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

April 4, 2022

Video Study

NTSB Case Number:
WPR22FA101

A. ACCIDENT

Location:	Newport Beach, California
Date:	February 19, 2022
Time:	1834 PST
Aircraft:	MD 500N helicopter

B. AUTHOR

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NTSB

C. ACCIDENT SUMMARY

On February 19, 2022, about 1834 Pacific standard time (PST), a McDonnell Douglas 500N helicopter, N521HB, was substantially damaged when it was involved in an accident in Newport Beach, California. The pilot sustained minor injuries, and the tactical flight officer (TFO) was fatally injured. The helicopter was operated as a public aircraft flight by the Huntington Beach Police Department.

D. DETAILS OF INVESTIGATION

The goal of this study was estimating the yaw rate of the helicopter based on a video. The video was recorded with a gimbaled L3Harris WESCAM MX-10 EO/IR imaging system mounted on the helicopter. The gimbal was capable of controlling the azimuth (yaw angle) and the elevation (pitch angle) of the camera. The analyzed video lasted about two minutes, had 1024x768 resolution and frame rate of 30 fps. An AeroComputers digital mapping system saved the video with superimposed information. Figure 1 shows a frame from the saved video that was acquired at time 18:33:07.

Figure 1. Frame from the Analyzed Video

The video frame in Figure 1 shows the location coordinates of the helicopter in degrees:minutes:seconds format. Because of the relatively low one-second location resolution, some video frames that were recorded at different times and at different locations were assigned the same coordinates. Figure 2 shows the area where the accident happened. The camera was looking at the sidewalk at 2203 West Balboa Boulevard in Newport Beach, on the west side of the boulevard. That location is marked in blue in the figure.

Five locations are marked in red in Figure 2. The numbers near the red marks are the seconds past 18:33:00. Because of the low location resolution, the helicopter locations recorded on the video between 18:33:06 and 18:33:08 are unchanged and the recorded locations between 18:33:09 and 18:33:11 are unchanged. The helicopter was moving during these periods.

There was an ADS-B record available that had time resolution better than one second. Figure 3 shows in red the helicopter locations from Figure 2, that are based on the video, and in yellow some of the helicopter locations from the ADS-B data. The numbers along both ground tracks are the times expressed as seconds past 18:33:00.

The video-based track shows video time and the ADS-B track shows ADS-B time. The last ADS-B data point was at 18:33:28.2. The last camera data point was at 18:33:21.

The two ground tracks are based on different data sources and, therefore, the tracks do not coincide exactly. However, locations corresponding to the same times are closer than 150 feet from each other, indicating a good agreement between the two sources of data.

Figure 2. Aerial View of the Accident Area

The green icons in Figure 1 show the orientation of the camera with respect to the helicopter. It shows that the camera turret azimuth angle was 91º and the gimbal elevation angle was -34º. The video frame also displays the time when the image was acquired and the altitude of the helicopter.

The image in Figure 1 is of the sidewalk at 2203 West Balboa Boulevard in Newport Beach, on the west side of the boulevard. That location is marked on the aerial view in in Figure 2. The sidewalk was used as a reference for helicopter yaw angle and yaw rate estimation. When traveling south on West Balboa Boulevard, the heading is 160º, i.e., the direction is 160º clockwise from north.

Figure 1 shows that the azimuth angle of the camera is 91º with respect to the longitudinal axis of the helicopter. The sidewalk orientation with respect to the bottom of the video frame can be measured in the figure as 16º counterclockwise. A simplistic and incorrect estimate of the helicopter yaw angle with respect to the sidewalk is that it was oriented 91º-16º=75º counterclockwise from the orientation when the helicopter nose points perpendicularly at the sidewalk. The 91º angle accounts for the yaw angle of the camera turret with respect of the helicopter and the 16º accounts for the yaw angle of the camera with respect to the sidewalk. However, this is incorrect as explained next.

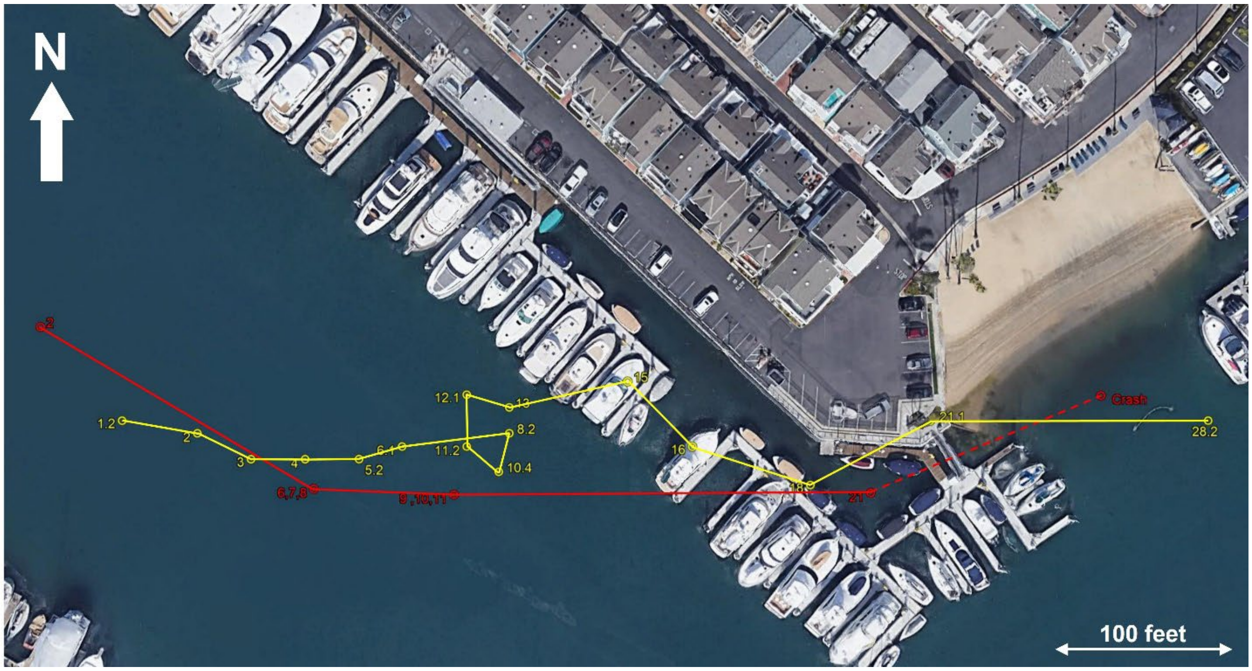

Figure 3. Helicopter Ground Track (red: based on video; yellow: based on ADS-B)

The yaw angle of the camera with respect to the sidewalk would have been correct if the camera was looking straight down at the sidewalk However, as can be seen in Figure 1, the elevation angle of the camera was -34º, i.e., the camera was looking at the sidewalk at an angle that was 34º relative to the horizontal plane. This made the width of the sidewalk in Figure 1 appear significantly narrower than what it would have been if the camera was looking straight down at the sidewalk. Consequently, the 16º angle measured in the figure is not the yaw angle between the camera and the sidewalk.

The correct method for estimating the yaw angle of the helicopter consists of placing a mathematical model of the helicopter at the location indicated by the latitude-longitude coordinates in Figure 1 and at the elevation indicated in the figure. A model of the camera is then placed on the helicopter and oriented by the indicated azimuth and elevation angles with respect to the helicopter.

A model of the sidewalk is then constructed consisting of two parallel lines spaced by 9 feet, the width of the sidewalk, and oriented by 160º, the orientation of the sidewalk with respect to north. A mathematical model of the camera can then be used to superimpose the images of the two lines on a frame from the video. This is followed by varying the helicopter yaw angle until the superimposed lines coincide with the real curb-side edge of the sidewalk and its real building-side edge. When optimal alignment of the superimposed lines and the real sidewalk edges is achieved, the yaw angle of the helicopter model is the optimal estimate of the real helicopter yaw angle when the analyzed video image was recorded.

Both the pitch angle and the roll angle of the helicopter affect the estimation of the yaw angle. However, there is no information available on these angles. Therefore, both were assumed to be zero. This is a reasonable assumption because while the helicopter was in stable flight, these angles were likely to be small. This Video Study only analyzed the helicopter yaw angle using this method while it was in stable flight.

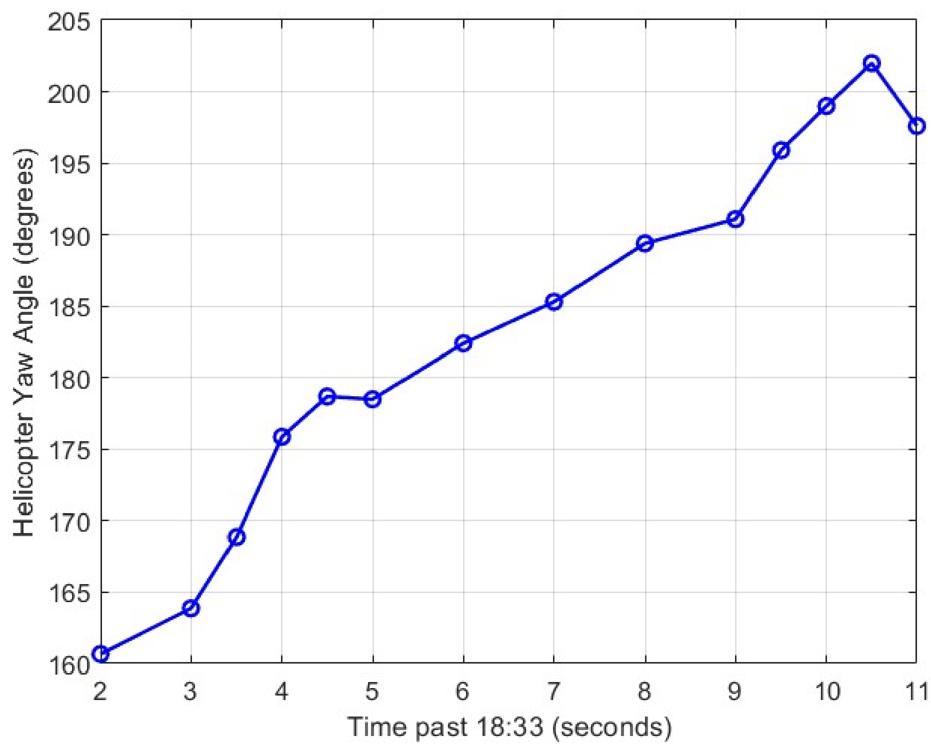

Figure 4. Estimated Helicopter Yaw Angle (clockwise from north)

Figure 4 shows the estimated helicopter yaw angle measured clockwise with respect to north at 14 times between 18:33:02 and 18:33:11. Figure 5 shows the estimated helicopter yaw rate. The yaw rate was computed by dividing the yaw angle difference by the time difference between pairs of adjacent data points. Because the yaw rate was estimated over short time periods, the accuracy of the data points in Figure 5 is ±2 degrees/second.

The time axes in Figures 4 and 5 end at time 18:33:11. Past that time, the camera azimuth angle was changing so fast that it was no longer possible to identify ground references in the video frames. Past time 18:33:11, the helicopter was no longer in stable flight or stable hover.

Figure 6 shows the camera yaw angle with respect to the helicopter, as it was read off video frames. Past time 18:33:12, the angle is increasing rapidly. It is assumed that the camera was rotating counterclockwise as it was attempting to keep pointing at 2203 West Balboa Boulevard while the helicopter was rotating clockwise. Therefore, the estimated yaw rate of the helicopter during the last six seconds of flight was about +134 degrees/second.

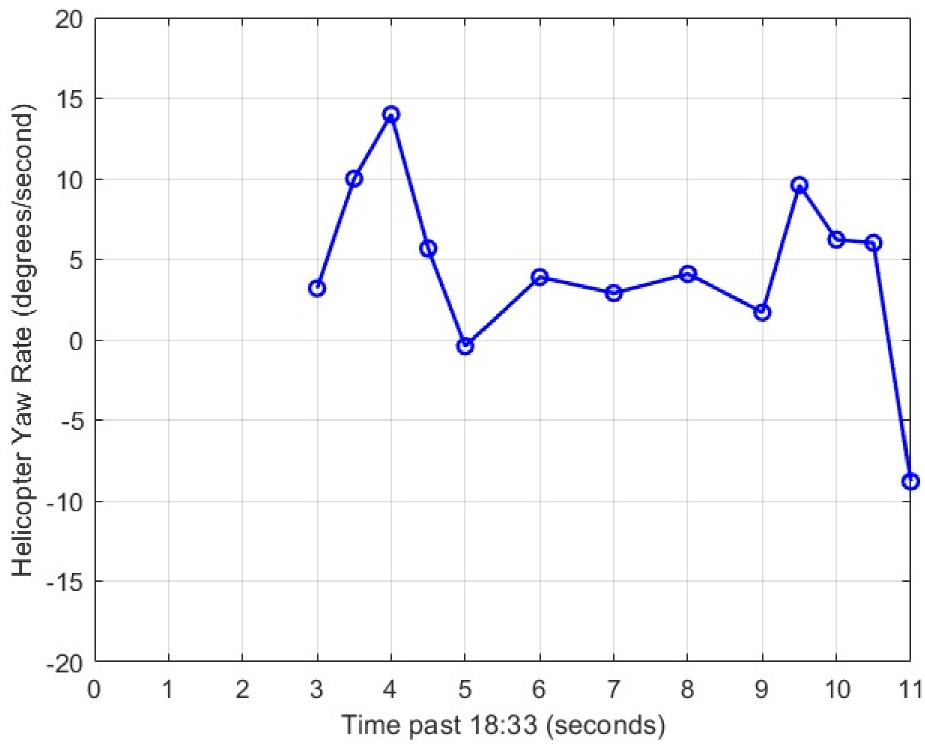

Figure 5. Estimated Helicopter Yaw Rate

A camera on the ground recorded the last seven seconds of the flight of the helicopter, ending at the time of water impact. The yaw rate of the helicopter during this period was estimated at about 140 degrees/second. The good agreement between this estimate and the one based on the camera yaw angle supports the assumption that the camera was offsetting the helicopter yaw rate by rotating in the opposite direction.

The estimated yaw rate of the helicopter shown in Figure 5 can be combined with the estimate of helicopter yaw rate based on the camera yaw angle with respect to the helicopter shown in Figure 6. Figure 5 shows that the estimated helicopter yaw rate between time 18:33:05 and time 18:33:10.5 was in the range between 0º and 10º, indicating a small right yaw. Figure 6 shows that past time 18:33:12 the helicopter was already in a high-rate right yaw indicated by the high negative yaw rate of the camera. At time 18:33:13.5, the helicopter was already yawing at the high rate of above 130 degrees/second that stayed approximately constant until water impact. This indicates that the helicopter transitioned from a stable controlled flight to an unstable right yaw in less than three seconds.

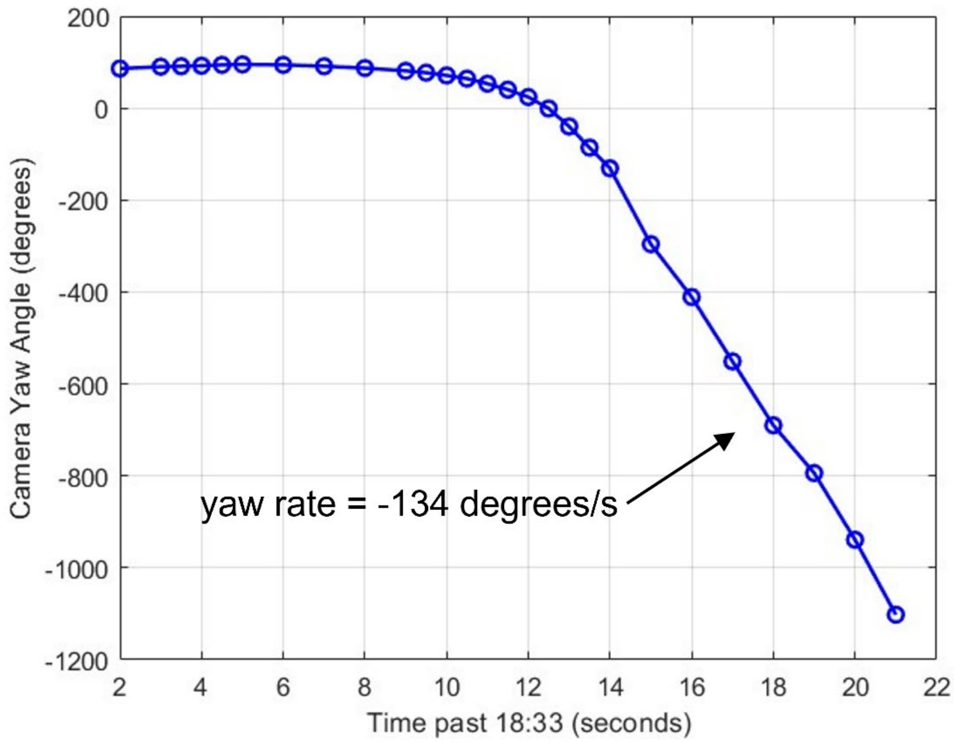

Figure 6. Camera Yaw Angle with Respect to Helicopter

The ADS-B ground track shown in yellow in Figure 3 shows an approximate 360º clockwise circular path between ADS-B time 18:33:8.2 and ADS-B time 18:33:13. The helicopter location stayed within a circle with a 50-foot diameter during this maneuver. It is likely that this maneuver and the sudden increase of the helicopter yaw rate point to the same transition from stable flight to the high yaw rate spin that ended in water impact.

E. CONCLUSIONS

The yaw rate of a helicopter that crashed was estimated based on a video recorded with a camera mounted on the helicopter. The yaw rate transitioned from a stable low-speed right yaw to a yaw rate higher than 130 degrees/second in less than three seconds. This high yaw rate continued until water impact.