



FLEXIPILOT

Weather conditions and IMU calibration

The document describes the influence of adverse weather conditions on typical autopilot and recalibration of the IMU module for optimal performance in low temperatures.

Humidity and rain

The IMU autopilot using inertial sensors and GPS receiver can return the plane home safely even in heavy rain: the limit is increased weight of the airplane and severely worsened wing lift efficiency.

The autopilot is capable of operating in 0%-90% humidity. However, you should avoid frost. While the FLEXIPILOT is naturally immune to fog, rain and clouds, it is against the laws in most countries to fly unmanned aircrafts without visual contact for the risk of collision with general aviation.

In the event you would inadvertently fly into the clouds, you can expect the lenses of your wireless video system to be quickly covered with fog. Therefore you should not rely on wireless link and visual control when there is a low cloud base.

The rain will also severely limit the operational range/quality of 2.4GHZ video transmission. Flying in the rain can significantly worsen your airplane gliding performance so it will never return to the landing site, and a strong wind updraft can occur below cloud level that cannot be overcome by the autopilot, as a result the plane would be pushed up into the cloud, trying to return to the takeoff site until the battery dies, most probably because of low temperature.

Flying during the rain poses serious hazard for the ground operator being struck by the lightning as he will be holding the RC transmitter with a long metal antenna in his hands during takeoff and landing.

Wind

In general, it is difficult to install a magnetometer on a small electric-powered plane in order to elongate it far enough from the power cables. Most small military UAV rely on high-speed flight. **It is a common advice from autopilot manufacturers to not allow the operation of the UAV if its flight speed is smaller than *twice* the wind speed.** This condition can be non-intuitive to evaluate, as the wind speed rises with altitude. **The real requirement for the UAV without magnetometer for navigation is to have positive groundspeed.**

From experience it can be assumed that GPS course is reliable with groundspeed over 10km/h. Because the autopilot uses full IMU enhanced course, it is ignoring the GPS course below those speeds, however the drift doesn't allow flying more than a minute in those conditions. Fortunately, as the error increases, at worst case the plane will fly momentarily sideways to the wind, increasing temporarily the groundspeed and providing the correct course update. As a result, flying against the strong wind manifests in persistent, long-term oscillations of the course, with UAV trying to acquire trustworthy GPS course every 10s.

Typical RC glider is expected to glide at around 40km/h, therefore maximum wind speed for loitering overhead are around 25km/h and require attentive supervision of the operator, always ready to take over the controls. The performance with 5-10km/h ground speed is marginal and is mostly used for entertainment and at low altitude (up to 100m).

Temperature

Electronic components and software

The autopilot performance is guaranteed in temperature range -20...60C. The main limitation is barometric pressure sensor precision, as all the electronics is compliant with industrial temperature range -40...85C (in particular this includes RC hardware override logic). All temperature sensors onboard are numerically capable of handling wide temperature range of -55...125C.

Battery

You have to include up to 40% more power battery capacity per flight compared to room temperature conditions. Please take into account that nominally, LiPo batteries are not guaranteed to operate correctly in negative temperatures (because their power rating and capacity are indeed 30% below nominal values in those conditions and some permanent damage worsening those parameters even further will occur). The batteries are heating themselves very well, it is sufficient to cover them in temperature insulating package.

Servos

The servos can freeze in negative temperature, in the sense that the internal electronics is usually not graded for negative temperature. As the servos will heat themselves as they are current receivers, it may be sufficient to cover them in temperature insulating package.

RC Receiver

As RC receiver is not guaranteed to operate correctly in negative temperatures and the air temperature diminishes about 5.5C per 1km or altitude gained, it is possible to use RXOVR-AUTO mode disabling completely the RC receiver above certain altitude. Refer to navigation programming guide for details. The RC receiver will of course remain powered, heating itself.

ESC motor controller

In exceptionally hot weather the ESC controller might cut off the motor, overriding the autopilot's action. The autopilot will be unable to detect the situation, therefore it is advised to plan the flights in such a way that the cruise altitude is obtained above the launch site. If the motor is cut off, the airplane will descend to RETHOME_MINAGL then head home. Refer to navigation manual for details.

IMU

Another factor to consider is that the IMU (Inertial Measurement Unit) responsible for determining plane orientation has been calibrated at room temperature. Using the IMU in the winter can result in a slight angular offset of the accelerometers. Basically the IMU angles are self-tuning and require no null point calibration, except for the accelerometers and yaw gyro drift. With the aid of the HyperTerminal or UAVStation, you can recalibrate your IMU without using any additional tools, bringing the IMU calibration into the temperature region you fly most.

You do not need to recalibrate the IMU for the lifetime of the product, however it may be beneficial for enhanced angular precision used for photo stitching.

Barometric pressure sensor

As the sensor is automatically calibrating after power-up, all you need to guarantee is sufficient time to cool down the whole autopilot to the ambient temperature, as even if the sensor will average the measurement, the temperature of the electronic might continue to drift for the following minutes introducing up to 40m offset.

Barometric sensor operational conditions

guaranteed operational range 300-1100hPa

(Standard Atmosphere formula relates this pressure range to altitudes: -726m...9142m)

11 coefficients temperature compensation

16bit resolution, 0.13m at sea level

calibrated for operational temperature range -10...+60[C]

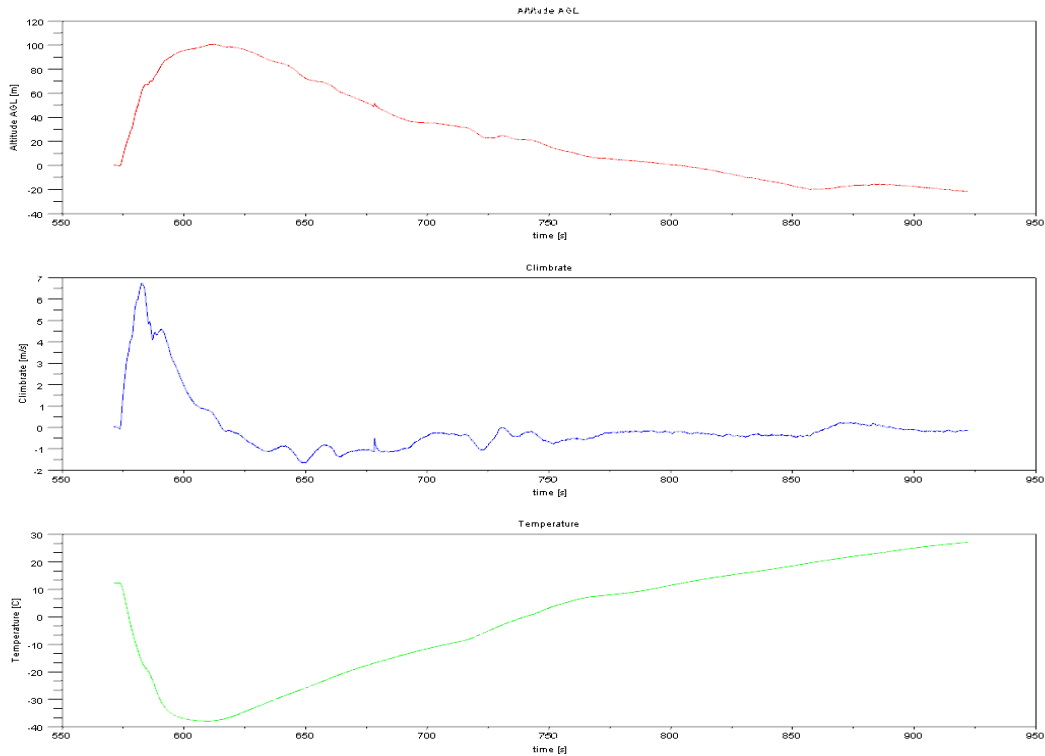
maximum error over temperature range 5hPa (40m difference at sea level)

relative pressure accuracy +/-2hPa (16m difference at sea level)

absolute pressure accuracy +/-3hPa (24m difference at sea level)

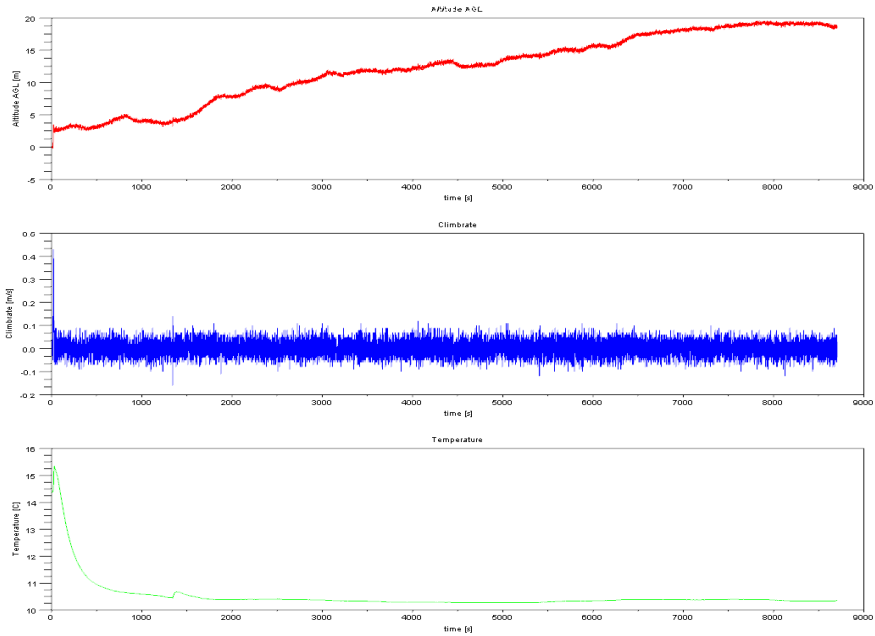
- 100m waterproof pressure sensor inlet
- Direct UV exposure alters reading without negative long-term effect
- Silicone gel protects the sensor from humidity, but avoid physically touching the transparent gel since rough surface might entrap air bubbles producing possible permanent reading instability
- Due to nature of all electronic pressure sensors it is advised to let the whole electronics to equalize with ambient temperature by letting your airplane out of the car for a few minutes before takeoff
- When the silicon gel surface becomes polluted, rinse it with cold, fresh water (avoid solvents and high water pressure!)

FIG. 1 Resistance to temperature shock and frost:



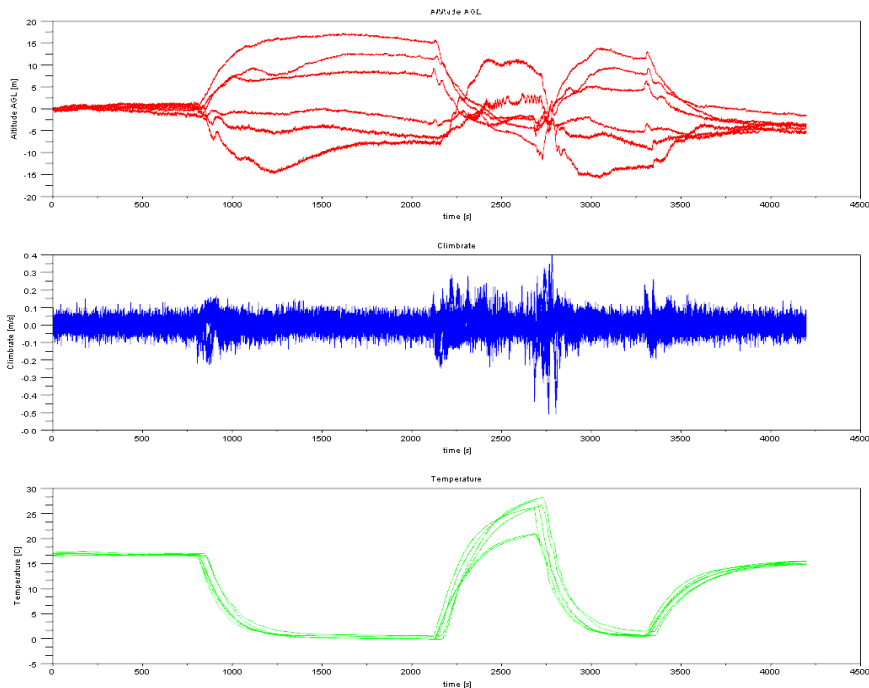
Sudden drop from 12C to -38C during 30s produced altitude overestimation of 100m.

FIG. 2 Long term altitude change over time, indoors:



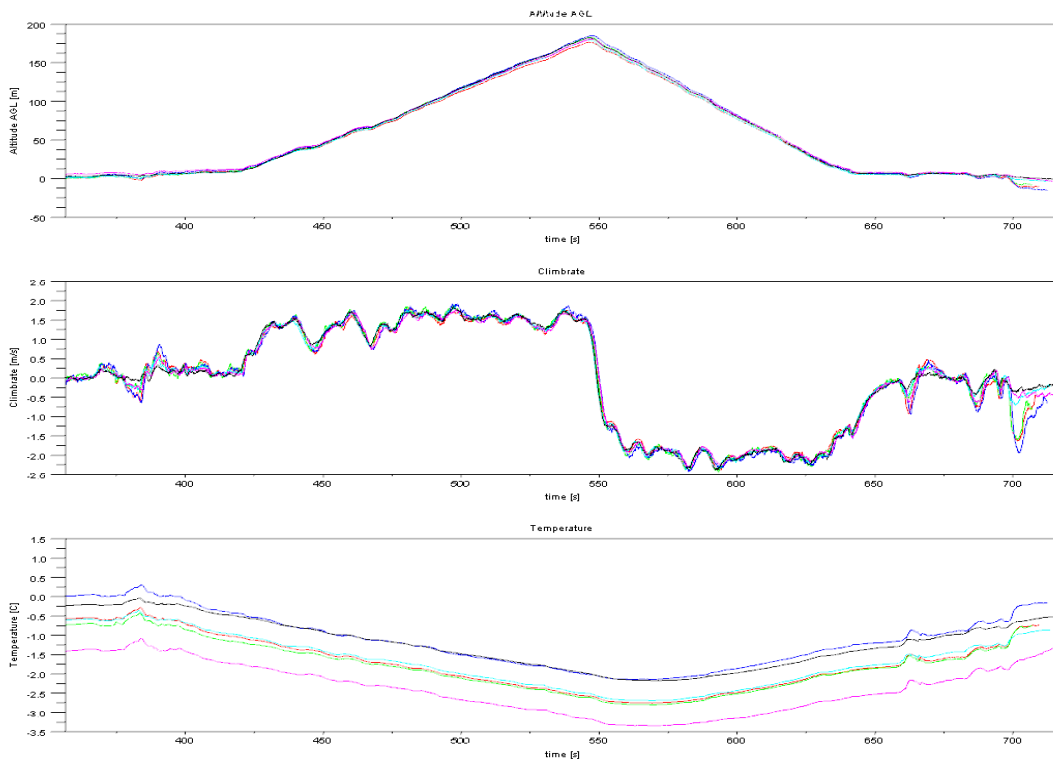
Essentially, the temperature settles, but as pressure changes due to weather conditions, the altitude drifts around 18m during 2.5h period.

FIG. 3 Long term altitude change with temperature, 6 different units:



We can observe around 1m error per 1C at ground level. Long term drift after 1h is -5m, essentially due to weather change. The differences in recorded temperature are reflecting non-uniform heating of the units due to random placement on measurement table. The climb rate oscillates at the beginning of temperature change because the objects are being moved.

FIG. 4 Representative measurement with 7 sensors, winter flight:



Preflight diagnostics and IMU recalibration

In order to gain experience using the autopilot, it is advised to launch the UAVStation before the first flights and observe the system performance.

Use **H/h** in order to toggle altitude debug output:

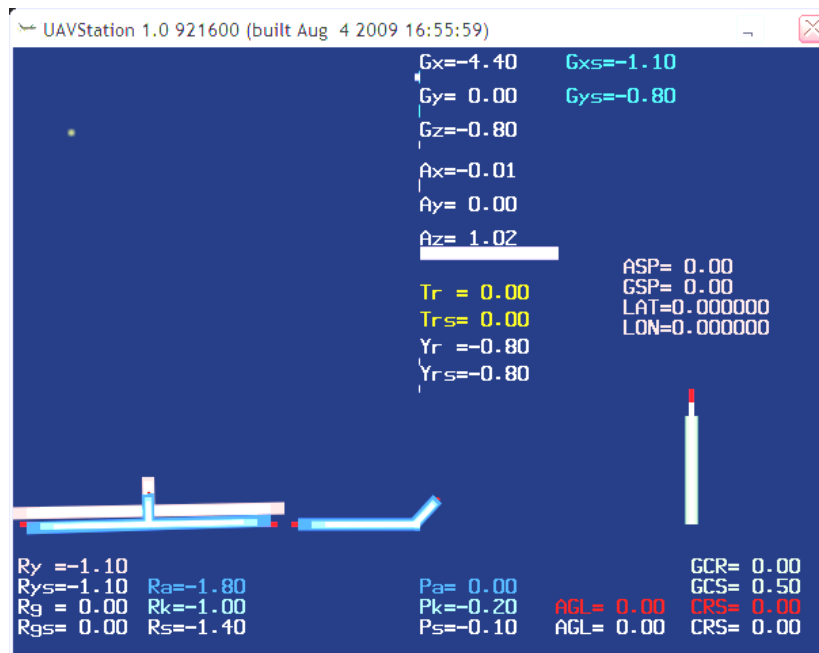
99735.80, T=+30.72, Hstd=+133.14, AGL=-0.14, dH=-0.54, OK=1, AT=+29.80

Most important parameters are:

T=+30.72[C]	Temperature sensor used for pressure correction
AT=+29.80[C]	Air temperature sensor, used for correcting IMU drift
AGL=-0.14[m]	Altitude above takeoff point, it is self-calibrating to 0 until takeoff condition is detected.
dH=-0.54[m/s]	Climbrate, depends mostly on the speed of self-calibration and can be ignored at this time.
OK=1	Status flag, indicates that the barometric pressure sensor has finished its minimum calibration routine and is ready for takeoff. This is also indicated by the blinking LED.

During inspection, particularly the temperature values should be reasonable; T is usually hotter than AT as it is placed inside a sensor that is powered.

Use **I/i** in order to toggle IMU debug output:



Orientation:

Observe if the roll (RK=, Rs=) angles and pitch (Pk=, Ps=) angles match plane's orientation within a few percent. If this is not the case, examine accelerometer status first.

In a system without airspeed sensor, rapid changes of the yaw will temporarily alter roll readings. This is normal. Observe as the smoothed course estimator (GCS=) properly indicates the plane's heading (offset relative to the last GPS course).

Accelerometer:

The values Ax, Ay, Az are the calibrated acceleration around all the axis, by consequence in upright position Az should be 1 +/-3%. If this is not the case perform the following actions:

1. Note the air temperature AT= from altitude debug output (**H/h**). This is IMU_ACCEL_REFTEMP.
2. Enable raw analog input (**A/a**)
394 71 568 465 479 677 585 571 A:585 571 677 G:465 479 568
Here, the numbers after A: signify Ax, Ay, Az respectively
The numbers after G: signify Gx, Gy, Gz respectively
3. Put the plane level on a flat surface. Note IMU_ACCELZ_MAX.
4. Put the plane upside-down (inverted flight) on a flat surface. Note IMU_ACCELZ_MIN.
5. Point the plane nose down. Note IMU_ACCELY_MIN.
6. Point the plane nose up. Note IMU_ACCELY_MAX.
7. Bank the plane to the right. Note IMU_ACCELX_MAX.
8. Bank the plane to the left. Note IMU_ACCELX_MIN.

Write all the variables, using the syntax `@@@IMU_ACCEL_REFTEMP=13.24`.

You can write all the variables in a notepad

then copy-paste them into UAVStation or use HyperTerminal.

After performing those actions, reset the autopilot with `@@@RESET` command.

Yaw gyro:

Yaw gyro precision is handled separately to the other axis as it is important for navigation precision. Observe Gz= parameter and value bar. It is not oscillating around zero, use `@@@GYROZAVGSTART` and `@@@GYROZAVGSTOP` and note the IMU_GYROZ_CENTER. Write it to the memory using `@@@IMU_GYROZ_CENTER=value` syntax.

After performing the above actions, you can perform RESET several times in 30s intervals and the IMU should converge to the optimal performance.

It could happen that after very unfortunate landing and poor accelerometer calibration, the estimated pitch angle and roll angle values are rotating around the axis of reference because the level position has been lost and the gyro null-point estimate is very bad.

This can take several minutes to converge.

In order to accelerate the convergence, note the Gx, Gy values from analog input display (**A/a**), then write those values to

IMU_GYROX_CENTER,

IMU_GYROY_CENTER,

IMU_GYROX_CENTER_STAB and

IMU_GYROY_CENTER_STAB, respectively.

Writing any of the variables using the syntax above always stops IMU status update to the nonvolatile memory.

Therefore, after writing a set of variables, you should reset the autopilot as the converged values will not be written back automatically before reset.