Project Note
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Use of Precision GPS for Air Tanker Drop Testing

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Introduction

The standard approach for measuring the flight path of an aircraft over a grid during drop test evaluations has been by visual means or by a GPS position from a device mounted in the plane. The flight path verification was used to document the aircraft flight path over the grid during the evaluation. The standalone GPS receivers operate at about 10m accuracy, and produce 1 or 2 readings while flying through the grid.

FPInnovations tested the use of a precision survey grade GPS operating in differential mode. The system was capable of 2 cm accuracy, and could produce approximately 100 measurements while flying through the grid. This gave the opportunity to see where the plane flew precisely, and also the ground speed and altitude of the drop. A precise vertical profile could be used in engineering flight analysis.

Objective

To assess the usefulness of a precision grade GPS for aircraft drop test evaluations.

Methods

Researchers established a differential base station at a known survey point. A point was chosen near the airport because the best accuracy can be achieved with shortest baseline between the reference station and the roving station. The system (Figure 1) consisted of a GPS receiver to calculate the offset from the known position, and a radio to transmit the corrections in real time to the aircraft receiver. The station logged all data to enable post processing and give the desired accuracy if the real time corrections did not achieve it. The station was initialized each morning, and no further interaction was required throughout the day.

Figure 1: Differential Base Station with reference GPS on the left, and radio on the right.

The aircraft setup for the roving GPS receiver consisted of securely attaching the GPS antenna inside the cockpit area so as to have a clear view of the sky through a window or skylight (Figure 2), and the receiver was housed in a backpack and either stored in the baggage compartment or securely attached to the seat (Figure 3). An antenna offset was put into the receiver to give the position of the door as opposed to the antenna. This offset would be unique to each aircraft and installation. The data was saved to the internal memory of the GPS after each flight to ensure data integrity. A new data file was created for each drop between flights.

Figure 2: GPS antenna securely attached inside the aircraft.

Figure 3: GPS receiver mounted in baggage compartment (left) and on rear seat (right).

At the end of each day, the data was processed with the equipment's software (LEICA Geo Office). If sufficient accuracy was not obtained due to flight attitudes or satellite geometry resulting in errors greater than 5 cm, post processing was done to achieve the 2 cm accuracy desired.

Microsoft Excel and the data from LEICA Geo Office were used to calculate horizontal ground speed and altitude.

The four outer corners of the grid were surveyed and used to determine where and when the aircraft entered and exited the grid. From the survey of the grid corners, the altitudes of the points was known and an average was calculated first from the points at the ends of the grids and then those averages were averaged to get the general level of the grid. Aircraft altitude above the ground level (AGL) was calculated with the average altitude of these points and the aircraft altitude as it flew through the grid.

Results/Discussion

Thirty five drops were conducted over 3 days. Of the 35 recorded flights, 33 had successful data recorded over the grid. On 2 flights, the data was completely lost over the grid due to data corruption likely caused by antenna shielding by the aircraft or poor satellite geometry at the time. Another flight had partial data (31 points over the grid) but the data was usable. Of the 33 successful flights, 13 of those required post processing to achieve the desired accuracy of less than 5 cm.

The location of the reference station near the drop zone is important for accuracy and post processing of the data. The error of a differential system increases with the increase in the baseline distance between the reference and the rover. The radio corrections are transmitted on a VHF radio and more correction data packets are lost with greater range thereby decreasing the real time accuracy. The optimum solution for the best accuracy is when both GPS see the same satellites and have the same corrections. Post processing can increase accuracy and sometimes fix corrupted data but it relies on a short baseline between the reference station and the rover. With a long baseline, if the rover GPS loses satellite lock, for example in a tight turn, it may take minutes to reacquire the lock, and the drop could be missed. It is always best to keep the stations as close as possible to each other.

The analysis of the data showed that approximately 100 data points were gathered as the aircraft transited the grid. It was found that both altitude and velocity were variable during the drops (Table 1). The information is useful because the load hits the grid with ground speed and not airspeed. This data could help explain unexpected results

Table 1: Examples of the desired and actual altitudes and ground speeds during drop testing

ALTITUDE						GROUND SPEED					
Desired Alt (ft AGL)	Avg Alt AGL (ft)	% Error	Desired Alt (ft AGL)	Avg Alt AGL (ft)	% Error	Desired Speed (Kts)	Avg Ground Speed (Kts)	% Error	Desired Speed (Kts)	Avg Ground Speed (Kts)	% Error
120	168	40	100	147	47	105	104	-1	95	104	9
120	150	25	100	101	1	105	104	-1	95	102	8
120	142	18	100	100	0	105	103	-2	95	101	6
120	140	17	100	100	0	105	103	-2	95	101	6
120	135	13	100	99	-1	105	102	-3	95	100	6
120	132	10	100	98	-2	105	100	-5	95	100	6
120	132	10	100	91	-9	105	99	-5	95	99	5
120	130	8	100	85	-15	105	98	-6	95	99	4
120	129	8	80	94	17	105	98	-7	95	98	3
120	127	6	80	89	11	105	98	-7	95	98	3
120	125	4	80	87	9	105	97	-8	95	96	1
120	122	1	80	85	7	105	96	-8	95	94	-1
120	111	-7	80	81	1	105	95	-9	95	92	-3
120	109	-9				105	90	-14			
120	91	-24				105	85	-19			

The GPS records the exact horizontal position of the aircraft during the flight. This information could be used if questions about the flight path needed to be answered after the flight. An example of the flight path from a drop during the test is shown in Figure 4.

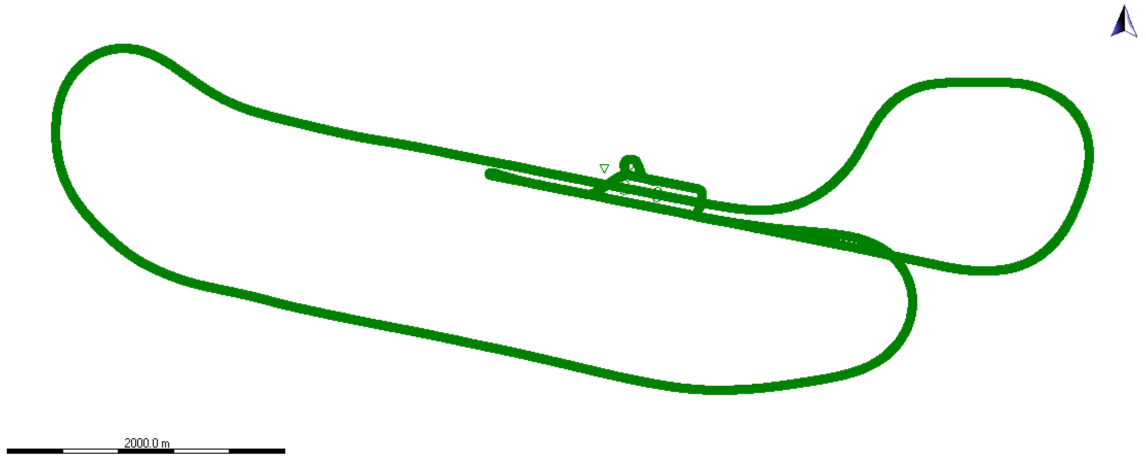

Figure 4: Flight Path Drop 24 Grid 22 AC 96G, documents exactly where the airplane flew during the tests.

By focusing in on the area of the drop, the grid corners and the flight path of the aircraft over the grid can be seen. This can verify that the aircraft passed over the grid and in the case of a missed drop, it can be verified exactly where the aircraft was. This would be important if there was any crosswind component to the drop. The close up detail from Figure 4 is shown in Figure 5. Figure 6 shows a different drop where the aircraft flew close to the grid boundary but was still inside. This was likely due to a crosswind component to the drop.

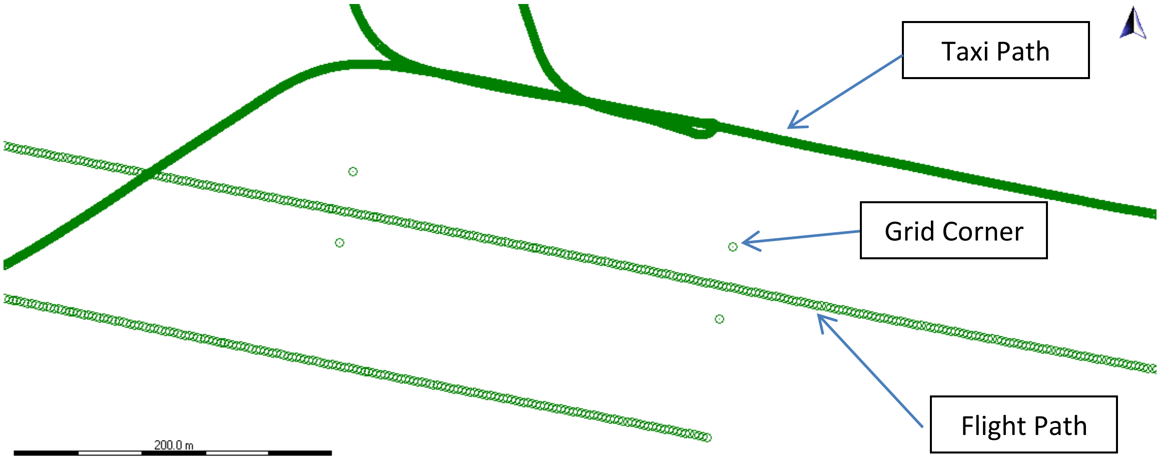

Figure 5: Grid Path Detail, Flight Direction West to East, showing that the aircraft traversed the grid.

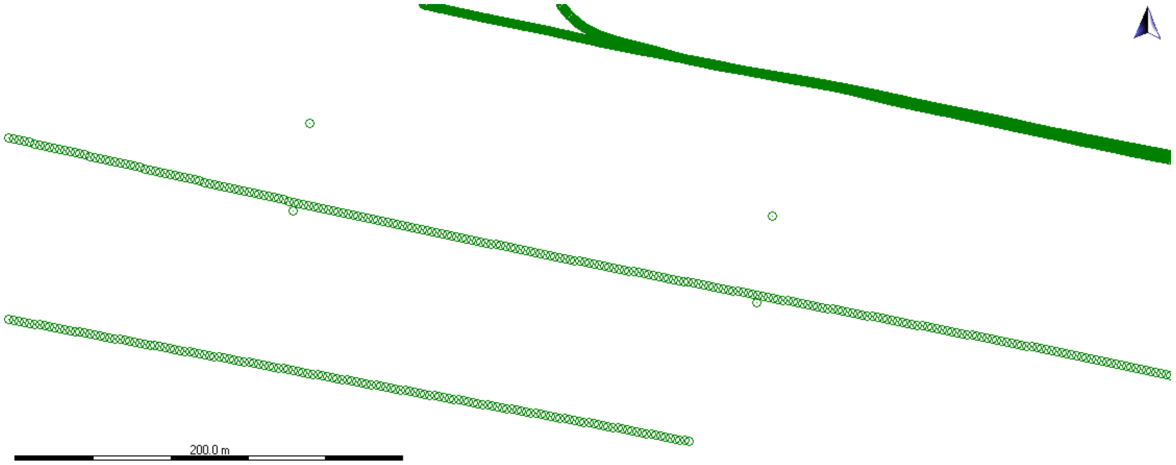

Figure 6: Grid Path Detail, Flight Direction East to West, showing that the aircraft traversed the grid but was close to the edge.

The grid altitude calculation used in the vertical profile is given in Table 2.

Table 2: Grid altitude determination from the grid corners

Grid Corner		Point	Point Alt	Avg Alt	Grid Alt
W	NW	R1-C1	343.2717	343.3391	
	SW	R1-C11	343.4065		
					343.53913
E	NE	R61-C1	343.7996	343.7392	
	SE	R61-C11	343.6787		

Once the average grid height was determined, that value could be subtracted from the GPS altitude of the aircraft. This would give the above ground level (AGL) height of the flight path. This can be important for analysing the ground coverage and can help explain unexpected results. Figure 7 and 8 show the vertical profile for two types of drops. This data was from the same aircraft and pilot, but a different load configuration.

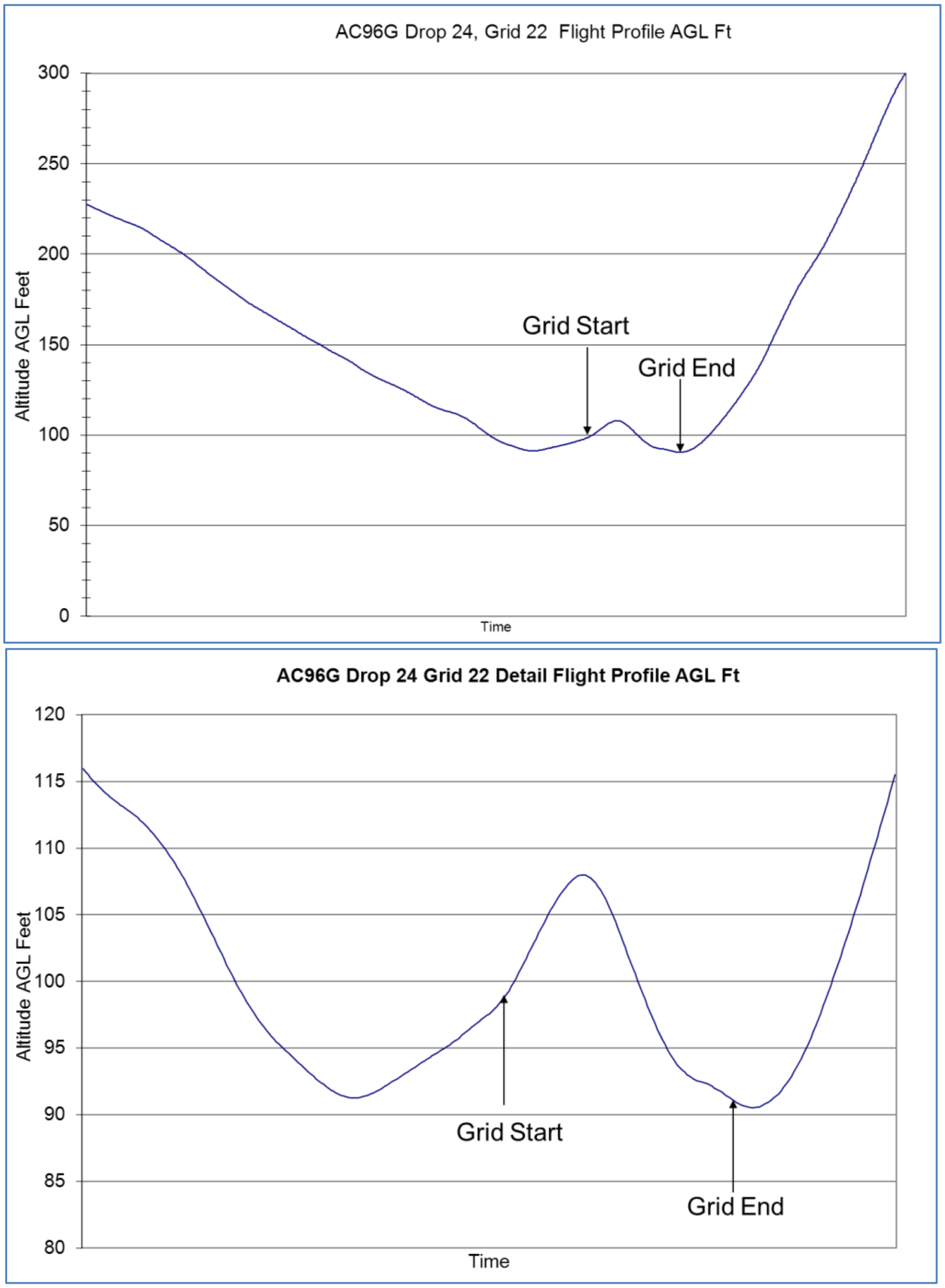

Figure 7: Vertical flight profile for ½ load at maximum flow rate.
Flight approach profile top and grid profile detail bottom.

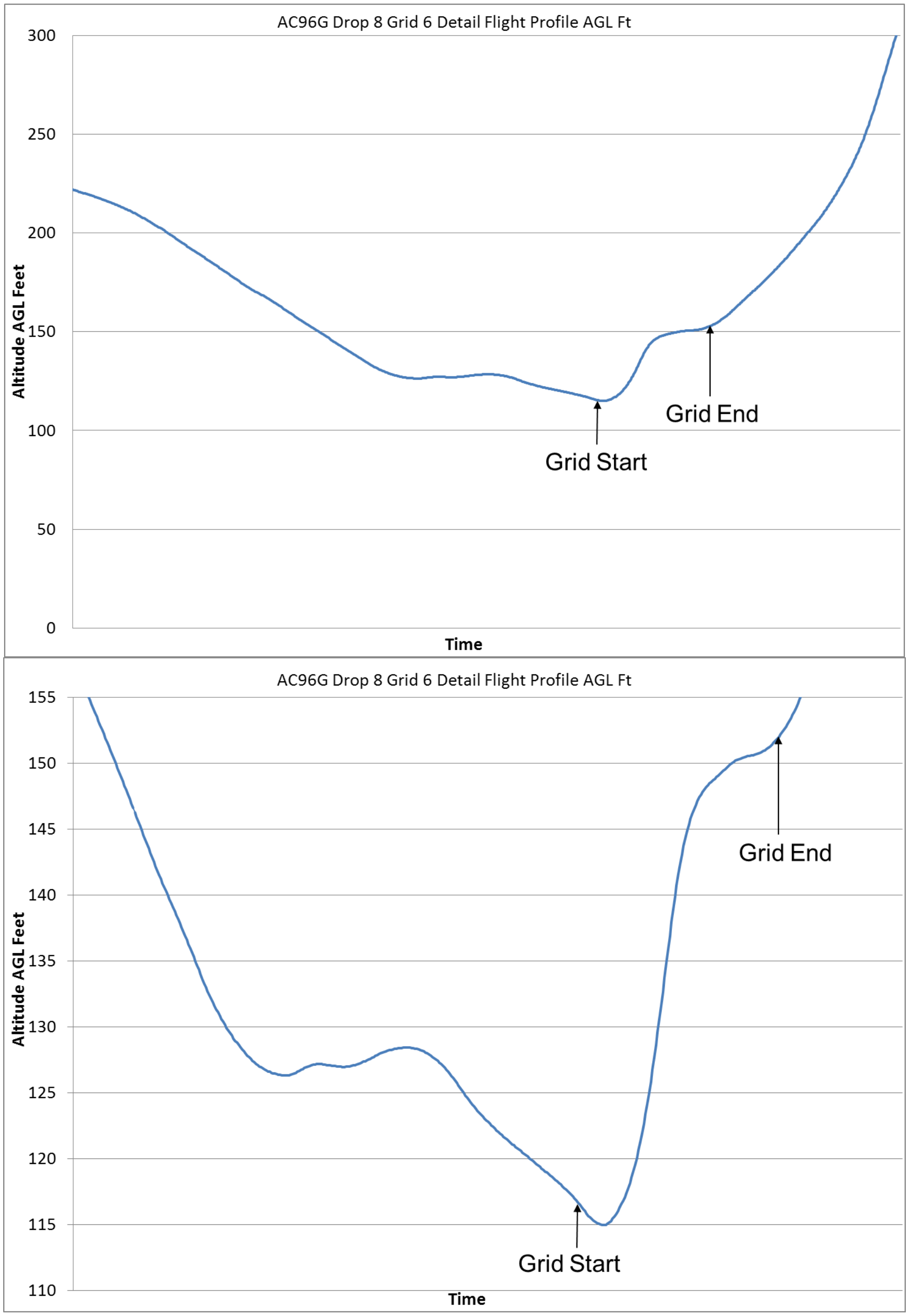

Figure 8: Vertical flight profile for full load at maximum flow rate.
Flight approach profile top and grid profile detail bottom.

Other flight factors, such as button press or doors open, could be added to the data. This could help explain some of the flight characteristics observed during the drops, and be useful when comparing different tank configurations, or flow parameters.

The entire setup was rented for one week for approximately $1500CDN. This was only incrementally more than renting an uncorrected survey grade GPS.

Conclusions

The use of precision GPS in differential mode gave more accurate information of the aircraft ground speed, height and track at multiple points over the drop grid. It allows for a better understanding of the dynamics at play during drop testing, and assists in the pairing of data from the flights. The data from Table 1 shows just how much variability there is in drop testing due to the aircraft attitude and altitude.

This is a superior product and approach for documenting aircraft conditions over a test grid and should be used for future drop tests.