National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

DCA22FA082

VIDEO STUDY

Specialist's Study

January 25, 2023

A. ACCIDENT

Location: Jolon, CA
Date: February 16, 2022
Time: 09:58 pacific standard time (PST)
UAS: Joby Aero Inc. JAS4-2, N542AJ

B. VIDEO STUDY SPECIALIST

Specialist: Sean Payne
Sr. Engineer
National Transportation Safety Board (NTSB)

C. DETAILS OF THE INVESTIGATION

A group was not convened. The NTSB Vehicle Recorder Division received the following electronic device and files:

Recorder Manufacturer/Model:	SanDisk Extreme 128GB microSD card
Recorder Serial Number:	D361YFHJ70QZ
Associated Device:	GoPro HERO MAX (Spherical Capture)

1.0 Device Description

GoPro HERO MAX

For a description of the device, refer to the Electronic Devices Specialist's Factual Report, which can be found in the public docket for this accident.

1.1 Data Recovery

GoPro HERO MAX

For details on the data recovery process associated with this device, refer to the Electronic Devices Specialist's Factual Report, which can be found in the public docket for this accident.

1.2 Recording Description

GoPro HERO MAX

The accident event was captured in a 6 minute, 41 second recording. Joby documents report that the position of the HERO MAX is roughly equivalent to eye level when seated at the operator's position. Figure 1 is a photograph of the memory device associated with the camera. The recording captured the earlier portions of the test point, through the flight test anomaly and ended after N542AJ had entered into a loss of control but prior to impact with terrain. The file was both processed independently by the NTSB and also made available to Joby.

Figure 1. GoPro HERO MAX installed in N542AJ.

1.3 Time Correlation

Data from the HRR was recorded in Universal Coordinated Time (UTC) and was assumed to be correct. The data was offset -28,880 seconds to bring it in alignment with Pacific standard time (PST) which was the local time of the accident.

Timing information for the GoPro HERO MAX was approximated by comparing values for motor speed at station 4 to the time of impact of the blade from station 3 shown in figure 11. Specifically, at 09:58:11.473 PST, values for motor speed of station 4 began to increase rapidly and diverge from the other stations. Time was then offset for each presented GoPro camera frame based on a frame rate of 29.97 frames per second (fps). The resultant time in shown in the narrative below and figure descriptions.

1.4 Video Data and Study

GoPro HERO MAX

The manufacturer's supplied software was used to orient the 360° recording such that the image frame was centered around station number 3 propellor. Screen captures that appear below provide a fundamental timeline of the flight test anomaly.

The time format is given in local time, PST. This time correlation was created by comparing with data from the HRR.

Using a CAD model of the aircraft, Joby created a method that allowed blade angle of visible propellors on station 3 to be estimated. Joby validated this method using images recorded prior to the test anomaly. Figure 2 is an overlay of the CAD model and station 3 of N543AJ showing a nominal position of [redacted] degrees. Note the CAD model's opacity has been altered to show internal structure such as the blade roots.

Figure 2. CAD overlay at nominal position of [redacted] degrees.

The first examined image provided in figure 3 was captured at 09:58:11.373 PST. This figure shows the blades at a nominal position for the given conditions. Note the position of the outboard upper blade in relation to a shadow cast on the blade itself. The shadow is cast on the entire blade. The shadow is annotated in figure 3.

Figure 3. Time 09:58:11.373 PST. Blade shown at a nominal blade angle for the given conditions.

Figure 4 is a screen capture containing the CAD model overlay that was created by Joby. The CAD model shows correlation between the model and the data reported from the HRR for station 3 commanded pitch angles at the annotated time (same time as figure 3). For information on the data reported from the HRR, see the Electronic Devices Specialist's Factual Report, which can be found in the public docket for this accident.

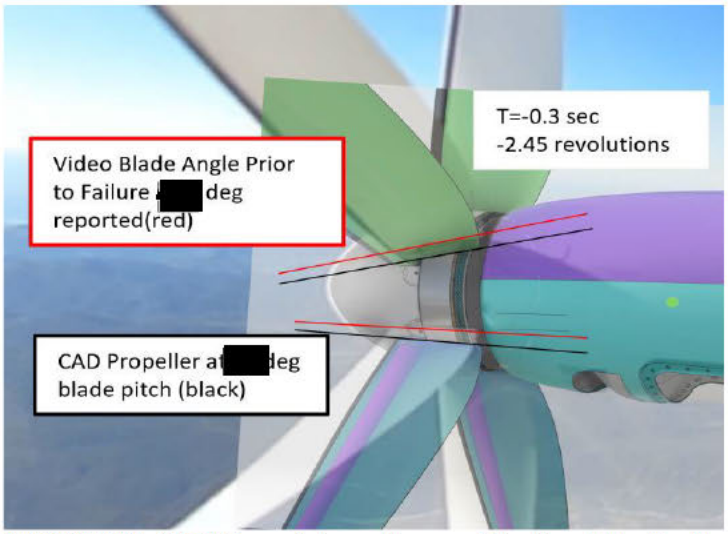

Figure 4. Time 09:58:11.373 PST. A CAD model overlay provided by Joby for the referenced time, showing nominal conditions.

The next screen capture provided in figure 5 was captured at 09:58:11.373 PST. The arrow points to an area of the upper outboard blade, which is no longer in shadow, showing that the blade had reached a steeper angle. For comparison, the upper outboard blade from the previous figure is inset to better illustrate the difference.

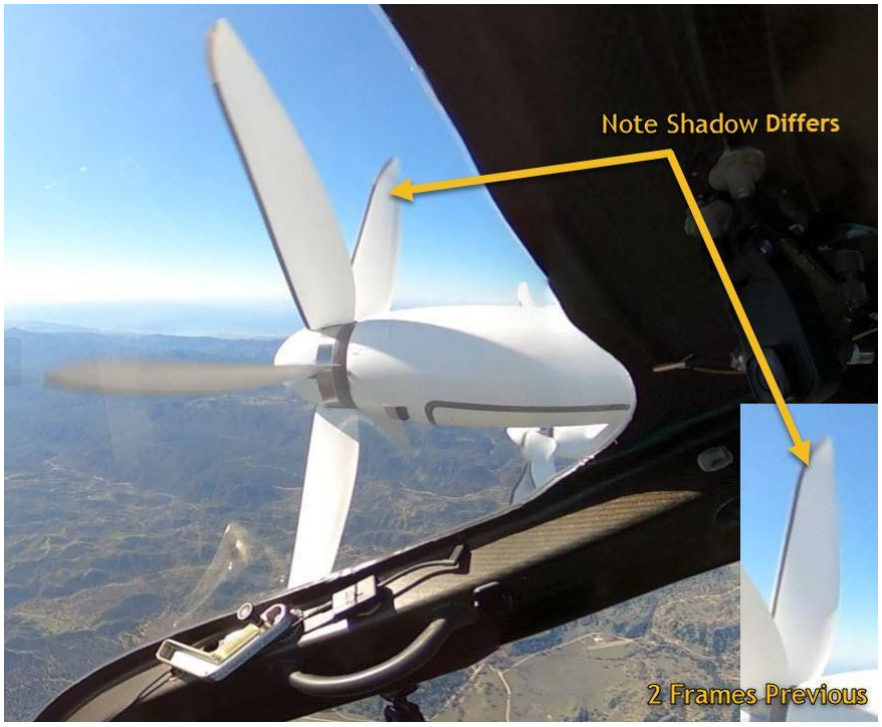

Figure 5. Time 09:58:11.373 PST. Blade shadow differences are illustrated.

The next screen capture provided in figure 6 was captured at 09:58:11.406 PST. A blade later identified to be the first to depart (herein referred to as the failure blade) shows a possible trailing edge split on the blade that would be first to depart station 3. A blade, later identified to be the second blade to depart station 3 exhibits a possible core disbond. Note the blade pitch angle at this time is flatter than the previous imagery.

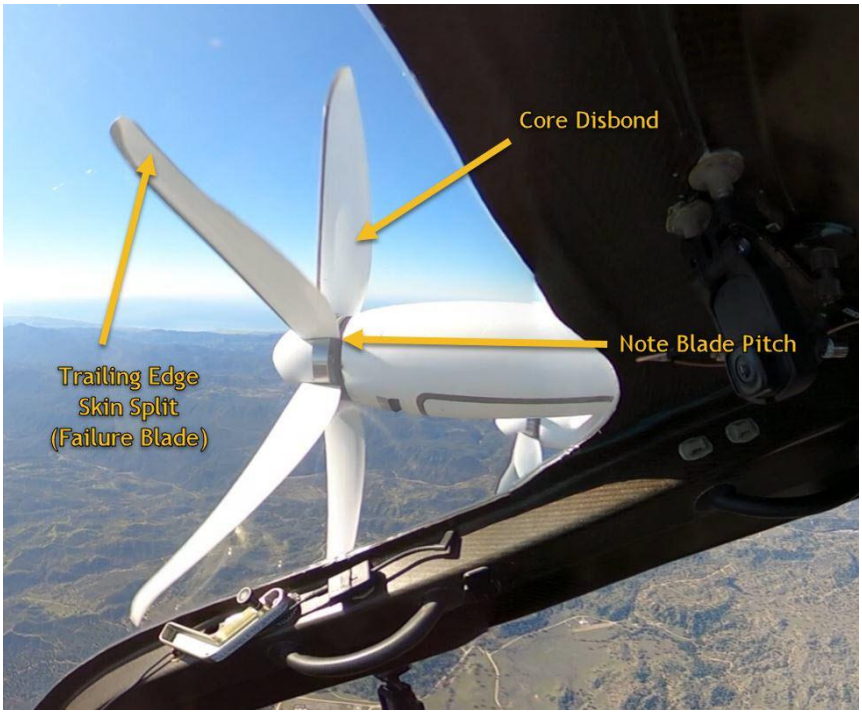

Figure 6. Time 09:58:11.406 PST. The image shows a core disbond, a possible trailing edge skin split and increased pitch angle of the ascending blade.

The next screen capture provided in figure 7 was captured at 09:58:11.440 PST. This image captures the moment the failure blade began to depart from station 3. Joby engineers identified a skin split[1] at this time, annotated in the figure. The blade appeared to become displaced radially from the hub. The blade also begins to trail its nominal position. Using the CAD model comparison method, the blade angle for the inboard ascending blade appears above the mechanical stop.

[1] Skin split – In this context, the skin of the propellor blade delaminates from the core structure. It appeared as separate of the two propellor blade skins at the trailing edge.

Figure 7. Time 09:58:11.440 PST. The frame shows the failure blade departing from station 3. The inboard ascending blade has pitched beyond its mechanical stop.

Figure 8 was captured at 09:58:11.473 PST. This image shows the failure blade impacting station 4.

Figure 8. Time 09:58:11.473 PST. The frame shows the failure blade contacting station 4.

Figure 9 was captured at 09:58:11.704 PST. This frame shows station 4 rotating downward and departing from its nominal position.

Figure 9. Time 09:58:11.704 PST. The frame shows station 4 departing from its nominal position.

Figure 10 was captured at 09:58:12.01 PST. This frame shows station 4 free from the UAS. An annotation shows the root area where the failure blade was once attached to station 3.

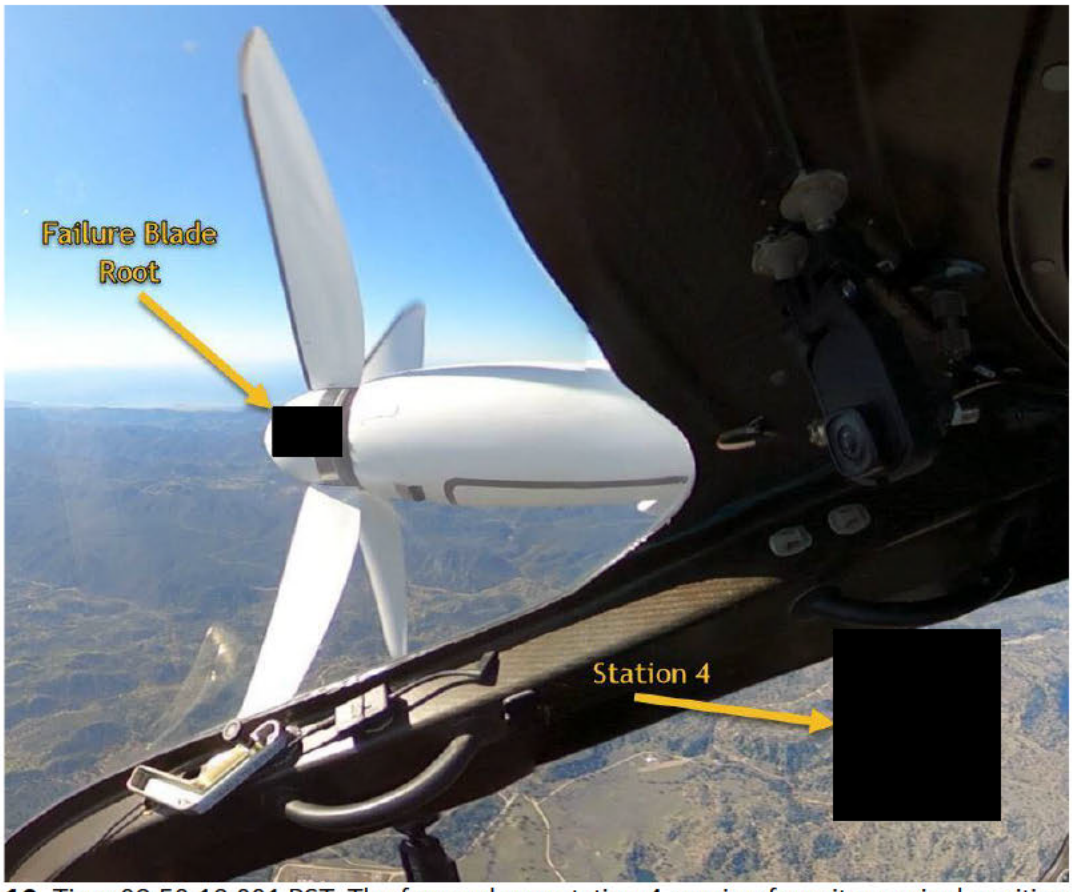

Figure 10. Time 09:58:12.001 PST. The frame shows station 4 moving from its nominal position. An annotation shows where the failure blade was once attached to station 3.

Figure 11 was captured at 09:58:12.793 PST. it shows the vehicle had pitched forward. Station 3 is missing numerous blades and station 4 was missing from the vehicle entirely. The glareshield detached and began to enter the cockpit area.

Figure 11. Time 09:58:12.793 PST. Shows the vehicle pitching forward, the missing blades from station 3, missing station 4. The glareshield had begun to detach.

No further imagery is discussed.