Return to Home

An unsystematic report on the experiment to have a radio-controlled model glider airplane return home autonomously.

While there exist onboard systems especially designed for this task, I have used standard RC components only. The experiment has resulted in a setup, where the model glider approaches the home position in **most** situations. The solution does not cover cases, where the model is flying too low to keep free of all obstacles without motor.

This report does not intend to offer a how-to guide. A completely watertight solution, as for example known from multicopters, does not seem possible with the approach described here. A better result might be achieved by coding a LUA app.

The experiment was for me a great way of learning the capabilities of the Jeti Duplex transmitters and receivers. This report will also serve me in setting this up for those of my other glider models, which are already equipped with a Jeti Duplex Assist receiver.

Components used

The radio control system consists of a **Jeti DC 16 (2016) transmitter** with a **Jeti REX 10A receiver.** The "A" denotes "Assist". This Assist receiver provides an integrated gyro system for stabilizing all 3 axes of the model plane.

For the location and direction information a **SM GPSLogger3** is used as sensor connected to the REX 10A receiver.

The glider model is a **NAN Orion with a wingspan of 2.4 m**, X-tail, electric motor, ailerons, flaps, elevator and rudder.

Basic concept

For the autonomous returning a separate flight mode Return to Home (R2H)[1] is established. This flight mode is forced by pressing a **push-button**. Your might call this push button the "panic button". To prevent that the model is unintentionally operated in R2H mode, this mode is only active as long as the push-button is pressed.

In R2H mode two processes are executed in parallel:

1. The glider model is stabilized to horizon mode by the gyro system of the receiver.
2. The model is steered into a turn, which will make it fly over the home position. This steering is performed by the transmitter based on the direction information provided by the GPSLogger.

1 Text in this font designates names, which I have assigned in the setup described here.

Implementation

In a first step horizon stabilization has been implemented. Once the model kept a stable horizontal positioning, the turning was implemented in a second step. Since the turning added additional instability, the horizon stabilization needed to be adapted to it in a third step.

Horizon stabilization

There are various sources for instructions for setting up the stabilization with Jeti Assist Receivers: The **Jeti Duplex receiver manuals** offer

- a short explanation of the Assist setup in [1]
- and the complete information in [2].

In addition I have found following **Youtube video tutorials** helpful:

- from Ingmar Grote [3] and
- from Harry Curzon [4] and following episodes.

The assist receivers allow using three different stabilization schemes: **Three assist modes, M1, M2 and M3** are defined and at any point in time the receiver operates in one of these three modes. I am using these three modes as follows:

- **M1 = Manual (Assist off)**, used for all flight modes other than takeoff/landing and R2H
- **M2 = Normal (Damping)**, for aileron damping during takeoff/landing. The stabilization gain for the elevator and rudder is set to minimum (no damping of these axes).
- **M3 = Horizon Hold**, for the Return to Home flight mode exclusively

Selecting the mode is done through channel 11. This channel is driven through **function** Stabi Mode, which has a flight mode dependent **Function Curve** and no associated control. The function curve is just a constant, which is +100 in flight mode Return to Home, 0 in flight mode Landing (also used for launch) and -100 in all other flight modes.

The Return to Home flight mode is only active as long as **push button** Si is pressed. This will prevent that the model is flying autonomously just because I overlooked that a switch is set.

The gain of the stabilization for all three axes is controlled by the same proportional control P5. **Each axis has its own function with a separate function curve and its own channel.**

Functions Assignment: [2]

Number	**Function**	**Control**
1	Aileron	P1
2	Elevator	P2
3	Rudder	P3
4	Throttle	P6
5	Flaps	P5

2 These tables where obtained from the model jsp file using **jemoview [5]**

6	Stabi Mode	-
7	Turning	MX3
8	StGainRoll	P5
9	StGainNick	P5
10	StGainYaw	P5

Servo Assignment:

Channel	Servo
1	Throttle1
2	Aileron1
3	Flap1
4	Flap2
5	Aileron2
6	Elevator1
7	Rudder1
11	Stabi Mode
13	StGainRoll
14	StGainNick
15	StGainYaw

Flight Modes:

Number	Label	Delay	Switch	Audio
1	Return to Home	0.0s	SI ↑	F-RETU~1.WAV
2	Landing	0.0s	SA ↑	F-LAND~1.WAV
3	Thermal	0.0s	SB ↓	F-THER~1.WAV
4	Speed	0.0s	SB ↑	F-SPEED.WAV
5	Cruise	0.0s	is default	F-CRUISE.WAV

Since it took me a while to find and to understand the working of the stabilization gains, I am repeating the formula for the gains here:

Effective gain = (Function Gain * ((Default Gain / 50) + (Tuning Gain / 100)) [6]
with

- Function Gain being specified per each of the three axes and per damping and holding
- Default Gain being specified per each of the three assist modes M1, M2, M3
- Tuning Gain being specified through the Gain Tuning Channel (here 13, 14 and 15)

The net seems to me that the Default Gain has a significant role when no Gain Tuning Channel is used (Tuning Gain = 0). In contrast, the Function Gain has always a strong influence.

Turning

Once the model kept flying stable horizontally in the Return to Home flight mode, it was time to add the logic for turning home.

The home point

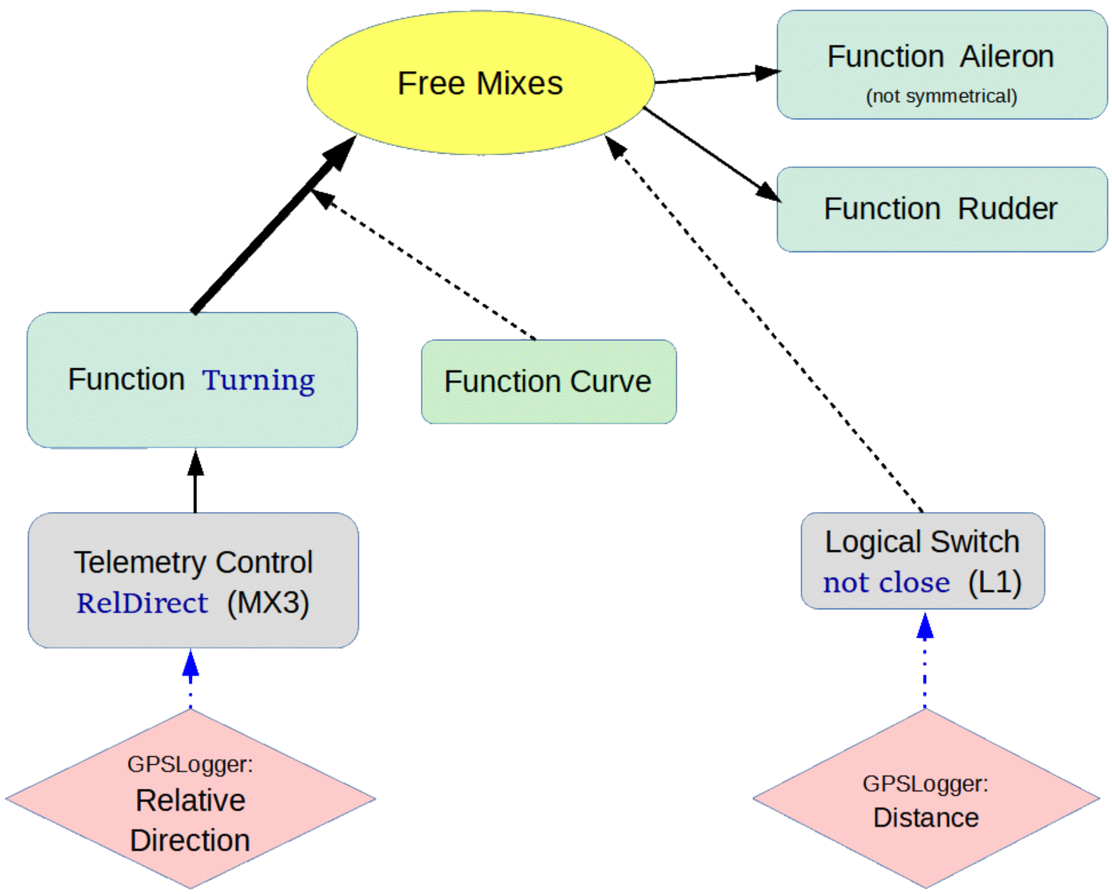
The SM GPSLogger3 sends among a multitude of data the relative direction of the model's course. The **absolute direction** is 0° for North, 90° for East, 180° for South and 270° for West. The **relative direction** is 0° when the model is flying away from the **reference point**, 180° when it is flying towards the reference point, and 90° when flying from left to right seen from the reference point. This reference point is the home point for our Return to Home flight mode.

Our home point (the reference point) can be set explicitly. When not set explicitly it defaults to the point, where the GPSLogger acquired the satellite fix after power up.

Steering towards the home point

When the **relative direction** is 180° the model is flying towards the home point. When the relative direction is between 0° and 180°, the model needs to keep turning right until 180° is reached. When the relative direction is between 180° and 360° a left turn is needed to return home. When the relative direction is 0°, both directions are appropriate for turning home.

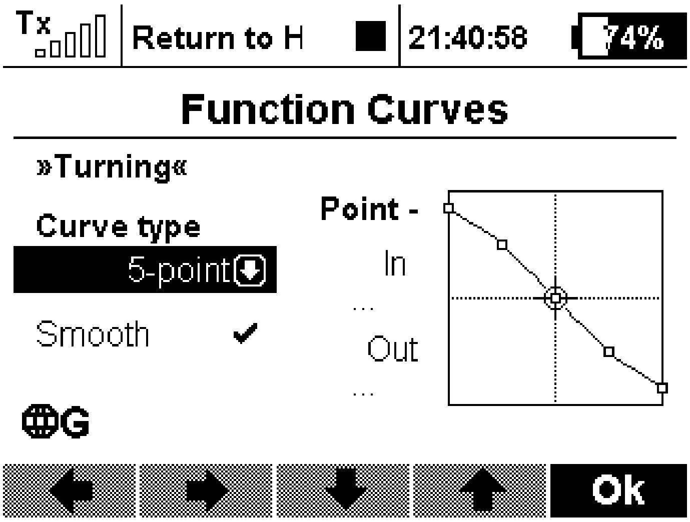
The turning is driven through free **mixes on aileron and rudder**. Mixing an addition to the rudder alone was not considered sufficient, as the horizon stabilization would prevent banking of the model. Therefore the model probably would slip instead of performing a decent turn.



The mix-in amount is generated in the function Turning, using an associated function curve. The input control to this function is a telemetry control which I called RelDirect. Reldirect is based on the GPSLogger sensor output relative direction and spans from 0 to 359 (degrees).

- At a relative direction of 180° we would like a mix-in of 0.
- At relative directions close to 0° we would like a significant positive mix-in for steering a right turn.
- At relative directions close to 359° we would like a significant negative mix-in for steering a left turn.
- At relative directions slightly less or greater than 180° we would like a small mix-in.

This behavior is achieved through the function curve associated to the function Turning:

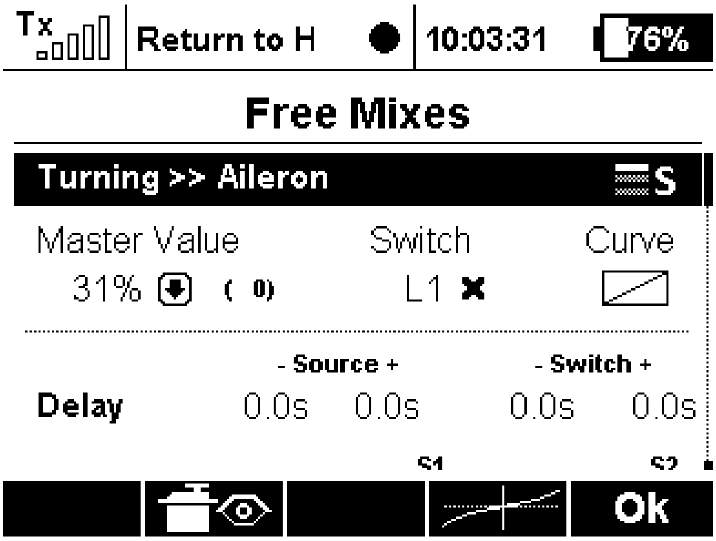


Function Curve for Function Turning

A difficult question is what kind of steering to apply to the model once it is close to home. The current thinking is that the pilot should recapture manual control. During the Return to Home phase the distance to the home point is continuously stated as an alarm voice output. This should let the pilot know when to expect the model overhead.

As long as the pilot does not take over control by letting go of the push button, the model will get into an away flight and the turning will start all over. This might lead to a more or less chaotic flight pattern.

Alternatively the model could be left to fly away on a straight course again, until a certain distance is reached again. When outside of the close area the turning would start again. To perform turning or to suspend it, the logical switch not close (L1) is specified together with the free mixes.



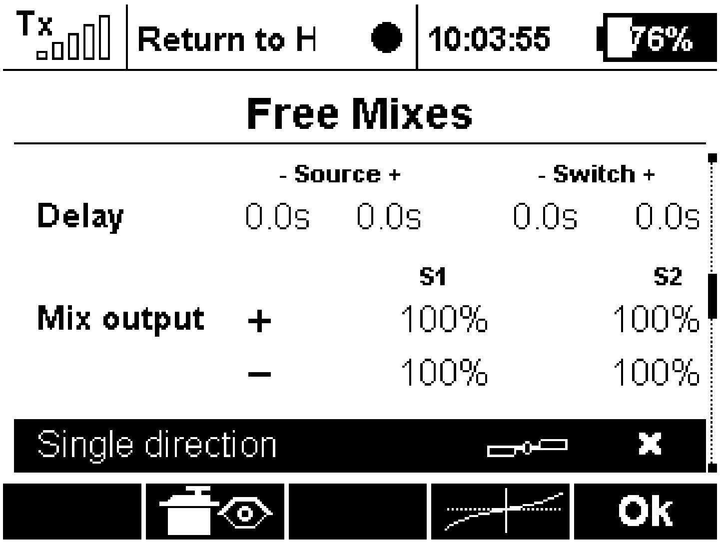
Logical switch L1 (not close) switches turning on/off

Tests and debugging

Testing the turning is hardly possible without moving the model. I assume that the GPSLogger calculates the relative direction based on the change in position. Therefore the model must either be flown or carried around on the ground.

I thought I would rather fly. But since I could not see the movement of ailerons in the air and since I had not logged both aileron channels, I did not notice that both aileron surfaces where always deflected in the same sense, like in Butterfly. Therefore in the first tests I saw the model fly horizontally as if there would be no steering at all.

Going through the menus again and again I discovered that the mix-in to aileron has a choice "Single direction" on/off. Single direction = on is the default and lets both aileron surfaces move in the same direction, up or down. What I needed for turning was single direction = off:



*The mix-in to aileron must **not** be **Single direction***

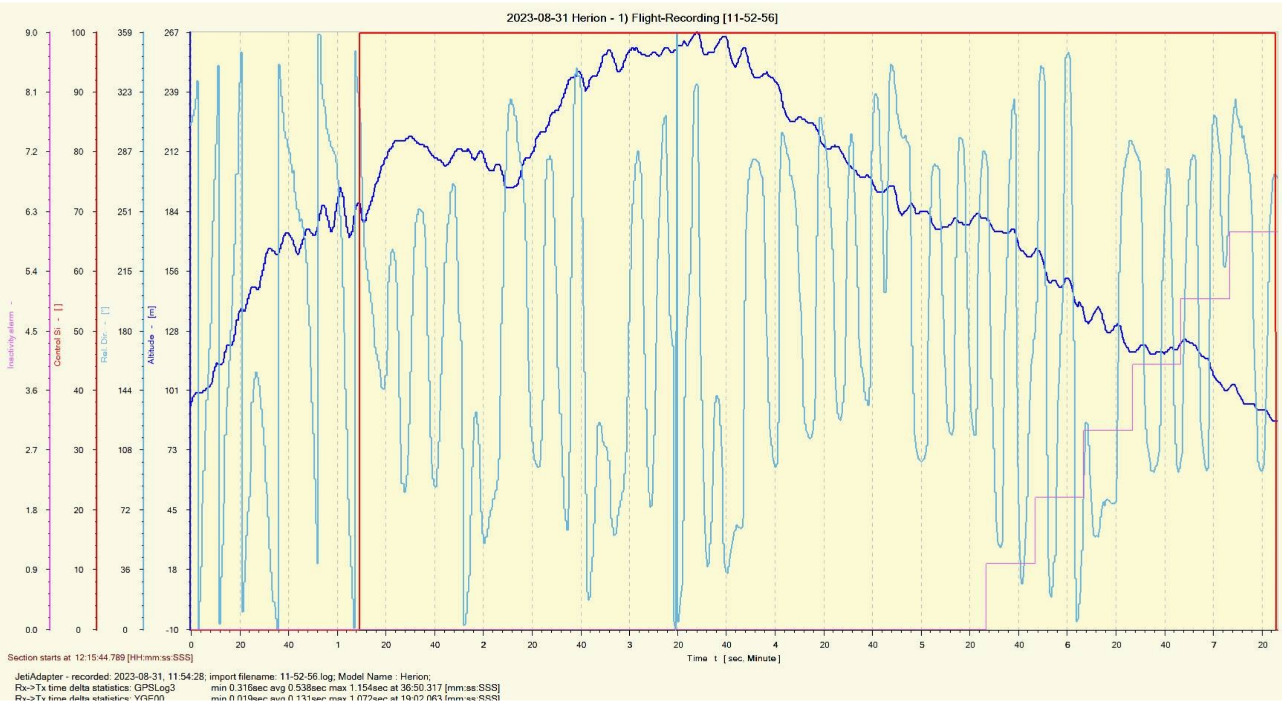
Once the mix-in to the aileron was **asymmetrical (Single direction = off)**, the next attempt had the model repeatedly turn onto a fly-away course. The function curve for Turning was not correct yet.

With the correct function curve the next tests showed a turning into a course for returning home. However, the turning was too little and I did not dare to let the model temporarily fly beyond my viewing distance. Therefore I increased the Turning mix-in to aileron and rudder.

The next tests with stronger mix-in values resulted in sharper turns. These turns where adequate for many situations. However, once it happened that the turn was sharp and the model started descending rapidly.

I varied the stabilization gains for all three axes, especially for the elevator. In later tests I arrived at a behavior, where the model returns to the home position quickly and then stays there taking various turns.

One sample from the test of 2023-08-31 is presented in Gnu Data Explorer's display of telemetry values. Gnu Data Explorer (GDE) [7] has the attractive capability to present the corresponding trace in the Google Earth view. This trace will also be shown.



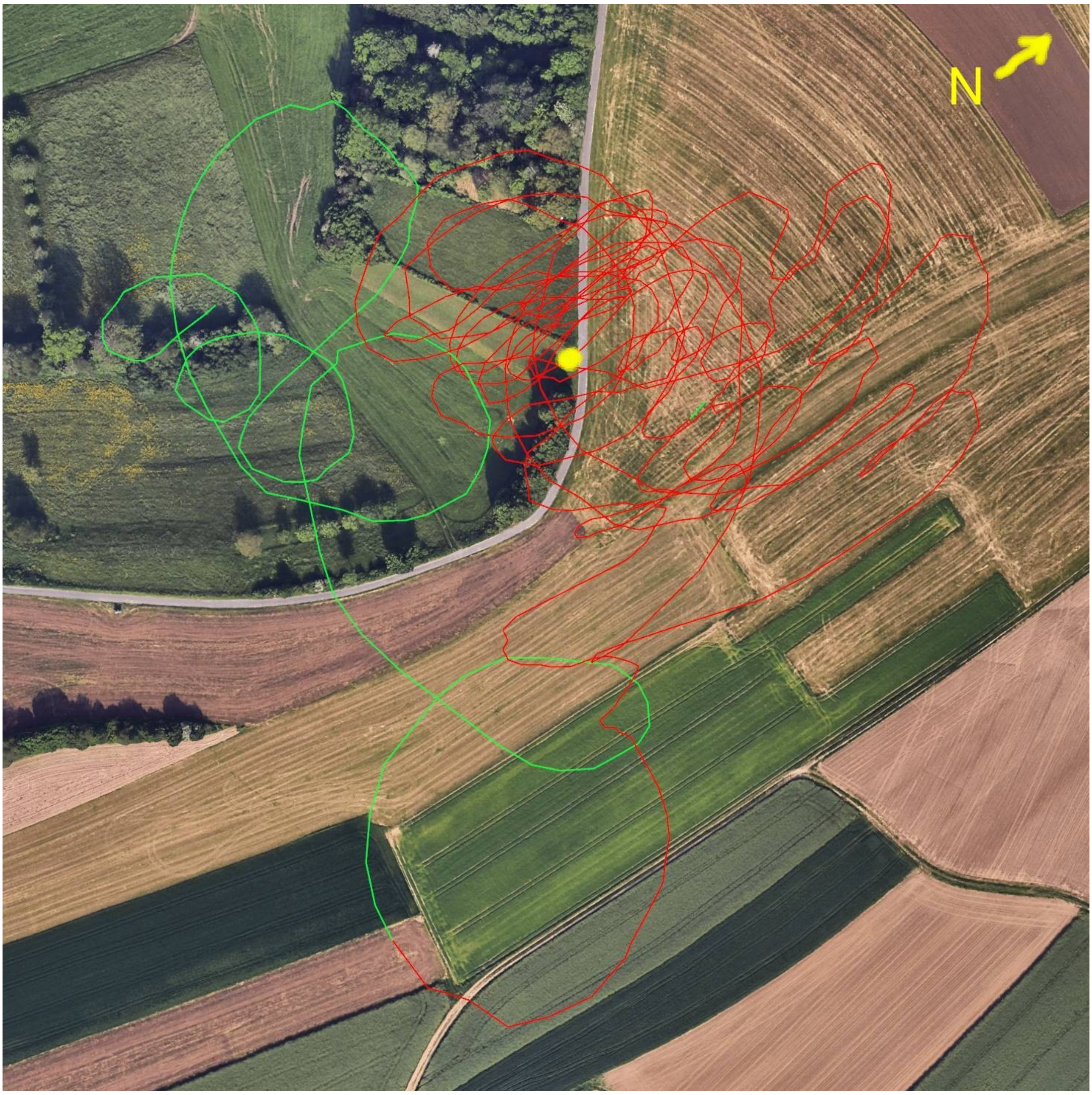
In red we have the push button signal. I have pressed the button starting at 1:10 and released it at 7:25. The model was flying autonomously for 6 minutes and 15 seconds. After about four minutes, around 5:30, the transmitter started raising inactivity alarms (magenta line stepping up each 20 seconds). My finger starting to become numb was not logged by the telemetry.

The line in light blue shows the relative direction, which oscillates between 0 and 359 degrees. During this phase I had the model circle in a thermal to gain altitude. Until 0:20 the line climbs from 0 to 359 and quickly drops to 0 to resume climbing again. This corresponds to a clockwise circling. Then it changes to decrease from 359 to 0 degrees and quickly jumps to 359 again. This corresponds to a counterclockwise circling.

As soon as the push button is pressed, the circling changes into a oscillations with smaller changes in the relative direction. This was a random pattern of turns, eights and loops.

The dark blue line represents the relative altitude. The model was in a good thermal uplift until 3:40.

The birds view representation of the models trace is using two colors: In green we have the pilot controlled flight mode. The red line shows the trace of the autonomous flight mode Return to Home:



The home point is marked by a yellow dot. The wind was about 5 m/s from West (upper left corner to lower right corner).

In green we see the circling in the thermal uplift, first clockwise, then counterclockwise. As the button is pressed and the color changes to red, the model is quickly turning towards the home point and approaching it with oscillations to the right and left. After that we see that the model is more slowly heading upwind in oscillations, then sometimes quickly drifting further downwind and then again travelling more slowly upwind.

Overall the behavior appeared quite reliable. I did not feel uncomfortable while looking away for ten seconds.

Points to watch out for

Let the model power up at the position where you will be standing during the time of flight. Check that the GPSLogger has acquired the satellite fix. This will make your position during flight the home point to return to.

Thoughts on further experimentation

Optimized behavior once the model is home

At this time the not close switch is not operational. It might add a bit more reliability to have the model fly a straight course until it leaves the proximity zone and then return in a wider curve with more speed. But an additional difficulty is that the telemetry reading for distance is dependent on the altitude (in 3D mode). I would not want to always use the GPSLogger in 2D mode just for the rare case of using the Return to Home flight mode. On the other hand I currently do not see a way of basing a logical switch on the difference of two telemetry values. Writing a LUA would certainly have a great advantage here.

Butterfly addition for excessive altitudes

Does it make sense to add Butterfly as long as the model is higher than a certain limit? This certainly would be very simple to implement. In the same way as basing a mix-in to aileron and rudder on the relative direction, a mix-in to the flaps can be based on the relative altitude. The horizon stabilization would make it unnecessary to add an appropriate signal to the elevator.

At the mini slopes where I am flying it is very rare to have a spectacular thermal uplift. Therefore I have not addressed this additional safe-guarding yet.

References

1: Basic Manual for REX Assist - English, https://www.jetimodel.com/uloz/basic-en-2022-2-web-1678969662.pdf/?1693553125

2: Manual for Duplex receivers "REX Assist" - English, https://www.jetimodel.com/uloz/993e41c6-2893-456a-b31f-99a715e37111.pdf/?1693553125

3: Grundeinstellung eines Jeti Assist Empfängers, https://www.youtube.com/watch?v=q0eRO7slj0A

4: Jeti - Assist episode 1 (.. episode 9), https://www.youtube.com/watch?v=jXLToBgaeYs

5: jemoview - Jeti Model Viewer,   https://github.com/werinza/jemoview
6: Jeti - Assist episode 9,   https://www.youtube.com/watch?v=m5Wict-FBuo
7: Gnu Data Explorer,   https://www.nongnu.org/dataexplorer/