NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

June 25, 2018

Video Study

NTSB Case Number:
ERA18FA006

A. ACCIDENT

Location:	Front Royal, Virginia
Date:	October 7, 2017
Time:	1345 EDT
Aircraft No. 1:	Piper PA-25-235 ('towplane')
Aircraft No. 2:	Schleicher ASK 21 ('glider')

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On October 7, 2017, about 1345 eastern daylight time, a Piper PA-25-235, N90866, was destroyed when it impacted terrain during initial climb from Front Royal-Warren County Airport (FRR), Front Royal, Virginia. The airline transport pilot was fatally injured. The airplane was operated by the Skyline Soaring Club as a glider-tow flight conducted under the provisions of 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed and no flight plan was filed for the local flight.

D. DETAILS OF INVESTIGATION

This study had two goals. The first was estimating the altitude difference between the glider and the towplane when the towplane was visible in the second of two videos recorded by a camera on the glider. There were two such instances in the second video, both shortly before the tow line connecting the glider to the towplane was separated.

The second goal was examining the feasibility of estimating the towplane propeller speed trend based on the videos.

Altitude Difference Estimation

The altitude difference was estimated with a model of the camera optics. The camera installed on the glider was a GoPro Hero 5. It recorded two videos with 1920x1080 resolution and frame rate of 60 fps. The first video recorded the takeoff and was about one minute long. The second video was about nine minutes long and recorded the image of the towplane twice, each time for a fraction of a second, shortly before the tow line was separated. The towplane was not visible in the video after the separation.

The camera had a wide field of view that resulted in barrel distortion of the video frames. The distortion was corrected mathematically using video frames such as the frame from the first video that is shown in Figure 1. Note that images and image reflections of individuals on board the glider were masked to protect their privacy. The runway white stripes were used as the reference for barrel distortion correction. The analysis described below was based on the corrected video frames.

The model of the optics of a camera consists of the three location coordinates (x, y and z), three orientation angles (yaw, pitch and roll) and the horizontal field of view angle (HFOV). In this specific case, altitude difference was measured with respect to the glider and, therefore, the camera location was irrelevant. It could be assumed that x=y=z=0. Since the camera was rigidly mounted on the glider, its location was the glider location.

The three orientation angles of the camera were defined with respect to the symmetry axes of the glider and had to be estimated. The camera was not aligned with the symmetry axes of the glider.

A unique feature in the analysis of this accident was the constraint due to the tow line. The distance from the glider to the tail of the towplane could not be more than the length of the tow line when the tow line was still attached.

The three camera orientation angles and the HFOV angle were estimated based on video frames similar to the one shown in Figure 1. The frames selected for analysis were those in which the two aircraft were moving and the tow line was straight. Its length was set to 160 feet based on the post-accident investigation and a discussion with the glider operator.

A 3D wireframe model of the towplane was constructed that included details of the wings, the empennage and the fuselage. The camera optics model was then used to superimpose on a video frame the wireframe model of the towplane. An iterative process was used where the three location coordinates, the three orientation angles, and the HFOV were varied until the wireframe model optimally matched the image of the towplane in the frame and the tow line length constraint was satisfied. At that time, the angles and the HFOV were the optimal estimates of these parameters and the camera optics model was calibrated.

Figure 1. Frame from the First Video Showing the Towplane on the Runway

Figure 2. Frame from the Second Video Showing the Towplane in Flight

Figure 2 shows a frame from the second video at a time when the towplane was seen for the second time in that video, at video time 8.8 seconds. The location of the towplane with respect to the glider at the time this video frame was acquired was estimated with the camera optics model with its orientation angles and HFOV set to their calibrated values. The process was similar to the calibration process. The wireframe model was superimposed on the video frame and the location and orientation of the wireframe model with respect to the glider were varied iteratively until there was an optimal match between the model and the image of the towplane, and the tow line length constraint was satisfied. At that time, the location and orientation of the wireframe model were the optimal estimates of these quantities.

Note in Figure 2 that the left wing and much of the fuselage of the towplane are not visible in the video frame. Therefore, the location and orientation estimates were based primarily on the right wing and the empennage.

The nominal estimate of the altitude difference between the glider and the towplane was 63 feet (glider at a higher altitude than the towplane). To account for analysis uncertainties, a ±10% tolerance band is assigned to the nominal estimate, resulting in 63±6 feet. With a 160-foot-long tow line, the nominal altitude difference to tow line length ratio is 63/160=0.39.

The yaw angle between the longitudinal axis of the glider to the tail of the towplane, measured in top view clockwise from the glider's longitudinal axis, was 38º. The yaw angle of the towplane with respect to the longitudinal axis of the glider, measured clockwise from the glider, was 15º.

The towplane was also visible in the second video about three seconds before the time of the above analysis. The towplane was less visible than at the later time, but its location and orientation could be estimated. The altitude difference between the glider and the towplane was in close agreement with the altitude difference at the later time.

The time gap between the end of the first video and the beginning of the second video was about 5 seconds. Therefore, the time elapsed between the end of the first video and the time when the video frame shown in Figure 2 was acquired was about 14 seconds. Based on the glider altimeter readings that can be seen in the videos, the glider climbed about 50 feet during this time, from 890 feet MSL to 940 feet MSL. Video analysis showed that the towplane altitude relative to the glider decreased by 63 feet during these 13 seconds. Therefore, the towplane altitude relative to ground decreased by about 63-50=13 feet during these 13 seconds.

Consequently, it is estimated that the towplane started its descent toward ground impact shortly before the time when the video frame shown in Figure 2 was acquired. It impacted ground about 12 seconds past the time when the video frame shown in Figure 2 was acquired.

Feasibility of Propeller Speed Estimation

An attempt was made to estimate the trend of the propeller speed based on the videos. There were two possible estimation methods, one based on the video frames and the other based on the audio channel in the video. Both turned out to be impossible as explained next.

The towplane Lycoming O-540-B2C5 engine has rated speed of 2575 rpm and Performance Cruise speed of 2350 rpm. The propeller had four blades, resulting in blade passage frequency of somewhere between 9400 and 10,300 blade passes per minute. The video frame rate was 60 frames per second, or 3600 frames per minute. Consequently, between 2.6 and 2.9 blades were passing the same angular location between two adjacent video frames. This severe under-sampling made it impossible to measure relatively small rotational speed changes based on visual inspection of video frames.

Spectral analysis of the sound channels was also performed. Spectra in one-second wide time windows were examined for frequencies that could have corresponded to four times engine rpm, twice engine rpm and engine rpm, in an attempt to detect traces of rotor wake. Additionally, because the engine had six cylinders, six times rpm and three times rpm frequencies were also considered.

However, such frequency components could not be consistently identified. The spectra had a large number of peaks near the frequencies of interest, but none of them could be associated with engine rpm and its harmonics. When a promising spectral peak corresponding to an engine harmonic was detected in one (one-second wide) analysis window, it could not be found in the following windows or in the preceding windows. It was concluded that such peaks were due to aerodynamic noise and glider vibrations that were not induced by the propeller or the engine and did not carry the information needed for estimating propeller speed variations.

In summary, the two videos do not contain visual or sound information that could be used to estimate propeller speed variations of the towplane.

E. CONCLUSIONS

Videos recorded by a camera mounted in a glider were used for estimating the altitude difference between the glider and the airplane towing it at a time when the towplane was last seen in a video. It was estimated that the altitude difference was 63±6 feet and the nominal altitude difference to tow line length ratio was 0.39. It was also estimated that at that time, the towplane was already in the early stage of the descent that ended in ground impact.