GPS Rescue 4.5

Betaflight 4.5 makes the following significant improvements to GPS rescue:

- Greatly improved support for UBlox GPS modules, particularly M9 and M10, improving rescue reliability and smoothness.
- Flyaways due to heading errors are now much less likely, due to major improvements in IMU heading determination code.
- Angle mode with earth referencing gives more effective roll during a rescue.
- Rescues can be initiated closer to home without disarming.
- Immediate disarm on rescue initiation close to home will now only occur when the quad is within 5m radius of home *and* below less than landing altitude.
- Safety following accidental initiation of a rescue on the ground soon after arming has been improved.
- The sanity check time-out for failures during switch-initiated failsafe testing is now 30s, giving more time to reverse the switch before the quad disarms.
- New CLI settings to fine-tune the disarm threshold, adjust the smoothing of the velocity D factor, and adjust how aggressively the IMU will handle a heading IMU error.
- Re-named some parameters to better reflect their purpose and scaling
- Added Initial Climb height to MSP so that it can be set via the Configurator GUI
- Configurator rescue parameters are re-arranged and tooltips updated.
- `RXLOSS` will appear in the OSD after a 100ms signal loss, and persist for 500ms. While `RXLOSS` is visible, the quad cannot be armed, but incoming valid radio packets will otherwise be handled normally.
- Some variables have been given more intuitive names.
- The Status CLI menu now reports the status of the connection to the GPS unit, including baud rate and the detected type of module
- Numerous bugfixes and tweaks for both safety and performance
- A new `GPS_CONNECTION` debug is provided to help resolve technical issues relating to the connection with the module and the CPU usage of the GPS code

With these changes, GPS Rescue is now far more reliable than ever before.

> **CAUTION**
>
> The user **must** configure the Stage 1 settings correctly, as described below, or the quad will drop and crash in a true signal loss failsafe.

For technical information about changes since 4.4, please see:

- PR12799, module hardware support: thanks to unit (Freasy), ctznooze, zzyzx and ledvinap
- PR12900, IMU heading fixes, bugfixes: thanks to ctznooze, ledvinap
- PR12859, IMU Yaw CoG gain: thanks to ledvinap

> **NOTE**
>
> NMEA support is now very limited:
>
> - Do not use NMEA if the module supports UBlox protocols!
> - 4800baud is no longer supported.
> - An NMEA GPS will only connect if the GPS Ports tab is set to a matching baud rate.
> - We do not attempt to re-configure the GPS data being sent from the module. Excessive amounts of data may be sent, choking the serial buffer, by some NMEA modules.
> - Do not use the module for GPS Rescue unless it sends data at 5Hz or more.
>
> On the plus side:
>
> - Betaflight will parse any incoming NMEA data strings, as before
> - Betaflight will send user-customised NMEA strings from the CLI to the module (but do not use these to change baud rate).
> - If the user sets their NMEA module to power up with appropriate settings, it should work properly, including for rescue purposes.
>
> Please read PR13044, minimal NMEA support for 4.5 before using NMEA.

> **NOTE**
>
> Some GPS modules that 'worked' in 4.4 may not work at all in 4.5.
> Usually this is because the module is not responding to standard UBLox auto-configuration requests. Such a module may 'work' in 4.5 if auto-configuration is disabled, but is not likely to be as reliable as it should be. We recommend either getting a newer (and better) M10 GPS module, or using uCenter or pyGpsClient to reset the module to defaults (which should accept external configuration requests).

About GPS Rescue

GPS Rescue is an advanced safety feature that can autonomously fly the craft home, after loss of the RC or video link for long enough to exceed the Stage 1 failsafe period, until it is close enough to re-gain control. It can also land and disarm with reasonable precision.

When activated, the craft should, sequentially:

- enable level mode and climb to a user-configured altitude, at the configured ascend rate,
- rotate at 180 deg/s until pointing towards home,
- pitch forward and fly towards home at a user-configurable speed (note: the nose of the quad will move up and down in pitch during the rescue in order to keep the forward speed accurately controlled),
- correct the attitude of the quad to keep it pointing to home if it drifts off-course due to wind, and will mix in some roll to minimise sideways drift
- when at a user-defined distance from home, start to descend at a configurable rate,
- reduce forward velocity as it approaches home, and reduce descent rate as it approaches ground
- enable impact detection when below the set landing altitude
- automatically disarm on touching down

Typical applications include:

- automatically and autonomously flying home, landing, and disarming, when the radio link is lost (requires failsafe stage 2 to be set to GPS Rescue, and appropriate Stage 1 settings)
- climbing and flying back when the FPV video link is lost; the pilot must activate a mode switch that either triggers failsafe (and set failsafe mode to GPS Rescue) or directly enables GPS Rescue
- a 'panic' switch for LOS pilots who lose orientation (requires mode switch activation by the pilot, set up as above)

Important:

> **CAUTION**
>
> - Only use the 10.10.x Configurator!

- Test GPS Rescue *very carefully** before relying on it. Initial testing should be done at close range, with defaults, over soft grass.
- **Remember: During a real failsafe, after the link is restored, the sticks MUST be wobbled by more than 30%, before you can regain control over the quad.** Control does not return to the pilot automatically! If you touch the sticks before video is returned, you may terminate the rescue. Hence, **During a real failsafe, DO NOT TOUCH THE STICKS**, at least not until:
  - your video has returned and is solid,
  - the `RXLOSS` indicator has gone,
  - the signal strength indicator is OK.
- If a switch-induced Rescue test has a problem, or seems to float around, DO NOT DISARM IN PANIC! Undo the Rescue switch *promptly* and you'll get full control back immediately. Do not wait more than 15s or it may disarm and crash.
- Stick wobbling is *not* required during a switch induced rescue; control is immediately returned immediately the switch is reset.
- **Be 100% sure you have a valid Home Point before arming** or the quad will disarm and crash when a true failsafe occurs.
- Do *NOT* enable a Magnetometer unless you have absolutely confirmed that the Heading of the quad is correct. Compare the compass value in your phone (set to show True North, not Magnetic North), with the heading on Configurator's main opening screen, the GPS tab in Configurator, or the Sensors tab debug line 5 in debug mode `GPS_RESCUE_HEADING`, and check that both are within 10 degrees of each other. If the heading always starts at North, and follows fast movements quickly but then jumps to some other value, the Mag is not right.
- Level mode MUST be trimmed to provide a stable, level, hover, for a rescue to work properly Check, using a level mode switch, before flying out. Sticks can be used to calibrate the Acc at the field.
- The GPS Rescue Hover throttle value and the Stage 1 failsafe Throttle channel value should be set return a stable hover. This method can be used to accurately determine the value to use:
  - set the Failsafe switch action to `Stage 2`, and the `Stage 2 Failsafe Procedure` to `Land`.
  - adjust the `Throttle value used while landing` until the quad descends gently.

    - set the `GPS Rescue Throttle Hover`, and the `Stage 1 Channel Fallback value` for throttle to this value.
    - return the `Stage 2 Failsafe Procedure` to `GPS Rescue`.
  - 3D mode is not supported! There will be no rescue if the quad is in 3D mode at the time of the failsafe.

Known issues

- **8k8k is not recommended - use 8k4k.** The GPS task is CPU intensive, when configured at 10hz with GPS Rescue enabled, and requires Angle mode, attitude estimation, and relatively complex OSD displays . To avoid transient processor overload during a rescue, we recommend using 8k4k, not 8k8k. If the GPS data is not to be used for a rescue, 1Hz 9600 baud or 2Hz 19200 baud will reduce the CPU load and may permit 8k8k on faster boards.
- **Heading** will be wrong, right at the start, if there is no Mag. After takeoff, the GPS requires at least several seconds of clean straight pitch forward speed in order to determine the heading of the quad from the course over ground. Check the arrow in the OSD! It must point correctly to home within 5-10s (50-80m) of take-off. If you are going to rely on the rescue, and the arrow isn't right after 10s, return to home, land, power cycle, and try again.
- **High head-winds in the return leg may cause rescue failure**. High winds can cause sideways drift during the rescue, IMU disorientation if the course over ground does not match the direction of the nose of the quad, and may simply blow the quad backwards. The quad must be configured with sufficient max pitch angle and sufficient max throttle to defeat a headwind. Before taking on high winds, do a test rescue and check that the quad can overcome the wind.
- **Do not enable the Compass *unless* it has been properly calibrated and the data confirmed, by logging, to be useful and accurate.**
- **Use UBlox; don't use NMEA**. GPS units configured to use NMEA often update only once per second, or even slower. This makes GPS Rescue very jerky, and almost unusable. We provide strong UBlox support, and little or no NMEA support. It's much better to use UBlox.
- **SBAS** mode may cause problems getting reliable GPS data, and may not function in some regions; if so, try setting SBAS mode off.
- **Unreliable GPS Modules**. GPS modules vary greatly in performance and reliability. Don't use unreliable modules, meaning those where you do not quickly get at least 10 solid sats, and modules that lose sats readily when the quad is put at an angle.
- **Using `GPS_RESCUE_ALLOW_ARMING_WITHOUT_FIX` is NOT recommended!** While you can take off without the long wait for the GPS fix, if you do need a rescue, due

to Rx loss, the quad will immediately disarm and crash. This option should only be used when the pilot only needs to record basic GPS info to the log, or their radio, to help them find it after they crash.

- **Do not use GPS rescue with a 1hz data update rate**. The minimum for smooth operation is 5Hz, although 2Hz can be used and should be successful, despite a jerky return. 1Hz and 2Hz are OK only suitable for showing latitude and longitude in the log or on the OSD.
- **DO NOT share the Failsafe switch aux channel activation range with any other flight mode!**

Hardware requirements

- A properly trimmed accelerometer, and a solid stable level hover. At the field, fine tuning can be done by hovering in angle mode, then using sticks to trim any drift. Stick trimming means: -- disarm -- staying disarmed, set the mode switch to level mode -- set throttle full up -- use taps of the pitch/roll stick to trim the acc. eg tap left 5-10 times to fix a tendency to drift right.
- A working GPS module that supports UBlox commands. UBlox is recommended and is now the default. We support M6 through M10 UBlox modules.
- If the GPS module doesn't support UBlox, NMEA can be used, but is not recommended unless you know how to check the module output, and re-configure its default power-on state. See the previous note about NMEA.

To be detected properly, the GPS module must be powered up at the same time as the flight controller.

> **TIP**
> Modules with a backup battery will regain satellites more quickly during subsequent power cycles.

- When checking a new GPS unit, connect up in Configurator and check how quickly satellites are gained, while stable on a desk outdoors. The Status CLI command should report baud rate set and returned, and (for UBlox only) the module type.

> **TIP**
> A good GPS will, from a cold start, get around 20 sats within a couple of minutes, and have 10-12 involved in the 3D 'fix', each showing a good signal level. The module should acquire each satellite progressively and not chop and change between them. Angling the quad should not cause loss of satellites

> involved in the fix. Zoom in on the map and see how the position moves around, especially if the quad is put on an angle and some satellites are lost. The position on the map should be stable. If it wanders around by many meters, that's not good. Since the module is 'still' on the table, the 'speed' should be zero. It never is, of course, but with a solid fix, the 'speed' should not exceed 10-20 cm/s and should mostly be under 10cm/s when it has a good 'fix'. Do not use a module that shows speeds > 25cm/s persistently while still, takes a long time to acquire satellites, doesn't have strong signal strength, moves around on the map, and loses position information when angled 45 degrees. Generally, physically larger GPS modules work better than smaller units. Note that the quality and speed of the fix has nothing to do with Betaflight; it is intrinsic to the performance of the module itself.

- If a Baro is present, enabling it will improve altitude estimations significantly, especially for short duration flights (5-10 minutes). Usually this results in better altitude control and more reliable landings. Check the Baro data in the sensors tab after enabling the `ALTITUDE` debug. It should be reasonably smooth after arming. Whether or not Baro is helpful is readily seen by doing some LOS rescues at low altitude over flat ground. For longer flights, and with some Baro hardware, Baro drift can be more of a problem than GPS drift. Hence long-range pilots may prefer to not use Baro; they should do some testing with it on or off and then set the Baro trust value appropriately for the kind of flying you intend to do.

- If a Compass (mag, or magnetometer) is available, and if it has been properly calibrated, and the data is noise free, it may improve heading estimation. Compasses must be positioned well away from magnetic fields, including those from current flowing through wires. This is very difficult even on a 7" setup. Using an incorrectly calibrated or noisy compass will adversely affect the rescue. Be sure to log your compass data and check that it is accurate and clean before enabling it. In most 5" or smaller drones, Mag is too noisy to be useful. Do not use the mag unless you log its information after flying a known 'square' course very accurately. The log should show clean 90 degree heading changes in the mag data. If not, don't use it. If in doubt, don't use it. We will be improving Mag integration in coming firmware releases.

Software settings

The defaults should be good for initial tests, but there are some important things that you must set for each quad:

- Calibrate your accelerometer so the quad hovers level

- Set the Stage 1 Failsafe fallback throttle value (the value on the throttle channel) to a value that will make the quad climb steadily. This is the value that will be applied when the quad initially loses signal. If it is too low, and you're flying over water, before the GPS Rescue code kicks in - one second after signal loss - you may descend enough to end up in the water
- Set the GPS Rescue throttle value to a value that is close to a hover. This is the initial value that gets applied once the rescue kicks in. The PIDs that control throttle will take over at this point, by adding or subtracting from this value. It should be a value that is close to the hover value.

The recommended baud rate is 57600. There is little to be gained by using 115200 with the recommended 10hz data rate. Lower baud rates reduce the CPU time required for parsing the incoming data and are more resistant to electrical noise.

The recommended data rate is 10Hz for GPS Rescue purposes. 5Hz or less is recommended if the GPS is only for fixes on the radio in case the quad is lost. **If an M8 module is set at 20Hz, it will revert to its own internal default rate, which could be very slow.** 20Hz requires 115200 and M9 or higher, and is not recommended as it may be susceptible to electrical interference.

Data Rate	Baud Rate	CPU cost	Comments
20hz	115200	Highest	M10 only; test carefully!
10hz	38400 or higher	Medium	57600 and 10hz is recommended for GPS Rescue
5hz	19200 or higher	Medium	For GPS Rescue or general use
1-2Hz	9600 or higher	Leasts	Too slow for smooth GPS rescue, OK for simple position/speed info

Otherwise, read all the software settings below, and make sure they are suitable for what you want to do. Do not change anything a long way off defaults quickly; take your time.

Ways to initiate a GPS Rescue

1. RC Link Loss

Here we want the quad to enter Stage 1 Failsafe for the Stage 1 duration, for long enough to be sure the link really is lost, then enter Stage 2 failsafe, which should be set to GPS Rescue and fly home. Once the link is restored, control can be restored by wiggling the sticks more than 30 degrees out from center.

> **DANGER**
> Do NOT wiggle the sticks until you've got an FPV video signal back, otherwise you may regain control but not know where you're going! Wait until your signal strength indicator is good and you have a decent FPV feed, **then** wiggle the sticks.

If the radio or FPV link never recover, let it fly home and it will land itself.

Setup

- ensure the firmware is cloud built with GPS support
- enable GPS and GPS Rescue
- check in Configurator that the module gains satellites and position reliably
- enable a Mode switch that will activate level mode
- in the Failsafe tab, set your Level Mode channel to activate Level 1 when in Stage 1. This will slow the quad down and level it out in preparation for the rescue.
- set the Stage 1 Throttle value so that the quad will hover during stage 1.
- set the GPS Rescue Hover Throttle value to the same hover value
- the hover value to use can be determined by enabling the `Land` mode of Failsafe Stage 2, as described above, at different `Throttle value used while landing` values.
- enable a Mode switch to activate failsafe, for testing purposes
- > **CAUTION**
  > DO NOT use or share Failsafe Mode switch with any other mode!
- test your failsafe switch by setting Failsafe Mode to `Land` mode and the failsafe mode to enter Stage 2 directly. The `Throttle value used while landing` should be set to lose altitude slowly. There is no auto-disarm on landing; we just check that the failsafe switch initiates landing mode. Then set Failsafe to initially go through Stage 1, after configuring Stage 1 settings as above. Now when you hit

the switch, you'll get 1.5s (by default) of Stage 1, which should put the quad into level mode, and hover for that time, then go to Stage 2. This is a simple close-range way to validate your Stage 1 failsafe settings and to confirm that your failsafe switch works.

- now, finally, in the Failsafe tab, set failsafe mode to `GPS rescue`
- the default GPS Rescue settings work for most quads. Read about them further down in this document in case you need to change them.
- if you have a Baro, check it using the ALTITUDE debug (see debug info at the end), and enable it only if it works well and improves altitude control.
- do initial tests using stick-induced failsafe, as below, confirming that it reliably flies home and lands. Remember to cancel the test any time you think the rescue is failing.
- only when you are 100% sure it will fly home reliably, test what happens with a hard radio link loss. Don't power down the radio to do this test! Otherwise when you power up it may require all switches to be 'off', leading to a disarm on re-connection. The best way to test RxLoss is to go to the menu section of the radio where you can turn off the Tx module in the radio. Maybe get a friend to turn the module off while you hover the quad not too far away. On the first test, let it fly home and land. Then repeat a few times to be sure. Finally, after disabling the module to initiate a Rescue, power the module back up again once the Rescue is under way. Then confirm that you regain control only by wiggling the sticks. This is the only way to regain control when the link is restored after failsafe.

2. Switch-initiated Failsafe emulation

When testing the Rescue configuration, we want the quad to emulate a real link loss. For this, the Failsafe mode must be set to Stage 1, so that when the switch is hit, the quad enters Stage 1 until it times out, and then enters Stage 2, when it starts the rescue, climbs, and starts to head home. When configured like this, we get a direct emulation of exactly what will happen in a real rescue, but we can exit anytime we like.

Stage 1 can be bypassed to go to Stage 2 directly in the Failsafe settings. This configuration allows the failsafe switch to directly start the Rescue without the stage 1 delay. This can be used to deal with FPV video loss, or to return towards home if disoriented while flying LOS.

To regain control after a switch-initiated failsafe, just undo the Failsafe switch.

> **TIP**
> DO NOT PANIC AND DISARM BY MISTAKE - just revert the failsafe switch!!!

Setup:

- basic config as above, including setting Mode switches for level mode and to enable failsafe
- test carefully using the failsafe switch

3. Directly enter GPS Rescue with the GPS Rescue Mode switch

This makes sense when we only need an emergency 'safety return' function, e.g. when you're long-ranging and lose FPV signal, or in Acro and lose control in the distance.

Here we want to hit the switch and have the quad to immediately level out, climb and start to fly home - without waiting; undo the switch, and immediately get back in control.

There is a specific 'GPS Rescue Mode' option in the Modes tab to provide this functionality on a given Mode channel (ie on a specific switch).

The main benefit of doing this is that Failsafe itself can be configured to include the Stage 1 delay before initiating a rescue. This allows short dropouts to show `RXLOSS` in the OSD, allowing the pilot to perhaps climb or fly home, without immediately initiating a rescue. At the same time, your 'rescue' switch can be set to GPS Rescue Mode to provide immediate rescue initiation, without any Stage 1 delay in the event of an FPV signal loss.

Setup:

- if you do not care about GPS rescue in the event of signal loss, you can just set the quad to drop on failsafe, and leave the Stage 1 settings at default.
- otherwise, we recommend that you configure and test GPS Rescue failsafe, including Stage 1, as described above, so that you will get a safe GPS Rescue if the signal is lost.
- for the GPS Rescue Mode switch to function properly, configure the GPS settings on the right side of the Failsafe panel, including the hover throttle value.
- configure the Mode switch to activate `GPS Rescue` (not failsafe).
- test to confirm immediate climb on activating the GPS Rescue switch, and immediate return of control when the switch is reversed.

Tips:

- **Do a LOT of GPS Rescue tests with switch initiation at close range over soft grass!** Do these tests initially up close! You need to be 100% confident that every rescue works properly before relying on it.

- **Test for loss and restoration of signal by disabling the Rx module, not by powering the radio off!**. Most radios, by default, have pre-flight checks that require all switches to be 'off' before they power up. This is a safety feature. The radio will not power up with the arming switch in the `ARMED` position. That means, when testing GPS Rescue, that if you power the radio off, and back on, you can't turn it back on without sending the `DISARMED` command to the quad, leading to an immediate crash. Most radios let you enable or disable the internal Tx module on their setup page. That's the 'safe' way to test for temporary link loss. You may need a buddy to go to the setup menu and disable / enable the module while you watch what is happening in the OSD. You should see `RXLOSS` in the OSD when the signal is lost. **Remember to wiggle the sticks to regain control after a signal loss episode!**

- **Remember to set the GPS Rescue Hover throttle value accurately!** The GPS Rescue Hover value is the starting point for throttle once the rescue starts. The GPS Rescue PIDs adjust throttle either side of the Hover value, within the min and max limits. If the hover throttle is set too low, the quad may lose altitude right at the start, while the PID's 'catch up'. If set too high, it will climb more aggressively, and not descend quite right. It is better to 'err slightly on the high side', because climbing too fast is usually less of a problem than dropping like a stone.

- **Remember to set the Stage 1 throttle value manually to a hover value!** When entering a true RF loss failsafe, the quad will use the Stage 1 settings for throttle during the Stage 1 period (the first second of the signal loss period) while hoping to recover signal. If the Stage 1 throttle channel value is set to `Auto`, the quad will immediately fall from the sky, since `Auto` means 'throttle off'. Set it to a hover value so that it won't do anything bad in the Stage 1 period, while hopefully the link can be restored before starting the rescue.

- **Always ensure that level mode hovers flat and true before taking off**. If the quad drifts sideways during return, it's usually because the accelerometer had an accelerometer trim error on roll. Trimming can, and should, be done with sticks at the field.

- **When setting up a new GPS module, check it functionally, outdoors, with a laptop and an internet connection.** The process is described above.

- Test whether `set GPS_UBLOX_USE_GALILEO = ON` improves the number of satellites found or the quality of the position lock.

- **Before takeoff, always check in the OSD that the GPS unit returns solid position readings**. At least 8 satellites are needed to arm, by default. 10 is preferable. After getting the sats, observe the speed and altitude values in the OSD. They should not be jumping all over the place Sometimes you need to wait another 30-60s before they stabilize. It should stabilize before takeoff. Do not rely on the blue light on the OSD. It will flash on a position lock, but that is not the same as having a home lock.

- **Ensure you have a Home Lock before takeoff, and that the Home Arrow points to Home when flying away!**. After arming, make sure the OSD shows the home icon, distance to home; after takeoff, ensure that the home arrow points to home.

- Display the `osd_gps_sats_show_pdop` value in the OSD; if this gets close to, or below, 1.0, it's a good indicator of a solid, accurate fix (thanks **@zzyzx**).

- Once you have a decent set of sats, and before arming, **tilt the quad to 45 degrees in all directions, and confirm that you don't lose a lot of your sats**. Sometimes if the signals are marginal, eg with micro or mini sized GPS modules, the quad will lose satellites when it pitches forward to fly home, and this can lead to a very erratic or failed rescue.

- **At the start of a mission-critical flight, confirm normal GPS Rescue behavior a by doing a close-range test rescue with a switch, before heading out into the distance**. Once you know that it turns and points to home, revert the test switch. You can enter and leave GPS Rescue with a switch with immediate effect anytime. This makes field checking easy.

- **Think carefully about the `GPS_SET_HOME_POINT_ONCE` option**. Resetting the home point on every new arm is OK for testing and normal use. Each time you arm, your home position is updated. The home position accuracy improves over time, so you're sure to get the best home position estimate when you finally do take off. The downside is that if you disarm during the flight, GPS rescue will take you back to that new arm point, not to home. If your craft disarms in a bad spot, even if you get signal back, it will never fly home. If you accidentally disarm during the flight, or during a rescue, you will lose the quad.

- **If you choose to only set the home position once, do not arm until you are sure you have a solid home position estimate, and arm for the first time when the quad is at the physical location you want the quad to return to!**

- **Think about whether or not to enter Angle Mode in Stage 1 Failsafe**. Assuming you have Angle mode on a switch, you can automatically enable

Angle Mode for Stage 1 Failsafe on that aux channel. Pitch, roll and yaw Stage 1 values can be left on auto (sticks will be 'centered', but throttle must be configured, as noted above, to a fixed value. When done correctly, entering Stage 1 Failsafe should cause the quad to level out, slow down, and hold its current altitude, provided that a suitable stage 1 throttle value has been set. However, entering Angle mode after only a 100ms signal loss may be annoying to long-range pilots, who may see frequent 'twitches' into Angle mode during short dropouts. Long-range pilots sometimes prefer to set their aux channels, and indeed all stage 1 channels to `Hold last values`, rather then entering Angle mode, so that their craft just keeps going 'as if nothing happened' during dropouts. They will see `RXLOSS` in the OSD for each dropout. Some extreme long-range pilots extend the stage 1 period to several seconds, before triggering the rescue, but this is not recommended.

- NOTE: without a compass, the quad 'learns' the heading of the quad from the direction of travel over ground from data provided by the GPS. **The craft must be traveling at least 1-2m/s, in clean nose-forward flight, for at least several seconds, before its attitude can be correctly determined from GPS data alone.** Always fly dead-straight after take-off, in clean pitch forward flight. If it is windy, fly directly into the wind, or directly with the wind, so that the flight path over ground matches the orientation of the quad. Check that the arrow rotates and points to home after short period of straight flying like this. Typically some 30-50m distance is required. If not, return, power cycle and try again.

- **In 4.5, a rescue can be initiated at very close range, even without proper heading information, immediately after takeoff.** In these cases, the quad will fly itself, pitched forward, and at a decent speed, in whatever heading it was at, until the IMU figures out what direction the nose of the quad is pointing. This can take some time; it can fly 50 or even 80m away before looping back towards home. That's why it's important to check the arrow before takeoff. If GPS Rescue is intended as an 'emergency help' switch while learning to fly LOS, be sure to arm and set home to the center of the field, then you can trigger the rescue anywhere on the field and the quad will return to the center.

- **The GPS Rescue 'mode' switch will immediately initiate GPS Rescue when activated**. It doesn't use the failsafe system. This can be used for 'emergency' rescue for loss of FPV signal or for disorientation when flying LOS. Note that the quad's momentum will keep it moving for at least a few seconds, so don't expect miracles.

- In strong winds the maximum allowed angle of the craft during a rescue, `GPS_RESCUE_ANGLE`, may need to be increased enough that the quad can make forward speed into a headwind. The max throttle value should be sufficient to overcome a strong headwind and to keep the craft at the configured angle

without losing height. Angles over 50 degrees can need a lot of throttle. The craft may overshoot or land roughly if the wind is very strong, especially a strong tailwind.

- During a rescue, the built-in Betaflight Crash Detection code is automatically activated (even if you disabled it in your settings). If the quad has a hard crash or impact at any time on the way home, it may disarm immediately. This mechanism is quite different from the much more sensitive landing impact detection, which is only activated late in the Rescue once the altitude of the quad falls below the `GPS_RESCUE_LANDING_ALT` height.

Phases of the Rescue

There are five "normal" phases in a Rescue: `ASCEND`, `ROTATE`, `FLY HOME`, `DESCEND`, `LAND`. They follow sequentially. Normally the phase is `IDLE`.

Each phase has different targets. Specific exit criteria must be met to enter the next phase.

`Sanity checks` monitor performance during each phase, and will disarm with prolonged failure.

Phase	Controlled axes	Functionality	Termination
`ASCEND`	Yaw and pitch	Ascend or descend at set rate, yaw quickly to reduce heading error	Fly home altitude attained
`ROTATE`	All axes except roll	Continue to yaw to reduce heading error	Heading to home error to less than 15 degrees
`FLY HOME`	All axes	Fly home at set altitude and velocity, keep adjusting yaw	Within `GPS_RESCUE_DESCENT_DIST` of home
`DESCEND`	All axes	Altitude and velocity reduced steadily, keep adjusting yaw	Altitude below `GPS_RESCUE_LANDING_ALT`

Phase	Controlled axes	Functionality	Termination
`LAND`	All axes except roll	Descend at set rate, with a zero forward velocity target, keep adjusting yaw	Impact with ground

Notes:

- Sanity check failure or a bad crash during the rescue can also terminate a rescue
- Yaw control is active in all phases, starting during the `ASCEND` phase. Yaw tries to keep the nose pointing towards the home point relative to the current estimated position of the craft, using a simple P controller. The maximum rotation rate to control yaw/heading error is 90 deg/s.
- Throttle is adjusted either side of the set `GPS_RESCUE_THROTTLE_HOVER` value, within limits set by `GPS_RESCUE_THROTTLE_MIN` and `GPS_RESCUE_THROTTLE_MAX`, at all phases of the rescue, to control altitude using PID controller that includes an acceleration element. Throttle is dynamically adjusted according to the angle of the craft (the angle away from horizontal).
- Pitch angle controls forward velocity, and becomes active, at half max rate, during the `ASCEND` phase, is fully active once the error angle to home is less than 45 degrees in `ROTATE` phase, and stays fully active until `LANDING` phase, when it again is reduced to half rate.
- Roll is added to yaw only at lower yaw rates, and is essential to deal with heading drift due to wind. It is active only during `FLY HOME` and `DESCEND` phases.
- During `DESCEND` phase, the craft tries to stay on the edge of a cylinder that is 2m away from the estimated landing point. It will point towards home while attempting to stay 2m out. The 2m distance is intended to minimise the risk of overshooting home, which then requires a 180 degree turn. In windy situations the craft will typically descend on the down-wind side of the 2m cylinder, and may sit on an equilibrium point further than 2m out.
- During landing mode, the quad can rotate, and will pitch forward and backward to try to land 2m out from the home point. If the GPS has drifted, the final distance to home and direction to home indicate where the GPS thinks 'home' is at the time of landing.
- Auto-Disarm is triggered by the accelerometer spike associated with touch-down with the ground. The threshold is not user-adjustable. It is only active after the altitude falls below the `GPS_RESCUE_LANDING_ALT` value in `DESCEND` mode.

If the altitude has drifted high, so that the craft hits the ground but the GPS thinks it is still high in the sky, it will not disarm on impact. If that happens, the landing sanity check should disarm the craft after about 10s (if the pilot has not done so).

- A `DO_NOTHING` phase, which is flat Level Mode with throttle 100 steps below the GPS Rescue hover throttle value, with a 20s limit, is applied in switch induced rescues that experience a fatal sanity check error, to give time for the pilot to reverse the switch rather than immediately disarming. Should a pilot notice a failure to follow the above sequence during a stick induced Rescue, they should immediately recover control, by reversing the switch, to avoid the disarm that will otherwise occur.

Altitude control options

The `GPS_RESCUE_ALT_MODE` setting, in association with the `GPS_RESCUE_RETURN_ALT` and `GPS_RESCUE_INITIAL_CLIMB` values, determine the target altitude for the flight home, as follows:

`GPS_RESCUE_ALT_MODE`	Notes
`MAX_ALT`	The default. Craft will climb to the highest altitude previously attained since arming, plus the `GPS_RESCUE_INITAL_CLIMB` height, in meters. Useful when the pilot climbs over the highest objects in the flight path before risking the failsafe.
`FIXED_ALT`	Craft will return at the exact height above Home Point as configured by the `GPS_RESCUE_RETURN_ALT` value in meters. If flying low, around trees or buildings, `FIXED_ALT` can be set to a known height that will clear them.
`CURRENT_ALT`	Craft will climb `GPS_RESCUE_INITAL_CLIMB` higher than the current altitude at the time the rescue starts. Useful for testing or for emergency 'panic' switch applications.

Settings

Item	Notes
`GPS_RESCUE_MIN_START_DIST`	The minimum distance from home required before a "normal" GPS Rescue can be initiated, in meters. Inside this distance, the rescue may not be as well-controlled as usual.
`GPS_RESCUE_ALT_MODE`	The return altitude mode. `FIXED` returns at the set `RETURN_ALT` value, `MAX` will return just above the maximum height attained during the flight, and `CURRENT` returns at the height the rescue started, plus the climb amount
`GPS_RESCUE_INITAL_CLIMB`	The amount of height to climb, above either current or max altitude (as set by `GPS_RESCUE_ALT_MODE`), in meters.
`GPS_RESCUE_ASCEND_RATE`	Target climb rate in cm/s during the `ASCEND` phase. Can be increased to speed up the climb, if desired.
`GPS_RESCUE_RETURN_ALT`	When in `FIXED_ALT` mode, the altitude to return at, in meters above take-off altitude.
`GPS_RESCUE_GROUND_SPEED`	The target velocity (in the direction of home) for the return flight, in cm/s.
`GPS_RESCUE_MAX_RESCUE_ANGLE`	Maximum allowed pitch (and roll) angle, in degrees, during a rescue. May need to be increased above default value if the craft has difficulty maintaining forward velocity against strong winds.
`GPS_RESCUE_ROLL_MIX`	The relative amount of roll included when the quad yaws during the return flight. 100 means the normal amount, zero means none. Don't turn it off, or the quad just slides sideways when there is wind drift.

Item	Notes
`GPS_RESCUE_PITCH_CUTOFF`	First order lowpass filter cutoff that is applied to the velocity D factor, to smooth out pitch jitters. Default of 75 means 0.75Hz. Slower is smoother but can result in slow wobble and poor control.
`GPS_RESCUE_IMU_YAW_GAIN`	Sets the aggressiveness of the IMU adaptation to heading error in high wind situations. Default is 10, with the range 5-20. Larger numbers result in a wider, slower correction for IMU heading errors. Too high may lead to endless circling.
`GPS_RESCUE_DESCENT_DIST`	The distance from home at which the craft starts to descend, in meters. Shorter distances make for a more vertical descent, which can lead to an overshoot when returning quickly
`GPS_RESCUE_DESCEND_RATE`	Target descend rate in cm/s during the `DESCEND` and `LANDING` phases. The descent rate at the start of the `DESCEND` phase can be up to twice this value, reducing to equal the set value by the time the craft is landing.
`GPS_RESCUE_LANDING_ALT`	The altitude above take-off point when auto-disarming is activated during descent, in meters. Also, will disarm if initiated below this altitude and within 5m of home.
`GPS_RESCUE_DISARM_THRESHOLD`	Sensitivity of the auto-disarm on impact feature. If the quad is noisy, and disarming early, try increasing the threshold. If too high, the quad may bounce around and fail to disarm on landing.

Item	Notes
`GPS_RESCUE_THROTTLE_MIN`	The lowest throttle value that can be applied by the GPS Rescue code. This usually does not require any modification. Heavy quads with a high throttle requirement just to hover should increase this a bit.
`GPS_RESCUE_THROTTLE_MAX`	The highest throttle value that can be applied by the GPS Rescue code. This is unlikely to need increasing unless the quad is very heavy, or has high drag and needs to be flown in high wind.
`GPS_RESCUE_THROTTLE_HOVER`	**Important** The hover throttle value that approximates the value required during the fly home phase, or will result in a steady slow climb in level mode. This is the basic throttle value about which the throttle PIDs vary throttle (within limits). It is important to set this value correctly, to ensure that the craft climbs, rather than drops, right at the start of a rescue, and descends in 'DO NOTHING' mode.
`GPS_RESCUE_SANITY_CHECKS`	Sets what happens if the Rescue fails. See the Sanity checks section
`GPS_RESCUE_MIN_SATS`	Value 5 - 50. The number of satellites required, as well as a 3D fix, for the Home point to be set, and to permit arming when GPS Rescue is configured. Setting this to lower values risks poor GPS control and mid-air disarms. Default is 8. With less than 5 we have no 3D fix and cannot control altitude from GPS alone. With a Baro this could be set to 5, since Baro can provide altitude with only a 2D GPS fix.

Item	Notes
`GPS_RESCUE_ALLOW_ARMING_WITHOUT_FIX`	Option that permits arming without a home fix (never do this, see below)
`GPS_RESCUE_THROTTLE_P`	P gain value that increases throttle when the altitude is less than it should be, and vice versa. Too high will cause oscillation, too low leaves more work for I, causing slow oscillations / poor control.
`GPS_RESCUE_THROTTLE_I`	I gain value that increases throttle when altitude is persistently less than it should be. Too high will cause slow oscillation, too low will lead to persisting altitude error.
`GPS_RESCUE_THROTTLE_D`	D gain value that increases throttle when the quad is descending rapidly, and vice versa. Too high will cause oscillation and/or jittery altitude control, most noticeable early in the descent phase. Too slow and altitude control will be slow.
`GPS_RESCUE_VELOCITY_P`	P gain value that increases pitch angle when forward velocity is too low.
`GPS_RESCUE_VELOCITY_I`	I gain value that increases pitch angle when forward velocity is too low over a sustained period of time.
`GPS_RESCUE_VELOCITY_D`	D gain value that increases pitch angle when the quad decelerates (loses velocity to home)
`ALTITUDE_LPF`	The cutoff value in Hz * 100 that will be used to smooth the altitude value. Too much smoothing leads to wobble.

Item	Notes
`ALTITUDE_D_LPF`	The cutoff value in Hz * 100 that will be used to smooth the altitude derivative (vertical velocity) value. This also smooths the Vario signal at present.
`GPS_RESCUE_USE_MAG`	Use magnetometer (compass) data to improve heading accuracy. Do not enable this unless the mag is calibrated and a log shows high-quality noise free compass data.

PID Tuning suggestions:

- `GPS_RESCUE_YAW_P` should be high enough that the quad rotates well enough at the chosen speed to track to home properly. If too high, the nose of the quad will wander left to right as you return. Default is pretty good.
- `GPS_RESCUE_ROLL_MIX` at 100 gives approximately the correct amount of roll to make 'co-ordinated' turns in level mode. A higher value increases the relative amount of roll:yaw and may be needed for higher speed returns. Zero means no roll at all. Use the debug `GPS_RESCUE_HEADING` to see the amount of yaw and roll applied, while comparing the attitude of the quad to the angle to home.
- Altitude PIDs (`GPS_RESCUE_THROTTLE_P`, `GPS_RESCUE_THROTTLE_I`, and `GPS_RESCUE_THROTTLE_D`) are best adjusted with a very low set groundspeed (eg 50 cm/s), the quad pointing to home when initiating GPS Return, and a relatively steep climb rate at the start. PIDs too high lead to vertical oscillations after the initial climb. D gives faster oscillations than P. Try to minimise them using classical PID control methods. There is a very big delay from pushing the motors to gaining altitude. The debug DEBUG_GPS_RESCUE_THROTTLE_PID will be most useful. It shows throttle P and D, with the measured altitude vs the altitude target.
- Velocity PIDs (`GPS_RESCUE_VELOCITY_P`, `GPS_RESCUE_VELOCITY_I`, and `GPS_RESCUE_VELOCITY_D`)are best adjusted after setting the altitude PIDs. They directly control the pitch angle of the quad. Too much P and/or D may cause slow oscillations on pitch. Too much I may cause overshoot. `DEBUG_GPS_RESCUE_VELOCITY` shows P and D with the speed to home and velocity targets. Tune these with zero I. Then add I until any residual over- or under-shoot is eliminated. Too much I will cause slow ongoing wobble.
- The defaults should be 'about right' for a typical 5" freestyle quad.

- The quad targets velocity in the direction of home. If it must fly into wind, the maximum angle (set by `GPS_RESCUE_ANGLE`), must be sufficient for the quad to overcome the wind. Provided the angle is sufficient, the return home velocity should be reasonably accurately maintained. `GPS_RESCUE_VELOCITY_I` is important when flying into the wind. On windy days, always confirm that the quad can overcome the wind. A lot of battery power can be consumed flying into the wind, always consider this when thinking about how far you fly out with the wind behind you.

Expected Behaviors

- The disarm switch should remain active during switch-induced failsafe, including GPS Rescue. Take care with disarm if the craft is configured to reset the home point after a disarm.
- To prevent flyaways, the low satellite sanity check will abort the rescue if satellite count falls below half the set GPS Rescue minimum sats for a cumulative increment/decrement period exceeding 10s.
- At the point of initiation of a rescue, if the basic initial sanity checks fail (eg not enough satellites), there is a 20s 'do nothing but hover' period, before the craft disarms. This applies, for example, in video loss scenarios where the pilot hits the switch and perhaps there were not enough satellites at the time. The craft should level out at the hover throttle value and wait for pilot input or for the sanity check to get corrected.
- Even if all sanity checks are disabled, there is now an incremental up/down limit of 20s of sanity failure before the quad will be disarmed. In other words, the quad will disarm itself, even if all sanity checks are 'off', in extreme failures of this kind. If you don't like this, speak up. It is a safety feature to prevent otherwise indefinite flyaways that could occur if sanity checks are disabled by the user. The all sanity checks off option is intended only for testing, not for actual use.
- The minimum velocity required for IMU orientation from a GPS over-ground path is 2m/s
- When GPS Rescue is switch-initiated via a failsafe switch, there is no need to move the sticks more than 30% to regain control. Control is regained immediately the switch is reversed.
- Minimum initiation distances of 20m, and altitudes as low as 2m allow closer range LOS setup, testing and tuning. Closer distances may be useful when GPS Rescue is used as a emergency safety switch for LOS beginners.
- The default minimum initiation distance of 30m and minimum initiation altitude of 5m allow easier setup and testing in a small park.
- GPS distance from home is measured and logged in cm (not meters) and angle in tenths of a degrees (not degrees) to improve accuracy and smoothness.

- If the user initiates GPS Rescue on a switch, the Aux channels are still "live". This allows disarming, starting or stopping logging, etc, during a switch induced failsafe. Flight channels (RPTY) will be set or held according to failsafe settings, and are live stick values are never passed during a failsafe, though the stick position is monitored since 30% stick wiggling is needed to exit GPS Rescue by stick movement.
- For all switch initiated rescues, if the pilot realises the rescue is failing, the switch should be reverted, and the pilot should regain control before the situation becomes irrecoverable.
- pitch angle change is limited to 25 deg/s.
- ascent and descent rates are user-configurable.
- max descent rate, when dropping from considerable height, is 2x the configured descent rate, reducing proportionally to the set descent rate as the craft gets closer to ground level.
- roll is mixed with the yaw correction to better maintain the intended path to home, especially in wind
- the default amount of roll is set as a percentage of the yaw value, with the default at 100 resulting in equal roll and yaw for small yaw rates, linearly reducing to no roll component at high yaw values
- GPS Rescue settings are now included in the blackbox log header fields.
- Debugs to compare set altitude and velocity are provided

Problems and solutions

Problem	Solution
Can't arm	GPS hasn't enough satellites. 10 is best. Be patient.
Floats around on switch initiation	In "Do nothing" mode due to failure to initialise, reverse the switch
Doesn't level out for 1 second	Wasn't set to enter level mode in Stage 1 failsafe
Suddenly drops on initiation, but recovers	Stage 1 throttle value set too low, or not set
Drops 1s after initiation, stays low	GPS Rescue hover throttle value set too low

Problem	Solution
Tracks to one side during return	Level mode not calibrated properly, or calibration lost during flight
Drifts in final landing phase	Level mode not calibrated properly, or lost calibration during flight
Disarms while flying home	Not within 50% of target velocity or altitude for 20s or more in fly home phase
Altitude on return consistently low or high	Hover value not set correctly, not enough throttle I
Altitude on return randomly low or high	GPS Altitude drift - check its stability before takeoff
Altitude overshoots at start	Normal behavior
Altitude droops below target at start	Set a higher altitude buffer if using current altitude `gps_rescue_alt_buffer`
Altitude droops below target at start	Throttle P and D too low
Altitude wobbles quickly during return	Throttle P and D too high
Altitude wobbles slowly during return	Throttle I too high
Long delay before turning	Delay reaching target altitude - large climb distance with ascent rate too slow
Long delay before turning	Delay reaching target altitude - hover value too low
Goes in wrong direction on initiation	Didn't fly forward at > 2m/s long enough for IMU to calibrate to GPS

Problem	Solution
Goes in wrong direction on initiation	Random unknown longstanding bug causing incorrect IMU heading value
Goes in wrong direction on initiation	Mag is used but is reporting bad information
Pitch wobbles up/down quickly during return	Normally present; Pitch P and D may be too high
Pitch wobbles up/down slowly return	Pitch P and D are too low, or pitch I is too high
Overshoots target on landing	Pitch I is too high, descent too fast or short
Yaw wobbles left/right all the time	Yaw P too high (unusual)
Yaw control is loose	Yaw P too low (likely only on large machines)
Landing is hard and doesn't disarm	GPS Altitude drift downwards, hits ground before landing altitude is reached - check GPS altitude stability before takeoff
Large control jumps every second	GPS unit is reporting values only once a second. If NMEA, use UBlox mode

Sanity Check Options

Sanity checks monitor the rescue. They do this for both switch-induced, and real loss, GPS Rescues. They are last ditch responses to a failure of the rescue process. They validate that:

- the Rescue system has a Home Point to aim at
- the craft is outside the minimum distance at the start of the rescue
- satellite count is OK at the start of the rescue
- the satellite count stays OK during the rescue

- during the `ASCEND` phase, the quad is not stuck in a tree or otherwise can't climb
- during the `FLY_HOME` phase, that velocity to home is at least half the set velocity during the fly home phase
- during the `LANDING` phase and descent phase, that the descent rate is at least half the set descent rate (not stuck in a tree)

When a sanity check fails, it means that the craft cannot complete the rescue successfully. It either has no idea where to go, or is already going in the wrong direction, or is stuck in a tree or something. After some reasonable time, the craft should be disarmed so that it will fall without travelling much further, climbing too high, flattening the battery or burning the motors. Each possible failure has a 'grace period' before the quad will disarm.

Sanity checks do not cover every failure possibility. There is no check on absolute altitude during the fly home phase, for example. If sanity checks are too aggressive, they can cause false or premature termination of the rescue, leading to an unnecessary disarm and crash. It is very difficult to find the right balance.

Note that 'performance based' sanity checks rely on GPS data. False or erratic data may not only send the craft the wrong way (without us having any way of knowing), it may also falsely trigger a sanity check, or may prevent sanity checks from identifying a true failure.

A sanity check failure due to GPS signal loss will inevitably be a disarm the craft, to prevent indefinite flyaways. For switch-induced failsafe, sanity checks have an extra delay period, to allow the pilot time to reverse the switch.

There are three sanity check modes:

- `RESCUE_SANITY_ON` - this gives the strongest sanity check behavior, with immediate disarm for hard errors like loss of GPS communication, flyaway, low sat count, and no home point on initiating the rescue. These responses will be the same whether the rescue is 'real' or if it was initiated by a switch.
- `RESCUE_SANITY_FS_ONLY` - this is the default mode, giving strong sanity check behavior for true RC link loss, but additional time to reverse the switch for switch-induced failsafe. For example, the quad will enter "Do Nothing" mode for 20s if a rescue is initiated by switch and there is no Home Point.
- `RESCUE_SANITY_OFF` - this is intended for testing only. When in this mode, the quad will immediately disarm only if arming without a Home Fix was permitted, there is no Home Fix, and there is a hard (Rx Link Lost) failsafe. In all other cases a failed sanity check results in "Do Nothing" mode for 20s and then a disarm. For safety reasons - to prevent indefinite flyaways - it does not not turn "all sanity checks off" anymore.

For sanity checks with a time element, we use a cumulative up/down counter. Starting from zero, the counter increases by 1 every second the value is 'bad', and decreases by 1 every second it is 'good'. Once the accumulator reaches the sanity check time-out, the sanity check fails.

This table explains the currently implemented sanity checks.

Mode	`SANITY_ON`, or true failsafe in `SANITY_FS_ONLY`	Stick induced `SANITY_FS_ONLY`, or `SANITY_OFF`	Notes
No Home Fix on initiation	Immediate disarm	`Do_Nothing` for 20s then disarm	Usually it is impossible to arm with no home fix.
Initiate inside min DTH	immediately enters landing mode	immediately enters landing mode	Craft should slowly land itself and disarm on touch-down
GPS hardware failure	immediate disarm	disarm after 10s	Should never occur mid-flight
Initiate but in crash recovery mode	immediate disarm	disarm after 10s	GPS Rescue cannot function while in crash recovery mode
Climb Phase failure	disarm after 10s	disarm after 10s	climb rate less than half the set rate for cumulative 10s
Low Sats	disarm after 10s	10s, `Do Nothing` for 20s, then disarm	sat count less than half the GPS Rescue minimum number for cumulative 10s
FlyHome failure	15s then disarm	15s, `Do Nothing` for 20s, then disarm	can't maintain at at least half the set velocity in the

Mode	`SANITY_ON`, or true failsafe in `SANITY_FS_ONLY`	Stick induced `SANITY_FS_ONLY`, or `SANITY_OFF`	Notes
			direction of home for cumulative 15s.
Landing Phase failure	10s then disarm	10s then disarm	descend rate less than half the set rate for cumulative 10s

- 'Do Nothing' centers sticks and hovers to give the user time to reverse the failsafe switch, if used, or in case you just get lucky and signal comes back.

** In `SANITY_OFF` mode, the craft can be armed with no home fix, but the rescue will fail, and the craft will disarm and crash after 10s of hovering, whenever the pilot attempts to enable a GPS Rescue.

Switch initiated GPS rescue may be helpful when FPV video is lost. The quad should quickly climb high enough to get video back. If something prevents the climb, the craft could be flying away in a weird direction, or stuck in a tree, or almost anything. Hence, if the video has not come back within 20-30s, it's best to undo the failsafe switch, disarm, and start searching. This will keep the quad relatively close to the point of video loss, and retain battery capacity by turning the motors off.

GPS_RESCUE_ALLOW_ARMING_WITHOUT_FIX

When GPS Rescue is enabled, arming is not permitted unless there is a GPS position fix and we have at least the required minimum number of satellites, set by `gps_rescue_min_sats`. This check can be bypassed by enabling `allow_arming_without_fix`.

When arming is permitted without a fix, and the machine is armed without a Home Point being set, and a GPS rescue is initiated, the craft will go into 'do nothing' mode (slow descent with landing detection enabled) for 20s then disarm. This will happen both for true RC Link loss failsafe, and for switch-initiated failsafe tests. It will not fly home under any circumstances, because it has no clue where home is. The 'do nothing' period of 20s exists only to give the pilot time to undo the switch if they realize that the quad is not going to return.

Never allow arming without a home point fix if you want GPS Rescue to get you home!

This option exists only for testing purposes.

DEBUGS

There are 4 debugs for GPS Rescue, of which the `GPS_RESCUE_TRACKING` debug gives a good overview of set vs achieved altitude and velocity. When checking out the altitude PIDs, use the `GPS_RESCUE_THROTTLE` debug, and for velocity home (pitch control) PIDs, use the `GPS_RESCUE_VELOCITY` debug. The `GPS_RESCUE_HEADING` debug is useful for checking heading related information, and can be used to compare GPS headings to magnetometer headings. Compass/Mag headings are always logged whenever a Mag is active.

All the GPS configuration settings are included in the Blackbox Log Header.

Name	Debug0	Debug1	Debug2	Debug3
GPS_RESCUE_THROTTLE	Throttle P	Throttle D	Current craft altitude, cm	Target altitude cm
GPS_RESCUE_VELOCITY	Velocity P	Velocity D	Current craft velocity cm/s	Target velocity cm/s
GPS_RESCUE_TRACKING	Velocity to home cm/s	Target velocity cm/s	Current craft altitude cm	Target altitude cm
GPS_RESCUE_HEADING	Yaw rescue rate deg/s * 10	Roll angle degrees * 1000	Estimated craft heading deg * 10	Estimate angle to home
GPS_RESCUE_CONNECTION	GPS dyn model requested	GPS Nav Data interval ms	time since last Nav data ms	Baud rat requeste
RTH	Max Altitude	Current Altitude	Rescue failure code	Seconds failing

Name	Debug0	Debug1	Debug2	Debug3
			(*10) + Rescue Phase	sanity (*100) + Seconds low sats
ALTITUDE	GPS Trust * 100	Baro Altitude cm*	GPS Altitude cm (zeroed on arming)	Vario*
ATTITUDE	AccADC Roll	AccADC Pitch	cogYawGain * 100	ez_ef * 100

Notes:

- Baro Altitude is zeroed and smoothed on arming
- Vario is smoothed only while armed, and is only present if Vario is enabled in the firmware build
- GPS connection Nav Data interval is the time between GPS packets by comparing their time-stamp
- GPS connection time since last Nav data is a stepped ramp, stepping up each time the GPS code runs, and resetting when new Nav data arrives.
- GPS connection dynamic model requested is normally 1 (default acquire model) at the start and 7 (default flight model) when we gain a 3D fix
- GPS connection state is calculated as main State * 100 + step, eg 413 is in the `CONFIGURE` main state, at step 13
- GPS connection Ack state is calculated as 0 = `IDLE`, 1 = `WAITING`, 2 = `ACK`, 3 = `NACK`

Rescue Phase codes

```
0    RESCUE_IDLE,
1    RESCUE_INITIALIZE,
2    RESCUE_ATTAIN_ALT,
3    RESCUE_ROTATE,
4    RESCUE_FLY_HOME,
5    RESCUE_DESCENT,
6    RESCUE_LANDING,
7    RESCUE_ABORT,
8    RESCUE_COMPLETE,
9    RESCUE_DO_NOTHING
```

Rescue Failure codes

```
0    RESCUE_HEALTHY,
1    RESCUE_FLYAWAY,
2    RESCUE_GPSLOST,
3    RESCUE_LOWSATS,
4    RESCUE_CRASH_FLIP_DETECTED,
5    RESCUE_STALLED,
6    RESCUE_TOO_CLOSE,
7    RESCUE_NO_HOME_POINT
```

Normal RTH Debug 2 progression - usually no error codes

Code seen	Phase	Notes
0	`RESCUE_IDLE`	Normal phase when no rescue is active
1	`RESCUE_INITIALIZE`	usually too brief to be seen in OSD or log
2	`RESCUE_ATTAIN_ALT`	climbing phase, no yaw
3	`RESCUE_ROTATE`	rotating (yawing)
4	`RESCUE_FLY_HOME`	pitches forward and flies home at set altitude
5	`RESCUE_DESCENT`	slows down and descends
6	`RESCUE_LANDING`	below landing altitude, waiting to hit ground
8	`RESCUE_COMPLETE`	too brief to be seen in OSD
0	`RESCUE_IDLE`	returns to idle

Some RTH Debug 2 errors (failure * 10 plus phase)

Code seen	Failure	Phase	Notes
17	`RESCUE_FLYAWAY`	`RESCUE_ABORT`	aborted the rescue due to a fly home failure

Code seen	Failure	Phase	Notes
19	`RESCUE_FLYAWAY`	`RESCUE_DO_NOTHING`	entered a `DO_NOTHING` state due to fly home failure
39	`RESCUE_LOWSATS`	`RESCUE_DO_NOTHING`	entered a `DO_NOTHING` state due to low sat count
69	`RESCUE_TOO_CLOSE`	`RESCUE_DO_NOTHING`	entered `DO_NOTHING` phase due to initiation too close

There should never be a failure code in the 'tens' column of Debug 2; the failure code should always be zero, meaning `RESCUE_HEALTHY`. An active failure code will trigger either `RESCUE_DO_NOTHING`, `9`, or `RESCUE_LANDING`, `6`, or `RESCUE_ABORT`, `7`, depending on the settings (see the sanity check table, above). NB: some events will be too transient to visualise in OSD or even to be logged.

RTH Debug 3 (sanity check counter) examples

Debug 3 should normally be zero. If the sanity check time-out counter is non-zero, the value will be shown in the hundreds column. When a sanity check isn't correcting itself, the value in the hundreds column just keeps incrementing until it hits its limit. Seconds failing is calculated so that:

- values in the hundreds indicate the time in seconds that the sanity timer accumulated
- values in digits indicate the accumulated low sat time

Code seen	Notes
0	Normal state = sanity check timers are zero, sats are more than half minimum
100	a sanity check has failed for 1s, satellite count is good
200	a sanity check has failed for 2s, satellite count is good
1203	a sanity check has failed for 12s, satellite count has been low for 3s

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