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

ANC23FA008

GLOBAL POSITIONING SYSTEM (GPS) & ATTITUDE HEADING REFERENCE SYSTEM (AHRS) DEVICE

Specialist's Factual Report

May 30, 2023

A. ACCIDENT

Location: Kaupo, HI
Date: December 15, 2022
Time: 21:14 Hawaii-Aleutian standard time (HST)
Aircraft: Raytheon Aircraft Company C90A, Guardian Flight LLC, N13GZ

B. GLOBAL POSITIONING SYSTEM (GPS) & ATTITUDE HEADING REFERENCE SYSTEM (AHRS) DEVICE SPECIALIST

Specialist: Sean Payne
Branch Chief – Vehicle Recorder Division
National Transportation Safety Board (NTSB)

C. DETAILS OF THE INVESTIGATION

A recorded flight data group was not convened. The NTSB Vehicle Recorder Division received the following electronic device:

Recorder Manufacturer/Model: Appareo Stratus 2S
Part Number: 153510-000008
Recorder Serial Number: Stratus2S005652

1.0 Appareo Stratus 2S Description

The Appareo Status device is a self-contained battery powered unit that contains an internal AHRS, GPS/WAAS receiver, and ADS-B receiver in one compact unit.[1, 2, 3] The unit communicates wirelessly with the pilot's iPad or iPhone ("iOS Device") to display all of the acquired information. The pilot needs to have a particular software application called ForeFlight installed on their iOS Device to view the Stratus data.[4] In addition to communicating with the iOS Device, the Stratus

[1] The Attitude Heading Reference System consists of a set of 3-axis gyroscope, accelerometers and heading reference sensors that enable the unit to compute pitch, roll, and yaw motions.
[2] The Wide Area Augmentation System (WAAS) is an air navigation aid to augment the Global Positioning System (GPS), by improving its accuracy, integrity, and availability.
[3] Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology deployed throughout the national airspace system. The ADS-B system is composed of aircraft avionics and a ground infrastructure. Onboard avionics determine the position of the aircraft by using the GNSS and transmit its position along with additional information about the aircraft to ground stations for use by ATC and other ADS-B services. This information is transmitted at a rate of approximately once per second. Operators equipped with ADS-B realize additional benefits from ADS-B broadcast services: Traffic Information Service - Broadcast (TIS-B) (traffic information) and Flight Information Service - Broadcast (FIS-B) (weather information).
[4] iOS Device app (program) that communicates wirelessly with the Appareo Status unit to display aircraft's attitude, navigation, weather, and traffic information.

device records GPS position and AHRS information internally on a non-volatile flash memory chip.[5] Internal memory has the space to store over 13 hours of data.

1.1 Appareo Stratus 2S Device Condition and Data Recovery

The device had evidence of light impact damage and had been submerged in seawater during the accident. The device was shipped to the NTSB Vehicle Recorder Laboratory in fresh water. The device is pictured in figure 1 in arrival condition.

The device was disassembled and the main board was removed an inspected. The main board had light corrosion damage, as shown in figure 2. The NVM chip containing the flight data was identified, removed, read out, and converted using NTSB software. The flight data is discussed below.

Figure 1. The front of the Appareo Stratus 2S.

[5] Type of solid-state memory that does not require electrical power to retain information.

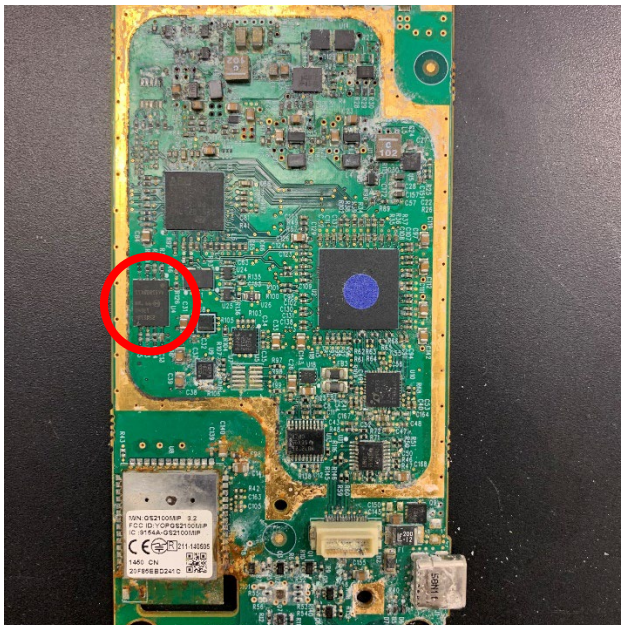

Figure 2. The main board and NMV chip (circled in red).

1.2 Appareo Stratus 2S Time Correlation

Data from the Appareo Vision 1000 was considered authoritative. The Appareo Stratus data in this report was compared to the Appareo Vision 1000 data and a time offset was created. It was determined that the Appareo Stratus dataset was 18 seconds ahead of the Appareo Vision dataset. The following time offset calculation was created:

Appareo Stratus Dataset – 18 Seconds = HST

1.3 Appareo Stratus 2S Parameters Provided

The parametric data were recorded at a sampling rate of 5 Hz. Table 1 lists the recorded parameters verified and provided in this report.

Parameter Name (unit)	Parameter Description	Source
Latitude_S (Degrees)	Geometric latitude (degrees)	Stratus
Longitude_S (Degrees)	Geometric longitude (degrees)	Stratus
BframeAcceleration_Y_S (g)	Longitudinal acceleration (gs)	Stratus
BframeAcceleration_X_S (g)	Lateral acceleration (gs)	Stratus
BframeAcceleration_Z_S (g)	Normal acceleration (gs)	Stratus
NormalAccel-V1K (g)	Normal acceleration (gs)	Vision 1000
Slip_S (g)	Slip (gs)	Stratus
Pitch_S (deg)	Pitch angle (degrees)	Stratus
Pitch-V1K (deg)	Pitch angle (degrees)	Vision 1000
Roll_S (deg)	Roll angle (degrees)	Stratus
Roll-V1K (deg)	Roll angle (degrees)	Vision 1000

Parameter Name (unit)	Parameter Description	Source
VerticalSpeed_S_2 (fpm)	Vertical speed (feet per minute)	Stratus
VerticalSpeed-V1K (fpm)	Vertical speed (feet per minute)	Vision 1000
Heading_S (deg)	Heading (degrees True)	Stratus
Heading-V1K (deg)	Heading (degrees True)	Vision 1000
Groundspeed_S (kts)	Groundspeed (kts)	Stratus
Groundspeed-V1K (kts)	Groundspeed (kts)	Vision 1000
Altitude_HMLS_S (ft)	Altitude (feet)	Stratus
Altitude-V1K (ft)	Altitude (feet)	Vision 1000

1.4 Appareo Stratus 2S Data Description

The device contained a dataset with similar recorded parameters that were retrieved from the Appareo Vision 1000 device. For details on the Appareo Vision 1000 dataset, see the Onboard Image and Parametric Recorder Group Chairman's Factual Report, which can be found in the public docket for this accident.

Unlike the Appareo Vision 1000 device which is hard mounted to the aircraft, the Appareo Stratus can be positioned in the cockpit using a number of different temporary methods. The two most popular ways to mount the device are via a suction cup mount, or with a rubber non-skid type mat which holds the device on a flat surface in the aircraft. Both of these mounts are provided by the manufacturer. Imagery from the Vision 1000 device used in the Onboard Image and Parametric Recorder Group Chairman's Factual Report did not reveal how the Appareo Stratus was mounted. Either mounting device is subject to allowing the device to come loose during abrupt maneuvers, such as in an accident scenario. Since the Appareo Stratus records its own motion, a loosely mounted device would provide only the positioning data of the device itself and not necessarily that of the accident aircraft.

Figures 3 through 5 are plots of the Appareo Stratus data compared with data from the hard mounted Appareo Vision 1000 device. Parameters from the Stratus device have the suffix "_S" and parameters from the Appareo Vision 1000 device have the suffix "-V1K."

Figure 3 is a plot from 20:45 to 21:20 HST. This time range shows the recovered dataset for the entire accident flight. Details of the data are discussed in the Onboard Image and Parametric Recorder Group Chairman's Factual Report, which can be found in the public docket for this accident.

Figure 4 is a plot of data for the time range between 21:05 and 21:15 HST. This plot shows the approximate last nine minutes of the accident flight.

Figure 5 is a plot of data for the time range between 21:13 and 21:14:15 HST. This plot shows the approximate last minute of the accident flight. Note that the plot shows areas in which the Appareo Stratus data began to diverge from that of the Appareo Vision 1000 data. It is possible the reason for this difference in the two datasets was due to the Appareo Stratus device becoming lose from its mount during the dynamic portion of the accident flight. The Onboard Image and Parametric

Recorder Group Chairman's Factual Report did not, however, indicate the Appareo Stratus was visible in the image frames during the dynamic portion of the accident flight. Since the two datasets diverged, specifically in pitch, roll, accelerations and derived track and speed data, the dataset from the Appareo Vision 1000 system was determined to be authoritative.

A Google Earth overlay was not created from the Appareo Stratus dataset. Instead, the Appareo Vision 1000 dataset provided tracklog data used for creating a Google Earth overlay, in the Onboard Image and Parametric Recorder Group Chairman's Factual Report, which can be found in the public docket for this accident.

All data that appears in figures 2 through 4 is appended to this report as Attachment 1 and is provided in comma separated format (.csv).

Submitted by:

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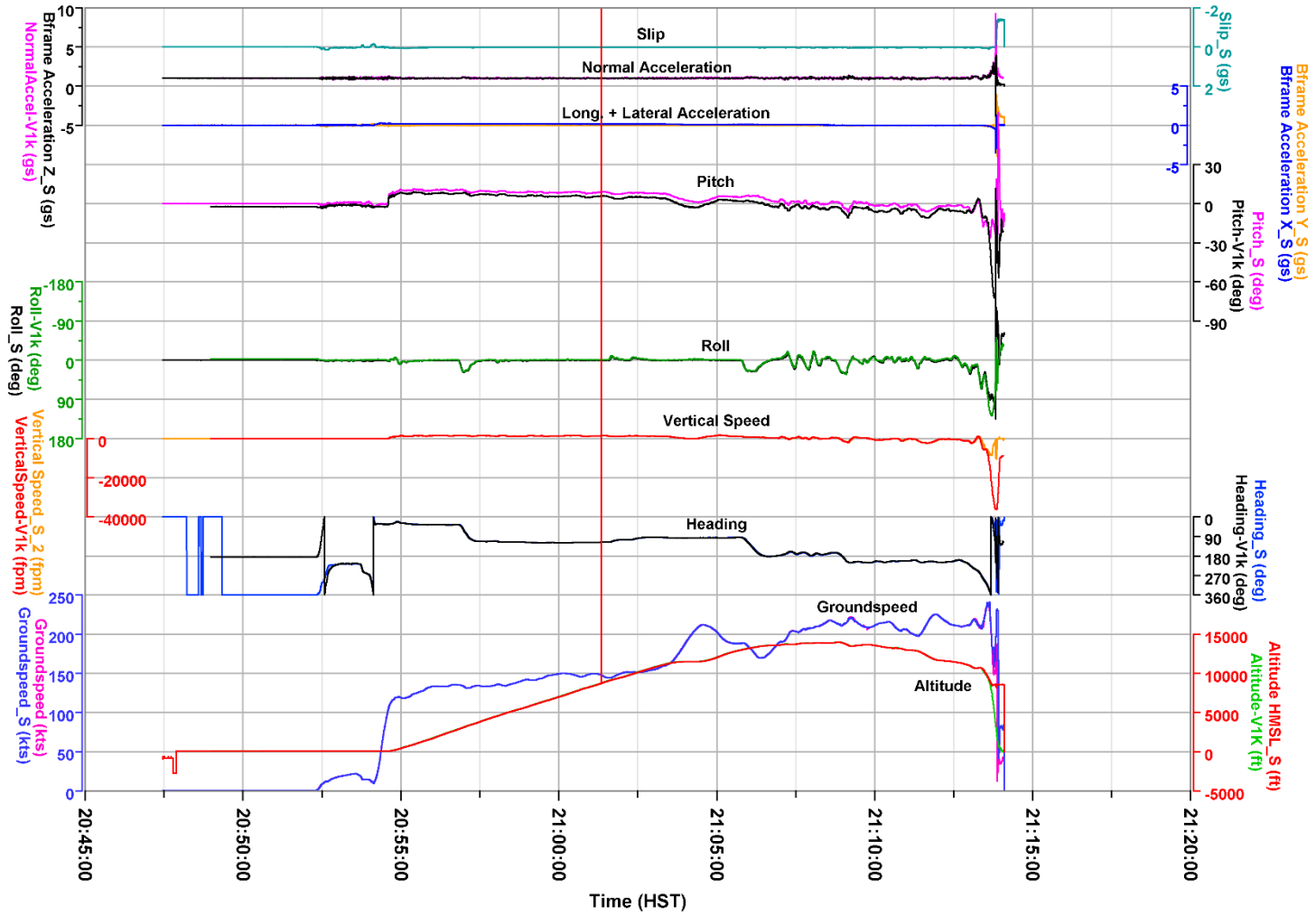

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Figure 3. A plot of both Appareo Stratus and Vision 1000 data from 20:45 to 21:20 HST. The red spike in Altitude_HMSL_S is a bad segment of data.

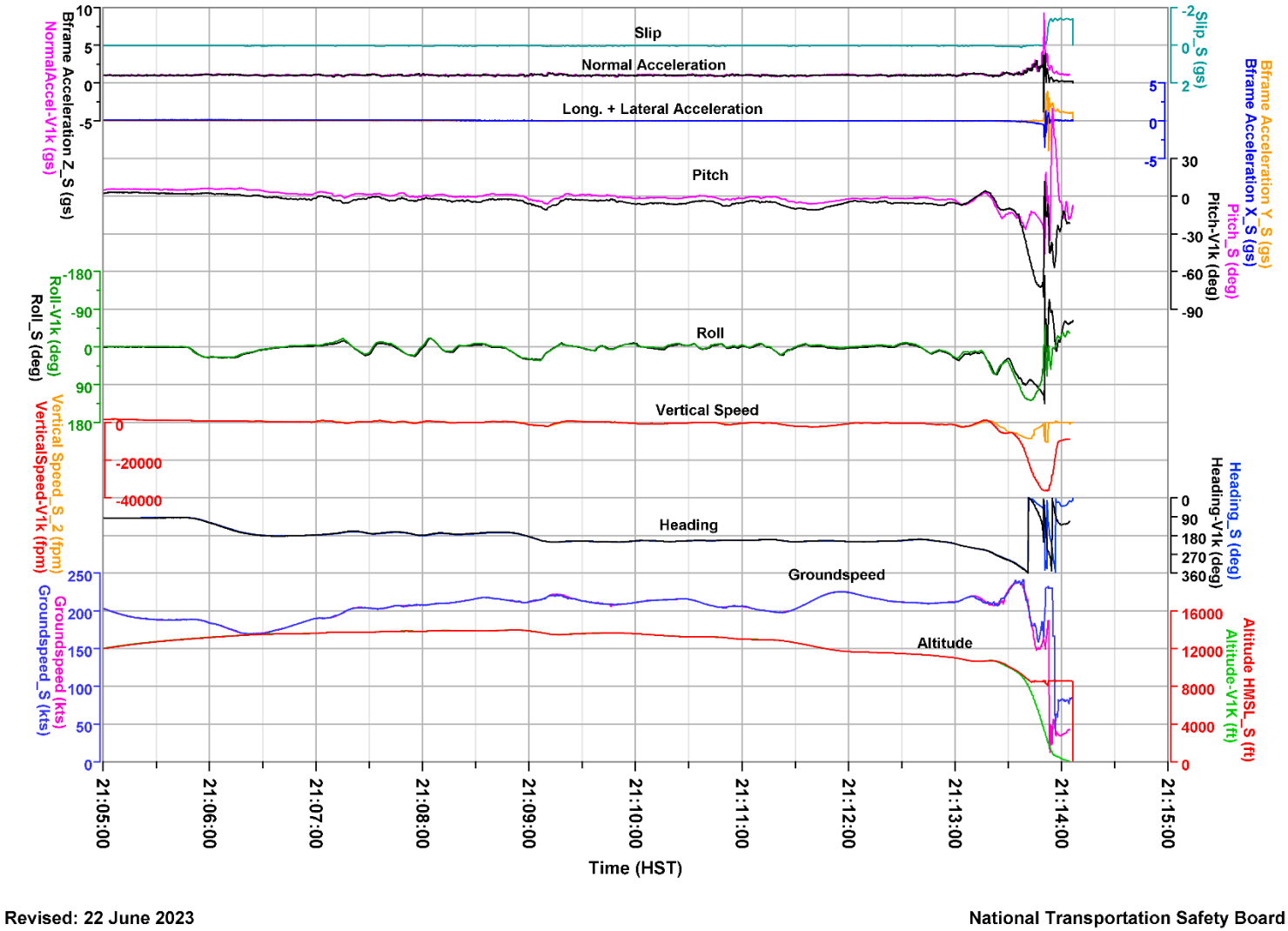

Figure 4. A plot of both Appareo Stratus and Vision 1000 data from 21:05 to 21:15 HST.

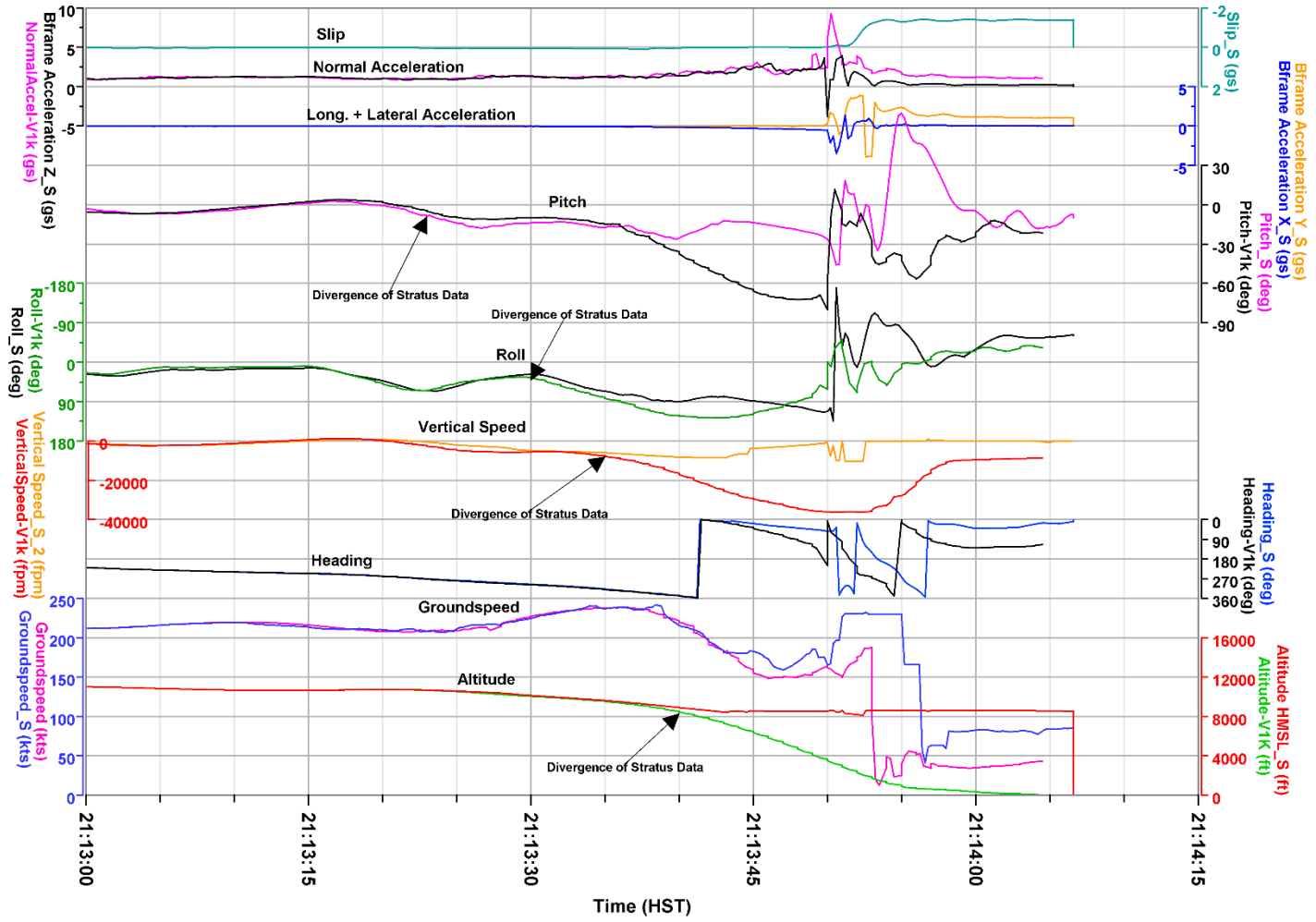

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Figure 5. A plot of both Appareo Stratus and Vision 1000 data from 20:13:00 to 21:14:15 HST.