SmartAP
Smart AutoPilot

SmartAP 4

Flight Control System

User's Guide

www.sky-drones.com

Contents

Introduction

SmartAP 4 Autopilot is the latest generation flight control system for multirotor Unmanned Aerial Vehicles of various configurations and sizes aimed at the wide range of applications. The main feature of the system is the capability of fully autonomous flight including take off, waypoints flight, landing and much more. The core is based on powerful 32-bit microcontroller ST Microelectronics® STM32F4 and 9-axis Inertial Measurement Unit. The latest UBlox® GPS module with integrated 3-axis magnetometer and pressure sensor can be connected externally for autonomous flight capabilities as well as wireless telemetry module for system configuration, mission planning & control and in-flight monitoring via specially designed SmartAP Ground Control Station and Configuration Tool. SmartAP 4 supports any type of multirotor UAV with outstanding flight performance, reliability, navigation and control precision. Compact size and weight makes integration of the system fast and easy, various I/O interfaces allow creating the applications for interaction with 3rd party electronics and payload.

Description

Flight performance

- Extremely stable flight in stabilize (user control), position hold (semi-autonomous control) and autonomous (navigation and control) modes
- Native support of SmartAP Ground Control Station and Configuration Tool
- Accurate GPS Position hold (up to 40cm), Accurate Altitude hold (up to 10 cm), manual
- Fully autonomous waypoints flight
- Return to home mode
- Failsafe detection and event triggering
- And many more…

General

- Powerful microcontroller 32 bit 168 MHz STM32F4 ARM Cortex M4
- Compatible with GPS/GLONASS receiver (UBlox NEO8, GPS/GLONASS, up to 24 sats, 10 Hz) active antenna
- Up to 12 PWM I/O support (5V out)
- USB interface for configuration / firmware update
- Various communication lines (UART, I2C, SPI)
- MicroSD, 4-bit SDIO interface for data-logging / parameters storage
- Backup battery for RTC
- 2x ADC inputs for battery voltage / current monitoring
- Electromagnetic sound audio indicator
- 3-channels LED support (up to 500mA / ch)
- 2-channels solid state relay

Processor

- ST Microelectronics STM32F427VI
- 32 bit 168 MHz ARM Cortex M4
- Hardware FPU
- 2 MB Flash
- 192 kB RAM

Sensors

- 2x 9-axis IMU InvenSense MPU-9250 (accelerometer, gyroscope, magnetometer)
- 2x Pressure sensor MS5611 (integrated and external)
- 1x 3-axis magnetometer HMC5883 (external)
- 1x UBlox M8N GPS Module (external)

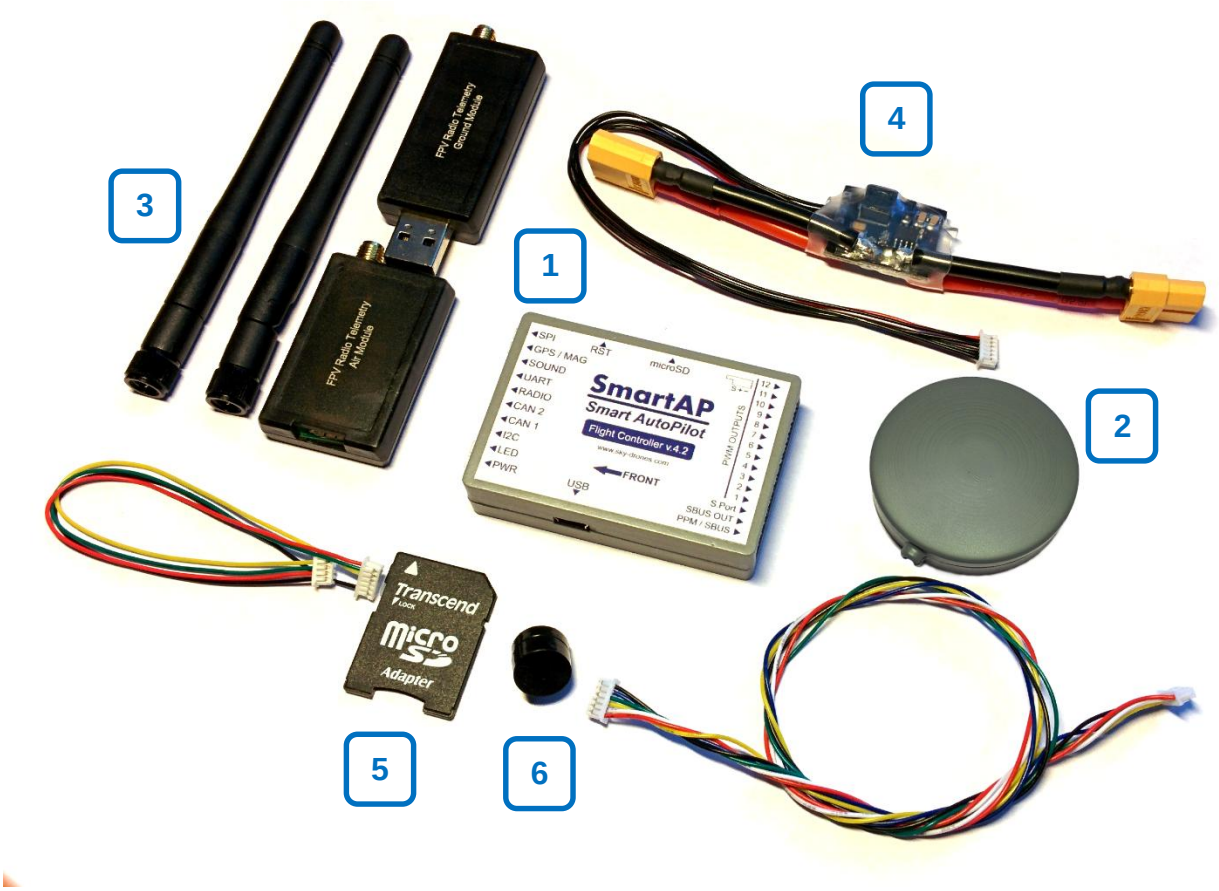
Interfaces

- 12x PWM I/O
- 1x PPM / SBUS Input
- 1x SBUS Output
- 1x Power Input port
- 1x LED Output port
- 3x UART
- 2x I2C
- 1x SPI
- 1x USB Mini-B

Size and Weight

- Length: 63mm
- Width: 43mm
- Height: 16mm
- Weight: 21g

Kit includes



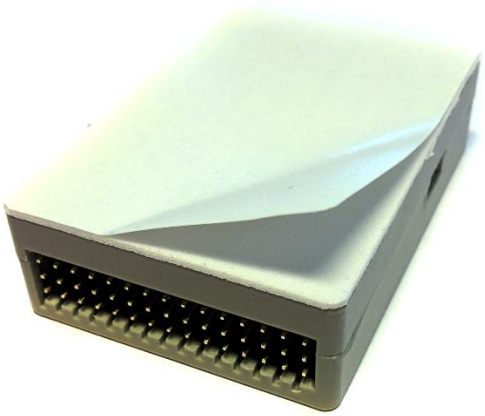
1. SmartAP 4 Flight Controller
2. GPS / GLONASS satellite navigation module with integrated 3-axis magnetometer
3. Telemetry kit (air and ground module with antennas and connection cable)
4. DC-DC Power module and current / voltage sensor
5. MicroSD card with adapter
6. Electromagnetic sounder

Getting Started

Mounting the System

Autopilot

The bottom side of the autopilot has special double-sided foam tape. Remove the protection layer of the anti-vibration tape and mount the autopilot any direction you want, the actual direction can be selected during configuration procedures later. It's recommended to mount the autopilot as close to the center of gravity as possible.



"FRONT" arrow indicated the original flight direction. Can be changed in the settings later.

GNSS / Compass

GNSS Module provides positioning information to the system and is sensitive to EMI noise. Make sure to place GNSS module as far as possible from:

- Main body of the airframe
- RF emitting devices, such as video transmitters
- High-current cables (ESC / motors power supply)

It's recommended to use GPS mast for that. Connect the cable and put the GPS on a mast.

"FRONT" arrow indicated the original flight direction. Can be changed in the settings later.

Connecting Peripherals

Ports Pinout

Front panel

Rear panel

Front panel connectors pinout:

SPI	GPS / MAG	BUZ / REL	UART	RADIO	CAN 2	CAN 1	I2C	LED	PWR
5V	5V	5V	5V	5V	5V	5V	5V	5V	5V
SCLK	TX	BUZ	TX	TX	H	H	SCL	LED 1	5V
MISO	RX	R_COM	RX	RX	L	L	SDA	5V	A
MOSI	SCL	R_OUT	GND	GND	GND	GND	GND	LED 2	V
CS	SDA							5V	GND
GND	GND							LED 3	GND

Rear panel connectors pinout:

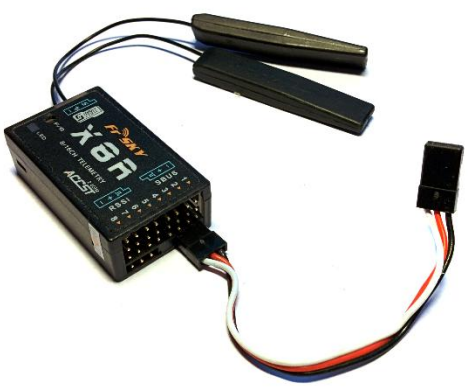
RC	SB	SP	1	2	3	4	5	6	7	8	9	10	11	12
5V		5V	5V	5V	5V	5V	5V	5V	5V	5V	5V	5V	5V	5V
GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND	GND

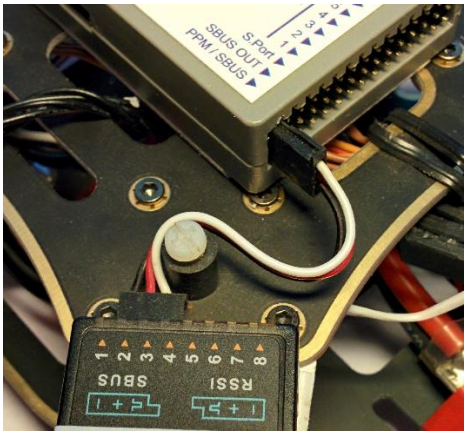
PWM Outputs

Make sure NOT to mix up polarity. GND line (black) is always near edge (bottom)

RC Receiver

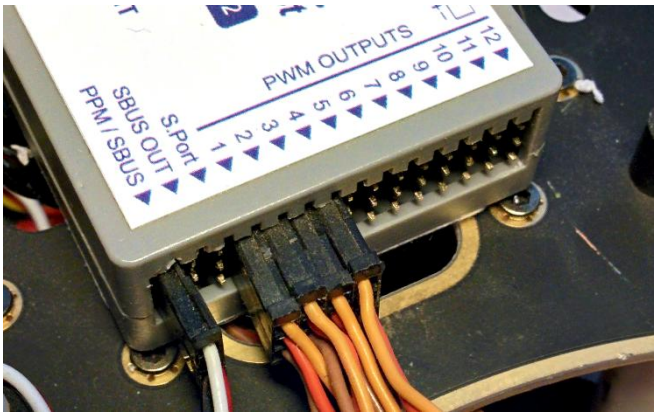
Connect PPM / SBUS output of the RC receiver to PPM / SBUS Input port of SmartAP.



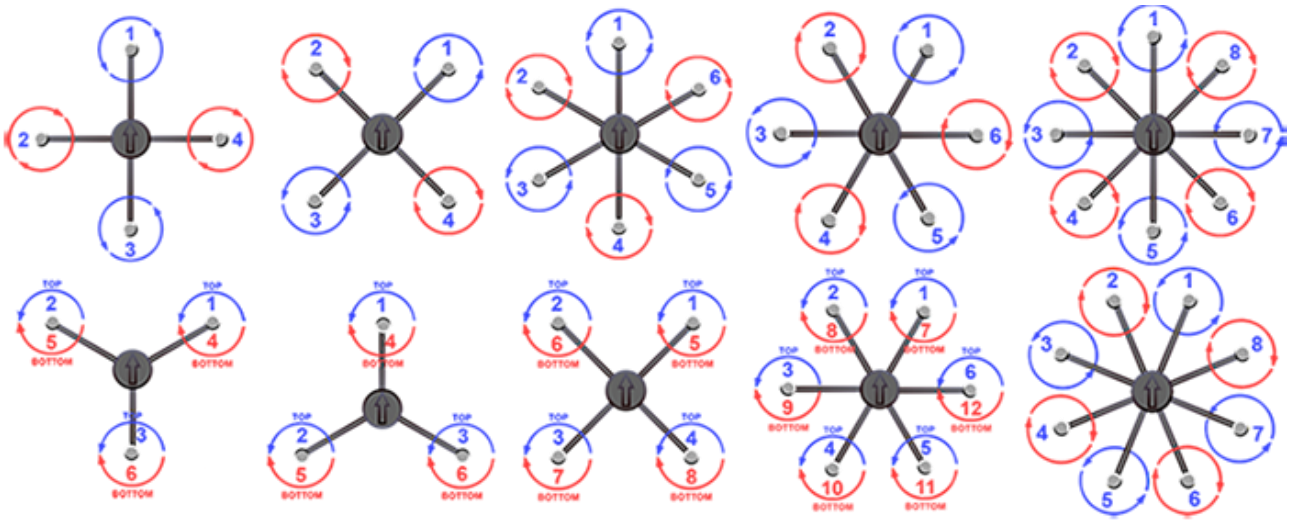


ESC / Motors PWM

Connect ESC cables to SmartAP PWM outputs 1-12 depending on the number of the motors your airframe has. The first motor is always front or front-right, it's spinning direction is CCW. Supported airframe types and motors number / spinning direction are shown below. PWM signals is the top wire, GND is the bottom one.



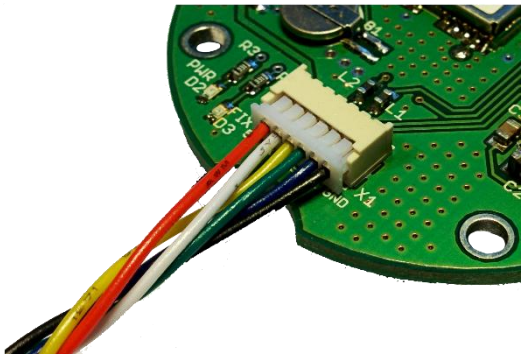
Connections for quadcopter are shown on the picture to the right:



*If you can't find your airframe in the list above, please, let us know at http://sky-drones.com/ and we'll add your airframe!

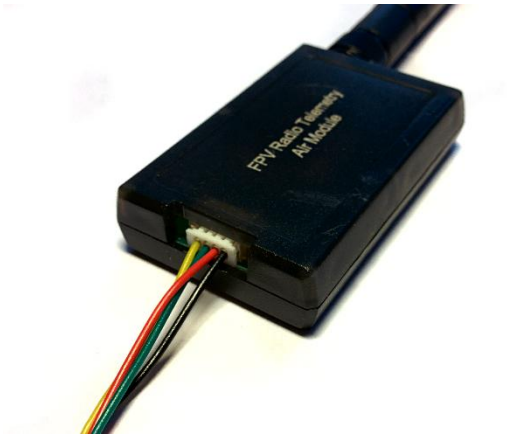
GNSS / Compass Module

Connect the one side of the cable to GNSS module and the other one to the GPS / MAG port of the autopilot as shown on the pictures below:



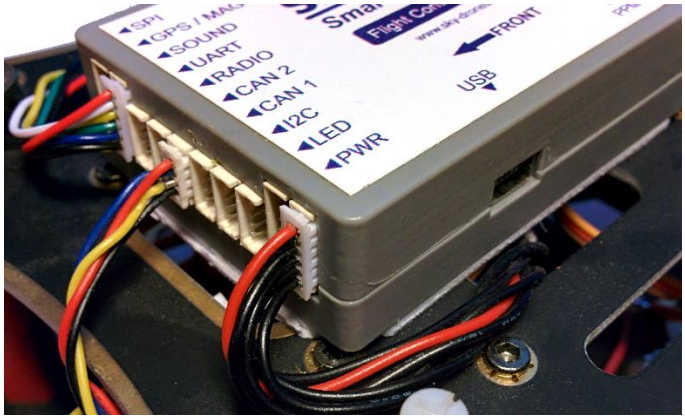
Telemetry Module

Connect the one side of the cable to air telemetry module and the other one to the RADIO port of the autopilot as shown on the pictures below:

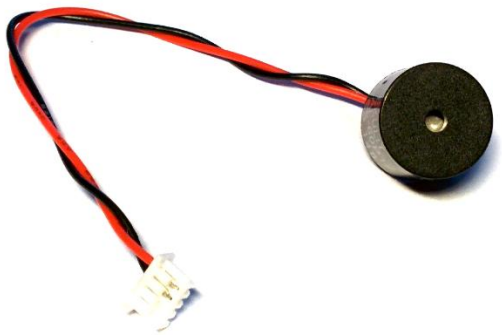


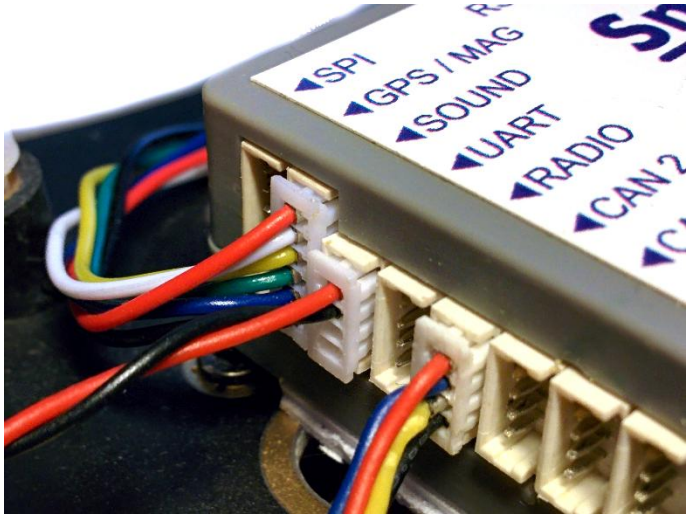
Power Module

Connect power supply cable (10-36 V, 3S – 8S) from main power distribution board of the UAV.



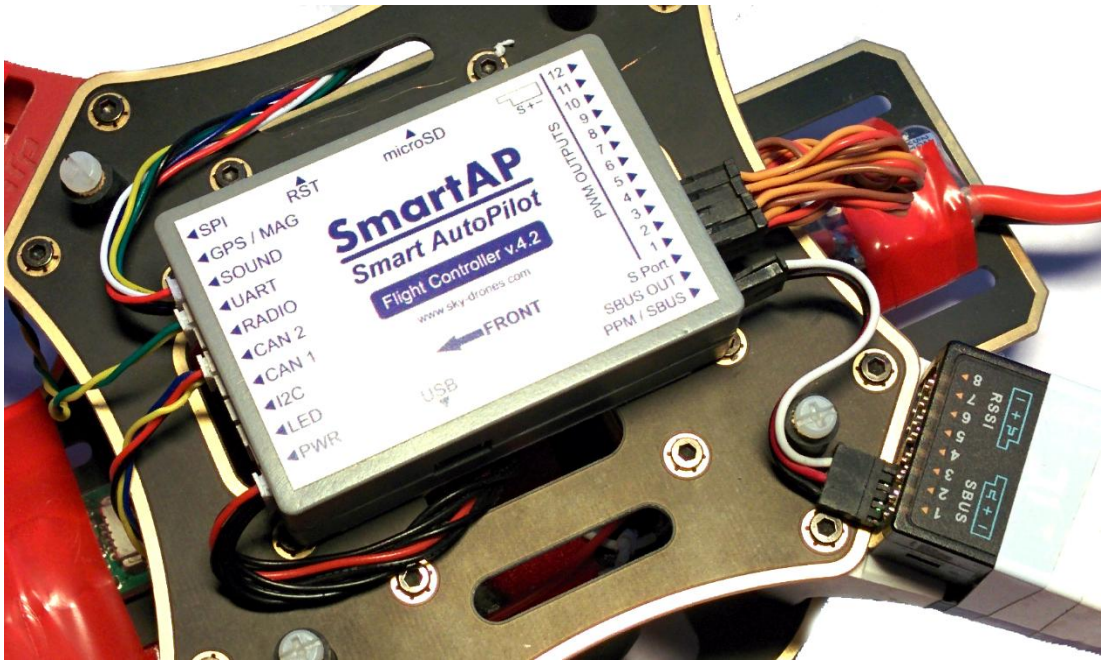
Electromagnetic sounder





Assembled System

Fully assembled and mounted system should look as follows:



Configuration

Getting the Software

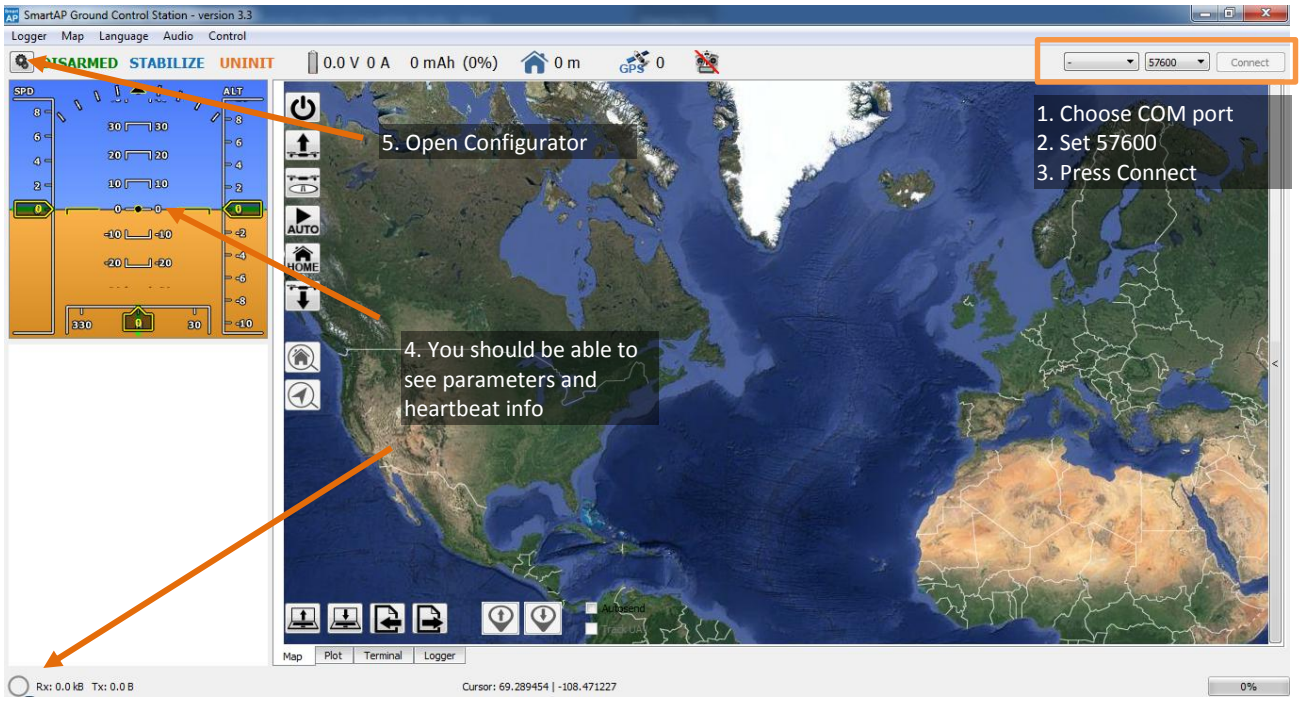
SmartAP GCS

Go to www.sky-drones.com website and download **SmartAP GCS**. This software will help you to configure the autopilot for your specific requirements and prepare it for the flight. After downloading the application install it and follow the steps described below.

General

Main window

After installing the application, you may open it and connect to the flight controller. Connection can be established via USB or wireless telemetry (for wireless telemetry choose rate 57600). During the configuration procedures it's recommended to use USB interface. In the top right corner select the COM port of your controller and press connect button.

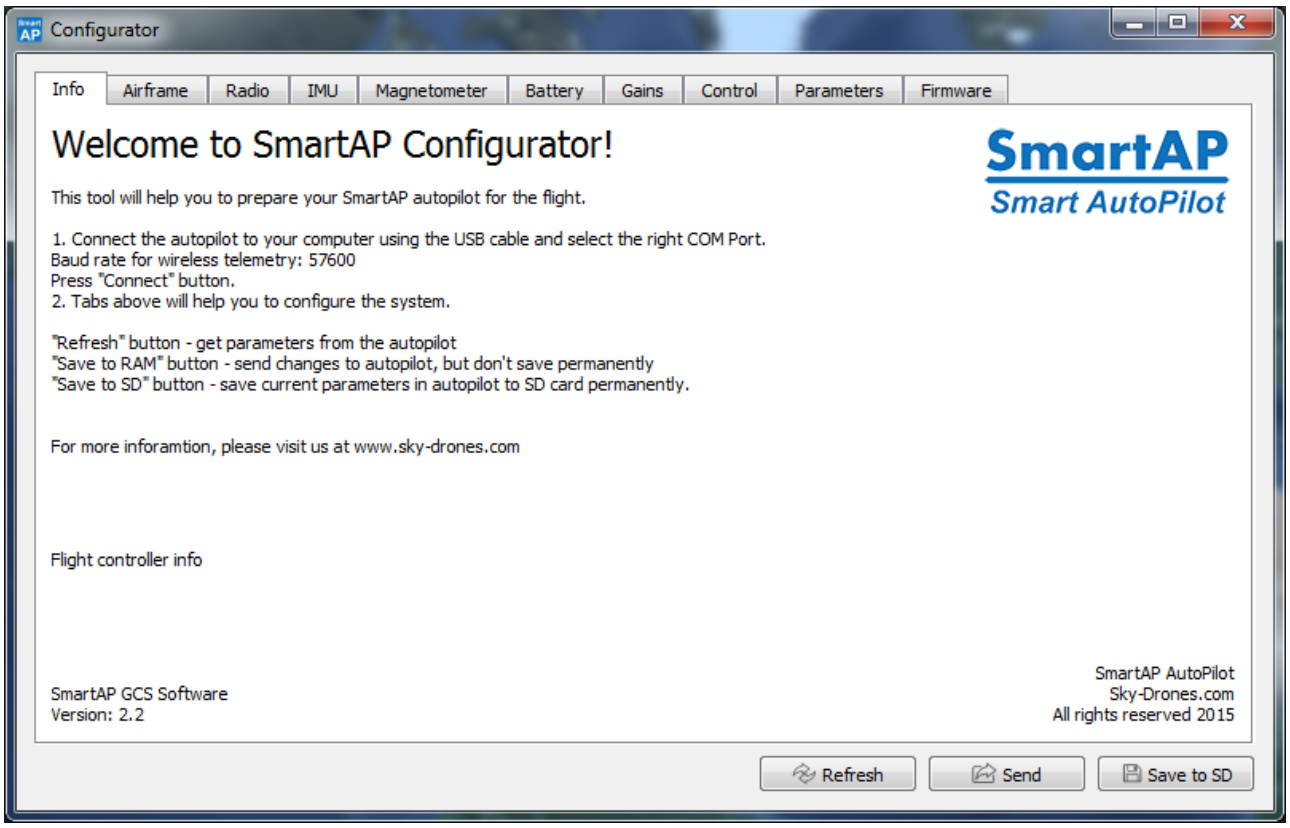


If you can see the Heartbeat icon blinking (bottom-left) and parameters loaded successfully then the connection has been established. Then you can go to Configuration tool (icon in the top left corner). Once you get there you'll see the window with the basic instructions.

Configuration window

Tabs at the top provide the navigation between various settings of the flight controller which will be described below. Configuration tab has 3 buttons:

- **Refresh** – read all parameters from the flight controller
- **Send** – send changed parameters to the flight controller
- **Save to SD** – save parameters permanently to SD card



Firmware update

Most likely new firmware version has been released and it's highly recommended to do the firmware update.

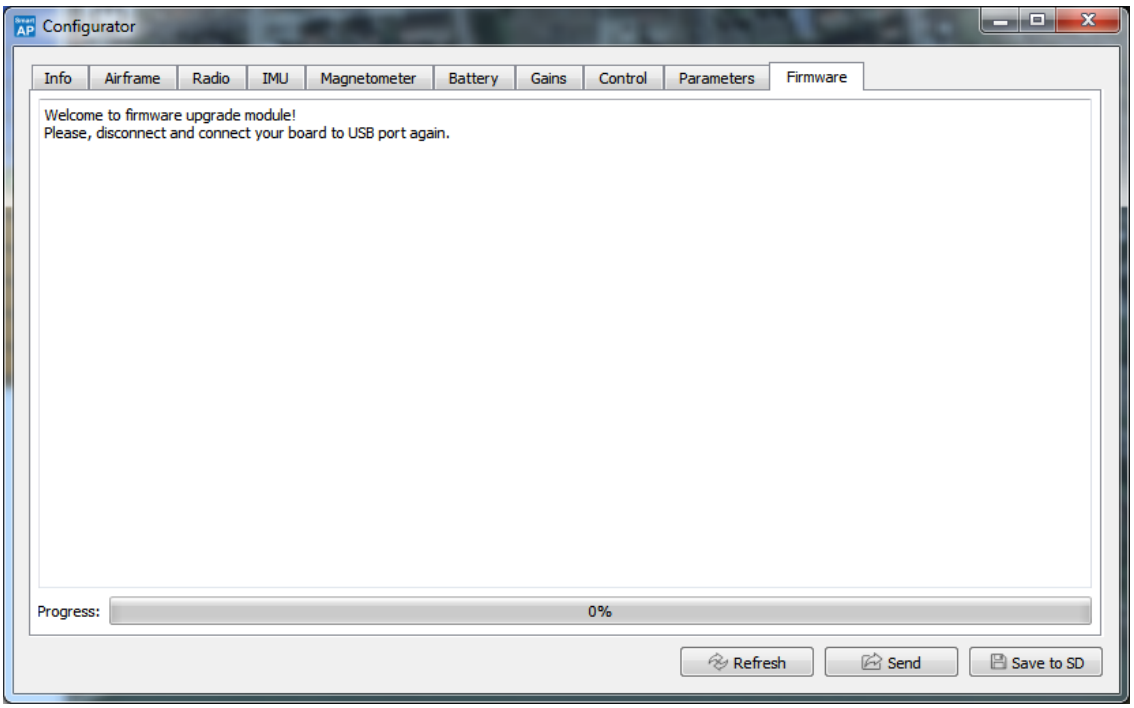
Getting the Firmware

The latest firmware for the flight control system including all required drivers and utilities can be found in the **downloads** section at Sky-Drones website: www.sky-drones.com

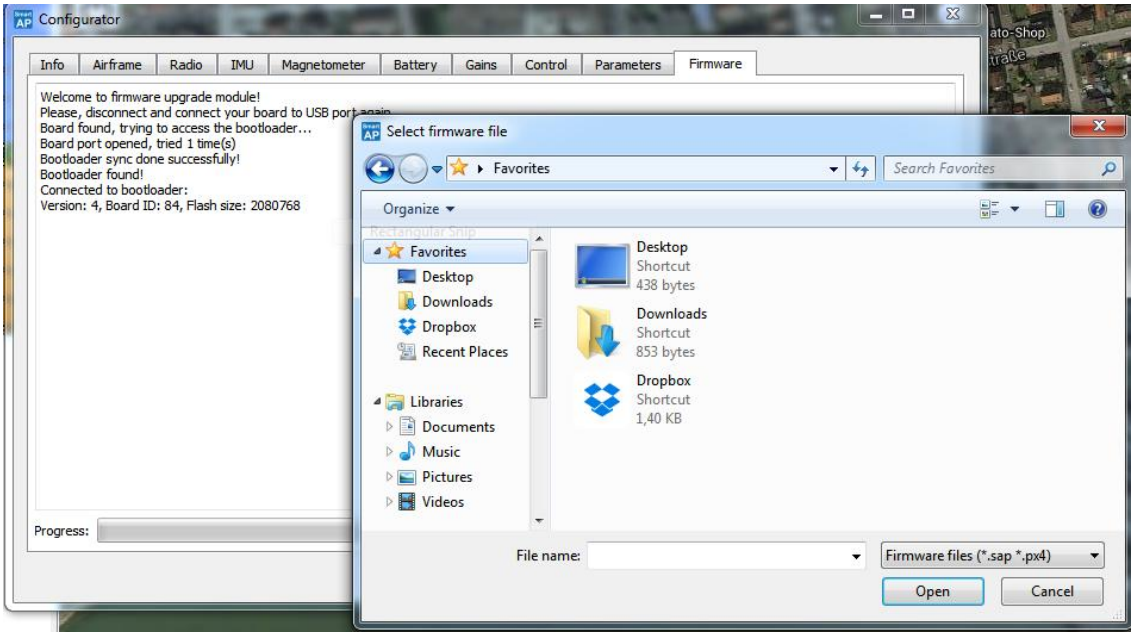
Firmwares

Name	Description	Version	Size
SmartAP 4 AutoPilot Firmware (latest)	.sap file for the Flight Control System	3.8.1 [11.05.2016]	198 KB
SmartAP 3.X Pro AutoPilot Firmware	.sap file for the Flight Control System	3.8.0 [29.03.2016]	191 KB
SmartAP 3.X Pro AutoPilot Firmware&Bootloader	.dfu file for the Flight Control System	3.8.0 [29.03.2016]	1 MB
SmartAP 2.0 AutoPilot Firmware (latest)	.dfu file for the Flight Control System	2.2.9	207 KB

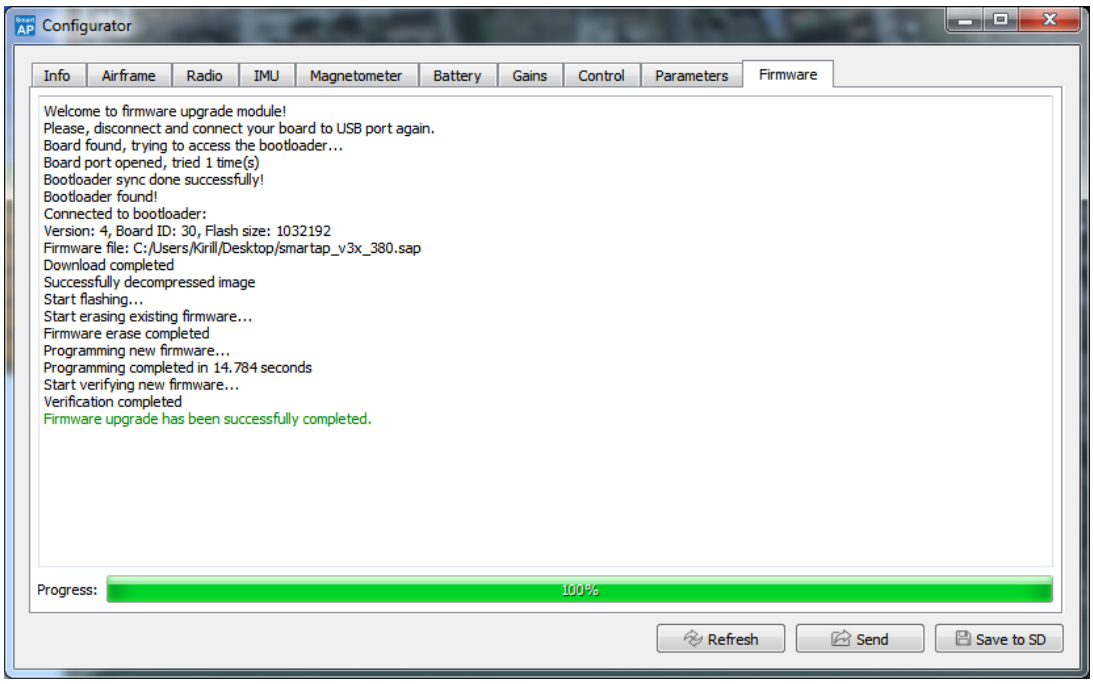
You need to download the latest .sap file of the firmware. Once you have it on your computer make sure to disconnect the autopilot and open SmartAP GCS again. Then go to Configurator > Firmware tab and connect the board via USB cable.



During the start-up of the board it will go to bootloader mode and the dialog will ask you to choose the firmware file to be upgraded. You will see the following dialog:



Select the firmware file to be uploaded and press Open, the update procedure will start instantly. Usually it takes up to 30 seconds, in then end you will see the status message that the firmware has been successfully updated:

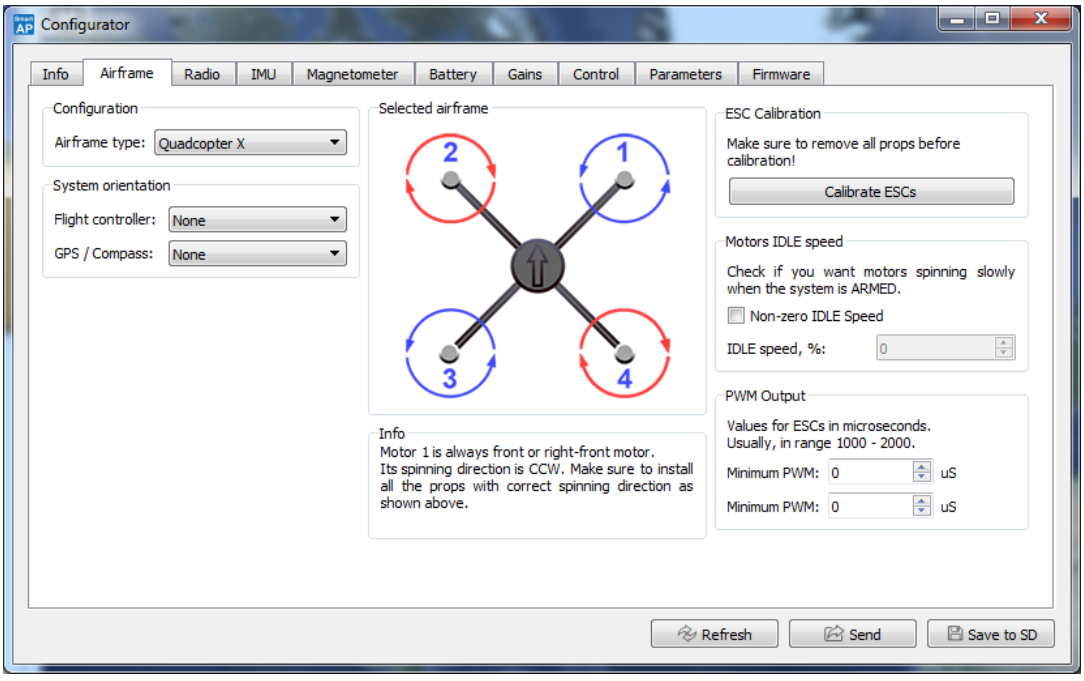


REMOVE ALL PROPS BEFORE PROCEEDING TO THE NEXT STEPS!

Now when the firmware is updated you can connect to the system again, go to Configurator and perform the setup. Let's take a look at the configuration tabs.

Airframe

Go to Airframe tab to choose your airframe from the drop-down menu. If you can't see your airframe tab in the list – feel free to contact us and we'll add the new airframe type for you.



System orientation

You can choose the desired orientation of the flight controller and GPS Module from the dropdown menus.

Motors IDLE speed

If you want the motors slightly spinning when the system is Armed you can set Motors IDLE speed checked and set the desired value of throttle in percent.

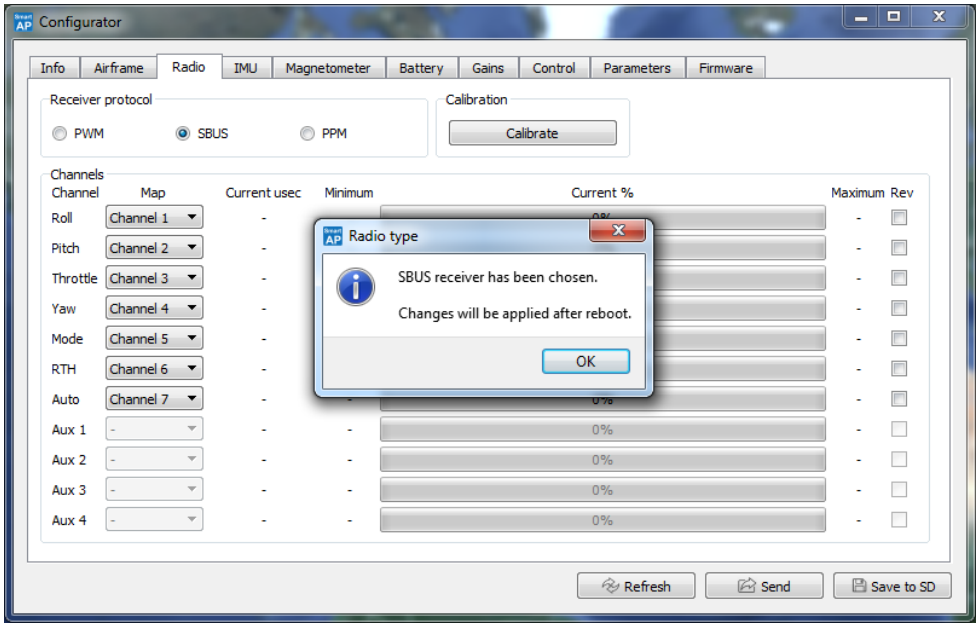
PWM Output

Minimum and maximum output PWM values can be set.

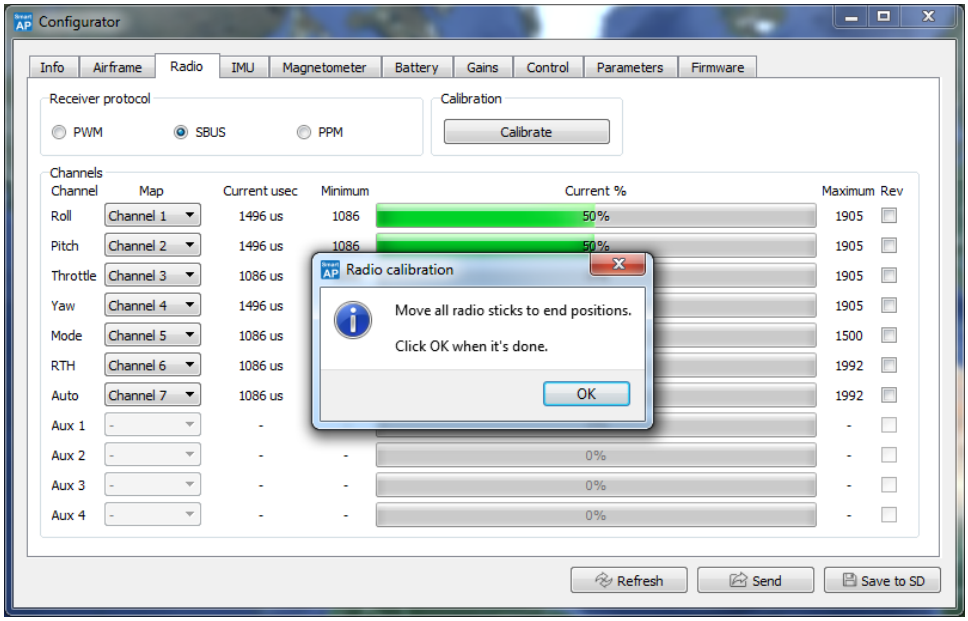
Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

Radio

Go to Radio tab and choose the RC receiver protocol corresponding to the one you're using. SBUS or PPM receivers are recommended. This change will take effect after the system is restarted. Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently. After that – reboot the board (disconnect the power and connect again).

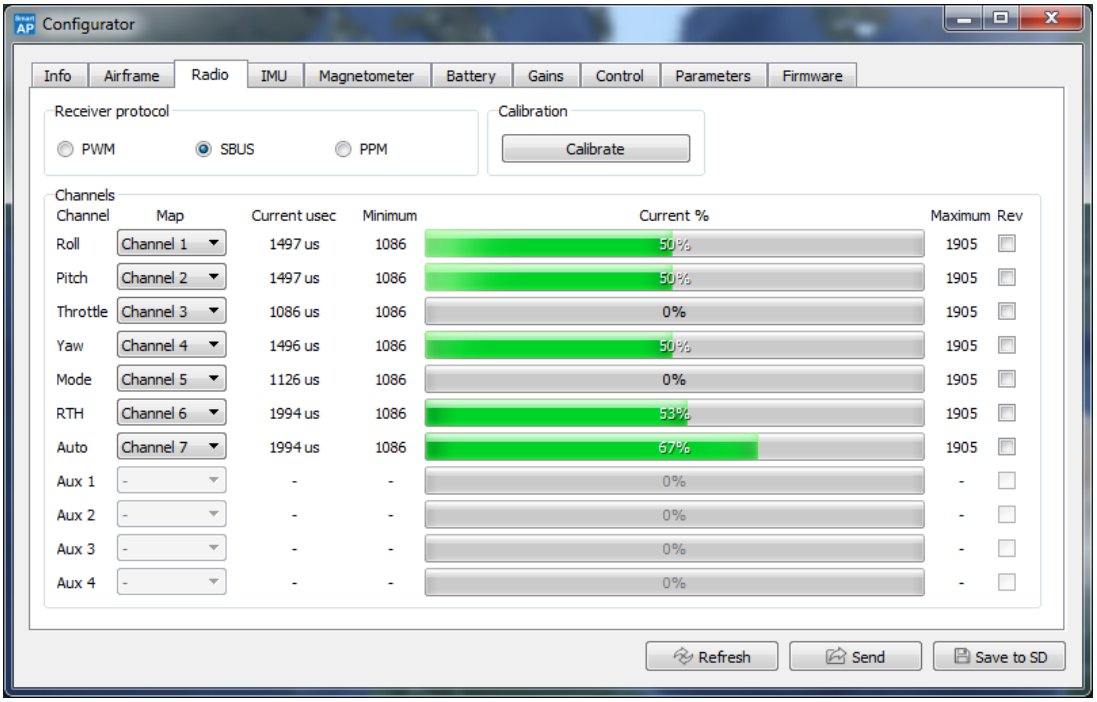


Go to Configuration > Radio again and make sure that your transmitter is turned on. You'll see the sticks positions displayed. Press Calibrate button and move all sticks to their end points.



When it's done – press OK button to stop calibration and set parameters.

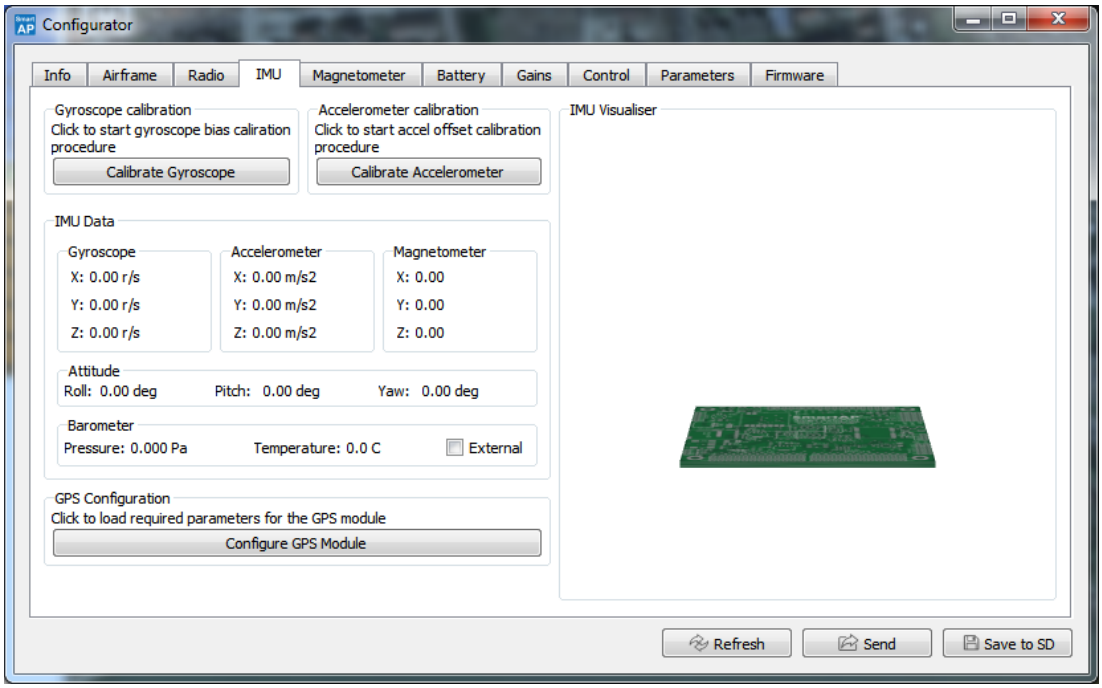
Also you can remap any action to the desired channel and apply reverse if needed.



Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

IMU

IMU configuration tab allows to perform gyroscope and accelerometer calibration which are very important for precise flight performance.



Gyroscope calibration

Don't move the board, put it still and click Calibrate Gyroscope button. You'll see pop-up message showing that the calibration is in progress which will be done in a few seconds

Accelerometer calibration

For accelerometer calibration you'll have to place the autopilot in 6 positions:

- Top side up
- Top side down
- Left side down
- Front side down
- Right side down
- Rear side down

Follow the instructions which will be shown after you press Calibrate Accelerometer button.

It's highly important to hold the system still in these position during the calibration. In each step the axis should be aligned with g-acceleration vector as precise as possible.

Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

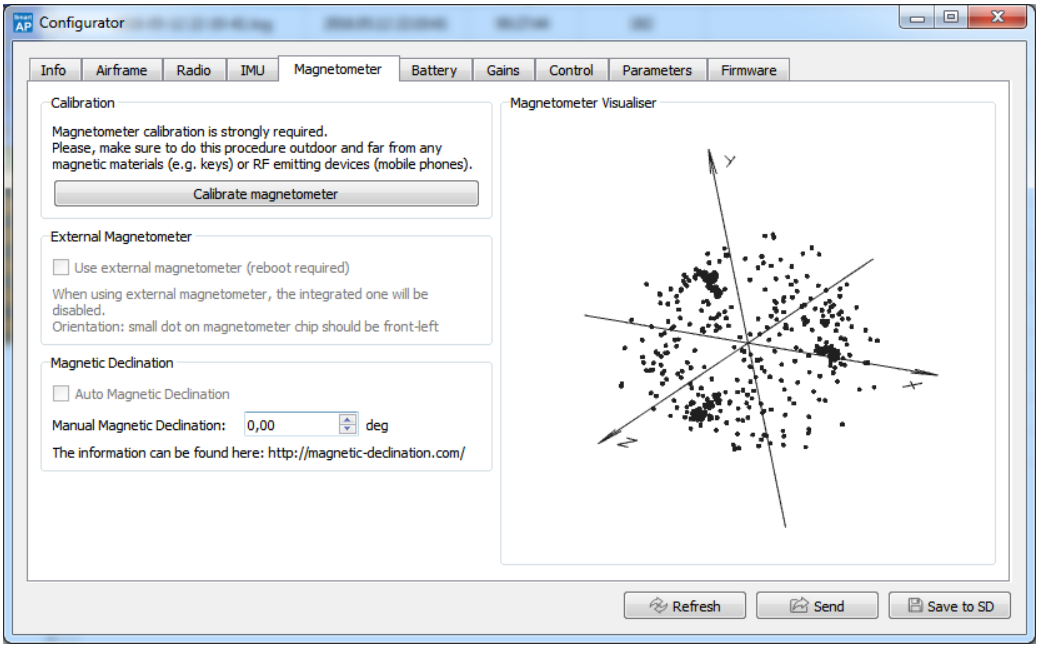
GPS Module Configuration

Make sure that the GPS module is connected to the autopilot before proceeding to this step. Also, make sure that the green LED indicating power supply of the module is solid green.

IMU tab also allows to configure the GPS module with the default parameters and messages required to work properly with SmartAP Autopilots. Press "Configure GPS Module" button, press OK and reboot the board. During the next start-up your GPS module will be automatically configured.

Magnetometer

Magnetometer calibration is highly important for precise position hold and autonomous flight modes. Make sure that you're outdoors and don't have any metals around and in your pockets (e.g. keys, cell phones, etc) before calibration. Press Calibrate Magnetometer button and rotate the vehicle around three major axes (roll, pitch, yaw). After 30 seconds magnetometer calibration will be automatically completed and pop-up calibration message will go out.

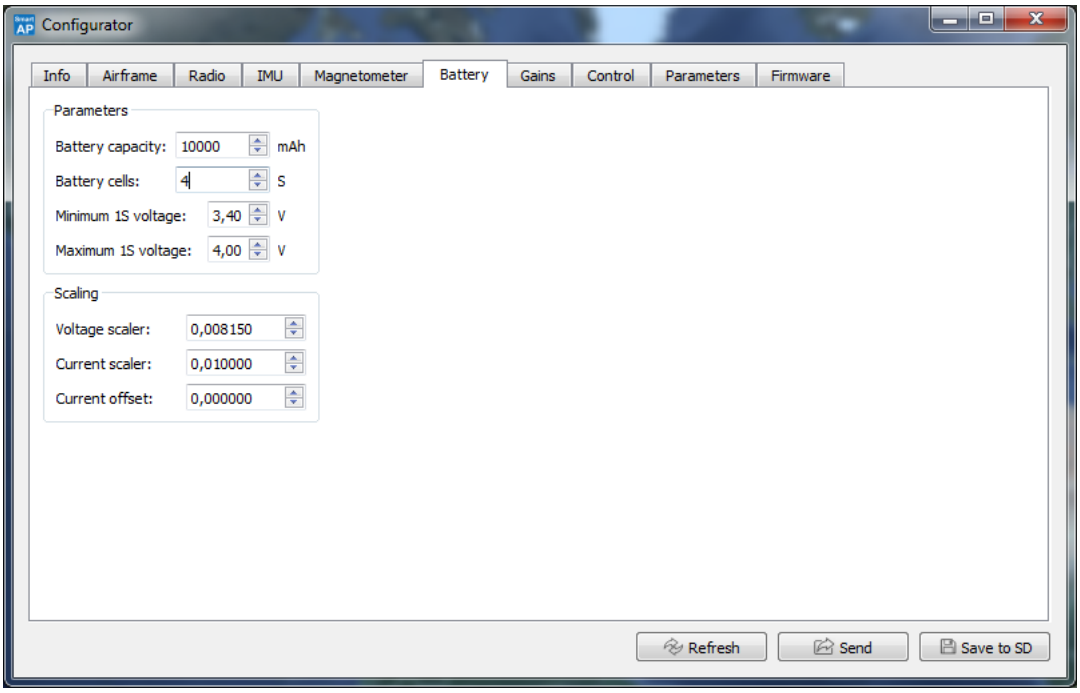


Correct magnetic declination is very important as well. You can find the information about the declination value for your region at http://magnetic-declination.com website. Set the value in degrees in settings.

Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

Battery

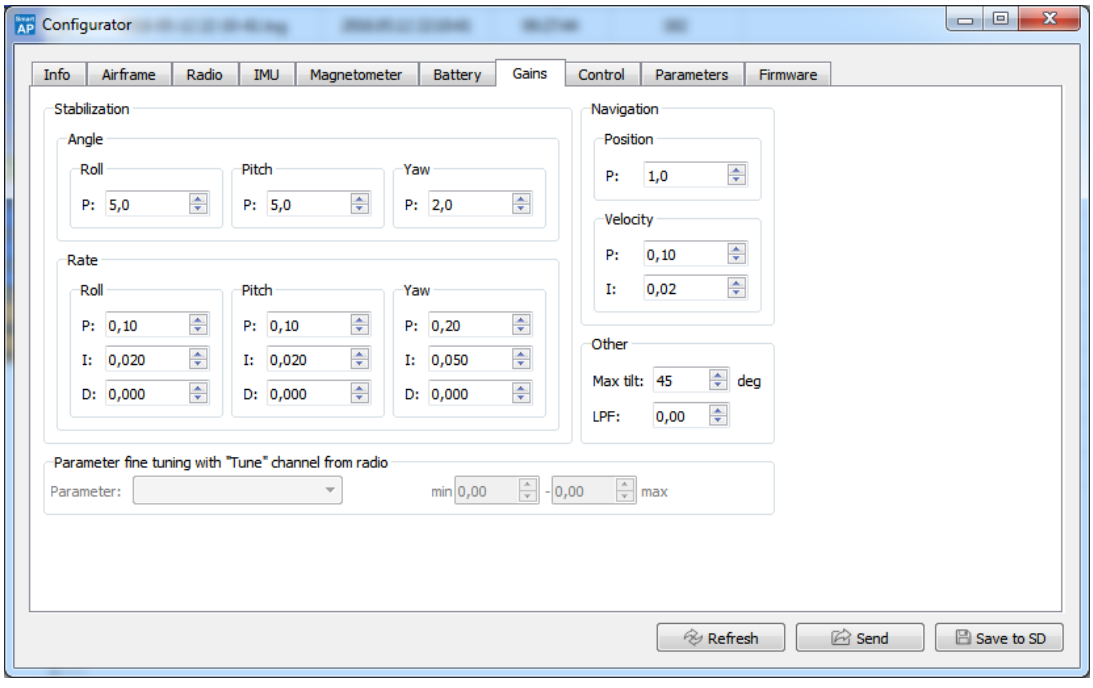
In the Battery configuration tab you can set your battery's capacity and thresholds for low-voltage level, so the system will notify when the charge is too low.



Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

Gains

SmartAP AutoPilot is based on P-PID control algorithm. It means that the stabilization (the ability to stay in the air) and navigation (the ability to follow desired trajectory) control algorithms include two loops: angle and rates control and position and velocity control. By default the gains (PIDs) are set to be the average for the majority of airframes, configurations and etc. Of course the parameters can be tuned precisely for the better flight performance.



Here is the brief guide and explanations for PID tuning:

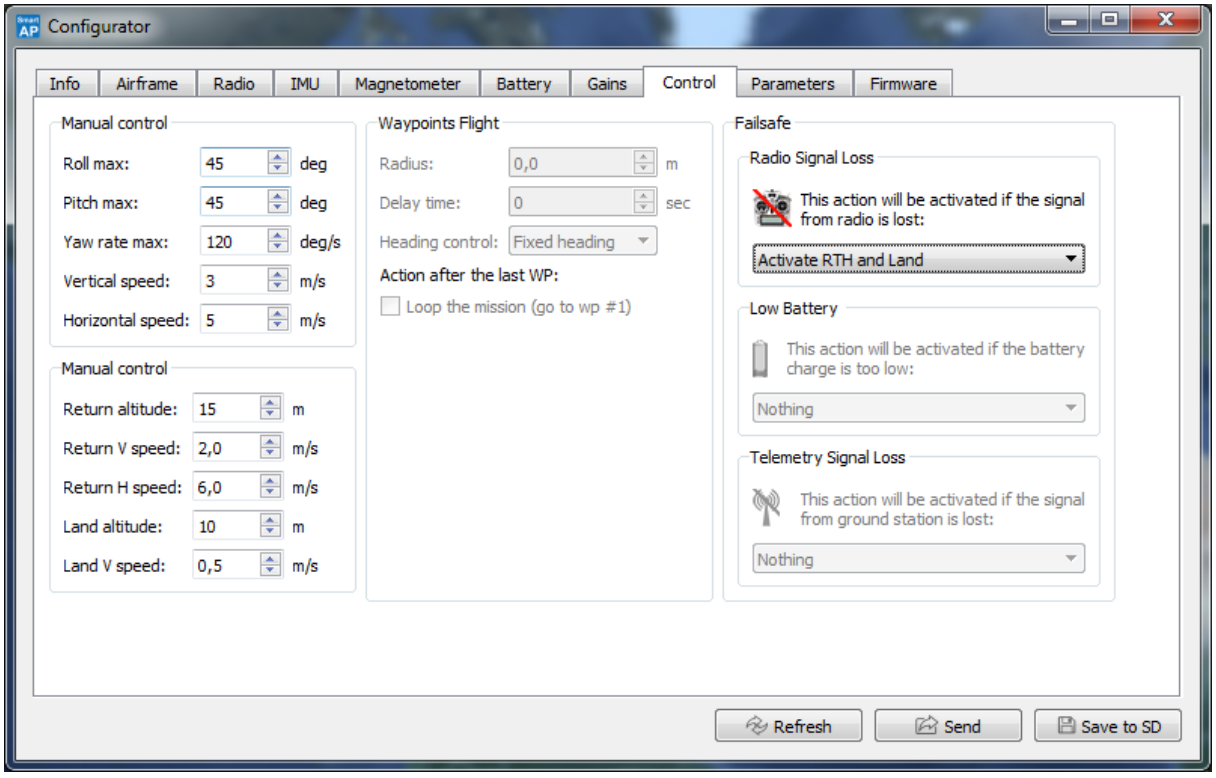
1. Set all values by default.
2. It's very important to tune Stabilization loop as perfect as possible, navigation is based on stabilization, so if it's not well - then the vehicle will not hover and fly waypoints precisely.
3. The most important parameters are **Stabilization Rate Roll / Pitch P**. Increase it until you see high-frequency oscillations or decrease if you can already see them. Normally, this value is in between **0.05 – 0.15** depending on your airframe size, motors, ESC, props and vibration level.
4. If the oscillations start too early (e.g. you can't increase **Stabilization Rate Roll / Pitch P** anymore and feel that the vehicle is not enough responsive to your stick movements) then you can increase **Stabilization Rate Roll / Pitch D** a little bit. It will smooth the oscillations, however, you will have the same control force response. Normally, **Stabilization Rate Roll / Pitch D** is in between **0.0001 – 0.002.**
5. If you can see low-frequency oscillations – it means that your **Stabilization Angle Roll / Pitch P** is too high and you need to decrease it. This value lays in range between **2 - 6**.

Navigation gains can be tuned using the same approach, however, this is not really important to tune this values since they're fine by default for the majority of the vehicles.

Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

Control

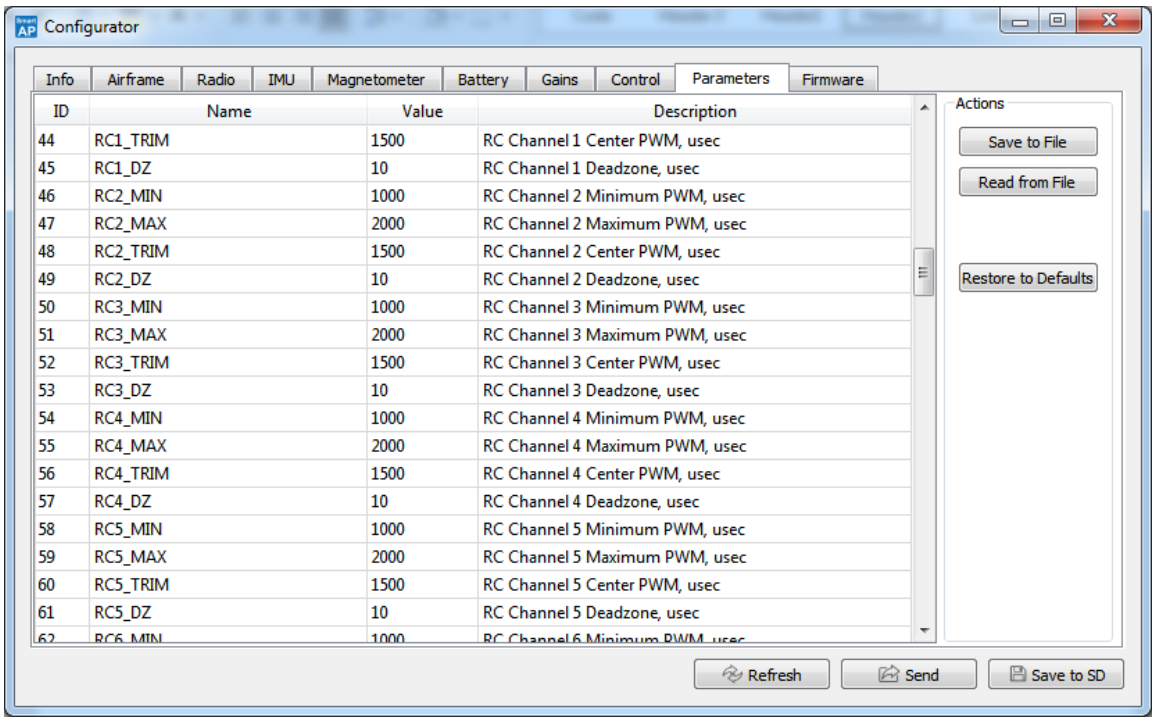
Control tab allows configuring user's manual control sensitivity, horizontal and vertical speed limits in various modes and failsafe actions.



Don't forget to press **Send** to perform update and **Save to SD** to save changes permanently.

Parameters

Parameters tab gives you direct access to all parameters available in the system. Also, you can save parameters to a file or read them from file.


Configurator
Info
Airframe
Radio
IMU
Magnetometer
Battery
Gains
Control
Parameters
Firmware
ID
Name
Value
Description
44 RC1_TRIM 1500 RC Channel 1 Center PWM, usec
45 RC1_DZ 10 RC Channel 1 Deadzone, usec
46 RC2_MIN 1000 RC Channel 2 Minimum PWM, usec
47 RC2_MAX 2000 RC Channel 2 Maximum PWM, usec
48 RC2_TRIM 1500 RC Channel 2 Center PWM, usec
49 RC2_DZ 10 RC Channel 2 Deadzone, usec
50 RC3_MIN 1000 RC Channel 3 Minimum PWM, usec
51 RC3_MAX 2000 RC Channel 3 Maximum PWM, usec
52 RC3_TRIM 1500 RC Channel 3 Center PWM, usec
53 RC3_DZ 10 RC Channel 3 Deadzone, usec
54 RC4_MIN 1000 RC Channel 4 Minimum PWM, usec
55 RC4_MAX 2000 RC Channel 4 Maximum PWM, usec
56 RC4_TRIM 1500 RC Channel 4 Center PWM, usec
57 RC4_DZ 10 RC Channel 4 Deadzone, usec
58 RC5_MIN 1000 RC Channel 5 Minimum PWM, usec
59 RC5_MAX 2000 RC Channel 5 Maximum PWM, usec
60 RC5_TRIM 1500 RC Channel 5 Center PWM, usec
61 RC5_DZ 10 RC Channel 5 Deadzone, usec
Actions
Save to File
Read from File
Restore to Defaults
Refresh
Send
Save to SD

Your First Flight

Flight Modes overview

SmartAP has 3 switches for modes control – one 3-position switch and two 2-position switches:

Mode Switch: 3 position switch (Main mode control):

- Stabilize
- Altitude hold
- Loiter (GPS Position hold + Altitude hold)

Auto Switch: 2 position switch (Auto mode control):

- On / Off - enable / disable autonomous waypoints flight (overrides previous switch)

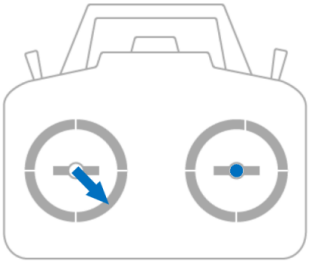
RTH Switch: 2 position switch (RTH mode control):

- On / Off - enable / disable return to home mode (overrides both previous switches)

In **Altitude Hold** and **Loiter modes** you will have altitude rate control with the throttle stick. Middle position means hold the altitude, raising or lowering the stick means going up or down with the speed from 0 to 3 m/s (by default, can be changed in Control tab).

Before take off

1. Set your throttle stick down
2. Power on the transmitter
3. Power on the copter
4. Make sure you're in Stabilize, Altitude hold or Loiter mode
5. When you're ready to fly – ARM the system by turning left stick right-down for 1 second
6. Release the stick after hearing the long beep
7. The system is armed and ready for take off

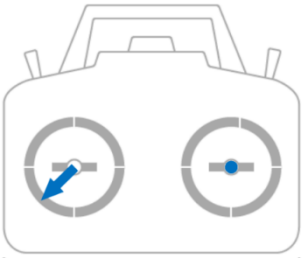


The Flight

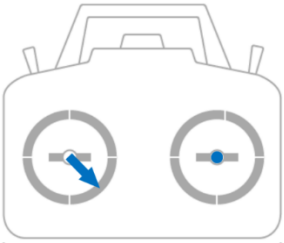
1. Slowly raise your throttle stick until the copter takes off from the ground
2. Use the right stick to control the lean angles / position of the copter
3. Use mode switches if you want to switch to Loiter / Auto / RTL etc. mode

After landing

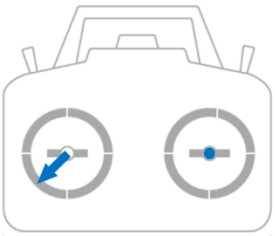
1. Disarm the system after landing by turning let stick left-down for a 1 second
2. Two short beeps mean that the system has been successfully disarmed
3. Power off the copter
4. Power off the transmitter



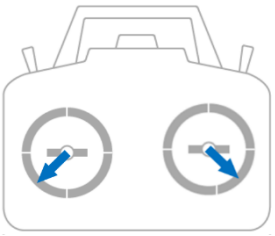
Transmitter commands



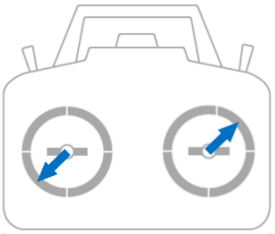
ARM
hold for 1 second and release
Performs all calibrations before take off and unlock motors. Long beep followed means that the system is ARMED and ready to fly.



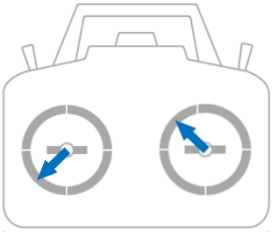
DISARM
hold for 1 second and release
Locks motors.
Two short beeps mean that the system is DISARMED and safe.



Accelerometer calibration start
hold for 3 seconds
Short beep means that the system goes into calibration mode. Short positive tone means that the calibration was done and you need to rotate the vehicle for the next calibration position. Once all six positions are calibrated you'll hear the tone meaning that the calibration completed successfully and saved to SD card.



Gyroscope calibration start
hold for 3 seconds
Short beep means that the system starts calibration. DO NOT move the vehicle during the calibration. Short positive tone means that the calibration was done successfully and saved to SD card.

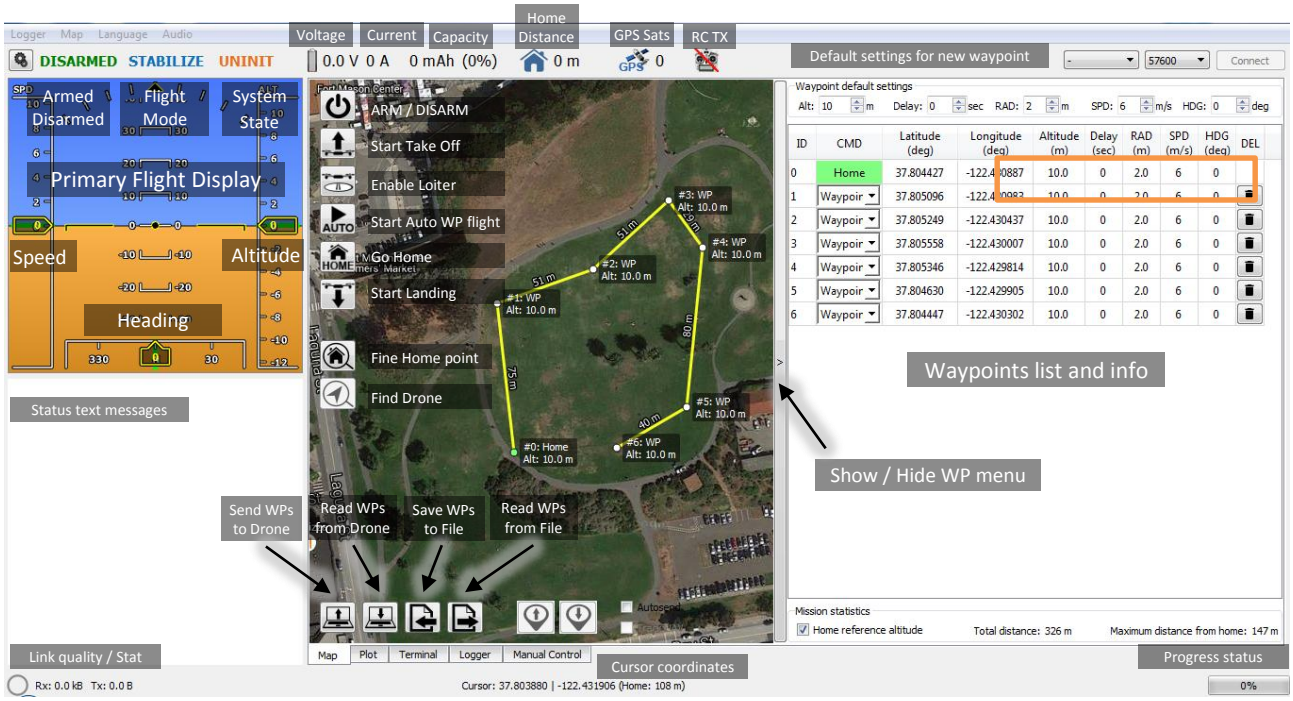


Magnetometer calibration start
hold for 3 seconds
Magnetometer calibration process starts after a beep. Short positive tone after 30 seconds means that the calibration was done successfully and saved to SD card.

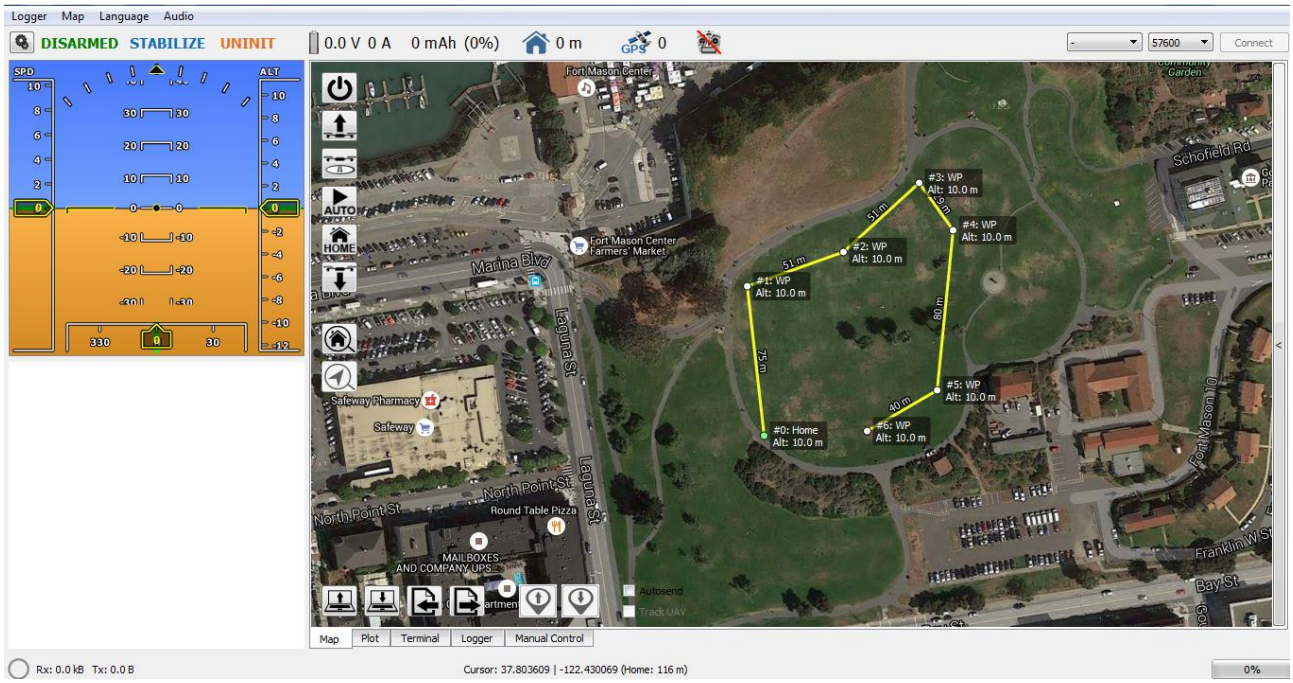
Flying with SmartAP GCS

Mainwindow overview

Here is the brief overview of the information, user interface and control buttons:



If you want to save some space on the screen you can hide the WP menu:



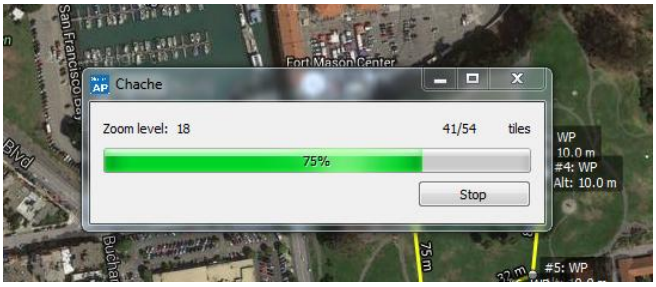
Creating the new mission

To create the new mission you need to do the following:

- Double-click on the map to insert a new waypoint
- Click "Send WPs to Drone" to send the waypoints

Caching the map

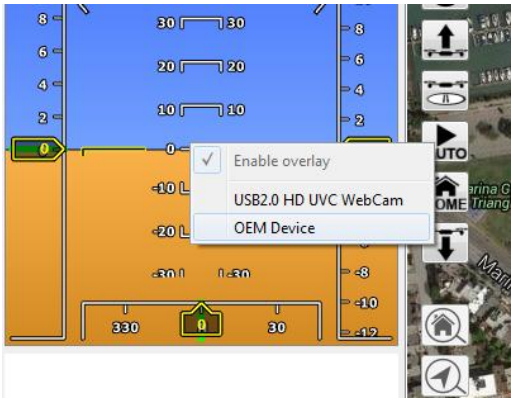
If you want to cache the part of the map in order to use it next time without internet connection you can set the map at the area you want, right click and choose "Cache current area". Cache window will pop-up. After the window is closed you can use this part of the map next time without internet connection.



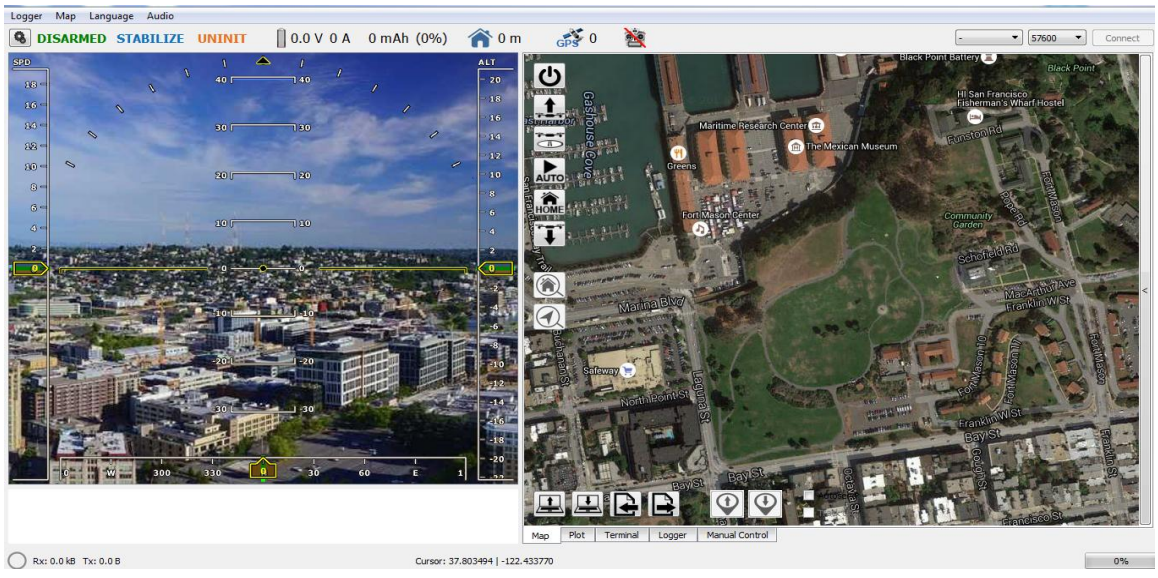
Getting the video

SmartAP GCS allows to see the real-time video feed right in the application under the Primary Flight Display (PFD). To get the video streaming you'll need a special USB adapter called EasyCAP. Right-click on the PFD and select the video source you would like to use. For EasyCAP it's usually OEM Device but for some other version this name might be different.

Make sure to connect EasyCAP to your computer before starting SmartAP GCS application.



After that you'll be able to see the video under PFD. Also you can disable overlay by unchecking "Enable overlay".



Safety

Operating a powered vehicle of any kind can be a lot of fun, but it carries certain inherent risks. Regulations governing the use of powered vehicles, including aircraft, vary from locale to locale, even within the same country or district. It is your responsibility to ensure that you understand and comply with all local laws and regulations.

Safety basics:
• Never operate the vehicle or software in a way that could be dangerous to you, other people, or property.
• Always keep propeller arcs free of objects and body parts while the vehicle is live.
• Keep in mind that software and hardware failures happen. Although we design our products to minimize such issues, you should always operate with the understanding that a failure could occur at any time and without warning. Accordingly, you should take the appropriate precautions to minimize danger in case of product failure.
• Never use the software or hardware for manned vehicles.
• Always operate within local laws and regulations.
• Do not operate the aircraft if you are under the age of 16.

Additional safety information:
• Be sure to maintain safe distances between people and your aircraft.
• Never operate your aircraft if your ability to do so with the utmost attention to safety is impaired in any way. Do not operate your aircraft while tired, under the influence of drugs or alcohol, or otherwise unable to operate it with the highest attention to safety.
• Environment conditions can change rapidly and can make operation difficult. If this occurs, land your aircraft and discontinue use immediately. Do not operate your aircraft if operating conditions are not ideal. This includes, but is not limited to, rain, snow or excessive wind.
• Always ensure the battery cable is disconnected from the aircraft until you are ready to fly, and ensure that your batteries are fully charged prior to use.
• Always turn on the transmitter and ensure the throttle stick is all the way down before connecting the battery.
• After landing, disarm your vehicle immediately and disconnect the battery cable.
• Do not turn off the transmitter until after you have disconnected the battery.
• Always remove the propellers while testing the motors.
• When the battery is connected, always assume the vehicle is live and the motors are armed.
• Do not attempt to fly longer than the battery's safe capacity.
• Do not operate the vehicle with excess weight attached.
• Ensure that all vehicle components are well maintained before each flight. Ensure that components are firmly attached and operating properly.
• Replace any worn or damaged components before each flight. Never operate with any damaged or worn components.

Support

For more information about SmartAP AutoPilot, please, visit www.sky-drones.com website.

If you have any questions, please, feel free to contact us at http://sky-drones.com/

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Revision History

#	Date	Ver.	Description
1.	16.05.2016	1.0	Initial release of the Guide
2.	26.05.2016	1.1	Images changed