Automatic high altitude retrieval system

Introduction:

The main objective was the test of an automatic retrieval system of high altitude payloads. The system designed to achieve this objective was a flying wing glider steered automatically to the launch point of the balloon. The separation of the flying wing from the balloon was commanded manually from the ground.

Through the participation in the InGos campaign we had the opportunity to test fly our system on real high altitude balloon flights in real high altitude flight conditions. We have brought two systems:

- 1.4 m wingspan flying wing- designed as a test flight vehicle
- 1.75 m wingspan flying wing- designed to carry an Aircore and provide an automatic recovery capability for Aircore flights

System description:

As a recovery vehicle we have designed and built a flying wing capable of achieving level flight at relatively high altitude (~22 km altitude) depending on wind conditions. The flying wing has a tracking system onboard that provides realtime positioning data as well as a command link that provides the capability of sending commands from the ground to the flying wing during the flight.

A hot-wire cutdown system is used to separate the flying wing from the carrier balloon at the chosen altitude. The hot-wire cutdown system is operated through two independent systems because of redundancy desire.

The flight of the flying wing is automatically controlled by a proprietary inertial autopilot using GPS updates.

Flights:

Due to aviation law restrictions we could not fly the large flying wing (1.75 m wingspan; 6.95 kg all up weight without the Aircore) without a transponder. It was impossible to find an adequate transponder during the InGos campaign. The aviation law restrictions become clear quite late and this was because the high altitude gliding system is relatively new and no well-established laws exist.

Fortunately, our smaller flying wing had a all-up-weight of 3 kg and was allowed to fly. The smaller flying wing has identical systems as the larger wing and uses similar aerodynamic design. Hence, we concentrated on validating our system by flying the smaller flying wing.

We performed three flights going from low altitude to high altitude.

The first flight was performed from 700 meters altitude; the flying wing was carried to that altitude by a balloon and then separated by using the cutdown command issued from the ground. After the separation the flying wing flew automatically back to the launch point. This flight demonstrated that the wing can fly and that it can return back home automatically. It has also demonstrated the functionality of the tracking system and cutdown command system.

The second flight was performed to 10380 m altitude. At that altitude the wing was at 18.7 km horizontal distance. Again the cutdown was initiated from the ground and the wing returned automatically back to the launch point in 60 minutes.

Because the small size of the wing we had to decrease the power of the tracking system installed onboard which led to loss of tracking updates after the wing flew higher than 3000 meters. The decrease in power was necessary because of interferences between the tracking system and the onboard electronics. However the flight data is also recorded onboard on a small SD card. The autopilot records altitude, GPS position, altitude as well as roll, pitch, yaw and a series of other important flight data. **Important: the interference problem is solely present on the small wing because of the small space available onboard of this wing. On the larger wing it was possible to install the electronics farther away and no interference problems were observed!**

The third flight was decided to take place at a higher altitude. Hence, the wing was flown to 26.022 meters at which moment was 32.4 km away from the launch point. For this flight the power of the tracking system was increased but not to the nominal power level in order to avoid the previously mentioned interferences with the onboard systems.

The wing glided back home and landed 1 hour and 40 minutes after cutdown. Once it reached the launch position in flight the wing had an extra 9 km altitude to spare and started (as programmed) to circle the launch point. The entire flight was automatically especially that the tracking covered only part of it (up to 17 km altitude).

Again the data from the autopilot was recorded onboard on a small SD card.

Problems encountered during experiment

The main problem was the impossibility to fly the larger wing due to lack of an appropriate transponder. Due to size/mass requirements a relatively small transponder is needed.

Another problem (solved partially) was the loss of tracking information. This was compensated by the fact that the rest of the systems performed excellent and the wing reached automatically the launch position in each of the 3 test flights. Loss of tracking information is compensated by the onboard data which is actually more complex than the tracking information.

We were aware about the tracking problem; however, the objective was to show that the system can get back automatically and not to validate the tracking solution. On the larger wing the tracking is not a problem because the tracking transmitter can be operated at maximum power (as it was used on our other high altitude balloon missions). At maximum power it offers more than needed range and no loss of tracking should appear (as tested and proved by us in other high altitude balloon missions, including last year's balloon missions from Sodankyla).

We considered that we achieved our objectives of demonstrating an automatic gliding system for recovery of high altitude payloads.

InGos was very useful in providing support to participate to this campaign and offering the opportunity to perform the high altitude balloon flights. At the same time we made contact with other research groups that might benefit from our capability of recovering automatically high altitude payloads to pre-determined locations. This is especially critical for the Aircores were they need to be recovered fast after landing in order to achieve maximum accuracy for their measurements.

We plan to develop further the system and improve on the tracking solution for the small flying wing. We have already identified the solution (low power, low interference) solution for tracking which we have previously tested on high altitude balloon missions.

We plan to publish results in a scientific journal once we will have tested the large flying wing as well.

Annex with graphs

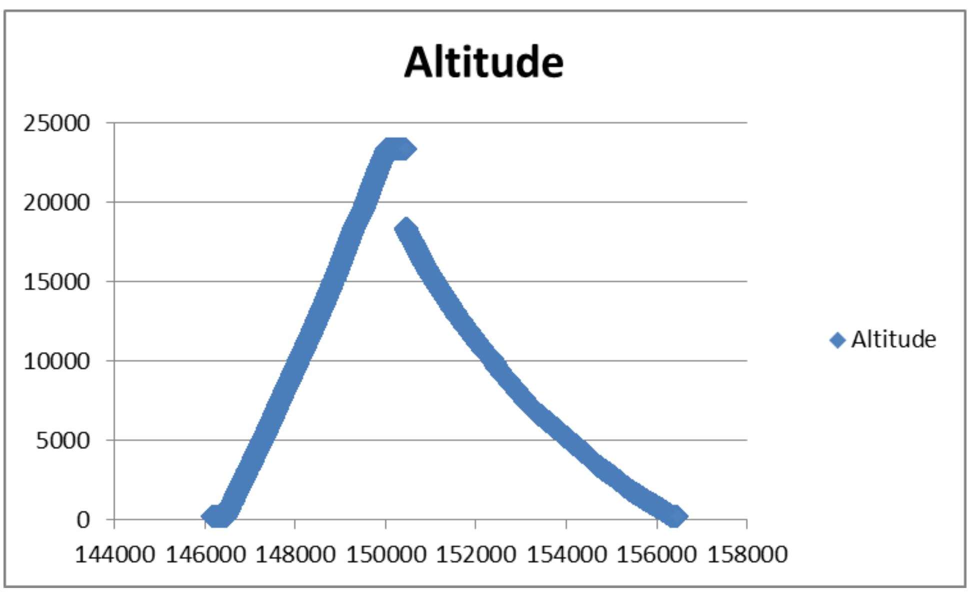

Fig. 1 Altitude vs. GPS time- 3rd flight

Note: the small wing was solely a test vehicle to validate systems, solution for the larger wing intended to carry an Aircore. Hence, the small wing did not have a high altitude GPS module (module designed to report altitudes over 24 km altitude) because we initially did not plan to fly the small wing at more than 20 km altitude. However, since the aviation rules prevented us from flying the large wing without a transponder we turned to the smaller wing and decided to push it to maximum altitude in order to fully validate the solution. Hence, over 23.9 km altitude the GPS stopped reporting the altitude and re-aquired lock/altitude when the flying wing was gliding and was lower than 18 km. This did not present a problem because the autopilot has performed the flight corrections inertially;only the positioning drifted during the GPS blackout and was refined once the GPS re-aquired lock at altitudes lower than 18 km.

However, from the ascent rate of the balloon and the duration from GPS blackout to balloon cutdown command (also visible in the Fig. 1) we can estimate the additional altitude as being ~2600 meters. This should be added to the 23900 km altitude (altitude at which GPS blackout occurred) and, hence, gives the final total altitude as being 23900+2600=26500 meters.

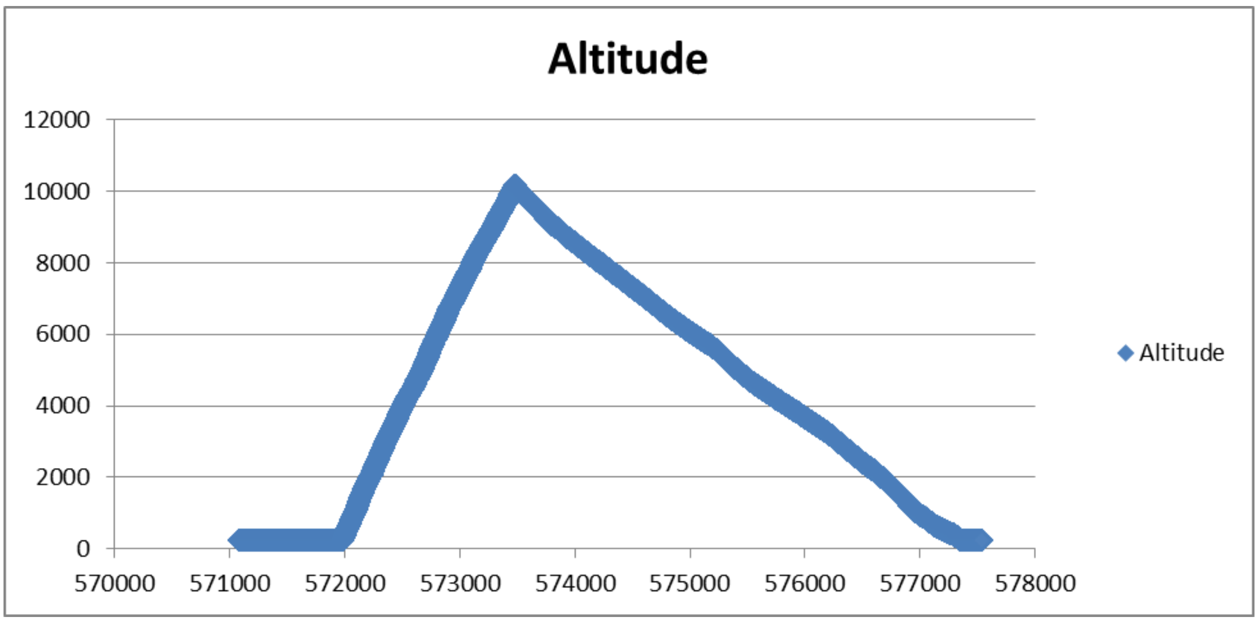

Fig. 2 Altitude vs. GPS time- 2rd flight

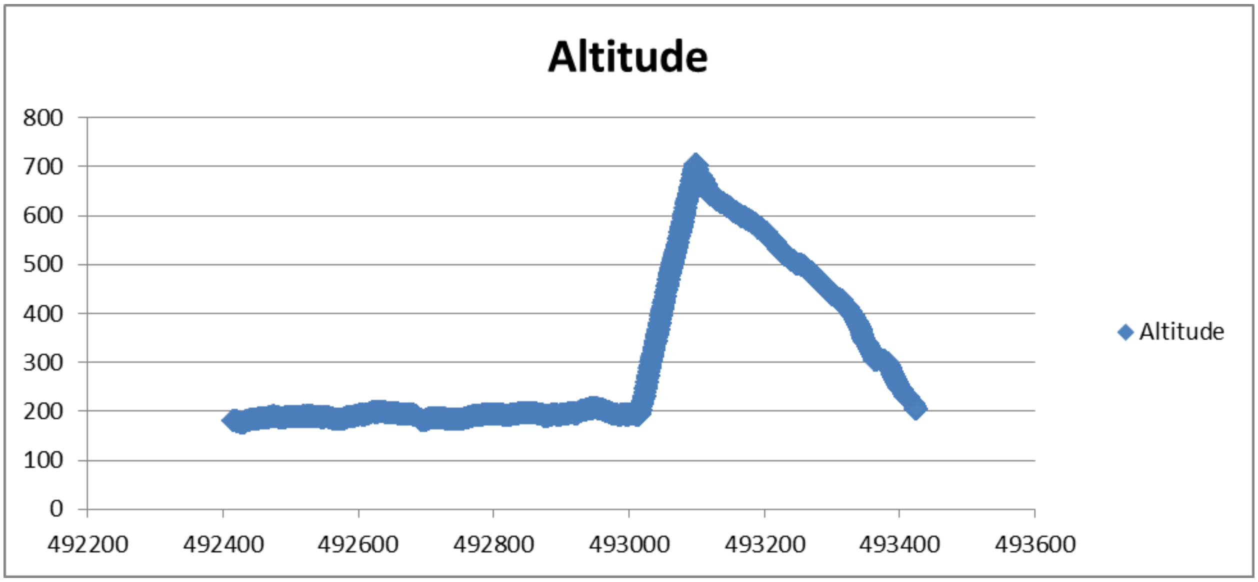

Fig. 3 Altitude vs. GPS time- 1st flight

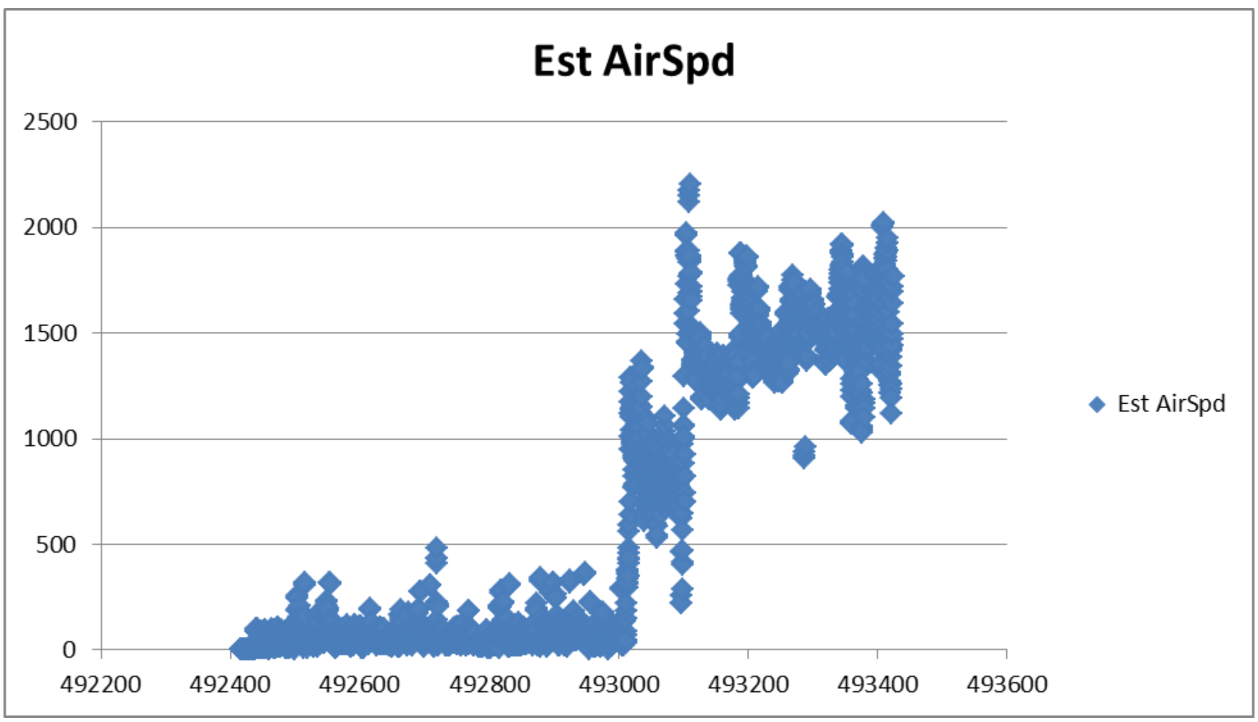

Fig. 4- Estimated airspeed during the 1st flight

Note: we can observe that the gliding airspeed at lower altitudes hovers around 20-25 m/s. The flying wing can accelerate by a combination of trim settings (possible to be done during the flight) as well as CG positioning (possible to be done before flight).

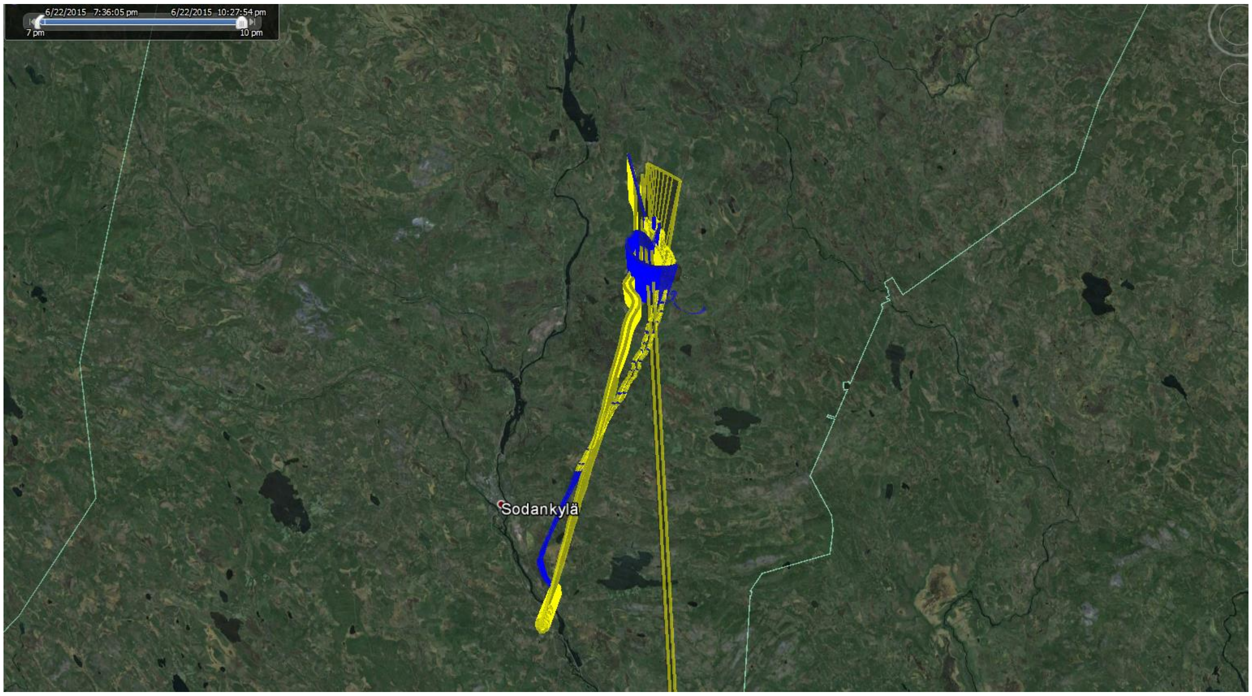

Fig. 5 Trajectory 3rd flight

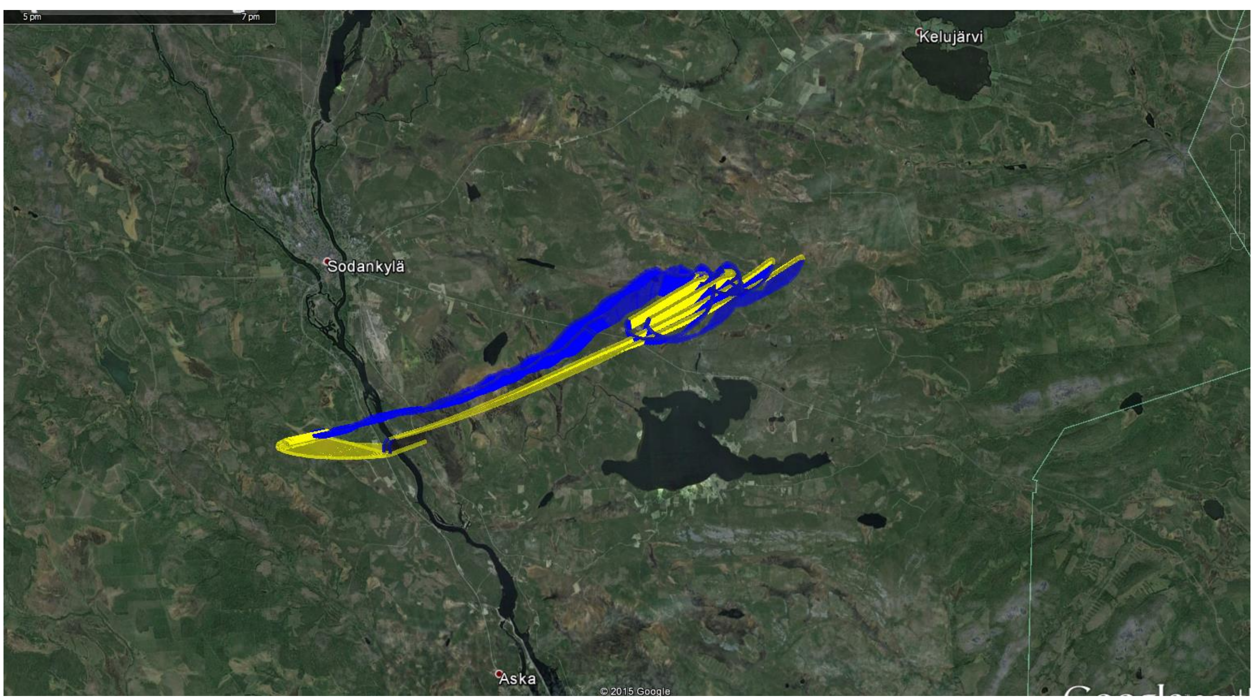

Fig. 6 Trajectory 2nd flight

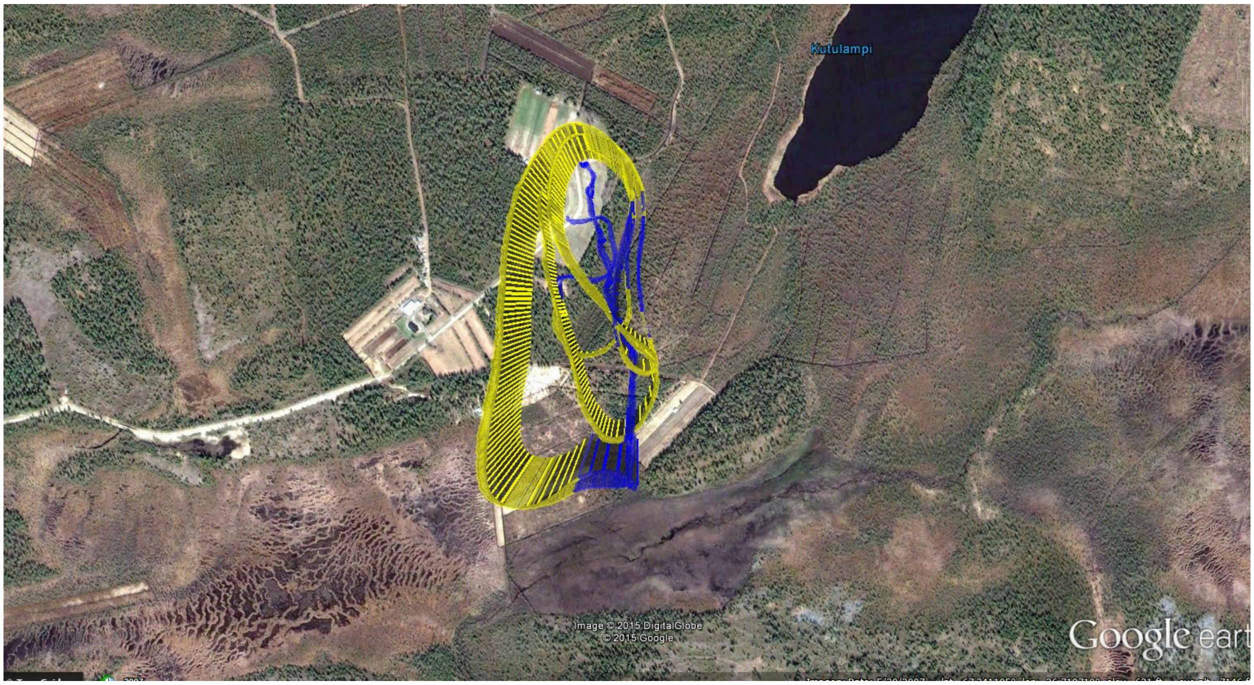

Fig. 7 Trajectory 1st flight

Fig. 8 APRS trajectory 3rd flight

Note: the APRS trajectory represents the trajectory as received during the flight on the ground; this is just partial trajectory because of the above described problems with the tracking transmitter power settings; we could not run on the small wing the transmitter at maximum power because of interferences with onboard electronics.