

# Ultrastick Flight Test Analysis: I

Rohit Pandita

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## 1 Flight Test No.1, 06 October 2007

Meteorological conditions: Moderate/Strong Winds, Gusting, ambient temperature 70 – 80degF.

### 1.1 Flight-1: Pitch and Roll Attitude Hold Autopilot test

In this autopilot mode, pilot's elevator and aileron stick positions are interpreted as pitch and roll attitude reference respectively. Pitch command authority is limited to  $+/- 30$  degrees and the roll  $+/- 50$  degrees. Pilot retains control of throttle and rudder, albeit through the flight computer. After take-off and climb, autopilot was engaged, after initial period of familiarization the pilot was able to fly the air vehicle in controlled trajectories successfully. In a test case, the air vehicle was put in a dive while in *manualmode* followed by engaging autopilot (with stick in neutral position), as expected autopilot was able to pull the air vehicle out of the dive and level out.

...data awaited...

### 1.2 Flight-2: Airspeed Hold (IHD) Autopilot test

In this autopilot mode, upon enabling, the current airspeed is latched as *referenceairspeed* and the autopilot tracks the reference by modulating pitch attitude based on the tracking error signal. Pilot retains control of throttle, ailerons and rudder through the flight computer.

In this test, some basic maneuvers like turning with autopilot engaged were tried, and the airspeed tracking was found satisfactory. In another test, climb and dive maneuvers were executed by increasing and decreasing throttle, respectively, from the ground. Again, the autopilot responded favorably by pitching the air vehicle up while at high throttle, resulting in a climb and vice-versa. Figures 1,2 and 3 show the various flight parameters. Around

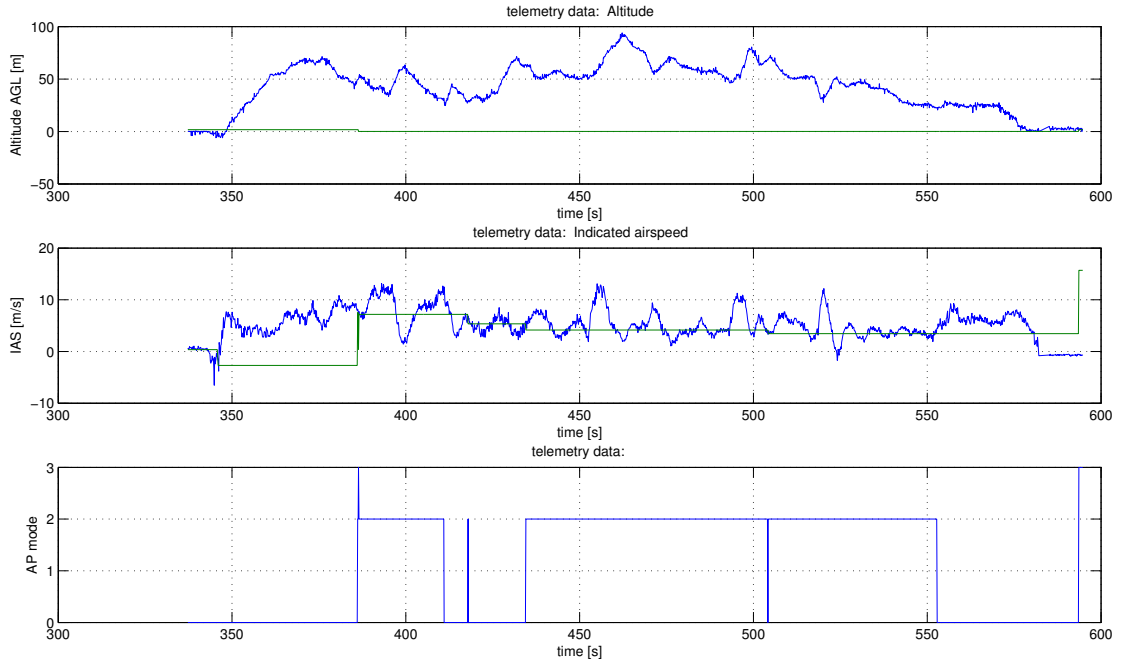


Figure 1: Airspeed hold autopilot test: Altitude, Indicated Airspeed, Autopilot Mode

450 seconds, the effect of throttle increase and subsequent climb can be seen. Also, around 525 seconds, the effect of reduced throttle is evident, the air vehicle loses altitude, while maintaining airspeed around the commanded reference.

During the period of IHD autopilot engagement (between 440 and 550 seconds), the air vehicle also executes roll maneuvers in the range of  $\pm 50$  degrees.

### 1.3 Flight-3: Fully autonomous Waypoint navigation (WPN) mode, first attempt

Waypoint mission plan was set to three points (X,Y),

1 : (0, -150)

2 : (100, -50)

3 : (0, 0), *thelaunchpoint*

Indicated Airspeed (IAS) reference was set to 7 m/s (inclusive of the offset error of approximately  $-3$  to  $-5$  m/s observed in IAS just prior to take-off, the reason for which is still unresolved and it varies for different flights. True IAS reference is hence expected to be around 10 – 12 m/s). Altitude reference was set to 100 meters Above Ground Level (AGL). Due to a bug in the autopilot software, computations were incorrect and waypoint navigation performance was undesirable. The bug was subsequently tracked down and rectified. However in this mode, the IHD and the Altitude hold (AHD) modes were active

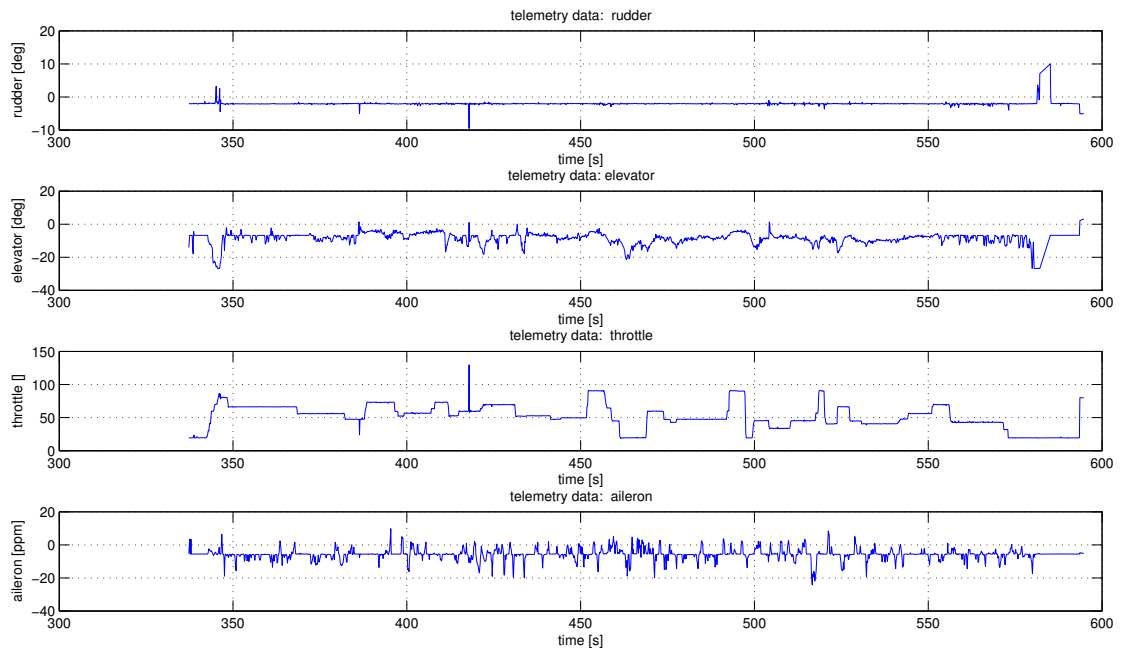


Figure 2: Airspeed hold autopilot test: rudder,elevator,throttle,aileron

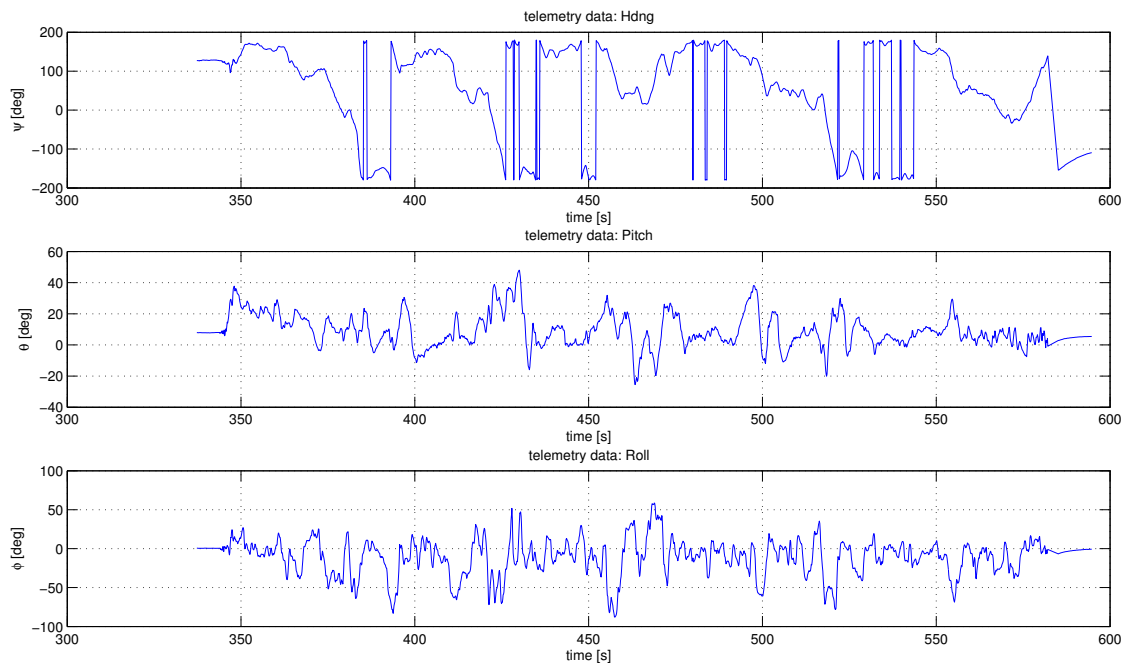


Figure 3: Airspeed hold autopilot test: Psi, Pitch, Roll

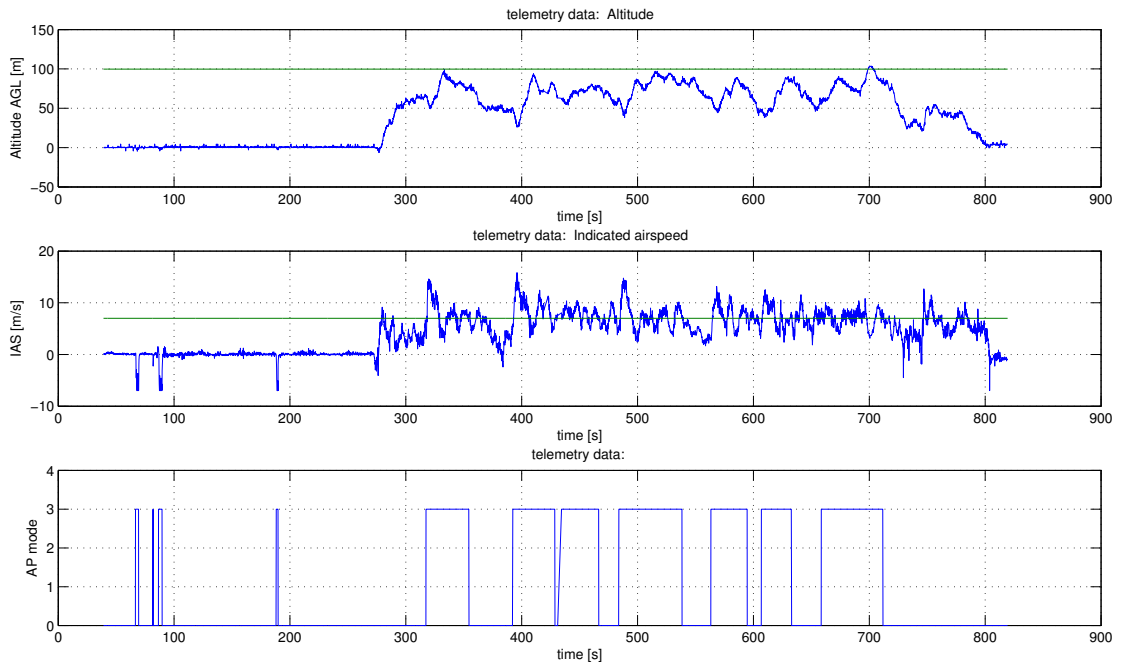


Figure 4: WPN autopilot test: Altitude, Indicated Airspeed, Autopilot Mode

and performed as expected. 5,6 and 4 are given below showing flight parameters for this test.

## 2 Flight Test No.2, 13 October 2007

Meteorological conditions: Calm/Light winds, Sunny, ambient temperature 60 – 65 deg.F. For this test, the bug experienced in last flight was tracked down the launched point GPS coordinates not being latched when flight computer was turned ON and GPS became available. The reason was found to be incorrect initialization of a discrete flag variable 'LaunchPointLatched'.

### 2.1 Flight-1: Fully Autonomous Waypoint Navigation Autopilot, test no.1

In this test, again identical waypoint mission was programmed. Altitude reference was reduced to 60m from 100m previously. After takeoff air vehicle was maneuvered so that it was flying in the direction opposite to the first waypoint (0, -150) and around midway point between launch point and first waypoint, the WPN mode was engaged. Air vehicle

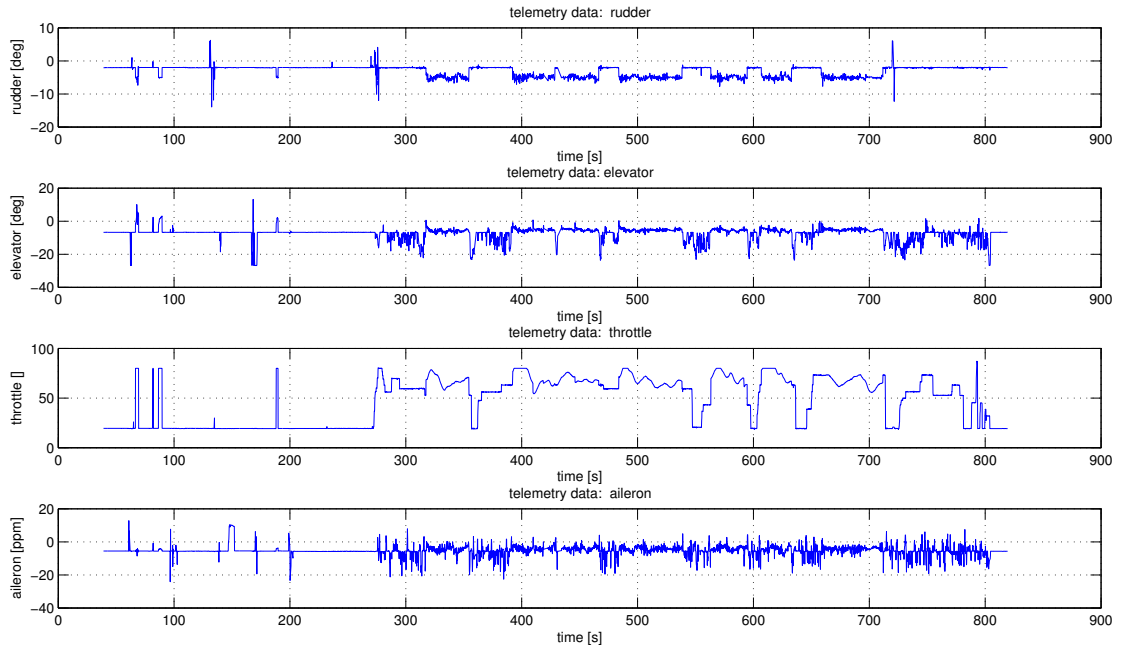


Figure 5: WPN test: rudder,elevator,throttle,aileron

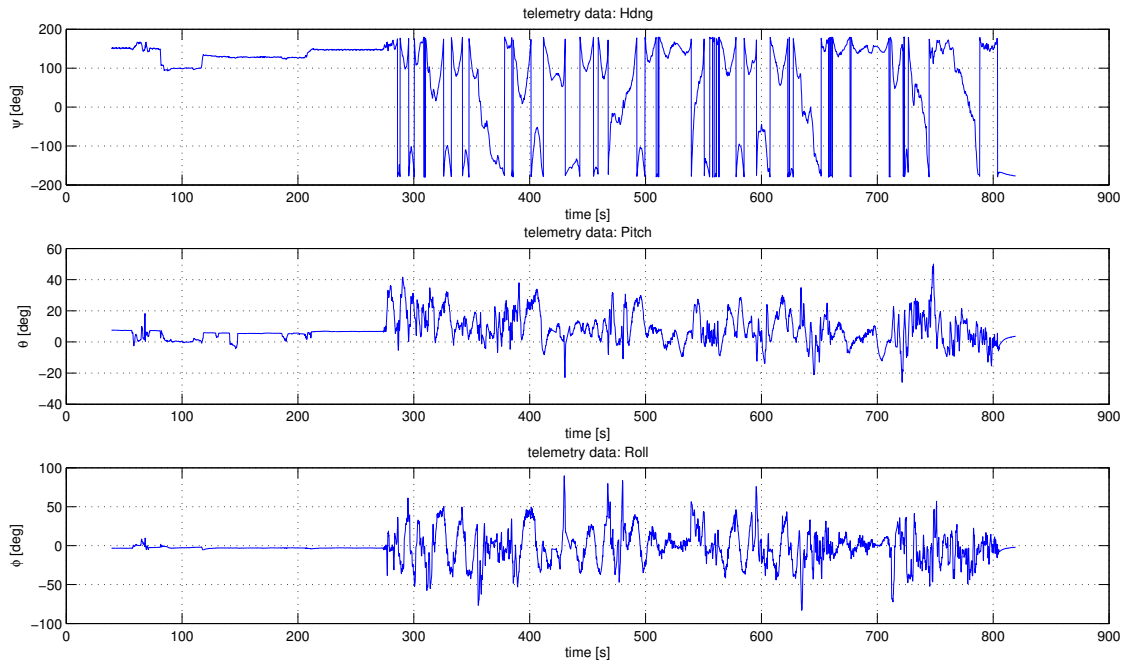


Figure 6: WPN autopilot test: Psi, Pitch, Roll

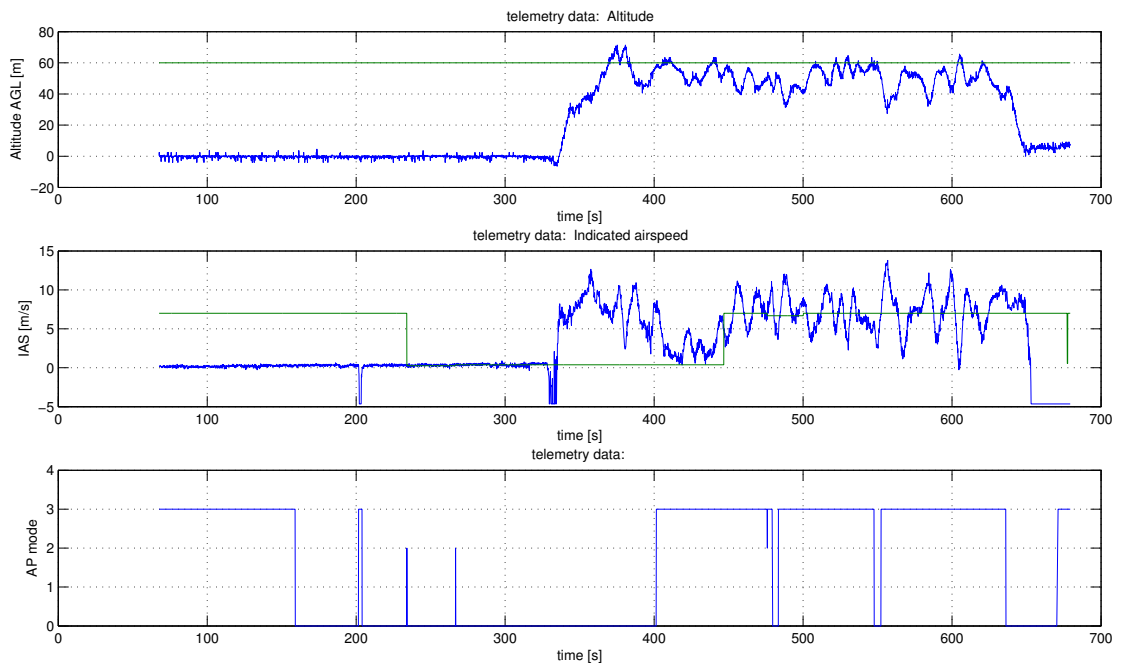


Figure 7: WPN autopilot test: Altitude, Indicated Airspeed, Autopilot Mode

turned around and headed in the direction of first waypoint, according to the autopilot logic, a waypoint is declared 'hit' as soon as the air vehicle falls within 20m radius of the waypoint. First waypoint hit was achieved, though the waypoint leg length was not enough to reduce cross-track error to zero. Following this, the autopilot switched target waypoint to waypoint number two, this was registered on the ground control station (GCS) display also, and executed a turn. However, subsequent behavior of the air vehicle was quite erratic in the sense that sometimes it would appear to be approaching the target waypoint, but as it approached the waypoint, it would mysteriously turn away in another direction before returning again towards the waypoint. Second waypoint hit was never registered and the mission was aborted after several failed re-engagement of the WPN mode. It was observed that even though the behavior was quite erratic, the air vehicle tended to remain within a bounded range around the waypoints.

As an experiment, the waypoint guidance algorithm was tried in the older Yardstick based simulink model, with c coded identical outer loop autopilot (Inner loops were redesigned as PID for Ultrastick vs lead-lag design for Yardstick). Identical waypoint mission was flown with airspeed around 12 m/s. The result of simulation was remarkably similar to the one observed in flight (fig.11). In another simulation, the waypoint mission plan was enlarged to 300m and 400m separation between waypoints and the autopilot performed well(fig.12, fig.13). To see the impact of lowering the reference airspeed, the 150m mission plan was simulated again, this time with IAS reference at 8 m/s (fig.14), again resulted in poor

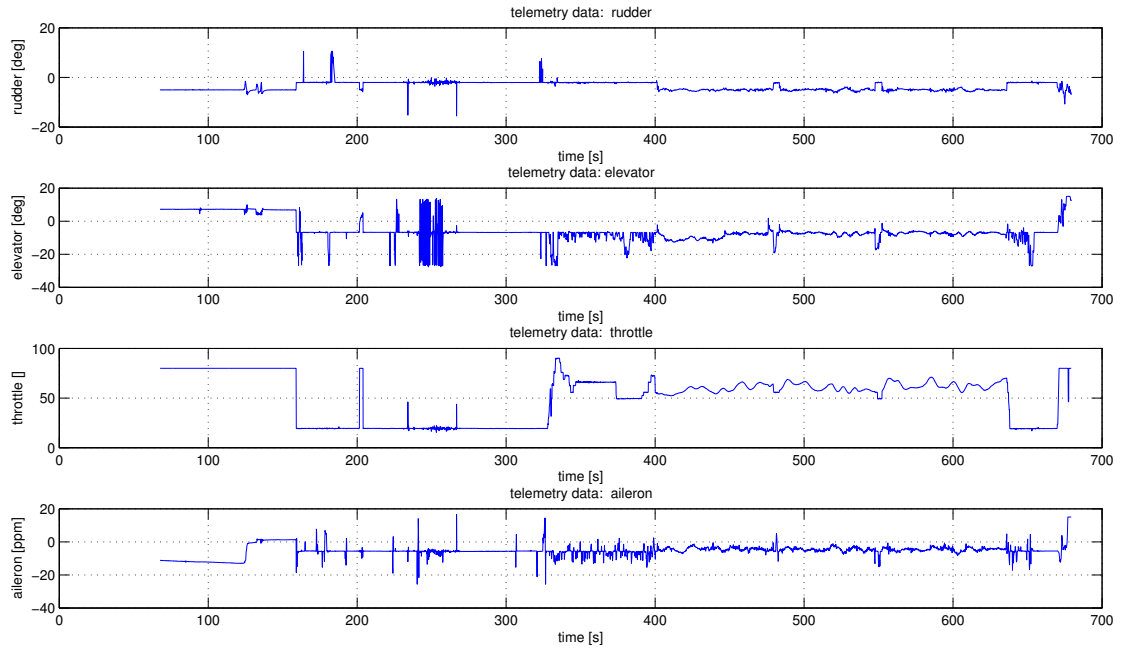


Figure 8: WPN autopilot test: rudder,elevator,throttle,aileron

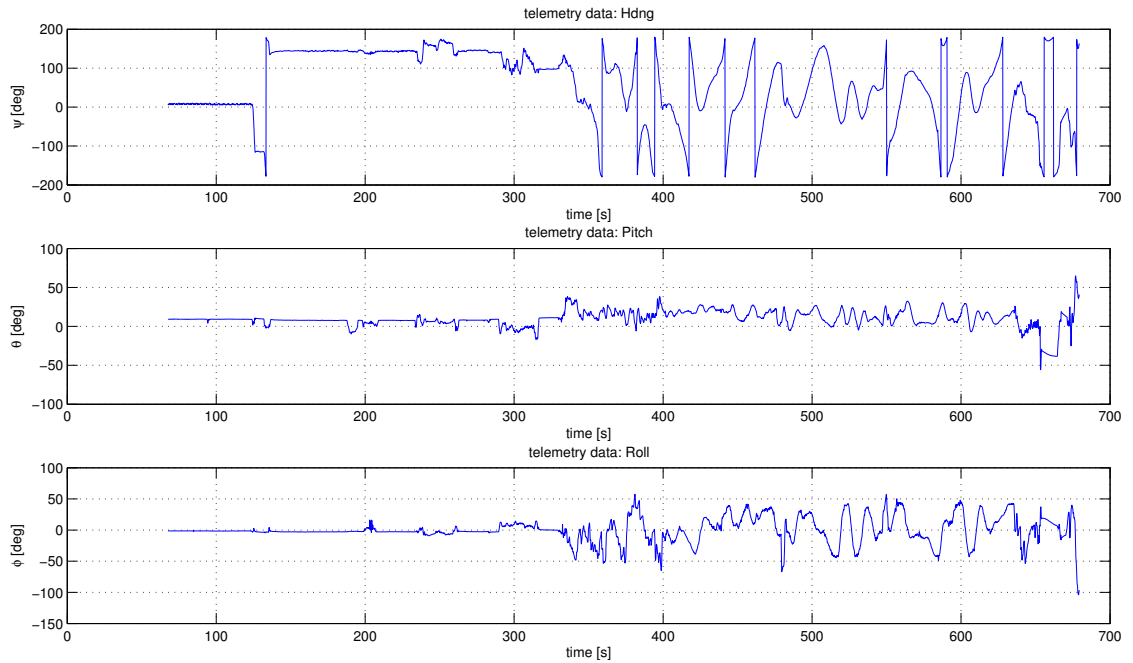


Figure 9: WPN autopilot test: Psi, Pitch, Roll

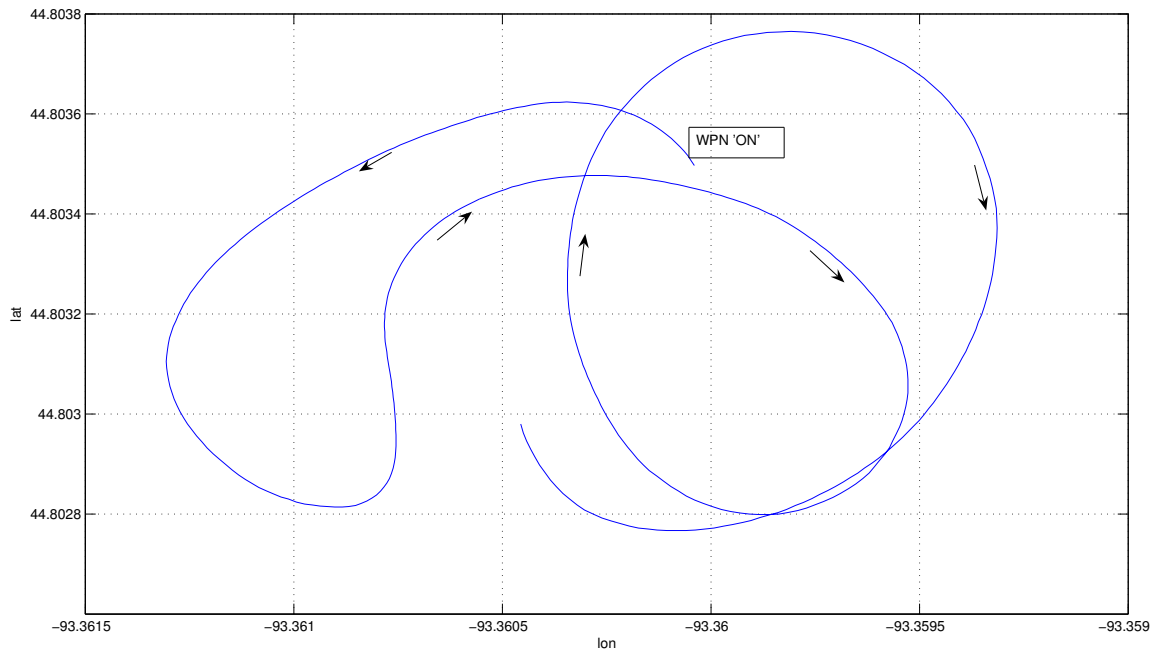


Figure 10: WPN autopilot test: LAT, LON

WPN autopilot performance. In the light of this, it seems to point towards some minimum waypoint separation requirement for the WPN control law to work. As we know it is a non-linear control law and its stability domains are not established or known. To prove this hypothesis, we'll need to fly a larger waypoint mission plan, but lack of confidence in autopilot, limited R/C range and pilot visual range present a challenge for future flight test and a suitable way forward will have to be found.



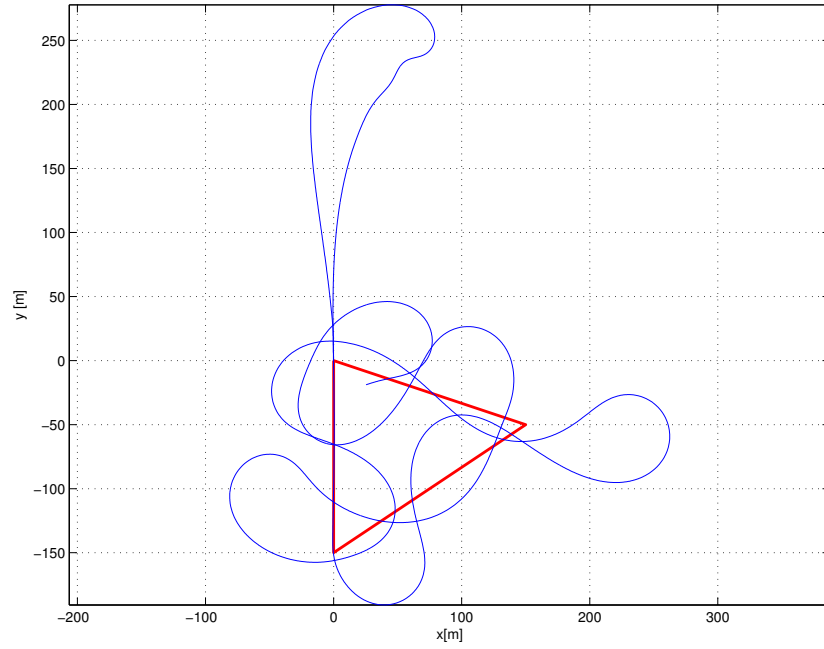


Figure 11: WPN autopilot simulation: X, Y

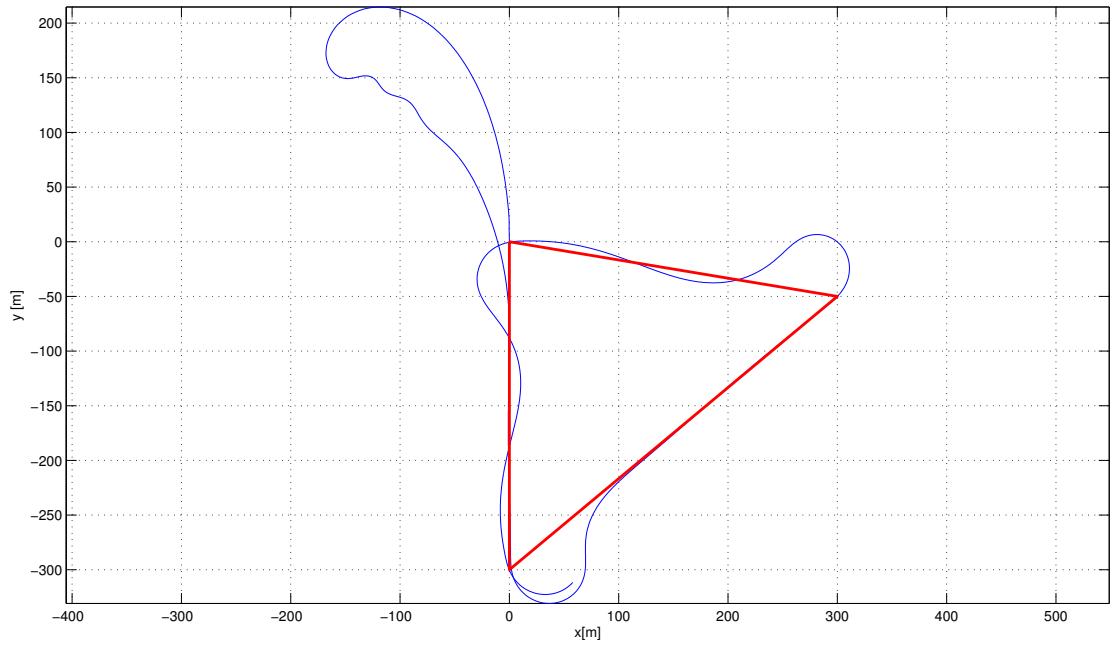


Figure 12: WPN autopilot simulation: X, Y

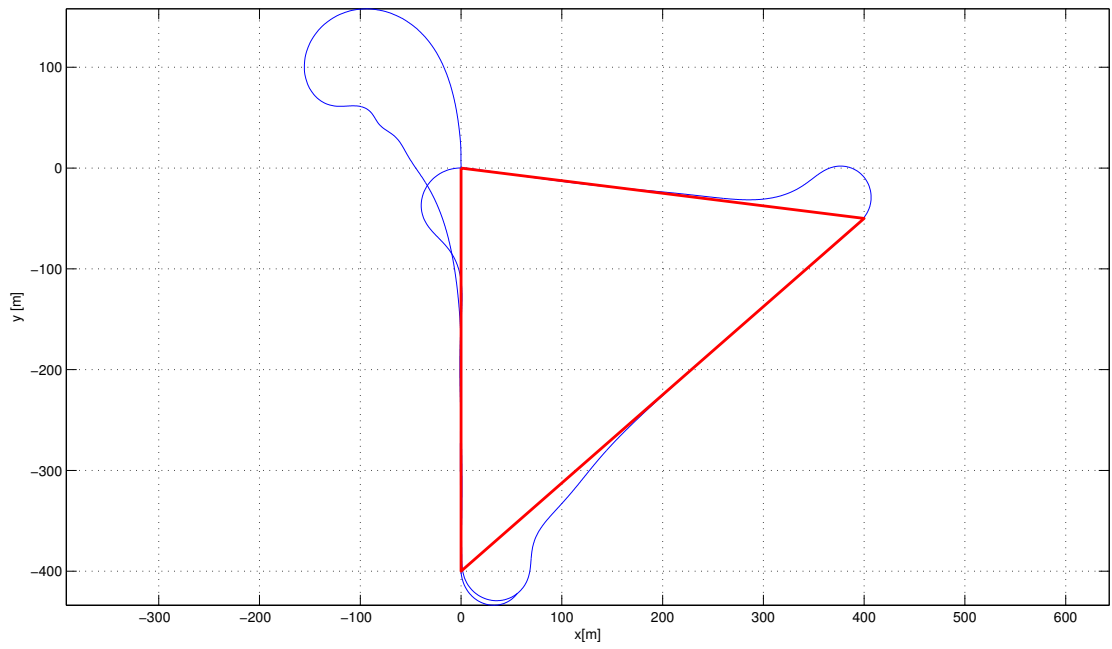


Figure 13: WPN autopilot simulation: X, Y

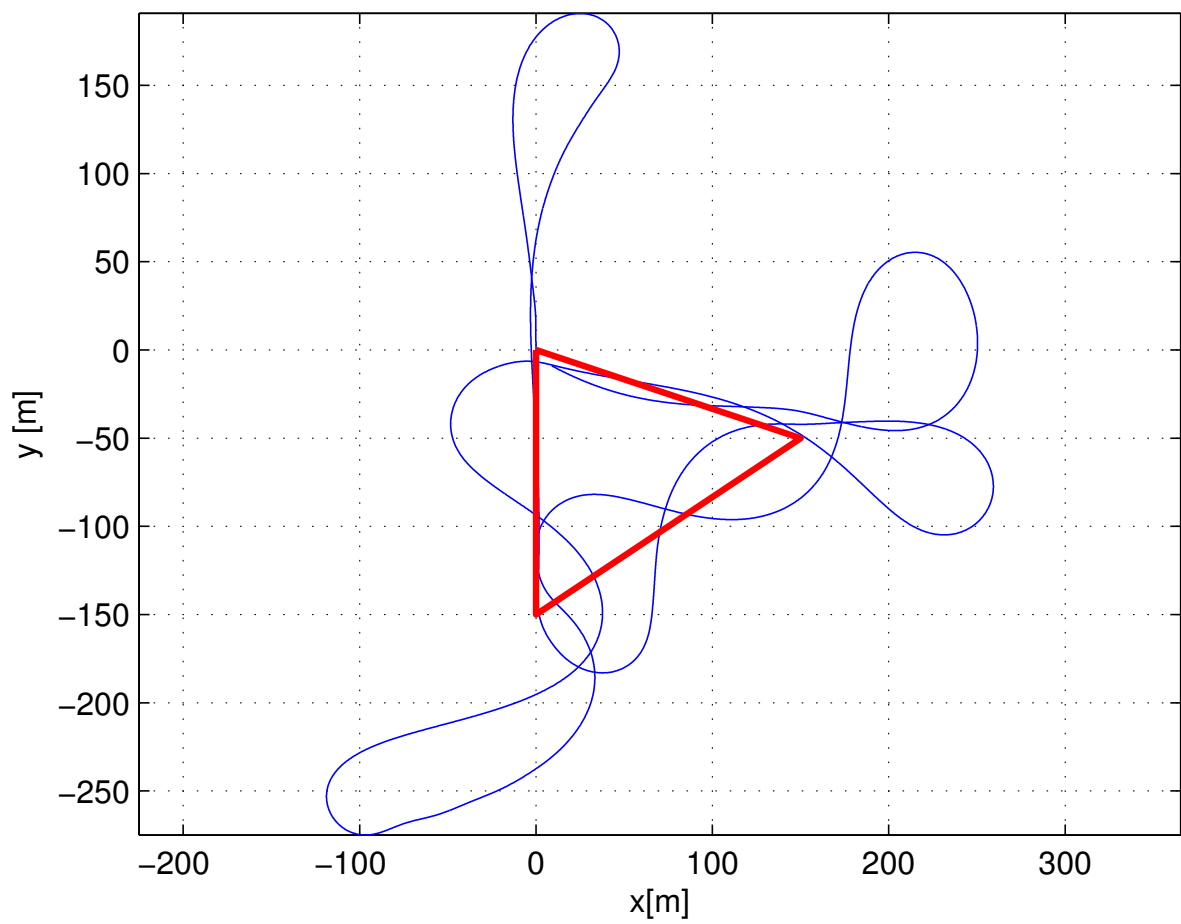


Figure 14: WPN autopilot simulation: X, Y