

AscTec Hummingbird with AutoPilot

User's Manual



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1 Introduction

Thank you for purchasing a Vertical Take-Off and Landing (VTOL) air vehicle equipped with the AscTec AutoPilot. Please read this manual carefully before you start to work with your new device.

WARNING!

The AscTec AutoPilot is a powerful tool, enabling the vehicle to hover autonomously in one place and thus making it very easy to control. However, it is important that you understand how to control the vehicle in situations where GPS reception is bad or not available. As a pilot you are required to always fly within visual range.

A motorized model aircraft like the AscTec Hummingbird is not a toy! It should only be flown by adults. Improper assembly or operating can lead to severe injuries and / or damages. Trouble with your remote control due to interferences can occur any time without prior notice. Sometimes, a model aircraft can suddenly become uncontrollable due to a failure of any component, including mechanical parts and electronics. In this case, the model can rapidly move towards any direction. Make sure you always keep a safe distance to people, animals, obstacles or things of any kind, traffic roads, etc.. There are country-specific laws regulating the operation of model aircrafts for non-commercial and also for commercial applications that definitely have to be obeyed. Furthermore, we strongly recommend to effect a liability insurance for such an aircraft in your application. Ascending Technologies does not have any influence on, nor can they monitor the correct final assembly and proper operation of your aircraft. Always be aware of the dangers mentioned above and act accordingly. There is no liability of the manufacturer nor the retailer at all, as far as legally approved.

Our products are designed for the civil market only.

It is strictly forbidden to use them in any military environment or to retail them to any military or military related organization. Using any of our components for larger scale flying objects is also not allowed.

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1.1 System overview

In this section you find some information about the subsystems used in the AscTec Hummingbird w/ AutoPilot.

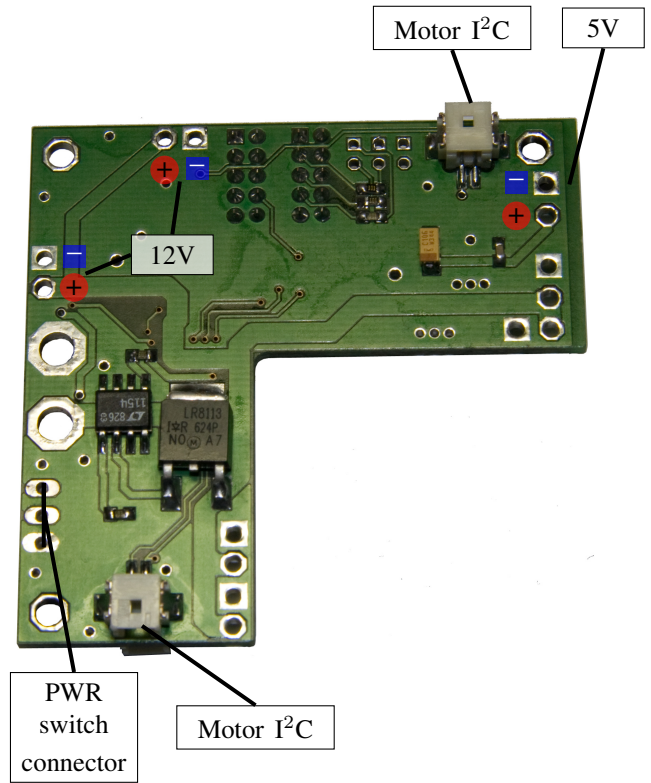
1.1.1 X-CSM

The X-CSM is the mechanical frame of the AscTec Hummingbird. The booms, which are made of a rigid carbon fiber-balsa wood sandwich material, can be replaced individually. The central unit of the frame called the "X-CSM Core" is made of light weight laser-cut magnesium parts. Being built out of these state-of-the-art materials the X-CSM is a very robust high-tech basis for your quadrotor aircraft.

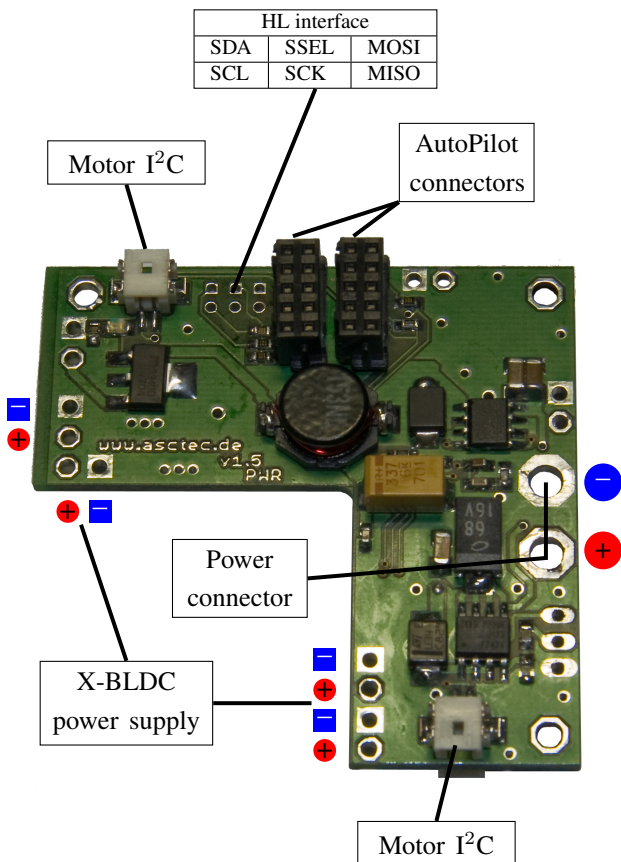


1.1.2 AscTec Hummingbird PowerBoard

The PowerBoard is used to distribute power and communication lines to all motor controllers. It comprises a switching power regulator to generate a stable 6V supply for the AscTec AutoPilot board, a high-power MosFET to switch the motor current ON and OFF and a 5V regulator to supply any custom payloads like e.g. a 2.4 GHz wireless video camera. There are also some soldering pads where extension boards can be connected to an SPI or I2C bus of the AscTec AutoPilot's high level processor. The ON-OFF switch is designed active low, so if for some reason the mechanical switch breaks or loses connection the vehicle is switched ON by default.



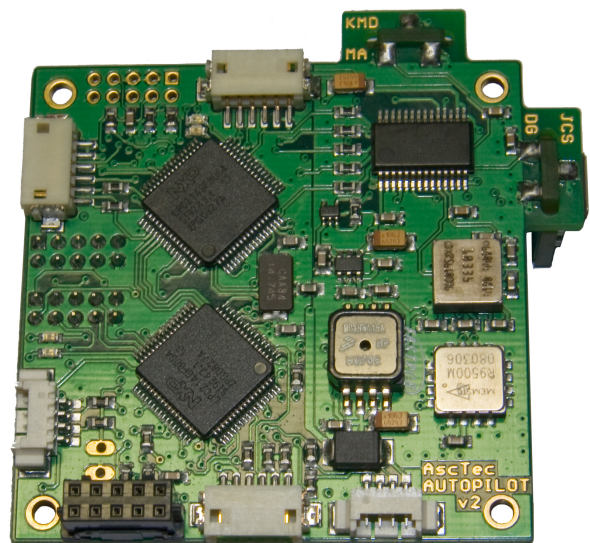
bottom side



top side

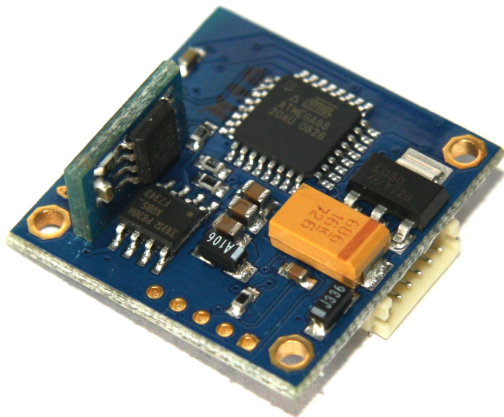
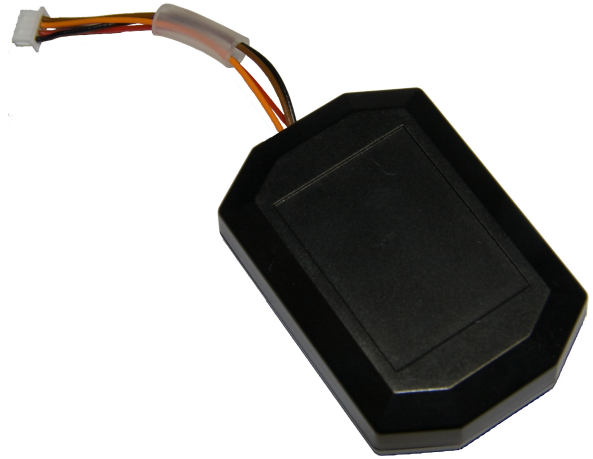
1.1.3 AscTec AutoPilot

The AscTec AutoPilot is the sensing and flight control unit of your Hummingbird.



1.1.4 AscTec 3D-MAG

The AscTec 3D-MAG is a triple-axial compass module used to determine the vehicles heading by measuring the Earth's magnetic field. The AscTec AutoPilot mathematically transforms the measured vector into the horizontal plane and can thus determine the correct heading even if the vehicle is tilted in pitch or roll. The 3D-MAG is a high resolution instrument, which is required as the Earth's magnetic field is relatively weak. Please be aware that adding payloads close to the compass, especially radio modules like a video transmitter or an antenna could severely interfere with the measurements and reduce GPS hovering performance. If you are experiencing difficulties and do not find a way to solve it please contact us for assistance.



1.1.5 GPS unit

The GPS unit is mounted on top of the X-CSM Core. Please make sure you do not add any payload which could comprise a free view of the sky.

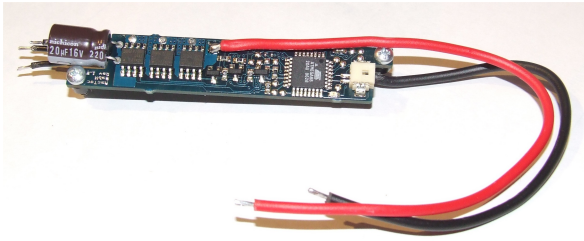
1.1.6 Motors

The X-BL-52s motors by HACKER Motors Germany are custom-built for the AscTec Hummingbird. The motors are perfectly suited for the application in this vehicle.



1.1.7 X-BLDC brushless motor controllers

Every motor is controlled by an independent X-BLDC brushless motor controller. The controllers are highly optimized for the X-BL-52s motors and thus ensure the highest efficiency possible. Please note that for this reason the controllers might not work with a different motor type.



1.1.8 Propellers

The AscTec Hummingbird's standard propellers are made of flexible PP-plastics. Their low mass and high flexibility make the vehicle one of the safest R/C quadrotor there is. This is especially convenient when conduction indoor experiments. However, please make sure you always keep a safe distance to people and follow the safety instructions above.

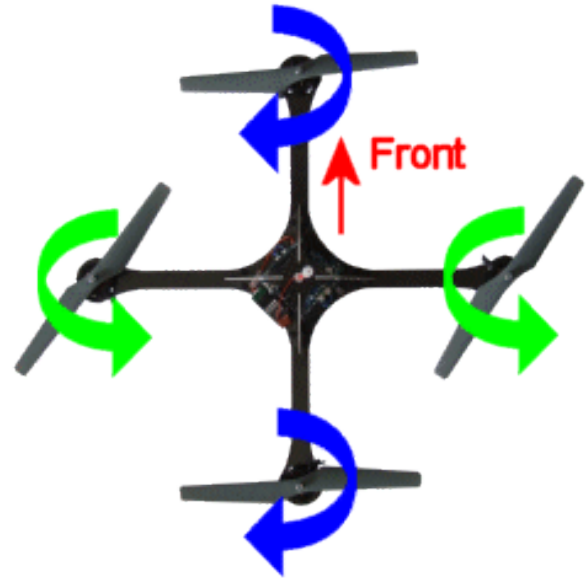
1.2 Transmitter

Any 6 or more channels R/C transmitter can be used to operate the AscTec Hummingbird w/ AutoPilot. Even if it is controlled autonomously using e.g. a PC-Software and a wireless data link, the transmitter is required as a backup. As a safety measure the AscTec AutoPilot is by default not able to launch without a valid signal from the R/C transmitter.



2 Things to do before the first flight

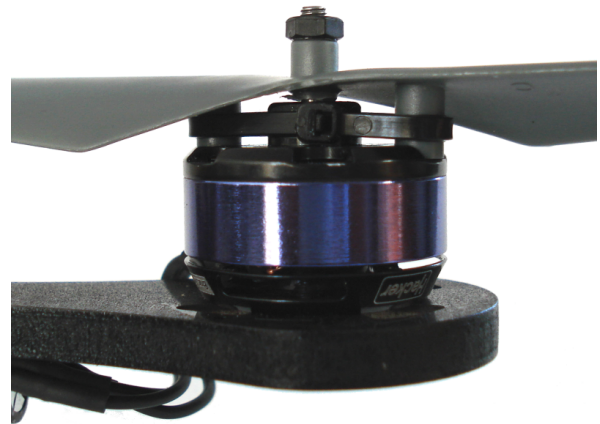
The AscTec Hummingbird w/ AutoPilot comes completely assembled and tested. You only have to do the following steps to make it work in combination with your equipment.



2.1 Mounting the propellers

The propellers can be slid over the axles and be fastened using a plastic nut. Do not fasten the nut too tight, as this would bend the propellers.

To improve the durability of the propellers during a crash you can optionally add a cable tie (e.g. 2.5 x 100 mm) as seen in the following picture.



Please note that there are two types of propellers: One pair of propellers is spinning clockwise, the other pair is spinning counterclockwise. The propellers spinning clockwise must be mounted to the front and the rear motor, whereas the counterclockwise rotating propellers must be mounted to the left and to the right motor.

2.2 Preparing your own battery

You need a 3s (three cells, 11.1V) Lithium Polymer (LiPo) Battery to operate the AscTec Hummingbird. We recommend capacities between 1500 and 2100

mAh. With a state-of-the-art 2100 mAh battery the vehicle is able to hover up to 20 minutes without any payload, and up to 12 minutes with 200 g of payload.

Make sure you prepare your battery such that it can definitely not get damaged by hitting the frame, even in a crash. Otherwise the battery could explode! Here is an example of how to mount a battery correctly:



The black foam on both sides prevents it from being hurt by the magnesium parts of the frame. Configured like this the battery slides into the battery slot of the vehicle and holds inside by friction. Of course, there are also other ways to prepare your battery for a safe operation. This is only an example.

Lithium Polymer Batteries (LiPo) can be very dangerous if not handled correctly. Please read and follow the instructions of the battery and charger manufacturers! Do never short circuit a LiPo battery and use safe connectors!

2.3 Teach-in of your transmitter

If you want to use your own transmitter, which you did not purchase bundled with your AscTec Hummingbird, please follow these steps:

Connect the USB module of your wireless data link (XBee 2.4GHz or Radiotronics 868/900

MHz) or the AscTec USB-to-cable adapter to your Windows PC. If your system requires a driver for the USB chip, please download it here: <http://www.ftdichip.com/Drivers/VCP.htm>. The USB module will then be recognized as a COMport and appear in the Windows device manager.

Turn on the vehicle and start the „AscTec AutoPilot Control“ software e-mailed to you after your purchase by an Ascending Technologies representative. If you are using the USB-to-cable adapter you need to connect it to „LL serial 0“ on the AutoPilot PCB. Click on „Setup“ in the top left corner of the software and select the right comport. Baudrate is „57600“ and Flowcontrol is „None“. Then Click on „Connect“ and on „Enable Data Polling“. The red dot next to „UART Comm“ on the right hand side of the form should turn green. If not, please check your connections and connection settings.

In the „Tools“-menu select „Flight Parameters“ and on that form click on „R/C Setup Wizard“. Click on „Start Wizard“ and follow the instructions given by the program. Please note that you need six channels to control the AutoPilot vehicle: four channels for pitch, roll, yaw and throttle (all four channels should be sticks on the R/C), one channel to enable and disable the serial data interface (two or three position switch) and one channel to switch between manual mode, height controlled mode and GPS + height controlled mode (three position switch). If you have never flown a model aircraft before we would recommend the following setup for the first four channels:



Once the R/C setup wizard says „Calibration data collected“ go back to the „Flight Parameters“ form and click on „Transmit Values“. The form should briefly turn yellow (while transmitting data) and then back to grey if the data was transmitted correctly. If it doesn't turn grey again click „Transmit Values“ again. After that, click „Write to FLASH“ to permanently store the new set of parameters in the vehicle's FLASH-memory.

Now, go back to the main form. In the field „RC Data“ you should now see the values coming from your R/C. With all sticks and switches centered the values should be around 2048. Please verify if your stick inputs are according to the following table:

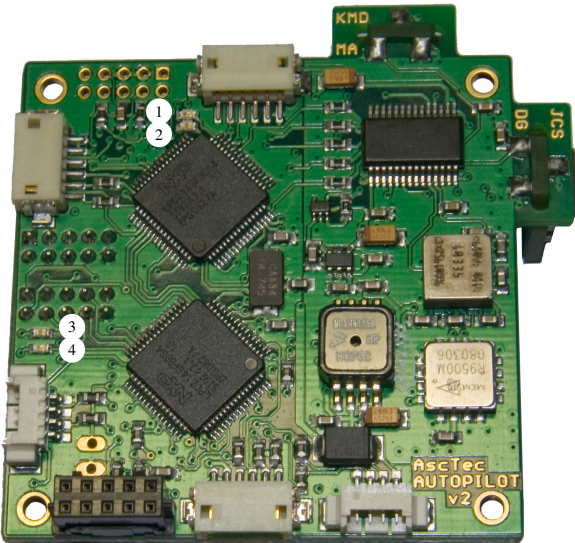
Command	Value
Pitch forward	4095
Pitch backward	0
Roll left	4095
Roll right	0
Yaw left	4095
Yaw right	0
Full throttle	4095
Minimum throttle	0

The correct function of the two switches can be verified by looking at the „Flight Mode“ field on the bottom of the form.

3 Operating the AscTec Hummingbird with AutoPilot

3.1 Status LEDs

There are four status LEDs on the AutoPilot board.



- **LED 1 (red)** is on as long the sensors are being initialized. Do not move the vehicle until this LED is off and LED 2 starts flashing.
- **LED 2 (green)** is the main-processor status LED. During normal operation this LED is blinking rapidly, indicating that the flight control software is running.
- **LED 3 (green)** is the GPS hardware OK indicator. It is blinking at 2.5 Hz during normal operation.
- **LED 4 (red)** is the GPS status indicator. If it is flashing, there is no valid GPS lock.

3.2 Acoustic signals given by the AscTec AutoPilot

- **Battery low warning:** A loud tone will appear if the battery voltage drops under 9.8 Volts.

The interval is getting faster the lower the battery voltage gets. At 9 volts (critical limit!) the tone stays steady. Please land the vehicle soon after the tone appears, as the LiPo battery might get damaged if it is discharged under 9V.

3.3 Important things to keep in mind

- Directly after turning the AscTec Hummingbird w/ AutoPilot on both the motors and the piezo speaker produce a short beep. It is perfectly normal that the propellers move slightly during that tone.
- Do not move the AscTec Hummingbird after turning it on until LED 2 of the AutoPilot starts blinking. Otherwise, the sensors can not be calibrated correctly and the vehicle might go crazy after turning on the motors. If you accidentally moved the system during startup simply turn it off and on again.
- After the startup phase the motors are still turned off and secured. To turn them on you have to move the yaw stick to the very left or to the very right while your throttle stick is in zero position. The motors will then start and keep running at their minimum speed. To turn the motors off you have to do the same procedure again: Move the yaw stick to the very left or to the very right while your throttle stick is in zero position. There is no flight maneuver where one would use this control input and thus you will not accidentally turn off your motors during flight. For safety reasons you should turn off the motors immediately if one of the propellers touches the ground or any other obstacle and hence the vehicle is not able to take off.

- Do not ignore the battery warning giving by the AutoPilot (acoustic signal as described above). Discharging the battery deeper than 9V could drastically reduce its lifetime.
- All sensors on the AutoPilot are compensated for temperature drift effects. However, if the ambient temperature changes too rapidly, for instance when you fly from a warm room to a cold outdoor environment, the angles estimated by the datafusion algorithms might not be totally correct. As a consequence, your vehicle would be tilted a bit, even with a neutral pitch and roll command. In this case we recommend to wait a few minutes, until all sensors have adapted to the ambient temperature.

until you are able to fly in tight spots.

Make sure that the battery is fully charged, connected and mounted correctly. Switch on the vehicle and be *really* careful during the startup phase. The vehicle must NOT be moved during startup as the gyro sensors are being initialized! If the vehicle was moved during startup simply turn it off and on again. The startup sequence is completed once LED 2 is blinking. Now the vehicle is ready to fly.

Before starting the motors make sure that the three-position switch on your R/C controlling channel 6 (GPS and height control OFF – height control enabled – GPS and height control enabled) is in OFF position.

3.4 Learning to fly

3.4.1 General hints

It is important that you learn to fly the vehicle manually before using the autonomous functions, i.e. you need to be able to fly without height control and position control by air pressure and GPS. Good GPS reception can never be guaranteed - consequently you must be able to take control manually at any time during flight. In most countries even by law a safety pilot must always be within visual range to an air vehicle as the AscTec Hummingbird and must be able to control it at any time. Due to the onboard sensors and the sophisticated flight control algorithms even in manual mode the vehicle is much easier to control than most other R/C aircrafts and therefore operating the vehicle is comparatively easy to learn.

3.4.2 First flights

We recommend to do the first flights on some big grassland, as the soft ground will soften possible emergency landings. If you have never controlled an R/C aircraft before you will have to practice a bit

To start the motors you have to move the yaw stick to the very left or right whilst holding throttle in zero position.

If it is the first flight after a while or the first flight at all hold your AscTec Hummingbird down to the ground. You can grab the center part of the frame, but make sure that you don't touch any of the rotors.

In case the vehicle tries to tilt in any direction and one or more of the propellers are going crazy: Turn the motors off immediately (same stick command as used for turning the motors on)! Then, switch the vehicle off and on again and try again. If the problem still occurs please read the troubleshooting section of this manual.

Angle stabilization in pitch and roll is active even when the propellers are running idle. Use this feature as you hold the vehicle from below and tilt it carefully to check that everything works. As you tilt it to one direction you must feel some counterforce from the motors if everything is o.k.. You can also try to steer the pitch and roll axis and see that you can directly steer the angles. Please check if the vehicle is leveled in your hand with the pitch and roll stick in neutral position. If not, correct any undesired tilt with the pitch and roll trimmers.

Before the first take-off make sure that the red mark

(front!) is pointing away from you, as in this case the vehicle will move forward if you push your pitch stick forward. Now, give a little throttle and the vehicle should lift off. In manual mode, the throttle stick on your remote directly controls the average thrust of the rotors, the pitch/roll stick sets a desired angle in these axes. Try hovering in a height of about 1m and concentrate on the red marking which is the front of your vehicle. It is perfectly normal that the vehicle drifts slowly in all directions without GPS control enabled. Try to compensate for these movements using the pitch/roll stick and try to hold the height of about 1m by gently moving the throttle stick up and down. After a while you will be able to keep the vehicle hovering in one place. After a few battery charges you will be able to fly in any room, and with some more practice you can even fly in small spaces and land on tables etc.. Good luck!

3.4.3 Enabling height control

Once you feel comfortable controlling the vehicle manually put the GPS/height control switch in center position ("height control enabled"). Now, the vehicle tries to hold its current height as long as the throttle stick is centered. Moving the stick up and down commands an ascending/descending rate. It is recommended to use the height control mode only outdoors. Please make sure you fly high enough above the ground (at least at eye level) when using the height control mode as turbulences or gusts might cause rapid changes in air pressure which might make the vehicle move up and down a bit without any command. As long as the vehicle is standing on the ground make sure you hold the throttle stick down (not in neutral position!) to keep the motors idle. When taking off from the ground in height control mode please make sure you push the throttle stick all the way up until the vehicle is at a safe height (at least eye level).

3.4.4 Flying in GPS mode

GPS operation in general

Flying the vehicle in GPS mode is very easy as long as GPS reception is good. However, as perfect GPS reception can never be guaranteed, the pilot *must* be able to control the vehicle manually in every situation. GPS mode is enabled by putting the GPS/height control switch on the R/C in GPS position. If the vehicle appears to become unstable in GPS mode or seems to not react to user commands you need to push the GPS/height control switch to manual mode immediately to take over control. As I pilot you are responsible to control your vehicle in a safe way, even if an electronic assistance like GPS control fails.

Please note that in GPS mode height control is always enabled, too.

It is perfectly normal that the vehicle is not absolutely stationary when hovering in GPS mode without any control command. The GPS position measurements are supported by the inertial sensors on-board, which makes the position estimate much more reliable than what can be expected from a standard GPS receiver. However, the inertial sensors can compensate for short-term effects like a jump in the GPS position when a new satellite comes in view, but they cannot compensate for long-term drift or position errors.

How to determine whether the GPS fix is valid

In all firmware versions LED 4 („GPS status indicator“) is flashing to warn the pilot, if there is no valid GPS fix. It stays off if the GPS signal is OK. There is a special firmware for the HighLevel-processor giving an acoustic warning if the GPS signal is bad. This firmware is usually not installed on the AscTec Hummingbird with AutoPilot, as this vehicle is often used for indoor research. Please note that the GPS controller is automatically disabled if there is no valid GPS fix. In this case, the vehicle reacts as if the GPS/height control switch was in center position (height control

enabled), even with the switch in GPS mode.

Hand control in GPS mode

When in GPS mode, the yaw and throttle/height control stick on the R/C still has the same function as in height control mode. The pitch and roll stick still controls the same axes, but the vehicle behaves different as in manual mode. When flying in GPS mode the vehicle always is in a speed controlled state. This means, no matter how far you push the pitch/roll stick, the vehicle will not travel faster than defined in its control parameters. In windy conditions it will travel at almost the same speed going up-wind and going down-wind. The moment you push the stick from center to any direction the vehicle will change its tilt in that direction rapidly to accelerate until it has reached the desired speed. Then it will tilt back to an angle at which it travels at the desired speed in the current wind conditions. The further you push the stick, the faster the vehicle goes. If you put the stick back to center the vehicle will stop at its current position. With the standard parameter set the vehicle will not move faster than about 2 meters per second in hand controlled GPS mode.

In GPS mode it is possible and also recommended to control one function of the vehicle at a time, e.g. first fly to a desired height, then move to a desired position, then turn the heading to a desired orientation.

Starting and landing in GPS mode

It is possible to launch the vehicle directly in GPS mode, but it has to be done with care as the vehicle might move a bit into any direction during the launch. If you do want to launch directly in GPS mode make sure that there is enough free space surrounding the vehicle and that persons are standing at least 10m away from it. After turning on the motors make sure you hold the throttle stick down (not in neutral position!) to keep the motors idle. When you are ready, you should start immediately by pushing the throttle stick all the way up until the vehicle hovers in a safe

height, at least at eye level. For the landing you also need to make sure that there is enough free space surrounding the vehicle, as especially close to the ground the GPS position might drift quite a bit due to signal reflections. For starting and landing in tight spots it is recommended to launch and land the vehicle in manual mode and switch to GPS mode once it is in a safe height.

Waypoint navigation

The vehicle only accepts waypoint commands by a PC or an external control computer mounted to it (e.g. a GumStix processor board) when the switch on the R/C is in GPS position. Any stick input on the R/C will override a waypoint command. For safety reasons it is absolutely necessary that there is always a safety pilot standing by with the R/C in his hands to take over control if something is not working as expected.

4 On-Board serial interface

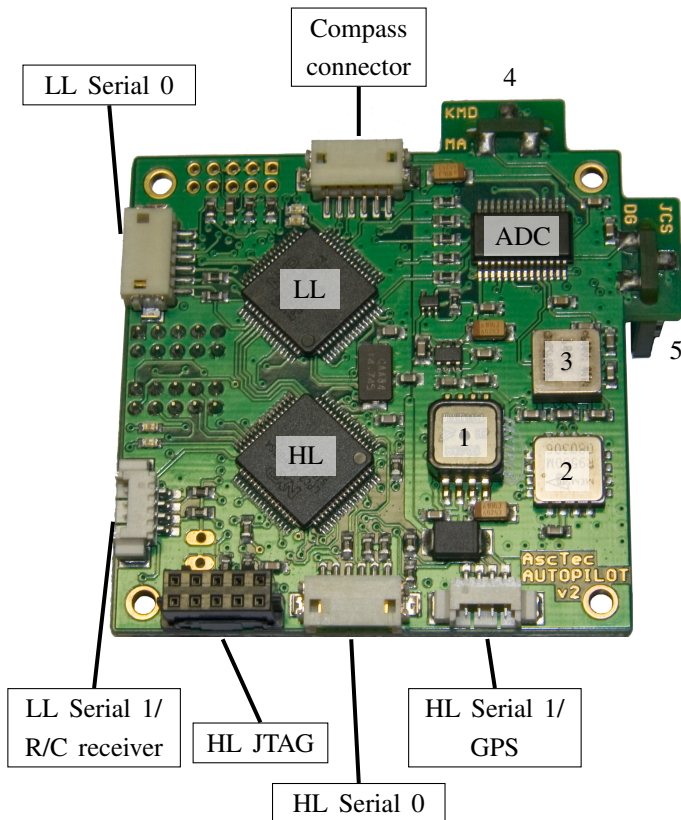
4.1 Physical interface

To communicate with the vehicle using the XBee link or USB cable adapter please connect to the correct virtual comport using the following connection settings:

Baudrate: 57600

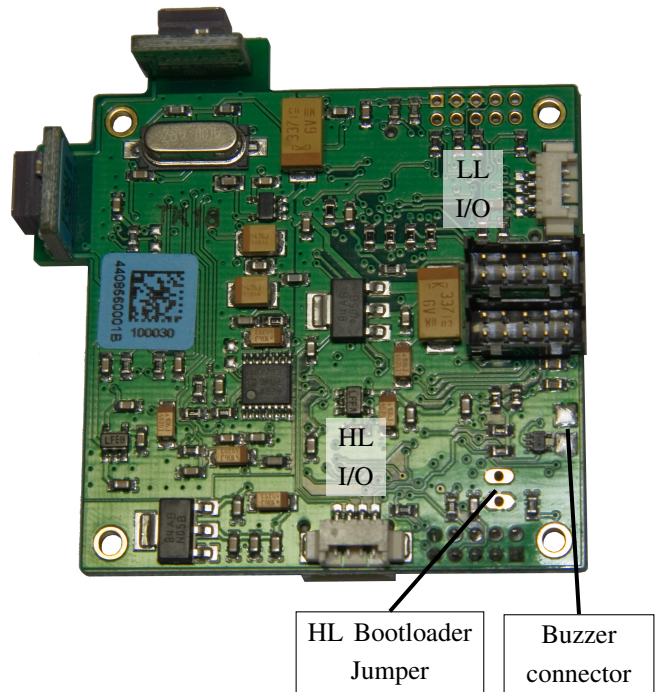
Flow control: "Hardware" for XBee, "None" for USB cable adapter

Databits: 8, 1 startbit, 1 stopbit, no parity



- | | |
|------------------------|--------------|
| 1: pressure sensor | 3: yaw gyro |
| 2: acceleration sensor | 4: nick gyro |
| | 5: roll gyro |

LL/HL Serial 0 (Pin 1..6):
TXD, RXD, CTS (Input), +3.3V, +6V, GND
Max. current: 300 mA!



4.2 Data protocol

4.2.1 Data output

Data structures

LL_STATUS: Status information of the low level processor

IMU_RAWDATA: Sensor raw-values

IMU_CALCDATA: Calibrated sensor outputs and data fusion results

CTRL_INTERNALOUT: Controller internals and outputs before output mapping

CTRL_OUT: Controller outputs after output mapping

RC_Data: Data received by the R/C receiver

GPS_Data: GPS data

GPS.Data.Advanced: GPS data + position and speed estimates after data fusion

The data structures in detail are shown in Appendix C.

There is a unique packet descriptor/ID for every structure. Here is a list of all packet descriptors used in the system:

```
//packet descriptors
#define PD_IMURAWDATA      0x01
#define PD_LLSTATUS       0x02
#define PD_IMUCALCDATA    0x03
#define PD_HLSTATUS       0x04
#define PD_DEBUGDATA      0x05

#define PD_CTRLOUT        0x11
#define PD_FLIGHTPARAMS  0x12
#define PD_CTRLCOMMANDS  0x13
#define PD_CTRLINTERNAL   0x14
#define PD_RCDATA        0x15
#define PD_CTRLSTATUS    0x16
#define PD_CTRLINPUT     0x17
#define PD_CTRLFALCON    0x18

#define PD_WAYPOINT       0x20
#define PD_CURRENTWAY     0x21
#define PD_NMEADATA      0x22
#define PD_GPSDATA       0x23
#define PD_SINGLEWAYPOINT 0x24
#define PD_GOTOCOMMAND   0x25
#define PD_LAUNCHCOMMAND 0x26
#define PD_LANDCOMMAND   0x27
#define PD_HOMECOMMAND   0x28
#define PD_GPSDATAADVANCED 0x29
```

All structures are sent as follows:

```
startstring:      >*>
length of structure: unsigned short
packet descriptor: unsigned char
the actual data structure: "length of structure" bytes
crc16:           unsigned short
stopstring:      <#<
```

CRC16 algorithm

```
unsigned short crc_update (unsigned \
    ->short crc, unsigned char data)
{
```

```
data ^= (crc & 0xff);
data ^= data << 4;

return (((unsigned short) data << \
    ->8) | ((crc>>8)&0xff)) ^ (unsigned\
    ->char) (data >> 4) ^ ((unsigned \
    ->short) data << 3));
}
```

```
unsigned short crc16(void* data, \
    ->unsigned short cnt)
{
    unsigned short crc=0xff;
    unsigned char * ptr=(unsigned char \
    ->*) data;
    int i;

    for (i=0;i<cnt;i++)
    {
        crc=crc_update(crc,*ptr);
        ptr++;
    }
    return crc;
}
```

example use:

```
unsigned short checksum=crc16(&\
    ->IMU_CalcData, sizeof(IMU_CalcData))\
    ->;
```

Requesting (polling) data structures

The user can select the desired data structures by sending the following string to the vehicle.

```
>*>p[unsigned short packets]
```

The following bits set in "packets" request a data structure:

- 0x0001 LL_Status
- 0x0002 IMU_RawData
- 0x0004 IMU_CalcData
- 0x0008 RC_Data
- 0x0010 CTRL_Out
- 0x0080 GPS_Data
- 0x0100 current_way
- 0x0200 GPS_Data_Advanced
- 0x0800 CAM_Data

Please note that you can set as many bits at a time as required in your application. The vehicle will then

transmit all structures that were requested and wait for the next poll. Due to the limited bandwidth of almost all kinds of radio modems it is recommended that you only request (poll) the packets you need, e.g. if you are only interested in the computed pitch and roll angles you should only poll IMU_CalcData and none of the other packets.

4.2.2 Command input

Operation

The serial command interface must be enabled by the switch on channel 5 of your 35 MHz or 72 MHz R/C. Please use the AscTec AutoPilot PC-Software to see which position of the switch enables the serial interface.

During operation through the serial command interface the R/C has to stay on all the time to enable a safety pilot to take over if the autonomous control is not working as desired. Please make sure that there is always a safety pilot ready to immediately disable the serial interface and to take manual control of the vehicle.

Data protocol

The current control dataset must be available in the following format:

```
struct CTRL_INPUT { //serial commands\  
→ (= Scientific Interface)  
    short pitch; //Pitch input: \  
        →-2047..+2047 (0=neutral)  
    short roll; //Roll input: \  
        →-2047..+2047 (0=neutral)  
    short yaw; // (=R/C Stick input) \  
        →-2047..+2047 (0=neutral)  
    short thrust; //Collective: 0..4095\  
        → = 0..100%  
    short ctrl; /*control byte:  
        bit 0: pitch control enabled  
        bit 1: roll control enabled  
        bit 2: yaw control enabled  
        bit 3: thrust control enabled
```

```
These bits can be used to only \  
→enable one axis at a time and\  
→ thus to control the other \  
→axes manually. This usually \  
→helps a lot to set up and \  
→finetune controllers for each\  
→ axis seperately. */
```

```
    short chksum;  
};  
struct CTRL_INPUT CTRL_Input;
```

The chksum is calculated as follows right before the structure is sent:

```
CTRL_Input.chksum = CTRL_Input.pitch \  
→+ CTRL_Input.roll + CTRL_Input.yaw \  
→+ CTRL_Input.thrust + CTRL_Input.\  
→ctrl + 0xAAAA;
```

The data should be sent to the vehicle with a minimum rate of 10 Hz over the XBee link as follows:

1. startstring: >*>di
2. directly followed by the above data structure, e.g.

```
UART_send( &CTRL_Input, sizeof(\  
→CTRL_Input));
```

If data is sent with significantly less than 10 Hz or if the transmission stops completely the system will switch back to manual control over the R/C.

4.3 System calibration

The AscTec Hummingbird with AutoPilot comes fully calibrated. Calibration usually lasts for the whole lifetime of the vehicle. If you feel something is wrong with the calibration of your system please contact Ascending Technologies for assistance.

5 Contact Information

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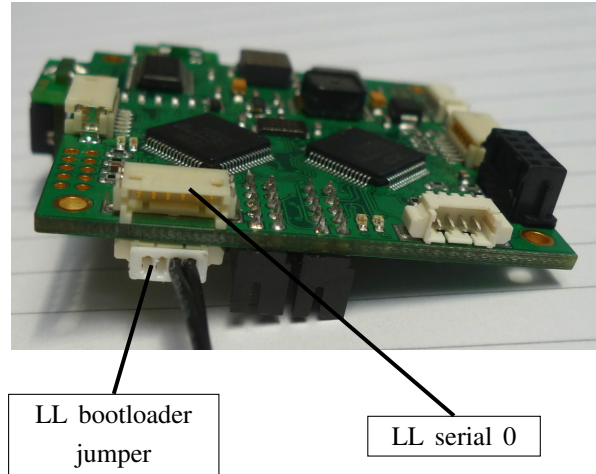
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A Installing firmware upgrades

A.1 Updating firmware on the LowLevel(LL)-processor

The LL-processor is the heart of the vehicle running all critical functions as sensing and filtering, attitude estimation and flight control. The code on this processor is protected and cannot be accessed using a JTAG interface nor be read through the serial interface. Software running on the LL-processor can only be changed by Ascending Technologies.



A.1.1 Tools required for the update

You will need the following items and software tools to perform a firmware upgrade on the LL-processor:

- Ascending Technologies Bootloader PC-Software
- AscTec USB-adapter with four wires and a grey 6-pin connector
- Bootloader Jumper cable or small screw driver or pincers
- New firmware file provided by Ascending Technologies (*.atp)

A.1.2 Uploading firmware to the LL-processor

The following photograph shows the connectors involved in the LL update process.

Please follow these steps to upload new code to the LL-processor:

- Connect the USB-adapter to your computer (install the FTDI virtual comport driver if this wasn't done before), then connect the USB-adapter to the „LL-serial 0“ connector of the AutoPilot.
- Turn on the vehicle while shorting (connecting) the LL-bootloader activation pins using a jumper or if not available using pincers (the two black cables in the above photograph are connecting the LL-bootloader activation pins). The green and the red LED on the right hand side of the AutoPilot board must be solid now. If not, there was no connection between the bootloader activation pins during start-up. Please make sure your pincers are conductive and try again.
- Start „AutoPilotUpdater.exe“, select the COM-port assigned to the USB-adapter, click on „Connect“ and select the new firmware file (*.atp).
- Click on „Start programming“.
- When programming is finished turn off the vehicle, disconnect the USB-adapter from the AutoPilot and turn the vehicle back on. Now, the

green status LED should be flashing again, signaling that the new code is running.

A.2 Updating firmware on the HighLevel(HL)-processor

In its factory programmed state the HL-processor is only used to monitor the battery voltage and to parse and forward GPS data. Plenty of computing power is left for user applications. Using the software development kit (SDK) provided by Ascending Technologies users can write their own code and upload it to the HL-processor. Please note that the firmware versions of HL and LL-processor have to be compatible. Therefore, if you purchased your vehicle a while ago and you want to upload new firmware generated with the newest SDK code base please contact us for an updated LL-processor firmware.

The HL-processor is not code-protected and consequently read- and writeable by the user. This can be done using NXPs official tools to program an LPC2146 ARM processor.

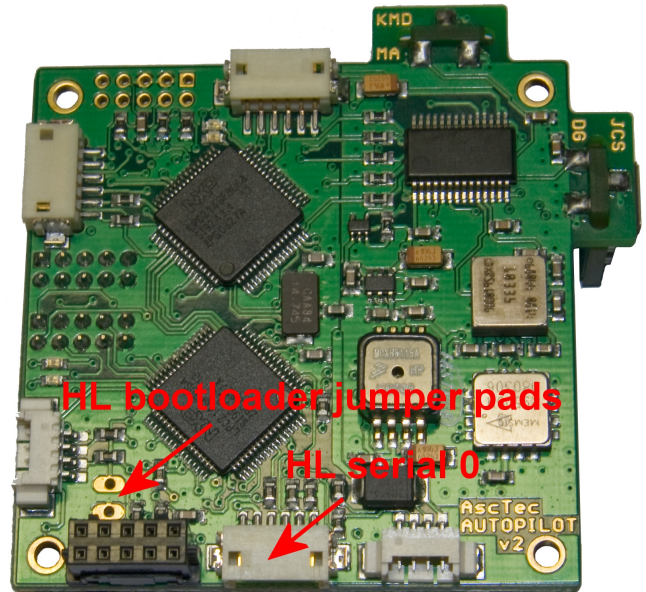
A.2.1 Tools required for the update

You will need the following items and software tools to perform a firmware upgrade on the LL-processor:

- LPC2146 flash tool, as for instance „FlashMagic“ (free software, available at www.flashmagictool.com)
- AscTec USB-adapter with four wires and a grey 6-pin connector
- Bootloader Jumper or pincers
- New firmware file, either provided by Ascending Technologies or generated by the SDK(*.hex)

A.2.2 Uploading firmware to the HL-processor

The following photograph shows the connectors involved in the update process.



Please follow these steps to upload new code to the HL-processor:

- Connect the USB-adapter to your computer (install the FTDI virtual comport driver if this wasn't done before), then connect the USB-adapter to the „HL-serial 0“ connector of the AutoPilot.
- Turn on the vehicle while holding the HL-bootloader jumper pads connected using pincers (or a jumper if installed). The two LEDs signaling the GPS state (next to the jumper pads) will stay off and the battery warning buzzer will make a loud noise. If not, there was no connection between the pads during start-up. Please make sure your pincers are conductive and try again. You may put some tape on the front of the buzzer to cancel the noise - it won't vanish before the update is done and the vehicle is reset.
- Start „Flash Magic“, select the COM-port assigned to the USB-adapter and set the other parameters to Baudrate 115200, Device LPC2146, Interface None(ISP), Oscillator 14.7456 MHz.
- Check „Erase all Flash and Code Rd Prot“, select the new firmware file (*.hex), uncheck all options under Step 4 and click on start programming.
- When programming is finished turn off the vehicle, disconnect the USB-adapter from the AutoPilot and turn the vehicle back on. Now, the

GPS status LEDs should be flashing again, signaling that the new code is running.

B Troubleshooting

This chapter holds solutions to problems which might occur during the operation of your AscTec Hummingbird w/AutoPilot.

B.1 Slight tilt in pitch/roll with the pitch/roll stick in neutral position

Due to unavoidable measurement errors or the unbalance of mechanical parts it is perfectly normal that the AscTec Hummingbird w/ Autopilot is not always 100% levelled during flight with the control sticks in neutral position. A slight tilt can easily be compensated by the trimmers on your remote control.

B.2 Considerable tilt in pitch or roll

There are some situations where the measured angle can considerably differ from the real angle, which results in big tilt-angles in pitch and/or roll while the pitch/roll stick on your remote is centered. This can have the following reasons:

- *Teach-in of your transmitter was not correct:* To check if your transmitter was taught-in correctly, please refer to section ??.
- *Rapid change of the ambient temperature or operation under extreme temperature conditions:* Temperature compensation is applied to all sensors of the AscTec AutoPilot. We have not encountered any problems with temperature yet. However, in theory it is possible that you might get drift effects and therefore unwanted tilt in pitch or roll if you for instance fly directly from a warm room into a very cold outdoor environment. If this happens, please turn the vehicle off, let the electronics adopt to the ambient temperature and try again.
- *Extremely fast maneuvers:* Fast maneuvers, which result in high accelerations interacting with your aircraft, can cause faulty measurements. If you fly several circles in a row in high speeds it can happen, that the measured angle differs several degrees from the real angle. If this is the case, you simply have to fly gently or hover for a few seconds until the unwanted tilt is gone, as the data fusion system usually is able to recover very quick.
- *Flying on a circular path in always the same direction for a longer period of time:* The centripetal force affecting your vehicle when flying on a circular path prevents the sensors from measuring the earth's gravity vector. In this case, the other sensors on-board the vehicle are used by the on-board software to estimate the real tilt of the vehicle. This works for quite a long time, but at some point the errors may become significant. Therefore it is recommended that after flying a full circle in one direction the pilot should fly straight for a couple of seconds or a circular path in the other direction. If you experience such a problem simply keep the vehicle hovering until
- *Shaking during initialization:* It is very important that the vehicle is not moved at all during the initialization phase. Calibration errors caused by shaking during startup can affect the system performance in many ways. If the vehicle tilts more and more after starting the motors it is very likely that it was moved during the initialization. In this case, please turn it off and on again and make sure that it is not moved until the AutoPilot displays the Ready to flyLED-pattern (LED 1 (red) off, LED 2 (green) blinking).

the unwanted tilt is gone.

- *Faulty calibration of the accelerometers:* If none of the reasons above apply the problem might be due to a bad system calibration. In this case please contact AscTec for assistance.

B.3 Bad reception during flight

If the vehicle does not react while it is airborne, please check if someone else uses the same channel. Make sure your TX battery is fully charged and that the antenna is fully extended.

C Data structures to be polled for information

```
struct LL_STATUS
{
    //battery voltages in mV
    short battery_voltage_1;
    short battery_voltage_2;

    //don't care
    short status;

    //Controller cycles per second (should be ~1000)
    short cpu_load;

    //don't care
    char compass_enabled;
    char chksum_error;
    char flying;
    char motors_on;
    short flightMode;

    //Time motors are turning
    short up_time;
};

struct IMU_RAWDATA
{
    //pressure sensor 24-bit value, not scaled but bias free
    int pressure;

    //16-bit gyro readings; 32768 = 2.5V
    short gyro_x;
    short gyro_y;
    short gyro_z;

    //10-bit magnetic field sensor readings
    short mag_x;
    short mag_y;
    short mag_z;

    //16-bit accelerometer readings
    short acc_x;
    short acc_y;
    short acc_z;
};
```



```
//16-bit temperature measurement using yaw-gyro internal sensor
    unsigned short temp_gyro;

//16-bit temperature measurement using ADC internal sensor
    unsigned int temp_ADC;
};

struct IMU_CALCDATA
{
    //angles derived by integration of gyro_outputs, drift compensated by data \
    -fusion; -90000..+90000 pitch(nick) and roll, 0..360000 yaw; 1000 = 1 \
    -degree
    int angle_nick;
    int angle_roll;
    int angle_yaw;

    //angular velocities, raw values [16 bit] but bias free
    int angvel_nick;
    int angvel_roll;
    int angvel_yaw;

    //acc-sensor outputs, calibrated: -10000..+10000 = -1g..+1g
    short acc_x_calib;
    short acc_y_calib;
    short acc_z_calib;

    //horizontal / vertical accelerations: -10000..+10000 = -1g..+1g
    short acc_x;
    short acc_y;
    short acc_z;

    //reference angles derived by accelerations only: -90000..+90000; 1000 = 1 \
    -degree
    int acc_angle_nick;
    int acc_angle_roll;

    //total acceleration measured (10000 = 1g)
    int acc_absolute_value;

    //magnetic field sensors output, offset free and scaled; units not \
    -determined, as only the direction of the field vector is taken into \
    -account
    int Hx;
    int Hy;
    int Hz;

    //compass reading: angle reference for angle_yaw: 0..360000; 1000 = 1 degree
    int mag_heading;
};
```

```
//pseudo speed measurements: integrated accelerations, pulled towards zero; \
- units unknown; used for short-term position stabilization
int speed_x;
int speed_y;
int speed_z;

//height in mm (after data fusion)
int height;

//diff. height in mm/s (after data fusion)
int dheight;

//diff. height measured by the pressure sensor [mm/s]
int dheight_reference;

//height measured by the pressure sensor [mm]
int height_reference;
};

struct GPS_DATA
{
    //latitude/longitude in deg * 10^7
    int latitude;
    int longitude;

    //GPS height in mm
    int height;

    //speed in x (E/W) and y(N/S) in mm/s
    int speed_x;
    int speed_y;

    //GPS heading in deg * 1000
    int heading;

    //accuracy estimates in mm and mm/s
    unsigned int horizontal_accuracy;
    unsigned int vertical_accuracy;
    unsigned int speed_accuracy;

    //number of satellite vehicles used in NAV solution
    unsigned int numSV;

    // GPS status information; 0x03 = valid GPS fix
    int status;
};

struct GPS_DATA_ADVANCED
{
    //latitude/longitude in deg * 10^7
```

```
    int latitude;
    int longitude;

//GPS height in mm
    int height;

//speed in x (E/W) and y(N/S) in mm/s
    int speed_x;
    int speed_y;

//GPS heading in deg * 1000
    int heading;

//accuracy estimates in mm and mm/s
    unsigned int horizontal_accuracy;
    unsigned int vertical_accuracy;
    unsigned int speed_accuracy;

//number of satellite vehicles used in NAV solution
    unsigned int numSV;

//GPS status information; 0x03 = valid GPS fix
    int status;

//coordinates of current origin in deg * 10^7
    int latitude_best_estimate;
    int longitude_best_estimate;

//velocities in X (E/W) and Y (N/S) after data fusion
    int speed_x_best_estimate;
    int speed_y_best_estimate;
};

struct RC_DATA
{
    //channels as read from R/C receiver
    unsigned short channels_in[8];

    //channels bias free, remapped and scaled to 0..4095
    unsigned short channels_out[8];

    //Indicator for valid R/C reception
    unsigned char lock;
};

struct CONTROLLER_OUTPUT
{
    //attitude controller outputs; 0..200 = -100 ..+100%
    int nick;
    int roll;
};
```

```
int yaw;  
//current thrust (height controller output); 0..200 = 0..100%  
int thrust;  
};
```