skipped that way. Also more overlap is usually better for post processing software. Too much overlap, however, will make the flight very inefficient because the grid lines need to be very close together. this will make the covered land surfaces smaller with the same flight time.

Using the camera calculator in Mission Planner:

1. go to the “Flight Planner” tab
2. right click the map and select “Map Tool > Camera”



With the Canon SX260HS you need to enter a Focal Length of 4.5, enter your preferred altitude (usually 100m) and the desired overlap.

“Flight line distance” shows every N meters a picture needs to be taken (interval). With 12m/s cruise speed this means roughly every 2.5 seconds. If the intervalometer is set to 0 sec “Interval sec” then the camera will take a picture roughly every 2.2 seconds[4].

4 This seems to be confusing. Once a picture is taken the camera needs some time to store it on the SD card. This takes about 2 seconds until the camera is ready again for the next picture.

“Across Flight line” shows how far away the grid lines need to be from each other.

Mission planning

Map caching / prefetching

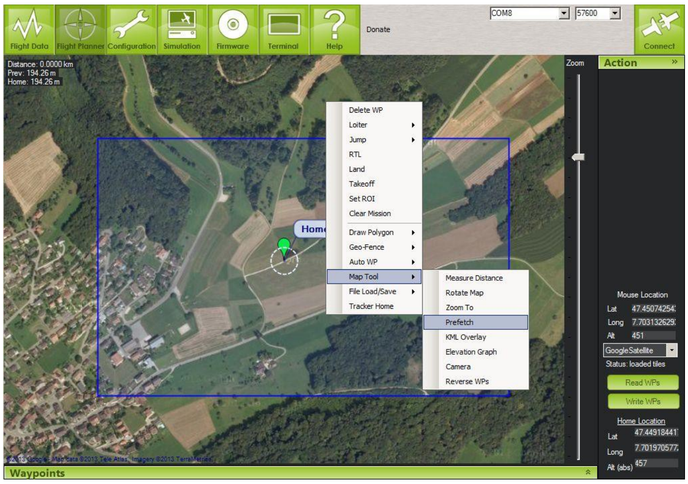
The Mission Planner software uses online maps. While operating the MAJA UAV in the field there might be no adequate or no internet connection for map download.

Mission Planner offers a feature to download map tiles onto your computer. It is accessed via the “Flight Planner” tab. Map data can use up quite some space on your hard drive. It is recommended to only download as much as needed because the map provide start to traffic-shape your connection from a certain amount of data which makes downloading slower and slower over time. Also, all the map data needs to be downloaded over your internet connection. A couple of square kilometers can quickly be in the gigabyte range (depending on the map provider and zoom steps).

1. Zoom into the desired location
2. draw a rectangle
   a. hold down the ALT key
   b. left-click drag
3. right click the map
4. select “Map Tool”
5. Prefetch

You will now be prompted to if you want to download maps at a certain zoom step. The higher the number, the more detailed the maps (and the more data to be fetched).

Zoom step 19 or 20 is usually the highest resolution you can get.

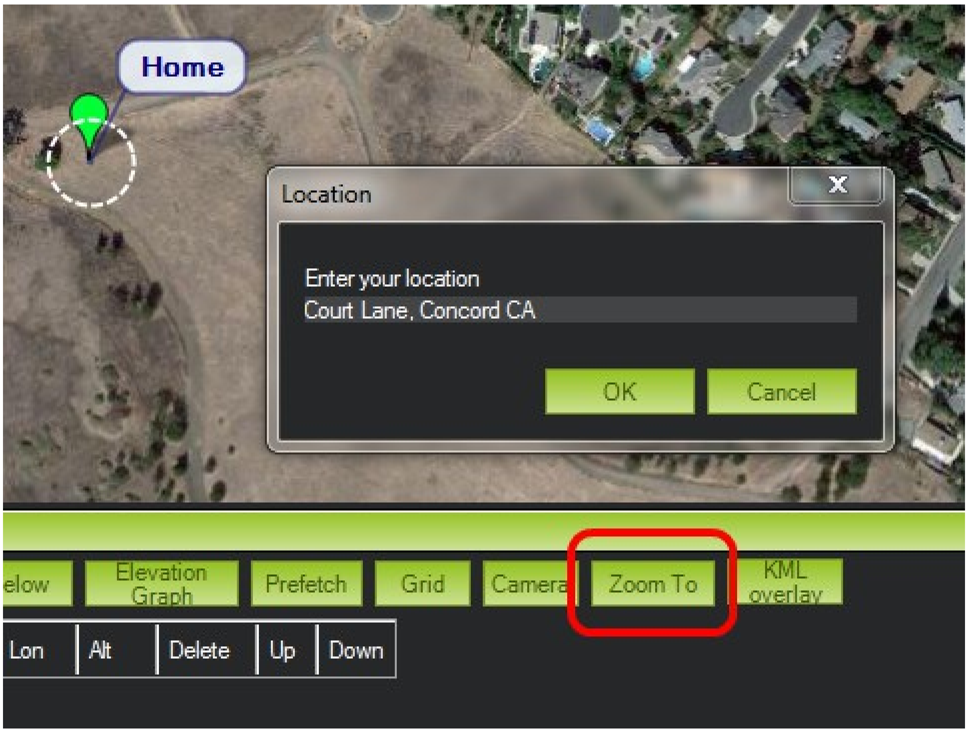


Planning a mission

Instructions

You can enter waypoints and other commands (see below for the full list). In the dropdown menus on each row, select the command you want. The column heading will change to show you what data that command requires. Lat and Lon can be entered by clicking on the map. Altitude is relative to your launch altitude, so if you set 100m, for example, it will fly 100m above you.

You can set a home position by clicking on the Home lat or lon and then clicking on the map. Or, if the map is not already centered on the field you're going to be flying at, you can search for it by clicking on the "Zoom To" button and entering your location in the search box, as shown:

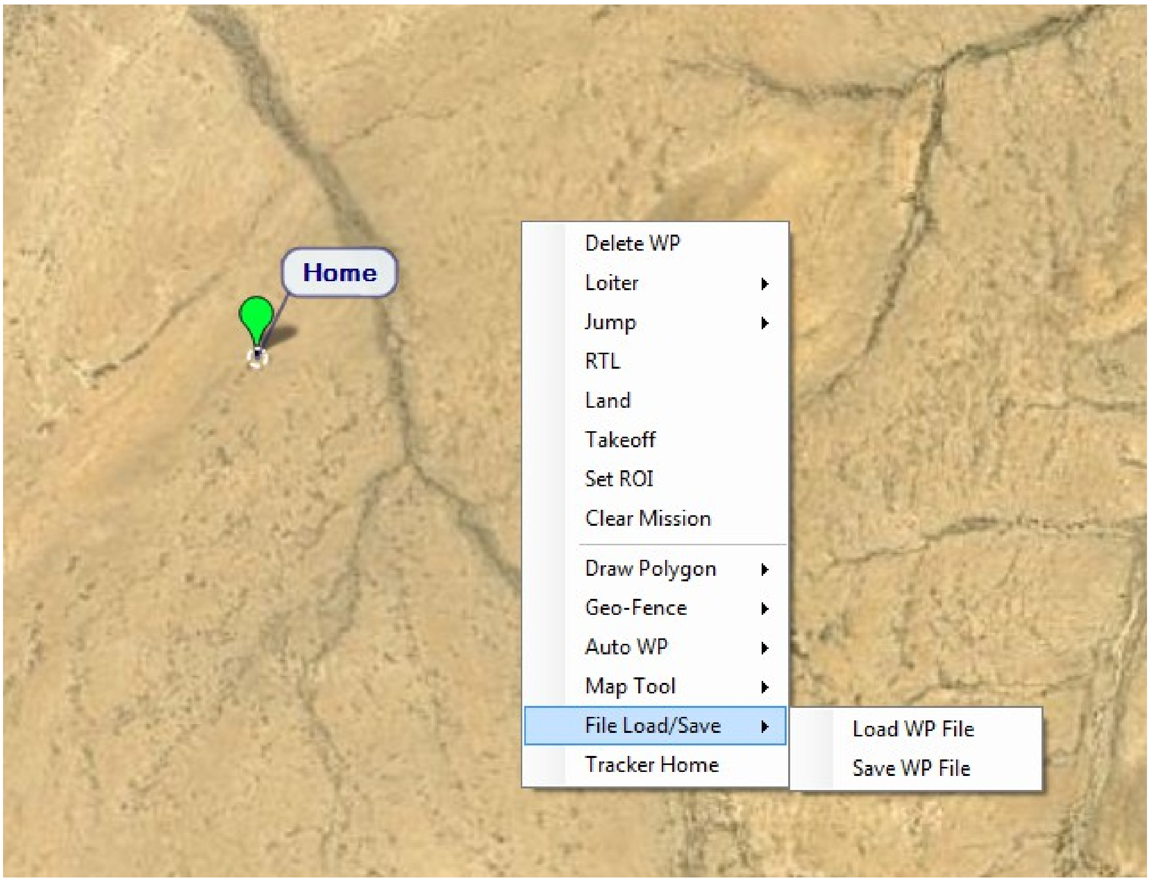


Note that if the "Absolute Alt" box is checked, the altitude used will be **altitude above sea level**, NOT altitude above your launch position. If that box is unchecked, ALT will be relative altitude, so 100m will be 100m above your "home" altitude, or where you're probably standing.

Default Alt is the default altitude when entering new waypoints. It's also the altitude RTL (return to launch) mode will fly at if you have "Hold Default ALT" checked; if you don't have that checked, your aircraft will try to maintain the altitude it was at when you switched on RTL.

Verify height means that the Mission Planner will use Google Earth topology data to adjust your desired altitude at each waypoint to reflect the height of the ground beneath. So if your waypoint is on a hill, if this option is selected the Mission Planner will increase your ALT setting by the height of the hill. This is a good way to make sure you don't crash into mountains!

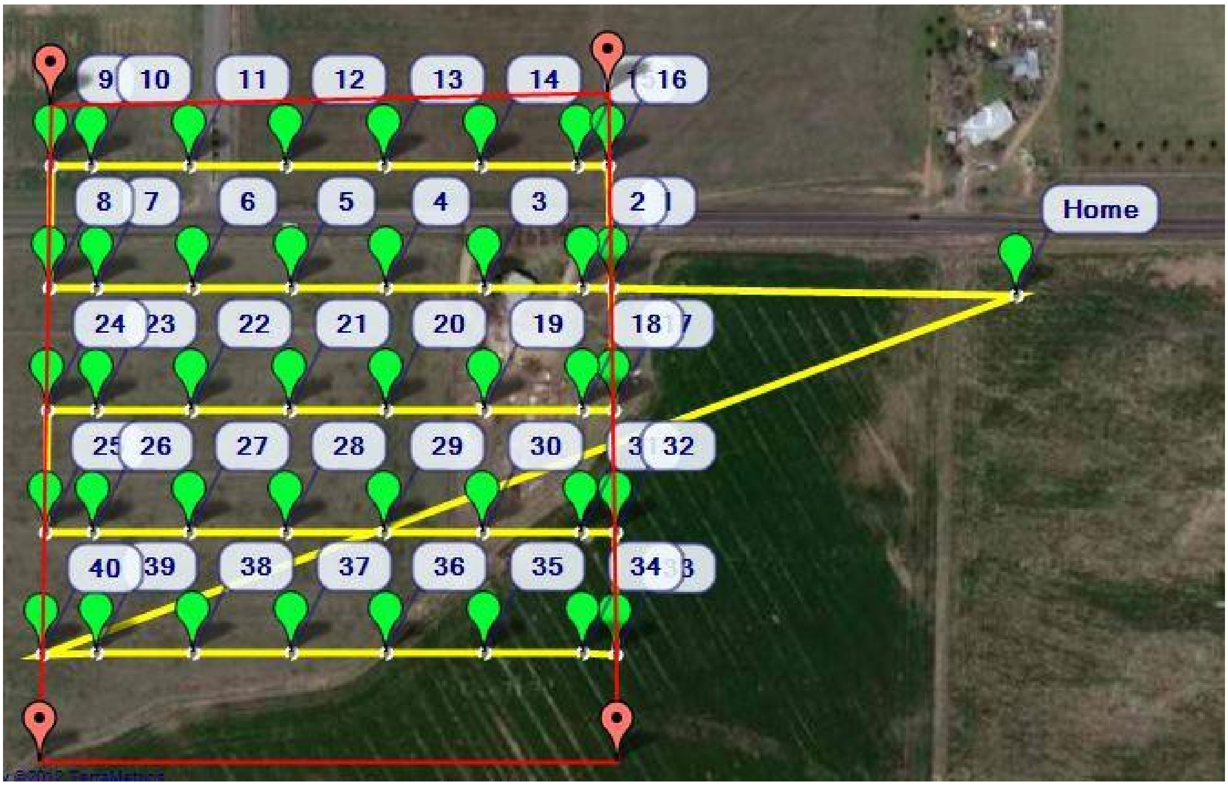
Once you are done with your mission, select "Write" and it will be sent to APM and saved in EEPROM. You should confirm that it's as you wanted by selecting "Read". You can save multiple mission files to your local hard drive by selecting "Save WP File" or read in files with "Load WP File" in the right-click menu:



Auto grid

You can also have the Mission Planner create a mission for you, which is useful for function like mapping missions, where the aircraft should just go back and forth in a "lawnmower" pattern over an area to collect photographs.

To do this, in the right-click menu select Polygon and draw a box around the area you want to map. Then select Auto WP, Grid. Follow the dialog box process to select altitude and spacing. The Mission Planner will then generate a mission that looks something like this:



Basic waypoint commands

A mission file is a little intimidating to the human eye, but is a powerful scripting language for the autopilot. (Again, remember that the GCS will soon take care of all of this for you. You shouldn't have to see it yourself for long!).

You can have as many commands as you want, ranging from pre-programmed ones to ones that you can create. Here are some common ones:

- {NAV_WAYPOINT n/a, alt, lat, lon}
- {NAV_TAKEOFF pitch, target altitude}
- {NAV_LAND n/a, alt, lat, lon}
- {DO_JUMP waypoint, n/a, repeat count, n/a} Goes to that waypoint and resumes mission there. Set repeat count to any number greater than 1 to do it that many times. or to -1 to do it forever. Good for looping missions.

(Note: DO_xxx commands currently need a dummy waypoint placed after the command
eg:

- WAYPOINT_1
- DO_SET_HOME
- WAYPOINT_2

Home will be set at WAYPOINT_1 but will not work if WAYPOINT_2 is not there.)
In the screenshot above, I've planned a mission that starts with an autotakeoff to 20m attitude, the three waypoints at 100m, ending with one that sets up a landing

pattern. Finally an autoland finishes the mission at 0m altitude.

Tips

- Prefetch: You can cache map data so you don't need Internet access at the field. Click the Prefetch button, and hold down Alt to draw a box to download the selected imagery of a location.
- Grid: This allows you to draw a polygon (right click) and automatically create waypoints over the selected area. Note that it does not do "island detection", which means if you have a big polygon and a little one inside of that, the little one will not be excluded from the big one (see this[5] for more). Also, in the case of any polygon that partialy doubles backs on itself (like the letter U), the open area in the center will be included as part of the flyover.
- Setting your home location to the current location is easy, just click "Home Location" above where you enter your home location, and it will set your home location to the current coordinates.
- You can measure the distance between waypoints by right-clicking at one end and selecting Measure Distance. Then right-click on the other end and select Measure Distance again. A dialog box will open with the distance between the two points.

Automatic Takeoff and Landing

ArduPilot Mega can automatically launch and land an aircraft, as part of a mission plan. Here's how:

Auto takeoff instructions

The basic idea of automatic takeoff is for the APM to set the throttle to maximum and climb until a designated altitude is reached. To cause the plane to execute a takeoff, add a NAV_TAKEOFF command to your mission, probably as the first command. The altitude parameter always specifies the altitude that must be attained before the APM will consider its takeoff complete and load the next Must command.

The APM will initially hold the wings level on takeoff, but as soon as a takeoff heading is established, the APM will adjust roll to maintain that heading.

As soon as the ground speed, as measured by the GPS, exceeds 3 m/s, the takeoff heading will be set to the magnetometer's yaw sensor.

The first parameter of the NAV_TAKEOFF command will specify the minimum pitch the APM will target on takeoff. The APM will adjust pitch to achieve airspeed_cruise which is 12m/s on the Maja (pitch up if airspeed is above cruise, pitch down if

5 http://wiki.openstreetmap.org/wiki/Relation:multipolygon

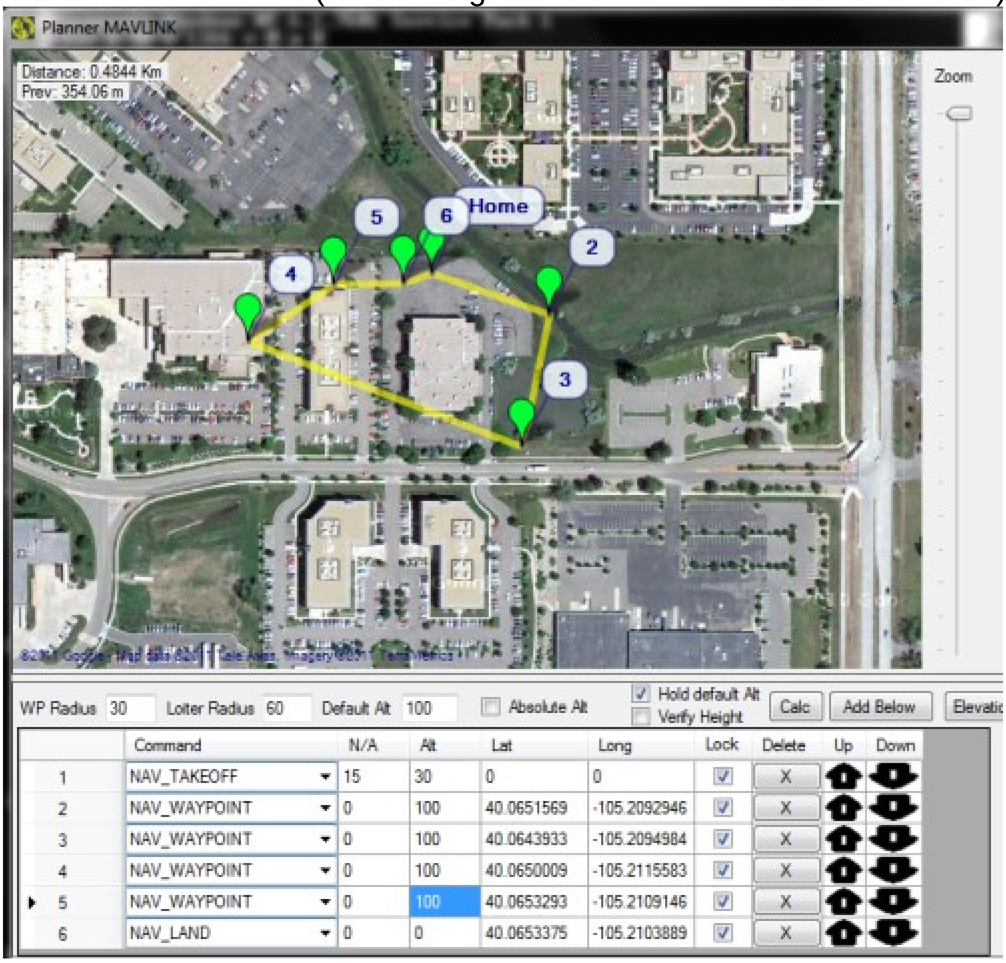
airspeed is below cruise), but it will not pitch below the minimum pitch set by NAV_TAKEOFF.

Auto landing instructions

To land the plane, simply add a NAV_LAND command to the end of your mission indicating the latitude, longitude and altitude of your desired touchdown point. In most cases, the altitude should be set to 0. During landing, the APM will shut down the throttle and hold the current heading as soon as the plane is within 2 seconds of the touchdown point horizontally, or as soon as the plane is lower than 3 meters above the touchdown point, whichever occurs first.
On approach, the APM will fly normally if you have an airspeed sensor.

Example

Here is an example mission around the Sparkfun building that autotakeoffs, goes around the building and then sets up a landing pattern for an autoland. Note that the waypoints kick in once the plane has reached 30m altitude after autotakeff, and that it lands at 0m altitude (altitude is given relative to home/launch altitude):



Note that in reality the above flight plan probably won't result in a successful landing in the desired area. Waypoint 5 is set with an altitude of 100 meters, and waypoint 6, which is the landing waypoint, is only a short distance away. Unless the particular airplane used has a very fast descent rate when gliding with the motor off, it will not be able to come down from 100 meters in the short distance planned here.

With the Maja it is recommended to use a 500m long leg to glide down from 100m.

It is more appropriate to step the altitude down over a few waypoints and make sure that the distance between the waypoint before the landing point and the landing point is sufficiently large for the altitude which must be lost. Make sure to stay clear of obstacles in your glide path.

Geofencing in ArduPlane

The GeoFencing support in ArduPlane allows you to set a virtual 'fence' around the area you want to fly in, specified as an enclosed polygon of GPS positions plus a minimum and maximum altitude.
When fencing is enabled, if your plane goes outside the fenced area then it will switch to GUIDED mode, and will fly back to a pre-defined return point, and loiter there ready for you to take over again. You then use a switch on your transmitter to take back control.

Use for R/C training

One of the main uses of geo-fencing is to teach yourself (or someone else) to fly radio controlled planes. When you have a properly configured geo-fence it is very hard to crash, and you can try maneuvers that would normally be too likely to end in a crash, trusting the APM to 'bounce' the plane off the geo-fence before the flight ends in disaster.

Geo-fencing can be combined with any APM flight mode. So for a raw beginner, you would combine it with one of the stabilised flight modes (such as STABILIZE or FBWA). Once the pilot has gained some confidence you could combine it with MANUAL mode, which gives direct control of the plane and allows for the most interesting aerobatic maneuvers. When used in this way the APM stays out of your way completely, just passing the controls to the servos directly, and only takes control if you go outside the fenced area or outside the defined altitude range.

Setting up geo-fencing

To setup geo-fencing in ArduPlane you need to configure six things:

1. the boundary of the fence, as a set GPS points
2. the action to take on fence breach
3. the location of the return point
4. the minimum and maximum altitude of the fenced area
5. what RC channel on your transmitter you will use to enable geo-fencing
6. how you want to take back control after a fence breach

These can all be setup using the APM Mission Planner. The geo-fencing support is still very new in the planner, so you may notice it changing a bit as the interface is improved.

There are a few rules that you must follow when setting up your fence boundary:

1. the return point must be inside the fence boundary
2. the fence boundary must be fully enclosed. This means it must have at least 4 points, and the last point must be the same as the first point
3. the boundary can have at most 18 points

If you setup your fence with the APM planner it should ensure you follow these rules. Please remember when making your fence boundary that your plane will have some momentum when it hits the fence, and will take time to turn back to the return point. For a plane like the SkyWalker we recommend an additional safety margin of around 30 meters inside the true boundary of where you want to fly. The same goes for the minimum altitude - you need to make it high enough that the APM has time to recover from a fast dive. How much margin you need depends on the flight characteristics of your plane.

Apart from the fence boundary, the following MAVLink parameters control geo-fencing behaviour:

1. FENCE_ACTION - the action to take on fence breach. This defaults to zero

which disables geo-fencing. Set it to 1 to enable geo-fencing and fly to the return point on fence breach.

2. FENCE_MINALT - the minimum altitude in meters. If this is zero then you will not have a minimum altitude.
3. FENCE_MAXALT - the maximum altitude in meters. If this is zero then you will not have a maximum altitude.
4. FENCE_CHANNEL - the RC input channel to watch for enabling the geo-fence. This defaults to zero, which disables geo-fencing. You should set it to a spare RC input channel that is connected to a two position switch on your transmitter. Fencing will be enabled when this channel goes above a PWM value of 1750. If your transmitter supports it it is also a good idea to enable audible feedback when this channel is enabled (a beep every few seconds), so you can tell if the fencing is enabled without looking down.
5. FENCE_TOTAL - the number of points in your fence (the return point plus the enclosed boundary). This should be set for you by the planner when you create the fence.

One additional parameter may be useful to get the most out of geo-fencing. When you breach the fence, the plane will switch to GUIDED mode and fly back to the return point. Once you are back inside the fence boundary you are able to take control again, and you need to tell the APM that you want to take control. You can do that in one of 3 ways:

1. changing modes using the APM mode switch on your transmitter
2. disabling and re-enabling geo-fencing using the FENCE_CHANNEL channel
3. set the RST_SWITCH_CH MAVLink parameter to another two-position channel that is attached to a spring loaded switch. The RST_SWITCH_CH parameter defaults to zero which disables it. If you set it to a channel then you can use this channel switch to take back control after a fence breach.
4. I find that using RST_SWITCH_CH is the best option for geo-fencing as it means that the APM has fencing enabled throughout the flight, and you don't get any behaviour change by switching modes. It does take up another channel though, so some people may not have enough channels to use it.

Setting up the fence boundary

To setup a fence boundary you should use the 'Flight Planner' screen in the APM Planner.
Start by right-clicking the location you want for the return point and choosing 'Set return location'. The return point should be somewhere in the middle of your flight area, and in easy visual range of where you will be standing when you fly.

After you've set the return point you should right click on the first point on the boundary of the fence you want. Choose 'Draw Polygon -> Add polygon point'. You are then in polygon mode, and you should left-click to add each point in the boundary of your fence. The planner will automatically complete the polygon by connecting the last point to the first one.

You can then right-click and choose geo-fencing upload to send your fence boundary to the APM. The planner will ask you for the minimum and maximum altitude (in meters) of your fence before uploading. You can also save your fence to a file for later loading.

Altitude of the return point

If you set FENCE_MINALT and FENCE_MAXALT to other than zero (and have FENCE_MAXALT greater than FENCE_MINALT) then the return point altitude will be half way between FENCE_MINALT and FENCE_MAXALT.

If you don't setup FENCE_MINALT and FENCE_MAXALT (ie. leave them at zero) then the return point altitude will be given by the ALT_HOLD_RTL parameter, which is also used for RTL mode. Note that ALT_HOLD_RTL is in centimeters, whereas FENCE_MINALT and FENCE_MAXALT are in meters.

If your flying club and local flying rules don't set a maximum altitude then we recommend you use a maximum altitude of at most 122 meters (which is around 400 feet). Beyond that altitude it becomes quite difficult to keep good eye contact with your model.

With FENCE_MINALT set at 30 meters (to allow for some dive momentum) and FENCE_MAXALT set to 122 meters, the return point will be 76 meters, which is quite a good altitude to leave the plane loitering while you are getting ready to have another go.

Stick-mixing on fence breach

The APM enables 'stick mixing' by default when in auto modes. This means that you can change the path of a loiter, for example, by using your transmitter sticks.

When you are using geo-fencing, stick mixing will be disabled on fence breach until your plane is back inside the fenced region. This is to ensure that the bad control inputs that caused you to breach the fence don't prevent it from recovering to the return point.

As soon as you are back inside the fence stick mixing will be re-enabled, allowing you to control the GUIDED mode that the plane will be in. If by using stick mixing you manage to take the plane outside the fence again then stick mixing will again be disabled until you are back inside the fence.

Tips for flying with geo-fencing

You should have geo-fencing disabled when on the ground and for takeoff. Be careful not to enable it on the ground, as it may declare a fence breach and try to fly to the return point.
Also remember to disable it for landing, as the altitude breach when you are coming in will make it very hard to land!

If you are using an APM1 and want to combine geo-fencing with MANUAL mode, then remember that on the APM1 the APM software is bypassed when using channel 8 for mode switching and a switch PWM channel value above 1750 (this is called 'hardware manual' on the APM1). So you either need to set a different switch position as MANUAL, or use a different mode switch control channel (and set FLTMODE_CH to the channel you are using).

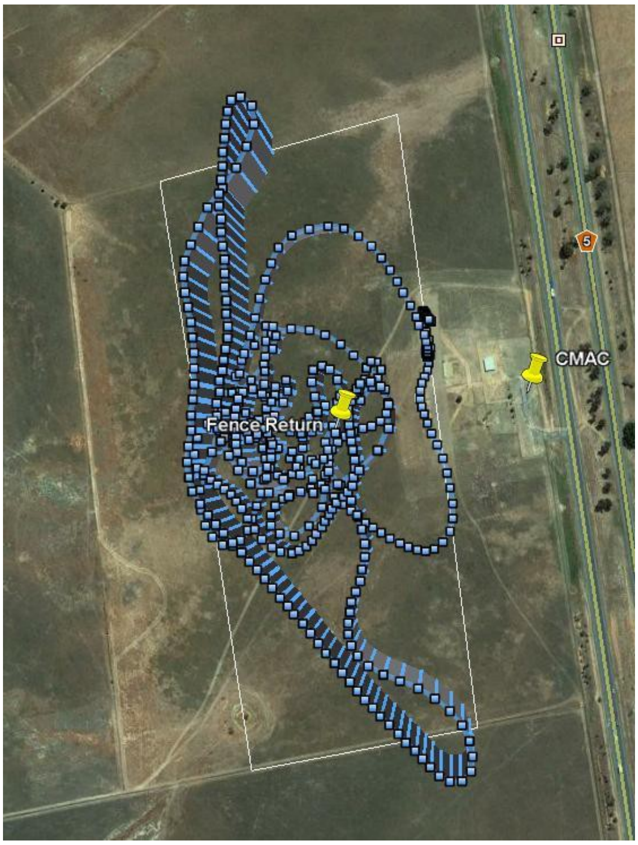
Before you takeoff and fly with geo-fencing make sure all the parameters are setup as described above, and also make sure you have a good GPS lock. If you lose GPS lock then geo-fencing will disable itself until GPS lock is regained, so don't use it if your GPS signal is marginal.

I'd also recommend you test it gently at first. Try slowly approaching a fence boundary and ensure it correctly 'bounces' off the virtual wall and returns to the return point OK. Then after taking control again, try slowly approaching the minimum altitude and ensure it bounces off the FENCE_MINALT you have set.

While developing geo-fencing I found that combining it with MANUAL mode is the most fun. It gives you all of the excitement of manual flight with sharp turns and fancy stunts while saving your plane when you make a mistake.

Example flight

This is the track from a flight with geo-fencing enabled at my local flying club while flying my SkyWalker. The white lines show the geo-fence boundary, plus you can see the return point in the middle. You can also see the points where the plane breached the geo-fence to the north, west and south. There were also numerous altitude breaches, as I was using this flight to try to improve my inverted flight skills in MANUAL mode. The plane would not have survived without the geo-fence!



Notice that the geo-fence in this example runs along the middle of the runway. This is to conform to my local club rules. The takeoff and landing were done with the fence disabled. I had FENCE_CHANNEL set to 7, and RST_SWITCH_CH set to 6. That allowed me to enable the fence after takeoff using one switch, then to take back control after a breach using the spring loaded trainer switch.

Geotagging Images

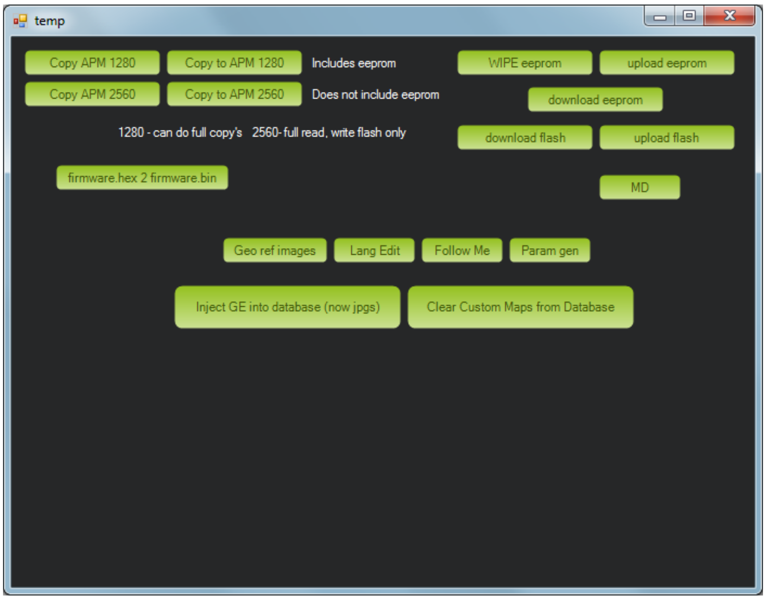
Geo-tagged aerial pictures are very useful for mosaic mapping as well as the creation of accurate 3D models from a terrain.

The Mission Planner has a handy feature that will inject GPS data into your photos' EXIF tags by using APM's telemetry log from a flight.

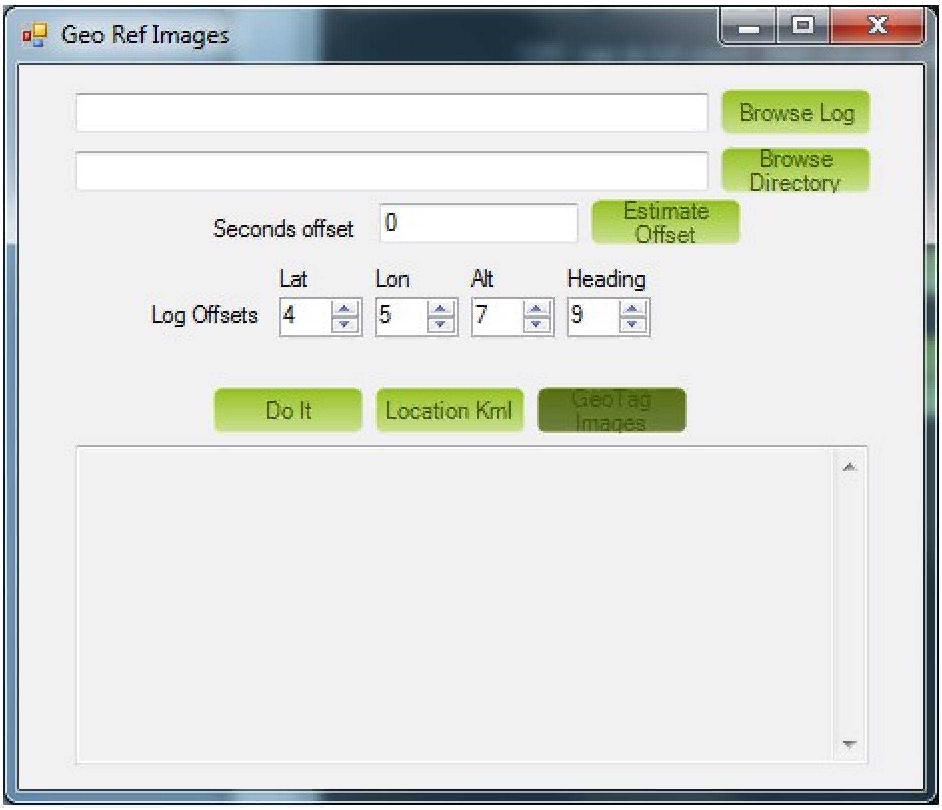
This tutorial was created to show you how does it work. (This is a work from Sandro Benigno and Guto Santaella who kindly provided the sample files and screenshots used for making this tutorial.)

Step by Step

1: Open the Mission Planner and press "Ctrl+F". It will open a hidden screen, like shown here:

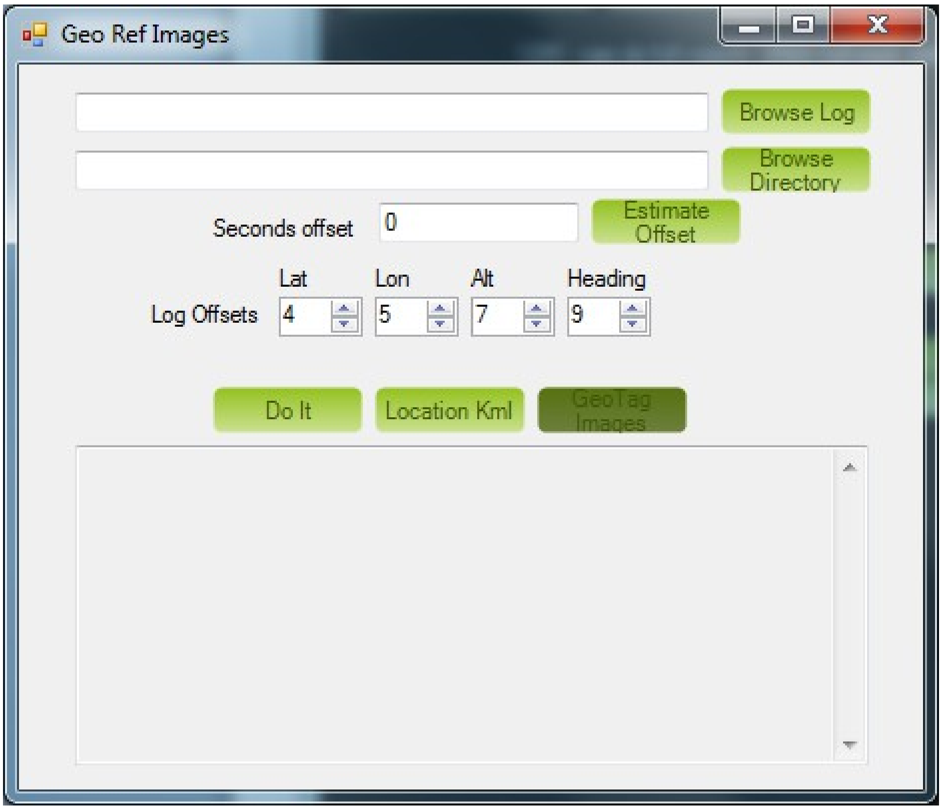


2: Click the button "Geo ref images". It will give you access to the Geo Tagging resource as shown below:



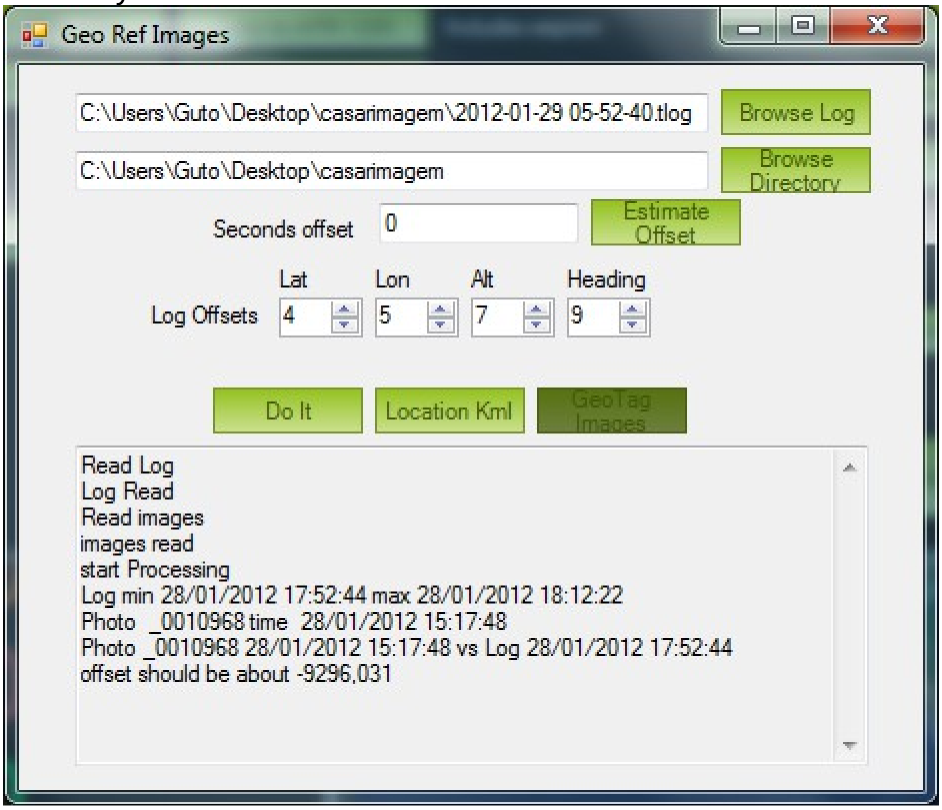
3: Click the button "Browse Log" and select the telemetry log (.tlog) of the flight related to the shooting session. Note: You can use both sources: the "Logs" folder from Mission Planner install or you can download it from the APM's dataflash through the USB port.

4: Click the button "Browse Directory" and select the folder where your aerial pictures was downloaded from your camera.



5: Just to illustrate, the screen below shows the mission used for creating this tutorial:

6: The next step is clicking on "Estimate Offset". It will try to extract the offset from the "Log Start Time" and the "Shooting Time" from the first picture taken. The result shows "offset should be about...". You need to take the guessing and insert it manually on the field "Seconds offset".



7: Click the button "Do it" and wait until the processing is finished. The number shown in "Done... matches" must be the number of pictures taken. Otherwise it means that the sync isn't good enough.

8: After the previous step you can verify the positioning of each picture on Google Earth by clicking "Location Kml".

9: Looking at the example above you'll see the estimated position of a picture. You can click any images at the list on left to check it. If the position is not accurate you can step back and retry it from the step "6" by increasing or decrasing the "Seconds offset" a little bit, just like a fine tuning.

10: After finishing the tuning, all you need to do is click "Geo Tag Images". This process will add geographic data to your picture, i.e. Latitude, Longitude and Altitude. The processing creates new files with a suffix "geotag". The original set of pictures remains untouched.

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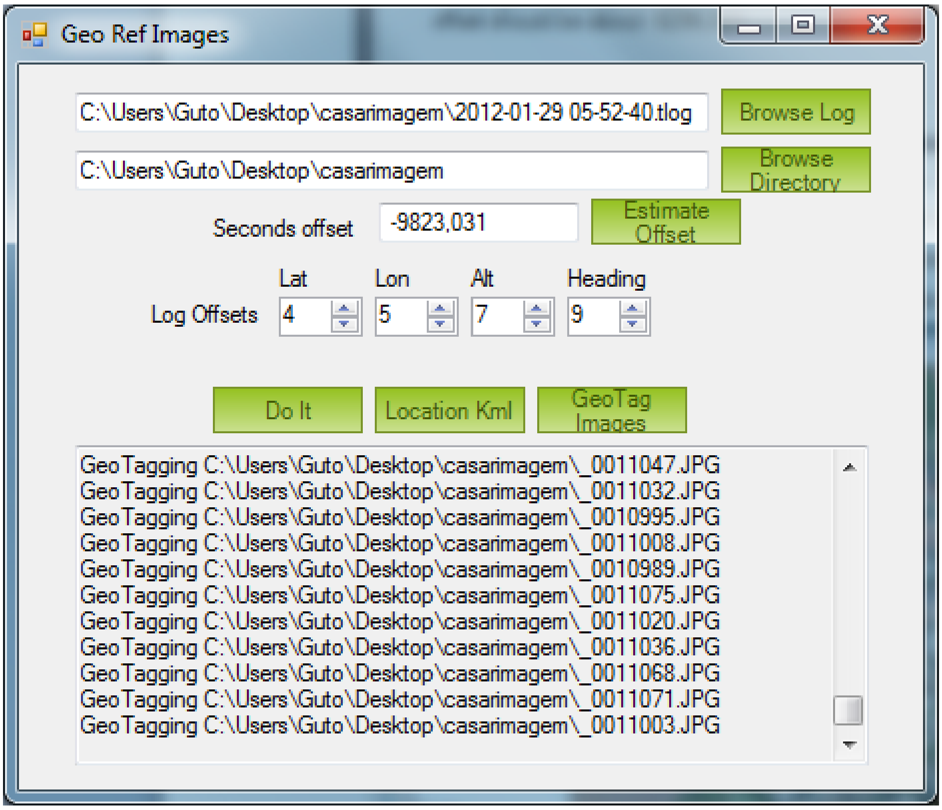
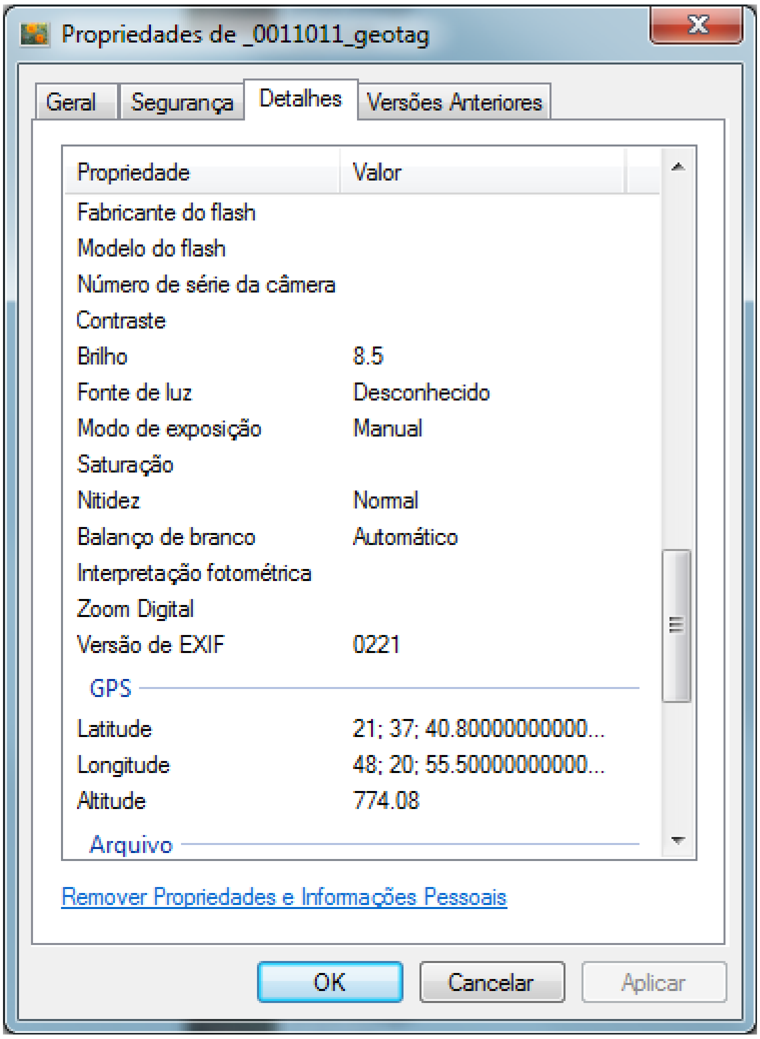
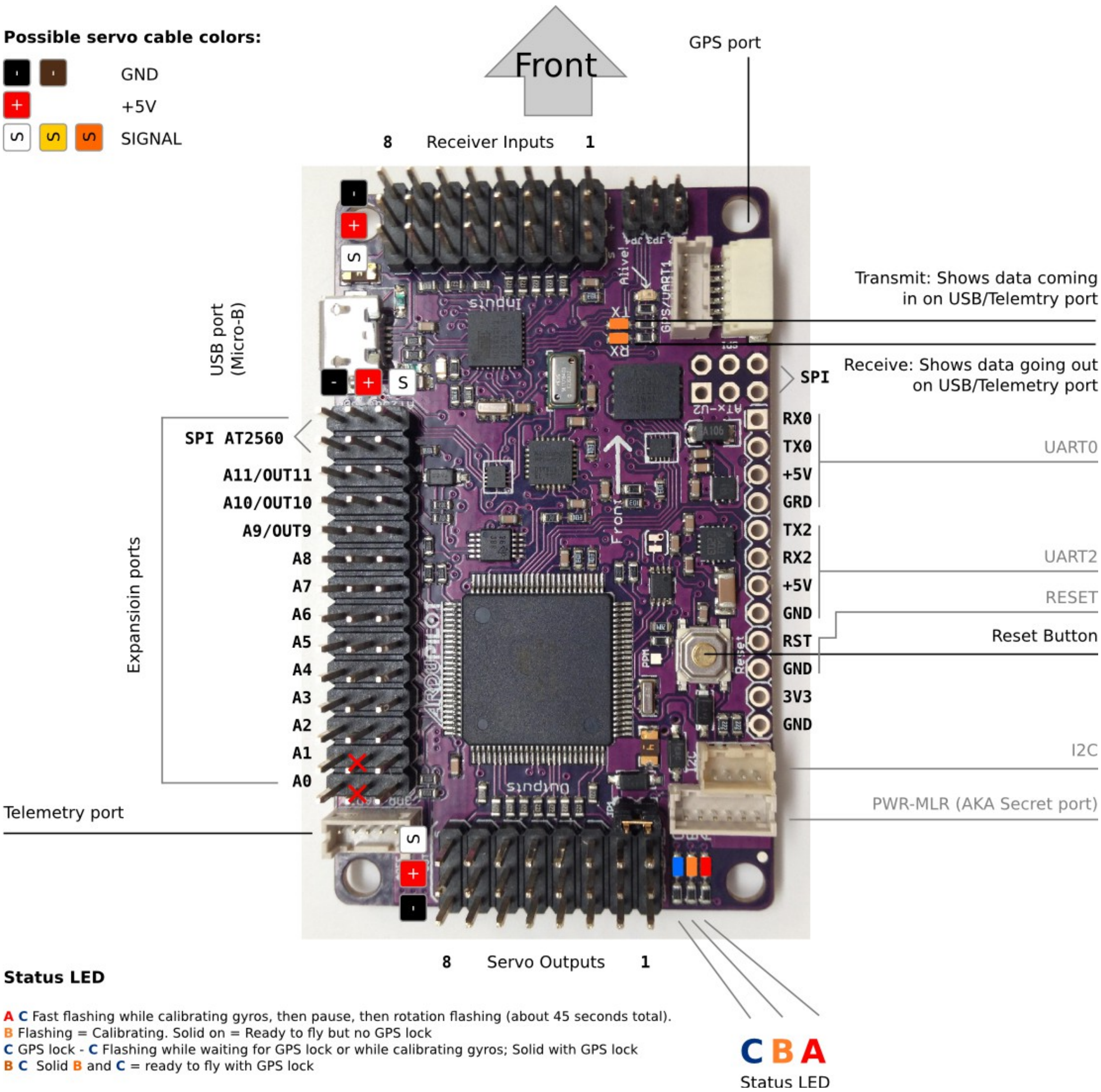


11: You can check your pictures by visualizing the file properties details. You should see the inserted GPS tags on the EXIF data.


Propriedades de _0011011_geotag
Geral
Segurança
Detalhes
Versões Anteriores
Propriedade
Valor
Fabricante do flash
Modelo do flash
Número de série da câmera
Contraste
Brilho
8.5
Fonte de luz
Desconhecido
Modo de exposição
Manual
Saturação
Nitidez
Normal
Balanço de branco
Automático
Interpretação fotométrica
Zoom Digital
Versão de EXIF
0221
GPS
Latitude
21; 37; 40.80000000000...
Longitude
48; 20; 55.50000000000...
Altitude
774.08
Arquivo
Remover Propriedades e Informações Pessoais
OK
Cancelar
Aplicar

Appendix

A) ArduPilot Mega 2.5 connectors description



B) Checklist

Pre-field check (including mission planning)

1. Cache/Prefetch map of mission location
2. Check for weather forecast
3. Charge and balance lipo batteries
4. Check all control surfaces, servos and motor are functional
5. Check still photograph camera is configured and functional
6. download logs if there are any left on the auto pilot
7. clear logs
8. check if all necessary things are ready and packed for field

Pre-flight check

1. Check battery power
2. Make sure the airframe is placed in a level position
3. Install battery in plane and make sure it is secured
4. Make sure throttle is set to 0 and mode switch is in Manual
5. Turn transmitter on, check transmitter battery power
6. STAY CLEAR OF THE PROPELLER
7. Power on
8. Close aft section of fuselage
9. reset APM
10. Block the airspeed sensor during initialisation
11. don't move the plane until the Autopilot is initialized
12. Blue LEDs should be on and steady (GPS lock acquired and initialized)
13. Make sure the airspeed sensor is clear
14. check if all surfaces move into the right direction in manual mode
15. check all surfaces in stabilize mode

Mission Planning

1. Connect telemetry Link
2. Set Home altitude (alt in HUD should now read 0)
3. Check if HUD is displaying airspeed 0 (tol <3). If not please reinitialize your APM system
4. Plan/Load mission in flight planner, check
    a. 1st waypoint must be
        i. of type Takeoff
        ii. 30° angle (for maja with airspeed sensor)
    b. Waypoint before land about 500m distance to landing point at 50m AGL (maja 1.8m version)
    c. landing waypoint
        i. set altitude to 0
5. Optional: Save your mission on laptop
6. Upload mission to Aircraft
7. Download mission again, verify if still the same as before upload
    a. Answer “No” to the dialog: “set home location to …?”
    b. verify that home location on the map is still the same
8. Switch to “Flight Data” tab and continue with Take-off check

Take-off check

1. Start camera with required settings (time active, interval, lens zoom)
2. Lock fuselage
3. check centre of gravity (maja: 8cm behind the front wing edge)
4. STAY CLEAR OF THE PROPELLER
5. Switch to auto mode (engine should start)
   a. if engine does not start hit [Restart Mission] in mission planner if telemetry is used
   b. without telemetry link, restart APM by unplugging the battery and restarting the checklist. check mission and upload mission again to APM if needed.
6. Elevator should move slightly upward
   a. if elevator does not move upward **ABORT**.
7. Check wind direction
8. Launch against wind, level (not nose up and not nose down), clear of obstacles.

Approach check

1. Constantly check altitude (if telemetry is available)
2. On final - nudge with rudder if there is an error in heading
3. on missed approach
   a. no obstacles in flight path: switch to RTL mode
   b. with obstacles: full throttle
      i. switch to stabilize mode
      ii. pull gently on the elevator to gain altitude
      iii. use rudder to correct heading
      iv. when clear of obstacles: switch to RTL mode

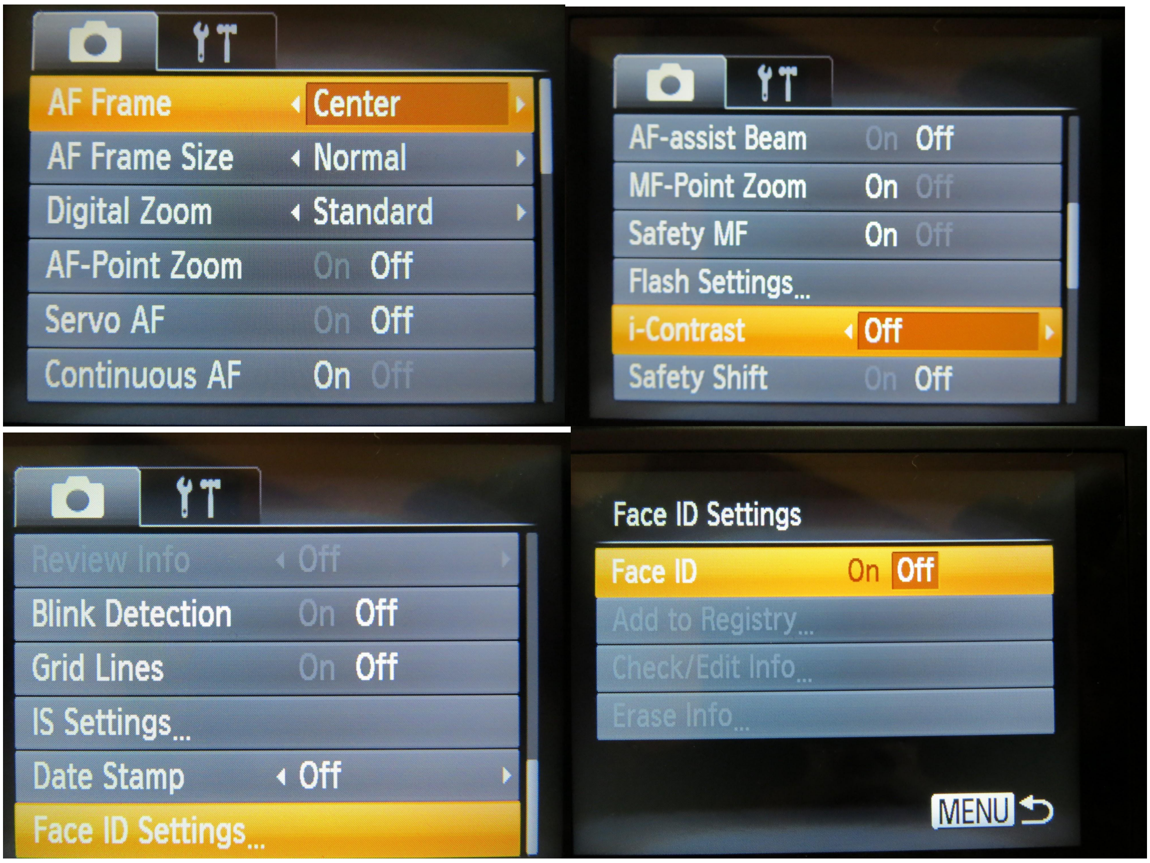
Post-mission check

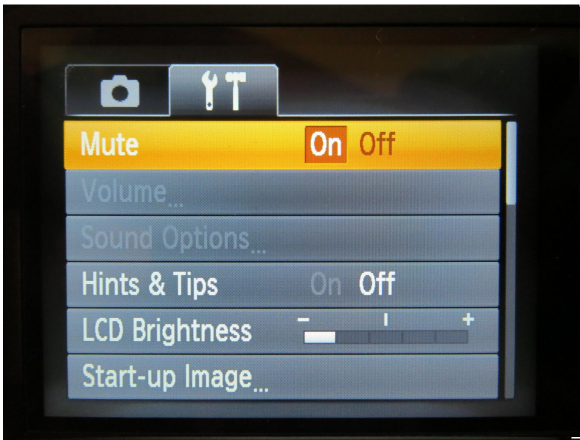
1. Download logs from APM to laptop
2. Clear logs in APM
3. Download photographs/videos from camera
4. Check all control surfaces, servos and motor are functional
5. Turn off transmitter

C) Canon SX260HS Settings

If CHDK is used you may get into the canon menu as follows:

- turn on camera
- hit shutter button
- hit menu botton




Mute On Off
Volume...
Sound Options...
Hints & Tips On Off
LCD Brightness
Start-up Image...

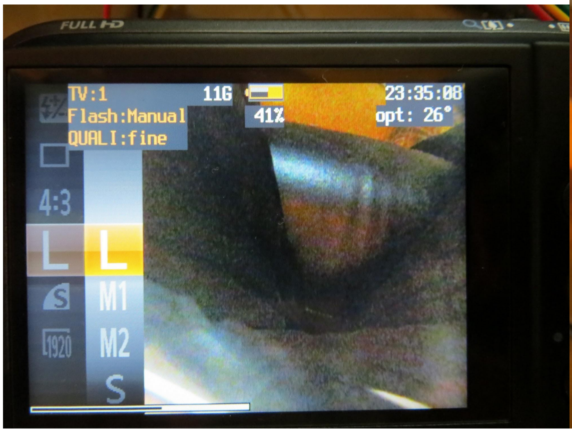

Format... 29.7GB
File Numbering Continuous
Create Folder Monthly
Lens Retract 1 min.
Power Saving...
Time Zone...


Date/Time... 12.01.'12 23:33
GPS Auto Time On Off
GPS Settings...
Units m/cm ft/in
Video System NTSC PAL
Ctrl via HDMI Enable Disable


GPS Settings
GPS On Off
GPS Logger On Off
Display Log Files...
Records GPS information
in image data
MENU


TV:1
Flash:Manual
QUALI:fine
11G
39%
23:34:11
opt: 26°


TV:1
Flash:Manual
QUALI:fine
11G
41%
23:34:49
opt: 26°
AUTO
100
200
400
800
1600

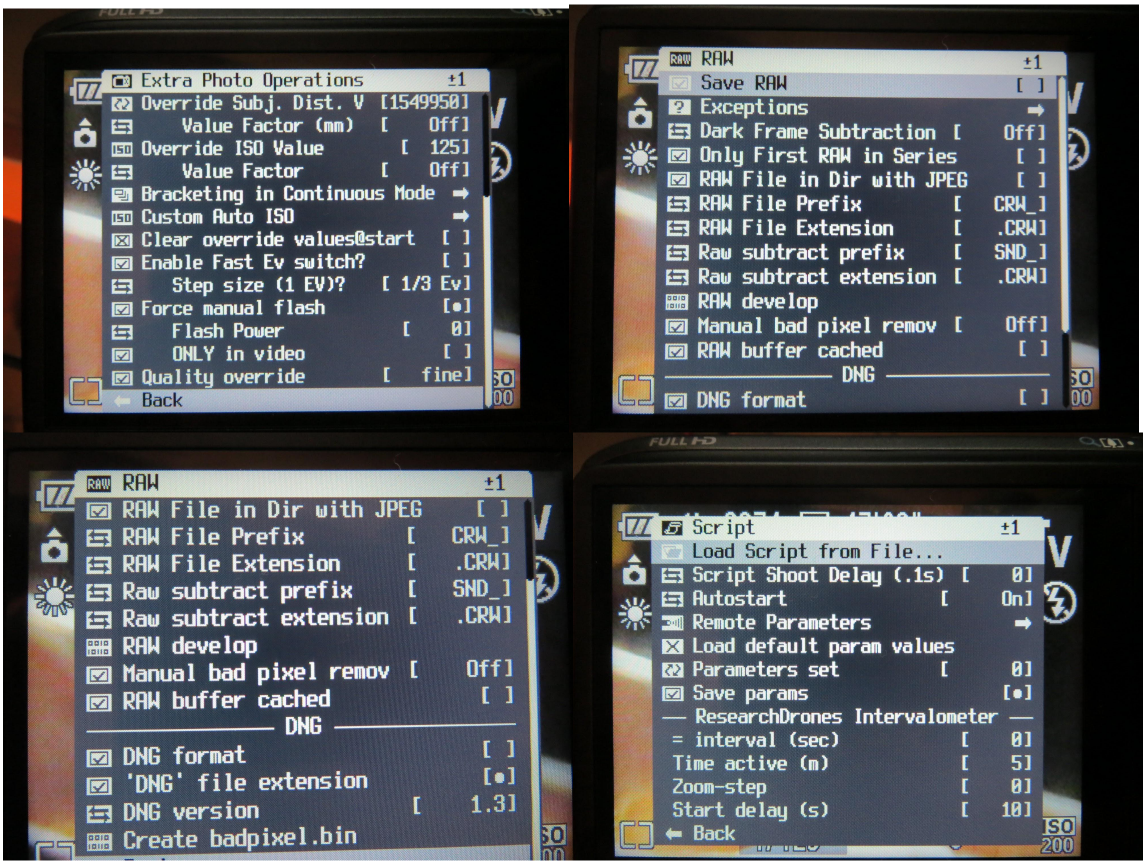

FULL HD
TV:1
Flash:Manual
QUALI:fine
11G
41%
23:35:08
opt: 26°
4:3
L
M1
M2
S
1920


TV:1
Flash:Manual
QUALI:fine
11G
39%
23:35:36
opt: 27°
4:3
L
S
1920

D) CHDK Configuration for SX260HS

Enter the CHDK menu by

- starting the camera
- hit the shutter button (in case the script is set to auto start)
- hit the Menu button



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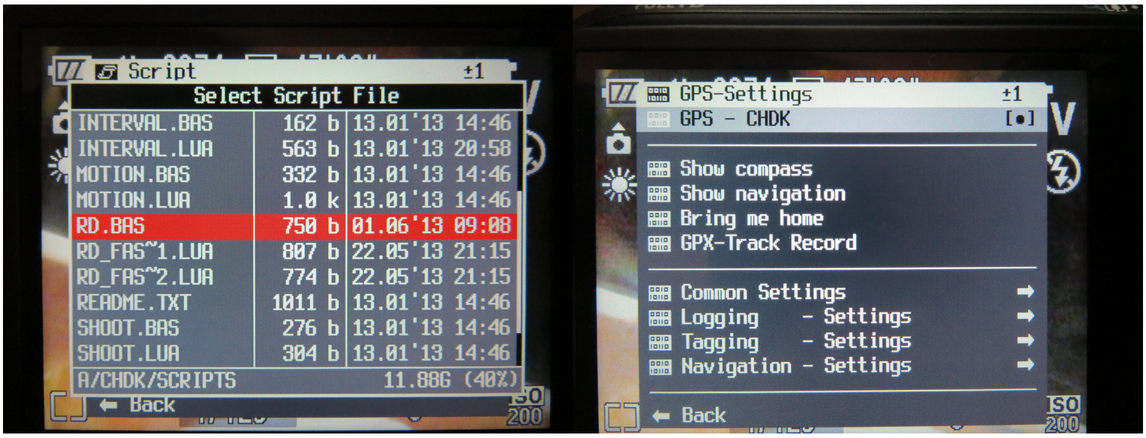

E) Intervalometer Script

The still cameras is using a special script to run the intervalometer. The customized software (CHDK) needs to be stored on the SD card, this is the location where the camera boots from. The script below must be stored on the card under «SDcard\CHDK\SCRIPTS\RD.bas» for the intervalometer to work. If you do not have the script, copy and paste the code below to notepad and store it in the mentioned location.

```
@title ResearchDrones Intervalometer
@param a = interval (sec)
@default a 0
@param c Time active (m)
@default c 5
@param j Zoom-step
@default j 0 rem step 30 is equivalent to 50 mm SLR focal length
@param z Start delay (s)
@default z 5

rem Starts indicator sound
playsound 4

rem e is time for script to remain active in milliseconds
e=c*60000

rem First shot
set_zoom j
shoot

rem Delay
for n=0 to z
   print "Starting in ";z-n;"s"
   sleep 1000
next n

rem g is time elapsed and f is start time and p is shots
g=0
f=get_tick_count
p=0
```

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```
do
   set_zoom j
   s = get_tick_count
                      shoot
   sleep a*1000 - (get_tick_count - s)
   g=s-f
   t=(e-g)/1000
   p=p+1
   if g>e then shut_down
until ( 0 )
```

F) Troubleshooting

ArduPilot Mega

If there is something wrong with the UAV it is most often a Software or AutoPilot issue. You can find a collection of troubleshooting options in the wiki of ArduPilot Mega:
https://code.google.com/p/ardupilot-mega/wiki/Troubleshooting

CHDK

If there are problems with the Still camera, check the CHDK for dummies guide:
http://chdk.wikia.com/wiki/CHDK_for_Dummies

G) Moving surfaces

Elevator	+30mm/-30mm
Aileron	+25mm/-25mm
Rudder	+20mm/-20mm

H) Useful links

Software

ArduPilot Mega

- **ArduPilot Mega Firmware**: Best way to use it is through Mission Planner's upload functionality. Be careful, Firmware updates are released early and often, they might be buggy. Please use the tested and recommended firmware from ResearchDrones. For tinkerers, the source code can be found here: https://code.google.com/p/ardupilot-mega/downloads/list

- **Mission Planner**: Also open source software for win32/64 only. Always make sure to test you MP version after an update before going into the field. Released early and often, it might be buggy sometimes, bugfixes come quick (sometimes within hours) so get a new version through the update feature if a bug is discovered. We recommend to settle with a working version for some time. Binaries and source code can be found here: https://code.google.com/p/ardupilot-mega/downloads/list

- **Arduino IDE**: If you want to modify/compile the firmware yourself and don't have a build environment installed on your computer you might want to use a modified version of Arduino IDE (no admin rights required, just unzip and start coding/compile/uploading):
  - Windows: https://ardupilot-mega.googlecode.com/files/ArduPilot-Arduino-1.0.3-windows.zip
  - OSX: https://ardupilot-mega.googlecode.com/files/ArduPilot-Arduino-1.0.3-Mac.zip

Post Processing / Stitching

- **Pix4D**: http://pix4d.com/
- **DroneMapper online Service**: http://dronemapper.com/
- **kolor autopano giga**: http://www.kolor.com/image-stitching-software-autopano-giga.html
- **Agisoft PhotoScan**: http://www.agisoft.ru/products
- **Synchronizing APM logs with Video**: http://gps4sport.com/

Simulators

- **X-Plane** (Win/OSX/Linux/iOS/Android): A real aicraft simulator (not r/c) which is often used for HIL or SITL testing (Hardware In the Loop or Software In The Loop) http://www.x-plane.com/

- **FlightGear** (Win/OSX/Linux/*BSD/Solaris): An open source flight simulator, free of charge http://www.flightgear.org/
- **RealFlight** (Windows): A sophisticated R/C simulator. An r/c transmitter is usually used as input device http://www.realflight.com/
- **Absolute RC Plane Sim** (Android): Smartphone/Table r/c sim. Input device is the touchscreen and therefore not very realistic (also, the flight model is not so close to the real deal) https://play.google.com/store/apps/details?id=com.rcflightsim.cvplane2
- **Leo's R/C Simulator** (Android): Another android r/c sim, has a more realistic flight model https://play.google.com/store/apps/details?id=leofs.android.free
- **Rc Plane 2** (iOS): An iPhone/iPad r/c sim, also with touchscreen input which doesn't give a too realistic "touch&feel" https://itunes.apple.com/en/app/rc-plane-2/id442082328?mt=8

Links to Documentation

- **ArduPilot Mega**:
  - Wiki: https://code.google.com/p/ardupilot-mega/wiki/home
  - Forum: http://diydrones.com/forum/categories/arduplane-2-x-software/listForCategory
  - User Group: http://diydrones.com/group/apmusergroup

- **Canon Hack Development Kit (CHDK)**: http://chdk.wikia.com/wiki/CHDK
  - Detailed CHDK firmware installation instructions http://conservationdrones.files.wordpress.com/2013/01/dronemapper_chdk.pdf
  - Detailed graphical instructions on optimal CHDK settings http://conservationdrones.files.wordpress.com/2013/01/dronemapper_chdk_settings-screenshots.pdf
  - Guidelines on aerial data collection and flight planning

    http://conservationdrones.files.wordpress.com/2013/01/dronemapper_aerialdatacollectionguidelinesplanning.pdf