Analysis of Results from ISSA Speed Skydiving World Series Finale and Doppler Tests Performed During Practice Days

Dunkeswell, United Kingdom

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INTRODUCTION

Previous Doppler tests validated FlySight's accuracy at speeds over 130 m/s. However, we were only able to gather one dataset in those tests.[i]

We were invited to attend the ISSA Speed Skydiving World Series Finale in Dunkeswell, UK, with two goals:

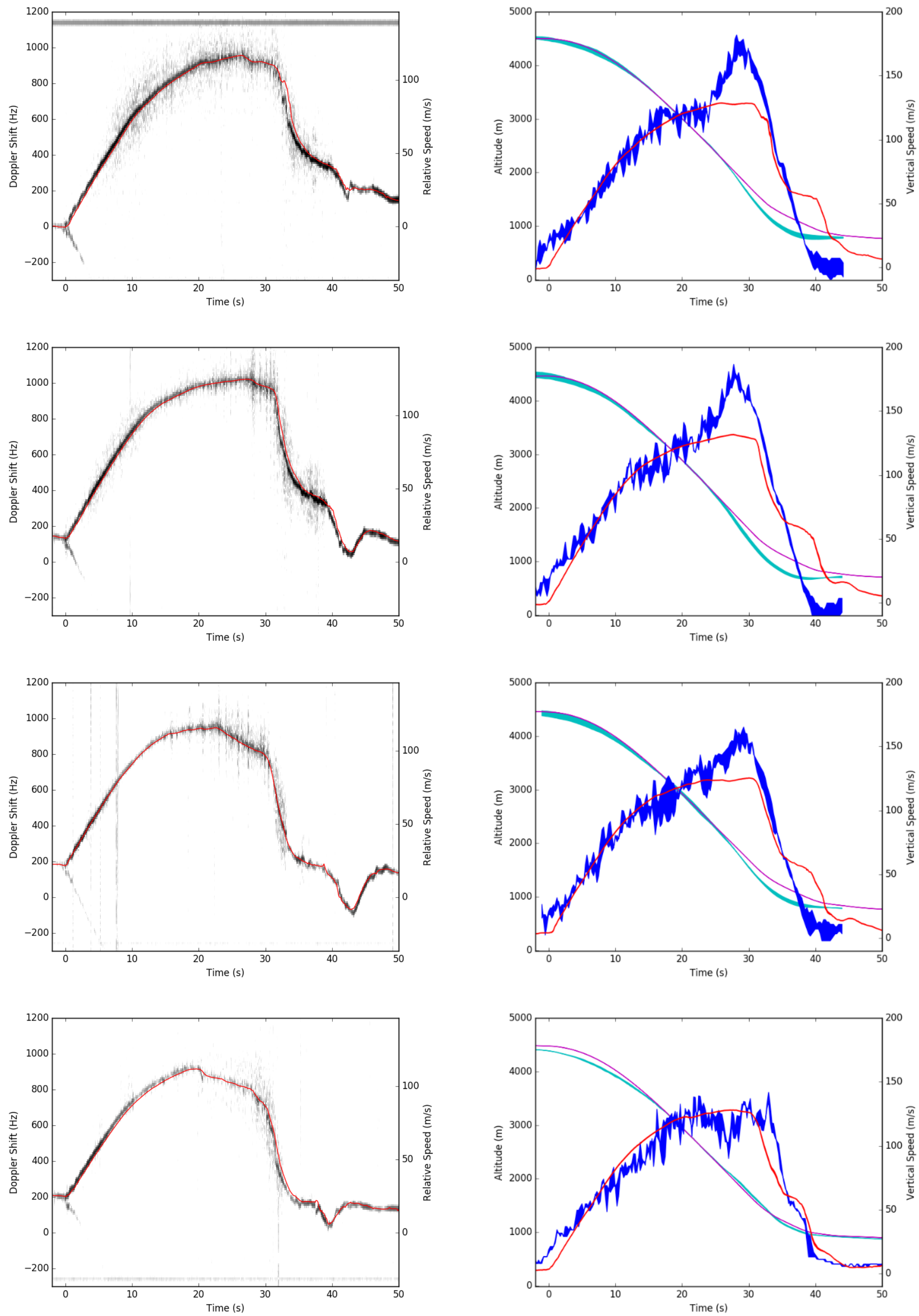
First, to perform additional Doppler tests in order to confirm our previous result. In addition, we wanted to gather ProTrack data on the same jumps, in order to make a comparison with FlySight's results.

Second, we wanted to operate a "shadow" scoring system for the event using FlySight and PPC in order to test how FlySight might work in a Speed Skydiving competition. Past tests, including at Australian and USPA Nationals, have placed two FlySights in the position indicated by FAI Speed Skydiving rules. However, we wanted to test how the system would work with a single FlySight mounted on the back of the competitor's helmet, as in Wingsuit Performance competitions.

DOPPLER TESTS

During the practice days leading up to the competition, we were able to repeat Doppler tests similar to the ones reported on previously. The results of these six tests are summarized in the plots on the left below. Doppler measurements are shown in gray, with FlySight measurements overlaid in red.

In addition, the jumper wore a pair of ProTrack speed measuring devices, mounted in accordance with FAI's Speed Skydiving rules. The plots on the right below compare ProTrack elevation and speed measurements (cyan/blue) with FlySight's measurements (magenta/red). Each plot is drawn as a band whose thickness indicates the measurement error.


Doppler Shift (Hz)
Relative Speed (m/s)
Time (s)
Altitude (m)
Vertical Speed (m/s)
Time (s)
Doppler Shift (Hz)
Relative Speed (m/s)
Time (s)
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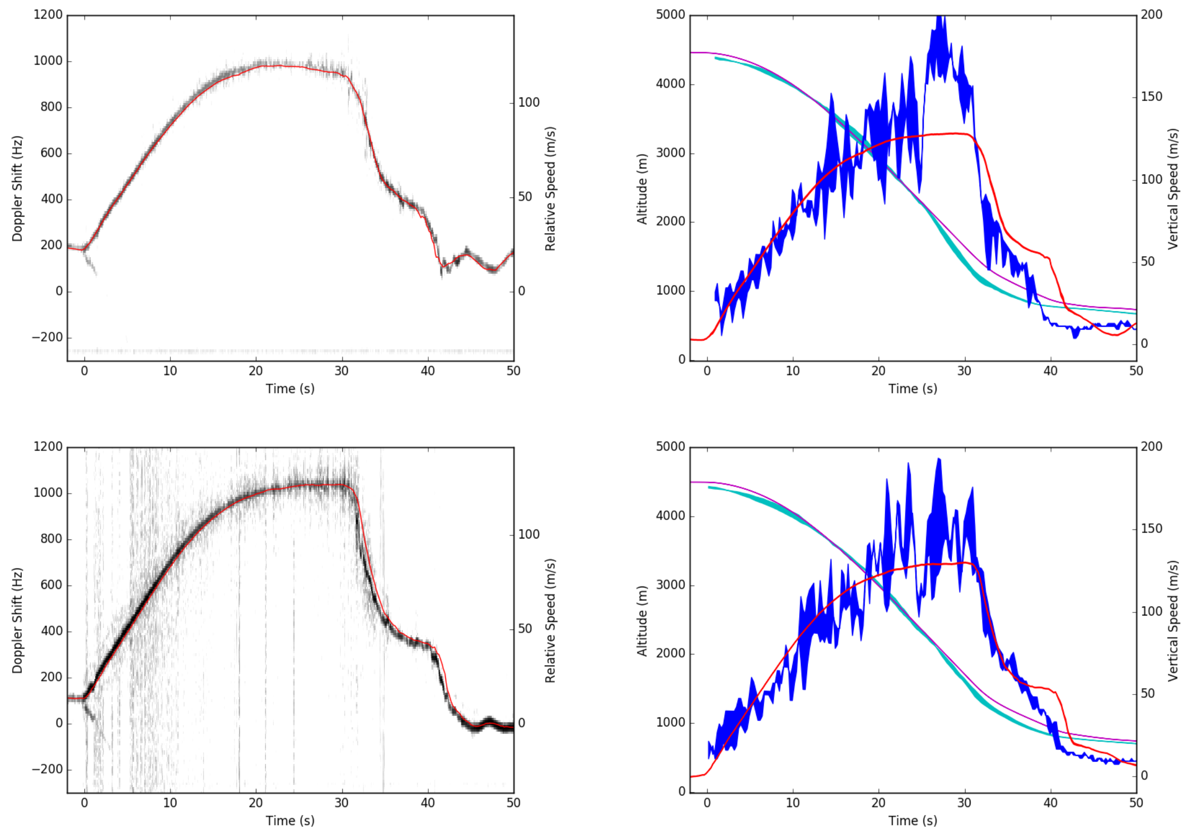
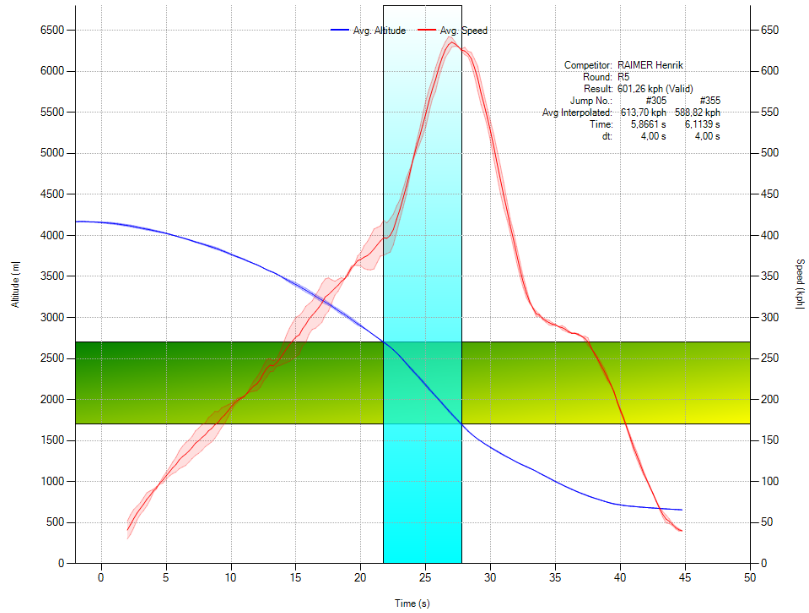
Doppler Shift (Hz)
Relative Speed (m/s)
Time (s)
Altitude (m)
Vertical Speed (m/s)
Time (s)



Three main results are apparent. First, FlySight's measurements are once again shown to be consistent with Doppler measurements.

Second, in the plots on the right, we see that FlySight's measurement error is much smaller than ProTrack's. In fact, FlySight's plots look like simple lines, although in fact they use the same banded representation as ProTrack's plots. In these plots, we have chosen to show both data sets with minimal smoothing. ProTrack results are usually smoothed over a 4-second window, which improves the noise inherent in the measurements, but also effectively reduces the time resolution of the data. FlySight is able to achieve the indicated accuracy with a time resolution of 200 ms or better.

Finally, particularly in the early tests, in the plot on the right we see a characteristic "bump" in the ProTrack data as the jumper exceeds about 400 km/h (111 m/s), which is completely absent in the FlySight data. We see the same bump, e.g., in Henrik Raimer's record 601 km/h jump. The plot for this jump from the ISSA website is reproduced below.[ii]



The results above would seem to demonstrate quite clearly that this kind of bump is an artifact caused by pressure changes near the jumper and is not related to the jumper's speed.

<u>COMPETITION JUMPS</u>

For the competition, we asked for volunteers to wear a FlySight on the back of their helmet in addition to the usual ProTracks. All but three of the competitors participated in this test.

Prior to the competition, FlySight competition units were turned on and left in an open area with the green light flashing for 15 minutes. Once this warm-up was complete, a single FlySight competition unit was mounted on the back of each participating competitor's helmet using gaffer's tape. Helmets were stored in the judging area, with the FlySight plugged into a charging system. For each jump, the following procedure was followed:

1. Prior to each jump, competitors would stop by the judging area to pick up their helmet
2. FlySights were turned on in the judging area as the helmet was given to each competitor
3. FlySights were left on throughout the climb to altitude and jump
4. Competitors would turn off the FlySight after they landed
5. Immediately following the jump, competitors would return to the judging area to turn in their helmet
6. Each FlySight would be plugged into the scoring system and results uploaded to PPC
7. The FlySight would once again be plugged into the charging system

In order to preserve the integrity of the official scoring system, PPC results were withheld from competitors and judges for the duration of the competition. However, each competitor's FlySight data was made available to them if requested.

COMPETITION RESULTS

During the competition, we had no FlySight failures. The final results from the PPC website (excluding the three competitors who did not participate in the test) are reproduced below:[iii]

Rank	Name	Round 1 (km/h)	Round 2 (km/h)	Round 3 (km/h)	Round 4 (km/h)	Round 5 (km/h)	Round 6 (km/h)	Round 7 (km/h)	Round 8 (km/h)	Ø best 5/8 (km/h)
1	Henrik Raimer	474.8	476.3	480.2	475.6	~~472.3~~	~~467.3~~	~~473.8~~	475.6	476.5
2	Jimmy McCarthy	467.3	460.1	~~446.4~~	~~451.4~~	~~415.8~~	466.9	465.1	468.4	465.6
3	Max Hurd	448.9	452.5	~~442.1~~	~~444.2~~	~~437.4~~	461.2	457.9	458.3	455.8
4	Reinhard Wiesenhofer	~~451.1~~	454.7	~~452.2~~	~~450.7~~	454.3	455.8	457.6	456.5	455.8
5	Michael Lovemore	~~428.0~~	452.9	~~446.8~~	~~445.3~~	457.6	455.0	458.3	450.0	454.8
6	Simone Bonfanti	~~425.2~~	430.2	430.2	~~418.3~~	438.5	~~425.9~~	426.2	432.4	431.5
7	Fabian Wernli	431.6	~~410.8~~	436.3	427.3	430.2	418.0	~~406.8~~	~~411.5~~	428.7
8	Markus Fuchs	429.5	~~373.0~~	~~378.0~~	439.2	418.7	~~361.4~~	424.4	430.6	428.5
9	Kirill Tyupanov	~~373.3~~	402.1	381.2	403.9	~~309.2~~	394.6	390.2	~~352.1~~	394.4
10	Stephen Slater	409.7	~~347.0~~	369.4	401.0	~~365.0~~	387.0	371.5	~~298.8~~	387.7
11	Andy Torbet	392.8	378.4	374.8	~~362.5~~	~~363.2~~	~~369.4~~	384.5	370.4	380.2
12	Leigh Pretty	357.5	330.8	361.8	380.5	357.5				357.6
13	Jamie Kinniburgh	269.6	~~259.2~~	280.1	279.7	280.8	~~240.1~~	335.5	~~265.7~~	289.2

And the final results from the ISSA website:[iv]

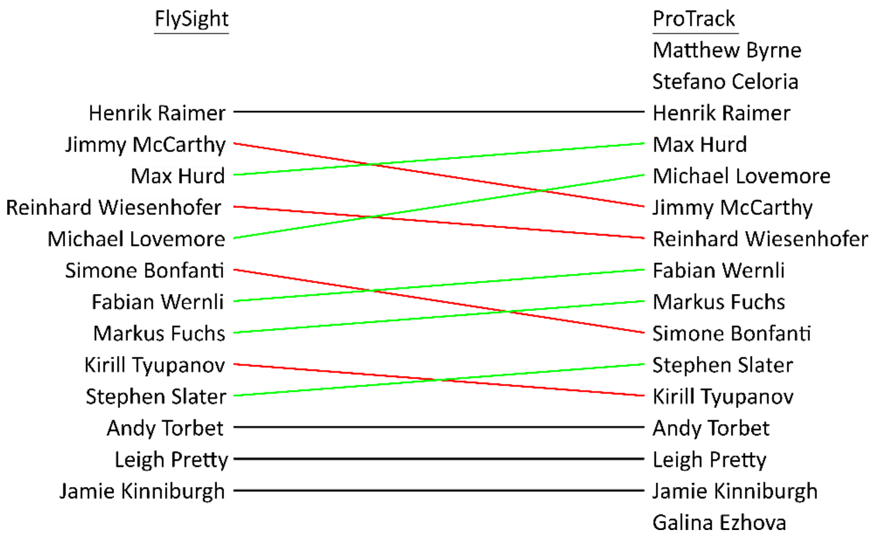
Rank	Name	Round 1 (km/h)	Round 2 (km/h)	Round 3 (km/h)	Round 4 (km/h)	Round 5 (km/h)	Round 6 (km/h)	Round 7 (km/h)	Round 8 (km/h)	Result (km/h)
1	Matthew Byrne	460.72	456.25	496.08	470.64	459.50	528.36	565.37	492.31	2552.76
2	Stefano Celoria	547.78 -0.02	487.47 -16.03	456.27 -23.79	0.00 OB	484.03 -14.57	485.60	472.35	0.00 OB	2477.23
3	Henrik Raimer	478.78	471.88	494.04	495.67	0.00 OB	483.11	493.93	487.57	2454.32
4	Max Hurd	460.90	470.90 -1.12	438.38	432.50 -0.19	445.31 -0.42	494.50	476.97	471.01	2374.28
5	Michael Lovemore	444.25	0.00 OB	478.57 -0.87	442.47 -9.30	445.40 -21.10	496.92 -2.99	0.00 OB	0.00	2307.61
6	Jimmy McCarthy	451.84	448.92	409.90 -15.27	438.34	397.14	436.05	430.81 -6.99	446.11	2221.26
7	Reinhard Wiesenhofer	0.00 OB	421.82 -0.22	400.57 -12.28	401.54 -18.44	405.43 -21.19	411.76	422.01 -9.27	414.43	2075.45
8	Fabian Wernli	405.10	0.00 OB	381.83 -24.85	410.33	395.75	412.38	367.74	372.82	2005.39
9	Markus Fuchs	399.98	372.92	374.28	415.31	394.62	368.89	386.25	408.46	2004.62
10	Simone Bonfanti	474.84	513.79	0.00 OB	0.00 OB	0.00 OB	0.00 OB	455.81 -14.24	498.07	1942.51
11	Stephen Slater	405.79	346.43	347.75	378.99	351.93	378.97	357.54	296.94	1873.22
12	Kirill Tyupanov	0.00 OB	379.28	337.51	382.94	298.27	364.98	346.66	332.98	1811.37
13	Andy Torbet	377.24 -3.66	362.41	356.81	346.84	348.66	328.38 -5.60	355.33	348.31	1800.45
14	Leigh Pretty	346.26	323.63	344.07	363.80	342.92	0.00 NJ	0.00 NJ	0.00	1720.68
15	Jamie Kinniburgh	254.91	248.20	268.54	265.50	266.75	233.07	313.93	260.45	1375.17
16	Galina Ezhova	240.24	264.66	250.27	272.75	268.06	268.16	259.04	230.48	1332.67

Notice that the of top competitors on the PPC website remain quite consistent from one round to the next—typically a single competitor's score varies by about ±5 km/h. This is what we expect from competitors who have dialed in their performance. Each competitor's final score is very much in line with their performance throughout the competition.

On the other hand, the scores on the ISSA website are much more erratic. A single competitor's score often varies by 40 km/h or more from one round to the next. Competitors will often move up or down one or more places because of seemingly random fluctuations in their score from round to round.

Our feeling is that competitors would benefit from more consistent scoring based on FlySight data. We would see more "jockeying for position" and less reliance on "winning the lottery" by achieving an unusually high score purely by chance.

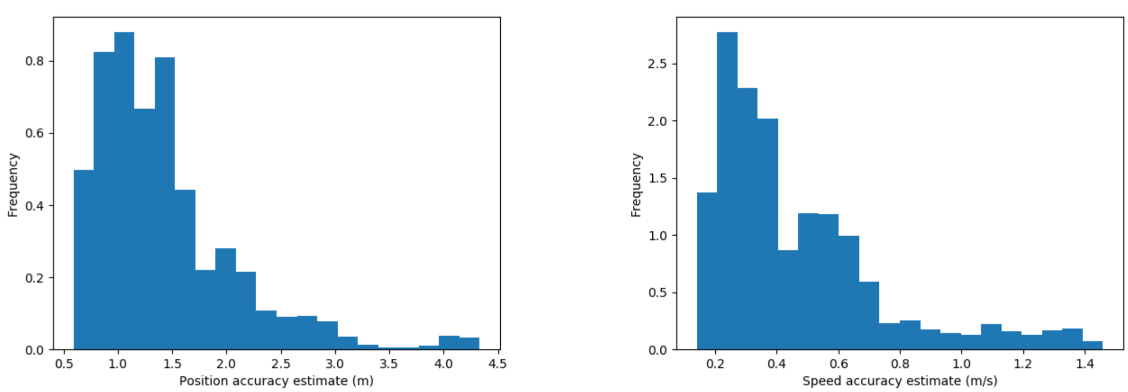
We can see that the final rankings are slightly different between the two scoring systems. The following image summarizes these changes:



We see an approximately equal number of moves in each direction, with competitors moving a maximum of two places up/down. This would seem to indicate that FlySight scoring would not radically change the competition but would simply provide more accurate results.

FLYSIGHT ACCURACY

The histograms below show the error estimates for vertical position (left) and speed (right) for all points recorded inside the competition window.



FlySight reports “accuracy estimates” for vertical position and speed. These estimates are based on a number of factors:

- Number of satellites in view
- Signal-to-noise levels
- Geometry of the satellites in view

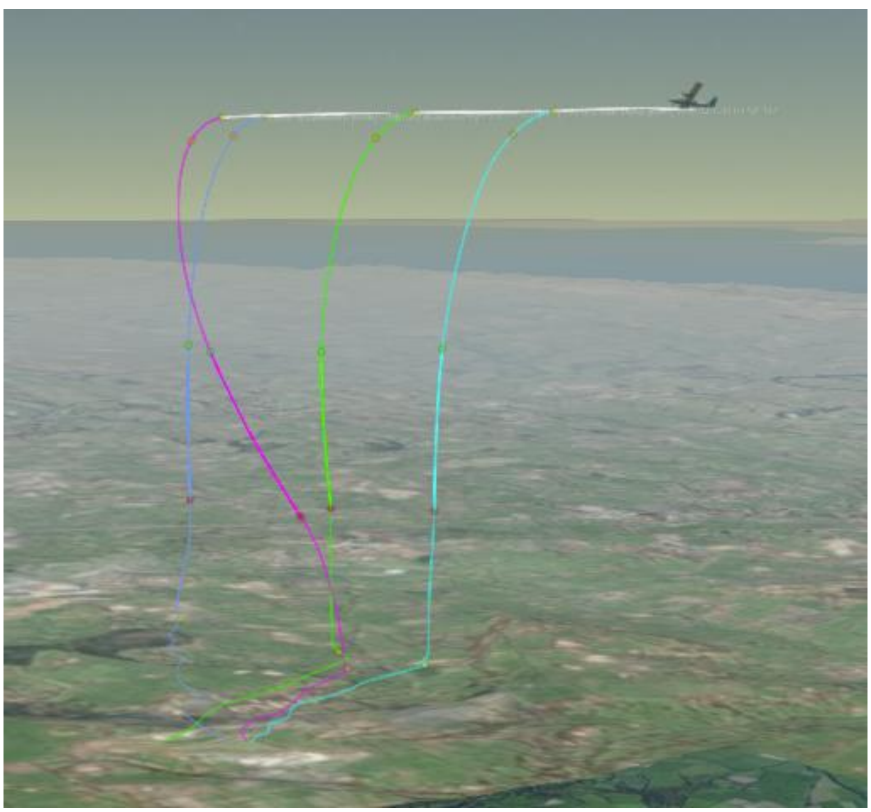
- Residual errors in the dynamic model

These accuracy estimates represent a 68% “confidence interval”—that is, 68% of the time, the true result should be within this margin of error. Of course, since we don’t know the jumper’s true position and speed, it is impossible to know exactly what the error is, which is why these are called estimates.

Reported accuracy estimates can be used to measure the health of the system. If a particular FlySight isn’t seeing enough satellites, for example, we would expect to see an unusually high error estimate. In Wingsuit Performance, we specify that the position logging device (PLD) must achieve a position accuracy of better than 10 m. Thus, we can say with some confidence that the final results are accurate to within 1%.

PPC SCORING SYSTEM

PPC is the “gold standard” scoring system for international Wingsuit Performance competition. In addition to giving competitors full access to data from every jump, PPC is also an invaluable tool for identifying potential safety issues before they become a problem. For example, we can easily identify tracks like this, where one jumper flew back down the jump run instead of perpendicular to it:



This kind of feedback simply isn’t possible with a barometric measurement system, but PPC makes it easy for judges to keep an eye on these things even for very large competitions.

CONCLUSION

We were able to gather Doppler measurements on six additional speed skydives. As in our previous tests, Doppler shifts predicted using FlySight data agreed closely with the measured results. This result validates the accuracy of FlySight's speed and position measurements.

We were also able to compare FlySight's measurements on those jumps with ProTrack measurements. This comparison showed significant inaccuracy in the ProTrack results. In particular, we were able to show that the prominent "bump" present in many Speed Skydiving tracks over 400 km/h is not tied to an increase in vertical speed—it appears to be an artifact of pressure changes near the jumper. This should cast doubt on any scores over 500 km/h obtained using a barometric system.

Finally, the "shadow" competition was a complete success, with no FlySight issues in 115 jumps (114 competition jumps and one rejump). With a single FlySight mounted on the back of the helmet, we saw vertical position accuracy in the window typically better than 2.5 m and speed accuracy typically better than 0.8 m/s.

We owe special thanks to Michael Lovemore, who volunteered to wear the Doppler transmitter during his practice jumps, and to Klaus Rheinwald, who made his PPC scoring system available for this test.

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[i] Cooper, Michael. "Comparing FlySight Speed Measurements with Doppler Shift Measurements." http://flysight.ca/fw/Doppler_Experiment.pdf. 2017.
[ii] http://www.speed-skydiving.com/index.php/live-results-menu/results-2016/257-results-mondial-2016.
[iii] https://ppc.paralog.net/showevent_compact.php?event=Speed+Test+Event+2018
[iv] http://www.speed-skydiving.com/index.php/live-results-menu/results-2018/290-results-dunkeswell-2018