

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ANC23FA008

ONBOARD IMAGE RECORDER (APPAREO)

Group Chair's Factual Report

September 18, 2024

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A. ACCIDENT

Location: Kaupo, Hawaii
Date: December 15, 2022
Time: 2114 Hawaii-Aleutian Standard Time (HST)
0714 Coordinated Universal Time (UTC)
Airplane: Raytheon Aircraft Company C90A, Guardian Flight, N13GZ

B. ONBOARD IMAGE RECORDER (APPAREO) GROUP

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Group Chair	David Case Computer Engineer / Vehicle Recorder Specialist National Transportation Safety Board
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Group Member	Michael Koenes Director of Safety Guardian Flight
Group Member	Ernest Hall Sr. Air Safety Investigator Raytheon / Textron Aviation
Group Member	Eddie Miller Sr. Aviation Accident Investigator FAA AVP-100

C. DETAILS OF THE INVESTIGATION

In agreement with the Investigator-In-Charge, an Appareo Vision 1000 group was convened on June 7, 2023, and a summary was prepared.

The NTSB Vehicle Recorder Division received the following onboard recorder:

Device Manufacturer/Model:	Appareo Vision 1000
Part Number:	150575-000021
Device Serial Number:	VIS-FGHW

1.0 Device Description

The Appareo Vision 1000 device is a small self-contained image, audio, and data recorder. The unit is typically mounted in the overhead panel of the aircraft's cockpit and records separate images at a rate of four times per second with its internal camera. The device is also capable of recording two tracks of audio that are synchronized with the image data. A GPS receiver is included that receives GPS satellite-based aircraft time, position, altitude, and speed. The Appareo unit also has a self-contained real-time inertial measuring unit that records 3-axis acceleration and derived pitch, roll and yaw data.

Two independent audio tracks can be recorded. One track is the internal microphone for the device. The second track can be wired to an external microphone.

The Vision 1000 records the image, audio, and parametric data on a removable SD¹ memory card that is inserted into the unit. Depending on card size, this removable memory retains approximately the last two hours of image and audio data and about the last 100 hours of parametric data. In addition to the removable memory the Vision 1000 is also equipped with a memory module that is mounted internal to the unit. This internal memory contains an exact duplicate of the data stored on the removable card.

The Appareo unit on this aircraft was connected to the aircraft's electrical bus. Any time the battery switch is turned on, the unit will start to record audio, images, and data. A new file is created for every electrical power application and can create multiple files for the same power cycle if the recording time exceeds a certain time limit.

¹ SD - Secure Digital - A type of nonvolatile memory card used extensively in portable devices.

1.1 Data Recovery

The device was damaged in the event and was submerged under 6,400 feet of saltwater for a month. The extent of the damage is shown in figure 1. The extraction of the memory module is shown in figures 2 and 3.

As provided to the lab, the Vision 1000 did not contain an SD Card. The device was disassembled, and the memory module was removed (figure 3).

A chip-off download of the memory contents was performed. Existing forensic tools were used to extract separate image files from the device but provided a difficult to decipher jumble of images.

A new set of software tools was written to extract data from the Vision 1000 which organized the images by timestamps stored alongside the data on the device. Images, audio, and flight data were also extracted from the device, and made readable with lab software. The accident sequence was captured.



Figure 1. Device

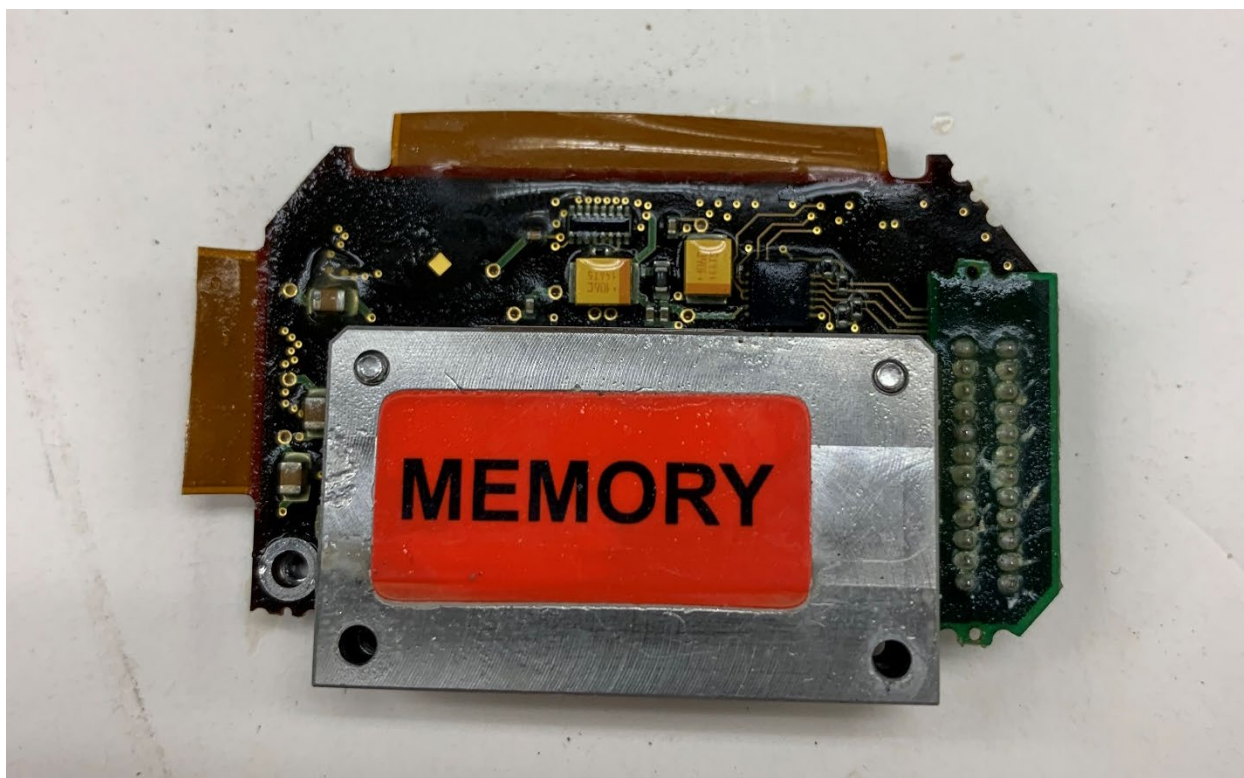


Figure 2. Memory module

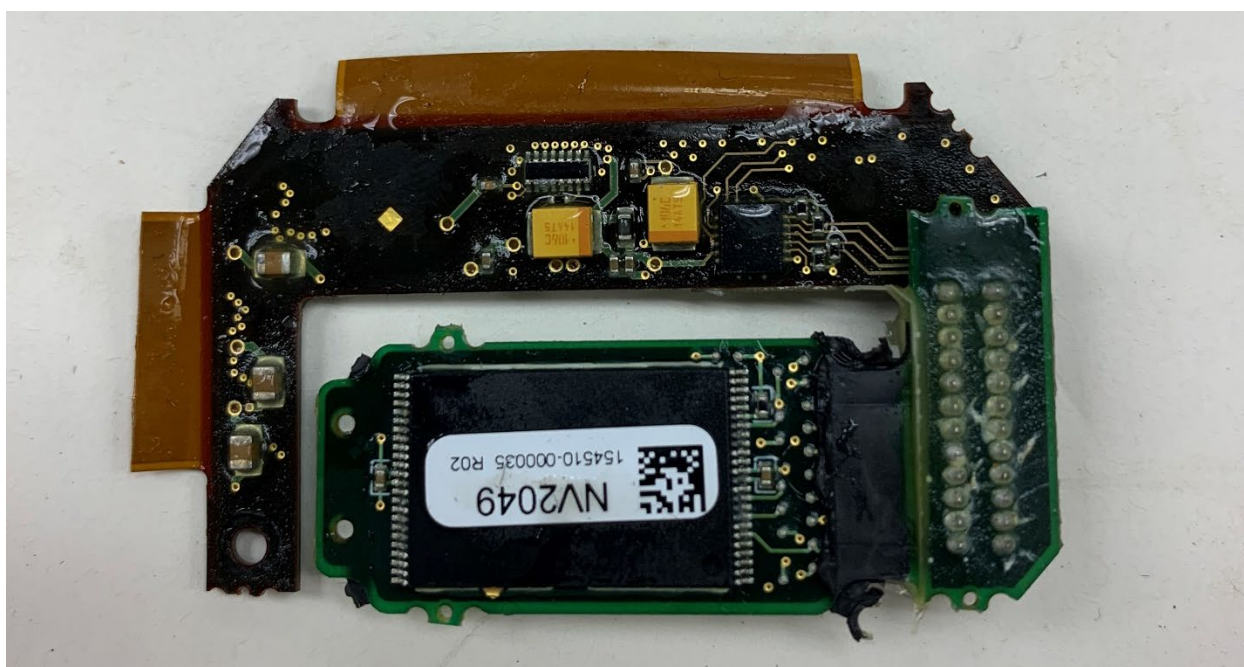


Figure 3. NVM Chip and circuit board after removal of metal cover piece.

1.2 Device Recording Description

The device memory contained video and audio for the last 4 flights, and flight data for another 187 flights. The last recording was of the accident.

2.0 Image/Video File(s) Information

The accident recording was made at a resolution of 1600x1200 pixels at a rate of 4 frames per second (fps). Two associated audio tracks were also recorded; one from the camera's internal microphone, and another that was sounds similar to narrow bandwidth brownian noise, equivalent to a microphone input without a microphone attached subject to automatic gain control. The camera was mounted to the frame of the aircraft and was oriented to show a forward-facing field of view that included a view of the instrument panel and rudder pedals. The field of view of the accident recording is shown in figure 4. The pilot has been redacted in all figures.

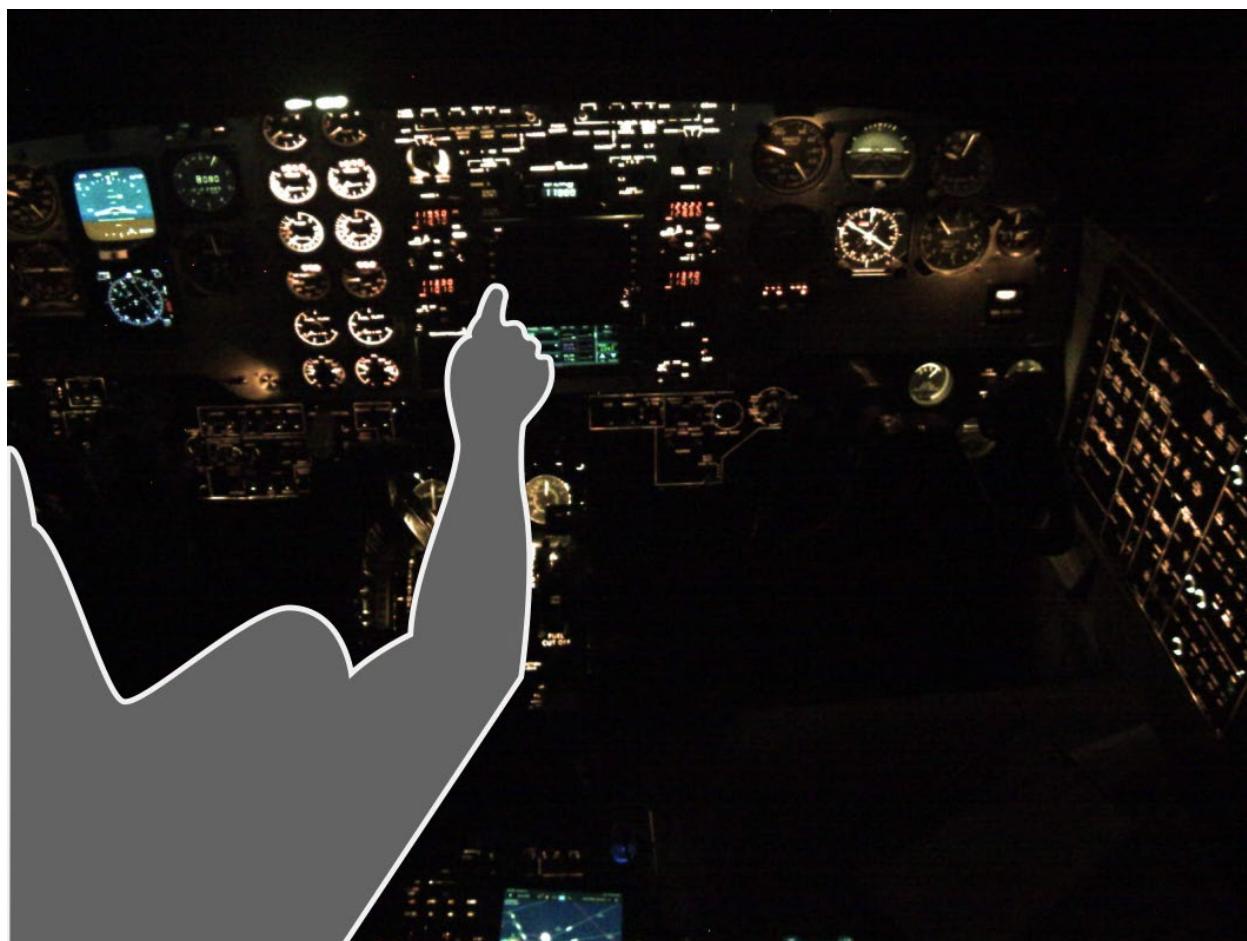


Figure 4. Image showing typical camera field of view.

3.0 Timing and Correlation

The times used in this report are expressed as Hawaii Standard Time (HST).

Timing of the transcript was determined by reading the GPS derived timestamp stored alongside the images on the device, and by noting that the images were recorded at a rate of 4 images (frames) per second (FPS). Audio from the Vision 1000 was synchronized to the video by comparing the filenames for the video and audio files, and confirmed by matching alert sounds with lights on the glare shield annunciator panel. It was also noted that the audio and video derived from the still images was the same length.

Cockpit Voice Recorder (CVR) audio was synchronized with the video by correlating common events between the CVR and the Vision 1000. The same alert tones used to sync the Vision 1000 audio and video were used for the CVR audio as well.

4.0 Recording Description

The audio recorded by the Vision 1000 was of poorer quality than the CVR audio. However, it did record cabin conversation with more clarity, and also kept recording after the CVR stopped. Two separate versions of the audio were provided to the group, one with the CVR audio mixed with the Vision 1000 audio, and one with only the Vision 1000 audio.

The original still images were also used by the group to gather details about particular moments during the flight.

4.1 Recording Details

Previous flights recorded by the Vision 1000 showed intermittent personal cell phone use by the pilot while in flight. It was not determined if this was the same pilot from the accident flight.

During the accident flight, the Collins Multifunction Display (MFD) showed signs consistent with having a blank or inoperative display.

The Vision 1000 image recording system stores data in fixed size chunks over a fixed length of time in a variable sized compressed data format (JPEG). The fixed sized chunks are written in round-robin fashion through the nonvolatile memory (NVM). Since data being written was of variable size, older images remain in the NVM as a jumble of images from previous flights in this 'over run' area.

The Collins MFD was not working in the last four flights of recorded video. However, images were found in the over-run area that showed the MFD working normally at an undetermined time in the past. (figure 5).



Figure 5. Image showing the Collins MFD working on a previous flight. The time of this image being taken could not be determined.

D. SUMMARY OF EVENTS, FIGURES, AND TABULAR DATA

Video, audio, and flight data from the Vision 1000 were used by the group to prepare the following summary.

The audio recorded by the Appareo is generally summarized in this document but marked in bold when quoted directly.

Figure 6 is a photograph of the instrument panel of N13GZ taken at some point before the accident. Significant instruments called out in the summary are numerated with explanatory text.

Figure 7 is two cropped frames from the video showing the dark Cathode Ray Tube (CRT) from the Collins MFD, and the one frame where it briefly lit up. The time of this event is later referenced in this report.

Figure 8 is two cropped frames from the video showing the Electronic Flight Instrument System (EFIS) before and after the attitude reference failure. The time of this event is later referenced in this report.

Figure 9 is a chart of the entire flight as recorded by the data recorder portion of the Vision 1000 dataset.

Figure 10 is a chart of the middle portion of the flight, specifically before and after the time of the loss of attitude reference.

Figure 11 is a chart that shows the end of the flight through the "Off Navigation" radio conversation, the loud metallic bang, and the end of the recording.

Figure 12 is a Google Earth map overlay of the entire flight. The weather and lighting conditions in Google Earth are not necessarily the weather and lighting conditions present at the time of the accident.

Figure 13 is a Google Earth map overlay of the middle portion of the flight, showing before and after the loss of attitude reference, at which point the autopilot was disabled and the pilot started hand flying the aircraft.

Figure 14 is a Google Earth map overlay of the "Off Navigation" radio conversation portion of the flight.

Figure 15 is a Google Earth map overlay of the end of the recording, but rotated around from the previous figure to show more clearly where the loud bang occurred.

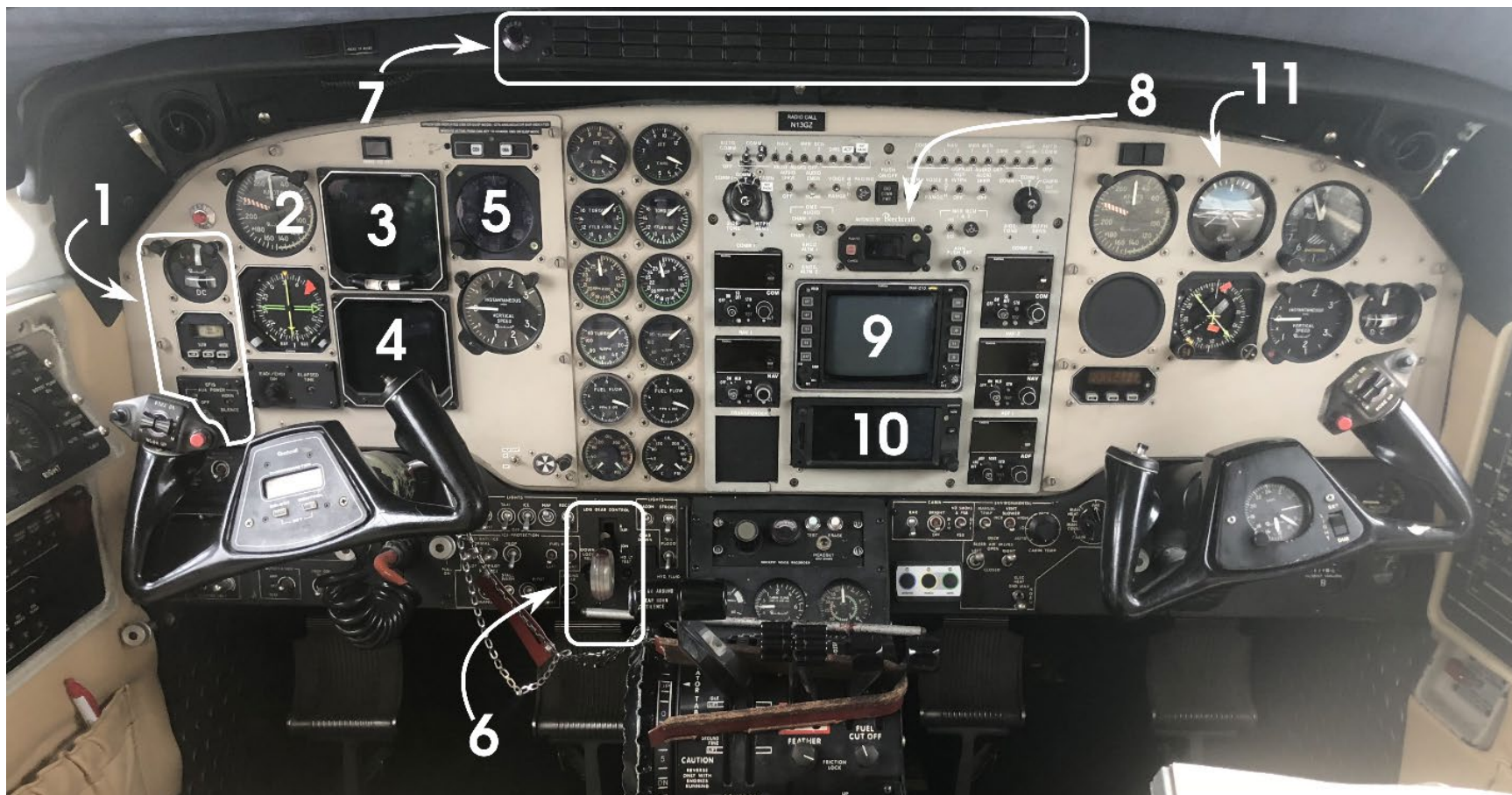


Figure 6. High resolution daytime photo of the cockpit panel in N13GZ

KEY FOR FIGURE 6:

- 1 The first column of instruments is outside the view of the Appareo camera. These 3 instruments are: the turn and bank indicator, the gyrocompass controls, and the electrical panel for the pilot's EFIS. It could not be determined if the pilot attempted to use the aux power for the EFIS during the flight.
- 2 Pilot's airspeed. Both the indicator needle (all white, showing 0 knots in the photograph) and the barber pole (striped white and red, pointing at Maximum Operating Speed (Vmo) - 226 knots) can be seen.
- 3 Pilot's EFIS. This is a Collins CRT display. Only the pilot's side of the instrument panel has this instrument, the copilot side has a traditional analog attitude indicator (instrument #11). All references to EFIS in this report are to this instrument.
- 4 Pilot's HSI, also a Collins CRT display.
- 5 Pilot's altitude. Contains both a rotating outer mark that completes 1 revolution per 1000 feet, and an LED readout displaying the instantaneous altitude.
- 6 The landing gear handle. It is made out of clear plastic and illuminates brightly when the gear are being cycled.
- 7 Glare shield annunciator panel.
- 8 Altitude bug control.
- 9 Collins MFD display
- 10 Garmin GTN-650
- 11 Copilot's attitude indicator (AI), used as a backup for the pilot's EFIS.

Time	Event
20:48:59	The recording started. Outside ambient lighting conditions were consistent with nighttime operation. The pilot was in the left seat, the right seat was empty. Power was supplied to the instrument panel and all the instruments appeared to be illuminated. The EFIS appeared to be in a boot state. The Collins MFD bezel was illuminated, but it's CRT was blank. The pilot appeared to be operating the engine controls. The Garmin radio was in the process of booting, and the pilot's iPad showed ForeFlight charts and was laying on the center pedestal. Nothing anomalous other than the Collins MFD being dark was noted. The clinicians in the back were audible having a conversation that lasted through the entire recording. For the most part, the conversation is present, but the recording is below the level of intelligibility. This conversation is transcribed when relevant and discernable. Starting from the left, the camera's field of view included most of the pilot's instrumentation, except for the first column of instruments to the pilot's left (the turn & bank indicator cannot be seen). The field of view extended to the fuse panel to the right of the copilot's seat. A thin sliver of windshield was visible at the top of the field of view, and some of the center console was visible at the bottom. (see figure 4).
20:49:22	The pilot set the altimeter.
20:49:42	The pilot set the radios.

20:49:34	The pilot obtained ATIS India and appeared to set the panel according to ATIS information.
20:49:52	The pilot scrolled through the flight plan page of the GTN-650.
20:50:32	The pilot received IFR clearance to Waimea Kohala airport (PHMU) Kamuela, HI.
20:50:57	The pilot read back the clearance, and it was confirmed by Air Traffic Control (ATC). The pilot manipulated the flight planning page of the GTN-650.
20:51:37	The pilot used a red LED headlamp to read paperwork in his lap. Moments later, he turned off the headlamp.
20:52:04	The pilot set the altitude bug to 11,000 feet.
20:52:19	The pilot told the tower that he was ready to taxi, and then read back the taxi clearance.
20:52:30	The pilot started taxiing.

20:52:52	The pilot turned on the landing, nav and strobe lights. He also turned on the pitot heat.
20:53:19	The aircraft was cleared for takeoff on runway 2 at echo.
20:54:12	The pilot appeared to line up with the runway, the compass swung right, the ball swung left during the (right) turn onto the runway. The EFIS was level in pitch and roll. The command bars were shown. The EFIS appeared nominal at this time. As the pilot lined up with runway 02 the primary Horizontal Situation Indicator (HSI) appeared to be showing 025 to 028 degrees, the backup HSI appeared close to 030.
20:54:18	The pilot advanced the throttle and started the takeoff roll. Takeoff propeller RPM was configured to 2200rpm, or slightly above. The needle was lined up with the red line denoting maximum design rpm on the gauge.
20:54:39	The pilot rotated and takeoff occurred.
20:54:50	At 160 ft (feet) the pilot engaged the autopilot. The autopilot control panel lights were not visible (below the field of view). There were no panel annunciations visible, the autopilot operation appeared nominal at this time.

20:54:59	The local controller handed the flight off to departure. The pilot set the new radio frequency and acknowledged.
20:55:14	As the aircraft passed through 700 ft, the pilot moved the gear handle to the up position and reduced propeller pitch. Propeller rpm decreased by approximately 200 rpm, then climbed back to 2200 rpm. The aircraft was climbing out over the ocean pointed away from the lights of Kahului, towards featureless dark night IMC/IFR conditions. The moon would not rise until after midnight.
20:55:27	The pilot called departure and acknowledged radar contact.
20:55:45	As the aircraft climbed through 1,400 ft, the pilot's voice was audible saying ' here '. A hand was visible passing paper money back towards the cabin, where the clinicians were seated.
20:55:56	After continued movement seen in the cabin, a conversation between male and female voice, " I can't see with the- " -- " sorry "
20:56:17	The pilot adjusted the propellor controls, decreasing the propeller speed to approximately 2000 rpm
20:56:20	A quiet " # " ² was said by the pilot.

² Expletives are replaced with a #

20:56:26	The pilot pulled out his phone, and navigated to a music app. He then set the phone down on the right seat.
20:56:54	The pilot started a standard rate turn to the right. The pilot's EFIS and the copilot's Attitude Indicator (AI) appeared to agree, and in general the left and right side instruments on the instrument panel agreed.
20:57:26	The pilot unlocked an iPad and used an Electronic Flight Bag (EFB) app consistent with ForeFlight. There was a map page with an approach plate overlay. The pilot was holding the iPad in his hand down and to his right; it was not mounted to the yoke. It cannot be determined if there's another iPad attached to the yoke. Moments later, he set the iPad down on the pedestal.
20:57:42	The pilot briefly picked up his phone and browsed through 'Glenn Miller - In Memorial' in the music app before picking a different song and sitting the phone back down.
20:58:07	The plane was level and in the process of climbing through 4500ft. The pilot picked up the iPad, looked at an approach plate, and started manipulating the radio panel. The pilot entered approach frequencies.
20:58:39	The pilot manipulated the HSI and Course Deviation Indicator (CDI) on the copilot side HSI.
20:58:59	The pilot turned back to using the iPad near his right knee. He manipulated what looked like an approach plate, and an airport

	diagram on the EFB. With his right hand he appeared to scroll through the flight plan page on the GTN-650.
21:00:12	The pilot set the elevation of the cabin pressurization controller while also consulting the EFB app on the iPad.
21:00:39 - 21:01:11	The plane climbed through 8000 ft. The pilot repeatedly attempted to manipulate the buttons on the Collins MFD, but the screen remained blank and unresponsive.
21:01:11	The Collins MFD CRT flashed very brightly for one frame of video, and then returned to darkness. (figure 6)
21:01:11 - 21:01:22	The pilot made further attempts at operating the Collins MFD. He attempted to use almost every button associated with the display to no noticeable effect.
21:01:22	While returning his hand to his lap, the pilot briefly raised his middle finger towards the Collins MFD display.
21:02:42	ATC handed the aircraft off to center. The pilot acknowledged.

21:02:48	The aircraft passed through 10,000 ft. The 1,000 ft altitude alert tone was audible and its corresponding annunciator light was visible on the panel. All normal.
21:02:59	The pilot changed the radio frequency and adjusted the propeller pitch.
21:03:09	The pilot changed the GTN-650 display from the flight planning page to the map page.
21:03:17	The plane climbed through 10,500 ft, the pilot contacted center, " levelling off at 11,000 ".
21:03:47	The controller came back and asked for the previous transmission, the pilot repeated " levelling off at 11,000 ".
21:03:55	The controller asked, and the pilot reported that he had weather and NOTAMS for the destination.
21:03:58	The controller asked which approach the pilot would like at the destination airport, the pilot responded with RNAV-4. The controller stated back.

21:04:01	The aircraft levelled off at 11,000 ft.
21:04:06	The controller asked if the pilot could climb and maintain 13,000 ft, the pilot responded " affirm ". Controller cleared the flight for 13,000 ft. The pilot adjusted the altitude bug.
21:05:24	As the aircraft passed through 12,000 ft, a sound similar to the 1,000 ft to go altitude alert tone was audible.
21:05:51	The autopilot began and maintained a standard rate turn to the south.
21:06:40	The autopilot levelled out as the aircraft approached 13,000ft. The indicated cabin pressure was equivalent to 2000ft of altitude.

21:06:58	The sound of the autopilot disconnect alert tone was audible, and the autopilot disconnect indicator (AP DIS) light illuminated on the annunciator panel. The EFIS no longer displayed attitude information, but was in a powered state, and was still showing some symbology. The AP DIS (autopilot disconnect) light flashed approximately 8 times and went solid after the pilot reset the master caution. Then the AP DIS extinguished. Red warnings on the EFIS flashed several times, and then remained lit. The pilot's EFIS did not show an artificial horizon for the remainder of the accident recording. The EFIS symbology before and after the illumination of the AP DIS annunciator is shown in figure 8. The pilot has been redacted. This event is also depicted as a vertical line on figures 9, 10 and 13.
21:07:01	The A/P FAIL (autopilot fail) annunciator illuminated, followed by the master caution illuminating a quarter second later. This event is also depicted as a vertical line on figures 9 and 10.
21:07:06	The pilot reset the master caution.
21:07:09	The A/P FAIL annunciator turned off. The pilot's left hand was not visible, his right hand was visible holding the right horn of the yoke. it was not clear if the pilot was actively manipulating the flight controls at this time.

21:07:24	The copilot side Attitude Indicator (AI) indicated a bank to the right.
21:07:32	The copilot side AI indicated a 30-degree right bank, the yoke visually moved in the roll axis to the left and the aircraft was brought back to a level attitude.
21:07:41	The altitude alert triggered (aural and visual), the aircraft was in a climbing trend, the altimeter read 13,220 ft.
21:07:45	The pilot manually adjusted pitch trim next to his right knee, approximately half a unit back (nose up).
21:07:54	The pilot adjusted the pitch trim, the copilot AI indicated a steepening right bank, and then reversed to a left turn.. The altitude increased to 13,260ft.
21:08:42	ATC called the aircraft and asked for a change of course to 180 degrees. The pilot confirmed turning to 180. The controller called back and asked for 200 degrees, pilot confirmed turning to 200.
21:08:59	The copilot side AI now indicated a descending and deepening right bank turn.

21:09:09	A clinician in the cabin asked, "is our auto pilot out?" (this statement was only picked up by the Appareo, it was absent on the CVR likely because of microphone placement). The pilot responded 'yep'.
21:09:32	The controller asked the pilot to descend and maintain 12,000ft. The aircraft was in a slight climbing trend. The pilot set the altitude bug to 12,000 ft.
21:09:54	The aircraft began to descend and the 1000 ft to go altitude alert sound was audible.
21:10:17	The controller asked the pilot to descend and maintain 8000 ft. The pilot set the altitude bug to 8000 ft and reduced power.
21:10:39	The aircraft appeared to level off around 12,600 ft.
21:10:53	The aircraft began another descent trend.
21:11:17	The aircraft continued descending and started a right bank.

21:11:29	ATC called for traffic, the plane had levelled off, but then started slowly turning to the left. The pilot responded he was looking for traffic.
21:11:42	Immediately following the pilot's response to ATC concerning the traffic call, the aircraft began an increasingly rapid descent through 12,000ft.
21:12:07	The aircraft levelled off at 11,120 ft. The assigned altitude at this time was still 8,000 ft.
21:12:19	ATC assigned a new heading of 180. The aircraft was in a slowly descending trend.
21:12:34	ATC cleared direct to TAMMI. Altitude was currently at 10,880 ft, descending. The aircraft was in a slight left, descending roll.
21:12:42	The pilot began to manipulate the flight plan page on the GTN-650. The copilot AI indicated an increasing right bank. The pilot selected direct to TAMMI.
21:12:59	The right hand turn rate increased, reversed, and came back towards, but never reached, level. The aircraft was descending at 1,000 feet per minute (fpm).

21:13:17	The aircraft increased its right turn and was briefly level in pitch.
21:13:21 – 21:13:40	[The time interval associated with this conversation is shown on figures 9, 10, and 11 as a grey bar, on the Google Earth plot in figure 14 as a white line, and in this table with a grey background.] The aircraft's current altitude was at 10,180ft and the rate of descent had increased. The roll increased to 65 degrees angle of bank to the right. ATC asked the pilot to verify that he was direct TAMMI. The pilot responded "uh ...one three golf zulu is uhhh off navigation... here... we're gonna give it a try (give it a try)". While the pilot was responding to ATC, the vertical speed indicator pegged at -3,500fpm. ATC read back the suggested course and altitude.
21:13:34	90 degrees of bank was displayed on the copilot side's AI. The lost navigation flag on the HSI was seen and the HSI was showing a rapid heading change to the right.
21:13:38	The airspeed indicator needle was at the red and white mark on the gauge (the barber pole). (This mark denotes the maximum operating speed Vmo which is 226 knots for this aircraft). While the aircraft passed through 9,000ft, the 1,000 feet to go altitude alert sound was audible.
21:13:41	At this time, the airspeed read >260kts and may have been higher due to the limits of the gauge. The copilot AI showed an inverted descending right turn. The yoke looked almost level. The turn coordinator trim ball was centered and indicated a right turn. The pilot's tablet never moved from the console.

21:13:44	As the aircraft passed through 7,700ft, the 300ft low altitude alert tone was audible. The pilot said "hang on". The indicated pitch, roll and airspeed was similar to the state previously described above. The aircraft was still descending in a right-hand roll. It's possible that the AI had reached its limit in properly displaying the aircraft's attitude (it was showing signs of being tumbled, or gimbal locked). As other instruments changed, the copilot's AI remained showing the aircraft inverted in a right rolling descent. Other gauges such as airspeed, and vertical speed (VSI) remained in their maximum positions. The altimeter was showing a very rapid descent. The engine gauges were showing parameters within normal range.
21:13:47	Increasing ambient wind noise was noted. The airspeed indicator remained above 260 kts.
21:13:50	The pilot's hands were still on the yoke. His left hand was unseen, and his right hand was holding on to the right horn of the yoke. The yoke first moved slightly forward, and then slightly more aft than previously seen. As the yoke moved aft, the gear handle illuminated, indicating in-transit (unsafe) gear. The power levers were visible and not retarded. The Garmin GTN-650 briefly showed a red status indication in the middle of the screen that was illegible on the video.

21:13:51	The indicated altitude was 4,000ft and rapidly decreasing. All other instruments appeared mostly unchanged. The ambient wind noise was noticeably increasing. The yoke seemed to move quickly forward and then aft in a jolt like manner. As the movement towards the aft position of the yoke occurred, a sound similar to a loud metallic bang was audible. The camera recorded a rapid jolt, and the field of view of the recorded image noticeably changed. The control panel illumination appeared to be extinguished, consistent with the aircraft main power bus failing, and switching over to battery power. Several annunciator panel lights were suddenly illuminated, their state was unable to be identified by the group. The engine throttle levers remained unchanged. After this event, only 3 instruments in camera view remained illuminated (pilot's altimeter, HSI, and EFIS). Two of the five radio heads appeared to have power and showed frequency information. The Garmin GTN-650 was dark, consistent with a loss of power. This event is depicted on figures 11 and 15 as a vertical line.
21:13:55	After the loud metallic bang, the cabin became much quieter and the whooshing ambient air sounds decreased but were still present. The altimeter appeared to pause briefly, then started rapidly decreasing again. Due to the decrease in ambient noise, cabin conversations became more intelligible.
21:13:58	A quiet voice was audible, "did I break (it?)³".
21:13:59	An unintelligible female voice made a brief statement.

³ Text in parenthesis denotes a questionable insertion.

21:14:04	A woman's voice asked calmly, " are we - are we in the air? "
21:14:04	A male voice stated bluntly, " we are in the air ".
21:14:06	The altimeter displayed approximately 400 feet. The pilot's iPad was visible, still lying face up on the center console and was displaying EFB information. This is the last recorded frame of the video and the end of the audio recording.

Submitted by:

David L. Case
Computer Engineer / Vehicle Recorder Specialist

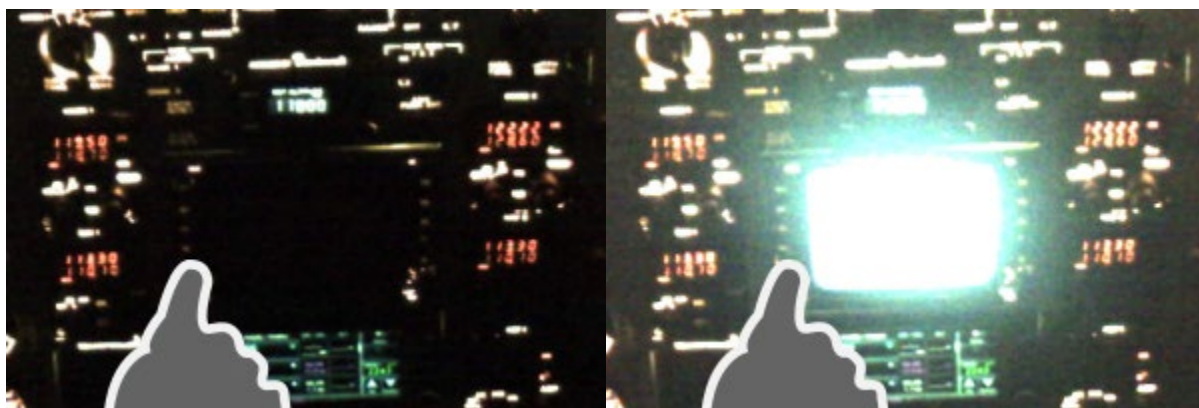


Figure 7. Collins MFD with dark CRT vs. the one frame it was lit up. Consecutive video frames at 21:01:11 HST.



Figure 8. Pilot's EFIS in normal operation vs. error state. Consecutive video frames at 21:06:58 HST.

Guardian Flight, Beech C90A, N13GZ

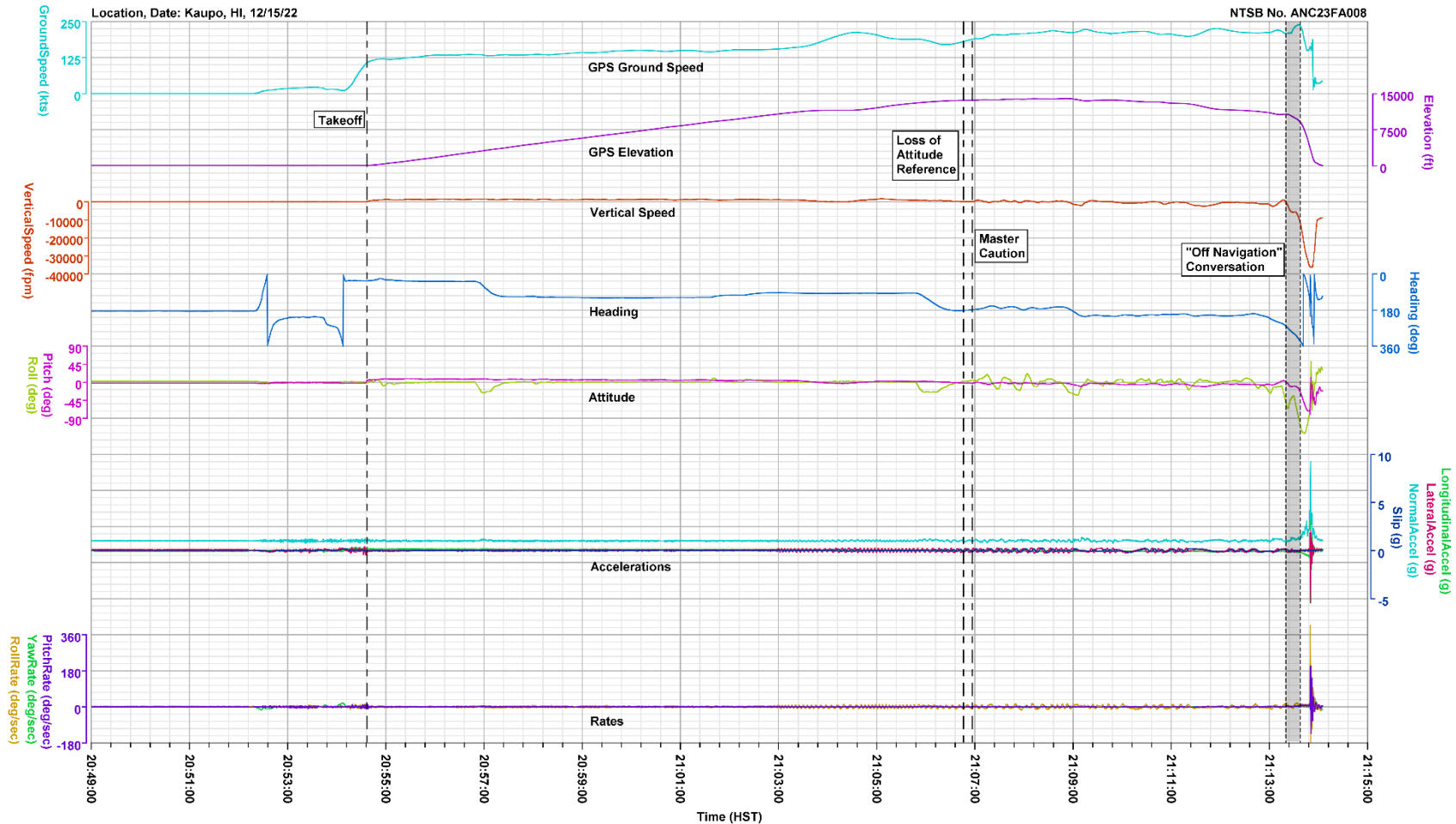


Figure 9. Flight Overview Plot for the time range between 2040 and 2115 HST. The grey bar denotes the time span of the 'off navigation' conversation on page 26 of the transcript and also depicted on figures 10, 11 and 14.

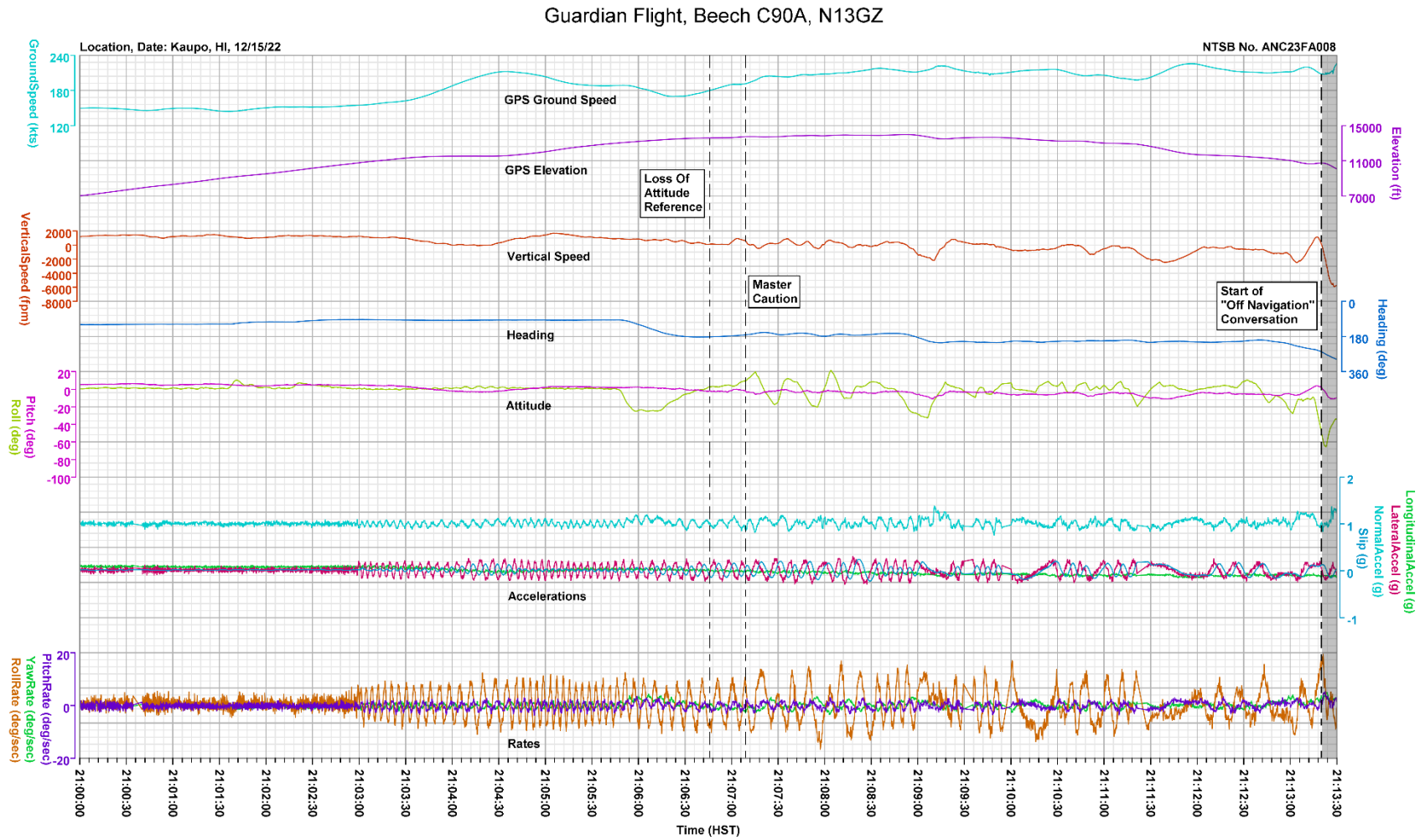


Figure 10. Mid-flight plot before and after loss of attitude reference. The plotted time interval is between 2100 and 2113 HST. The grey bar denotes the time span of the 'off navigation' conversation on page 26 of the transcript and also depicted on figures 9, 11 and 14.

Guardian Flight, Beech C90A, N13GZ

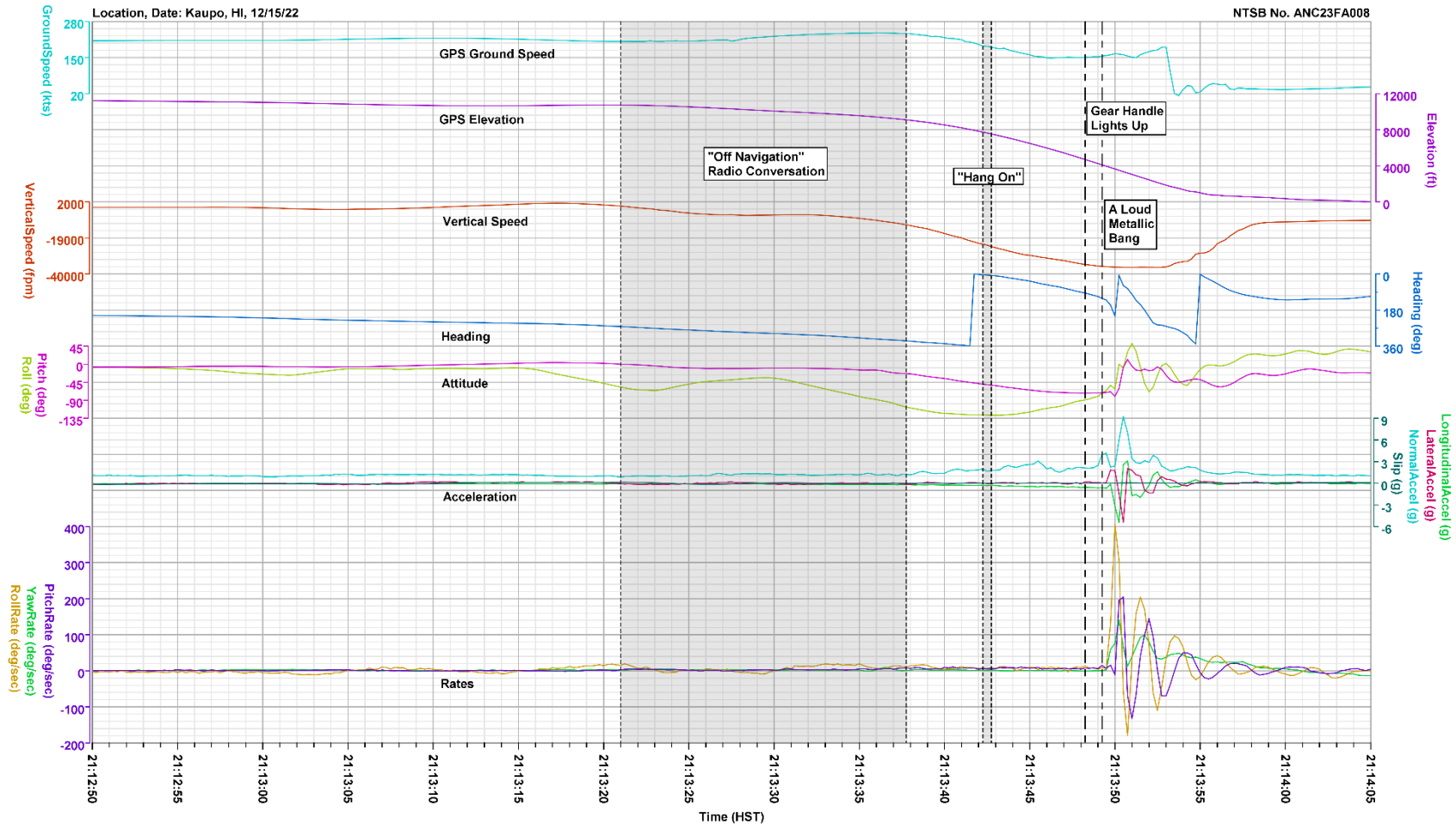


Figure 11. The Accident portion of the recording. The plotted time interval is between 21:12:15 and 21:14:05 HST. Last data occurred at 21:14:05 HST. The grey bar denotes the time span of the 'off navigation' conversation on page 26 of the transcript and also depicted on figures 9, 10 and 14.

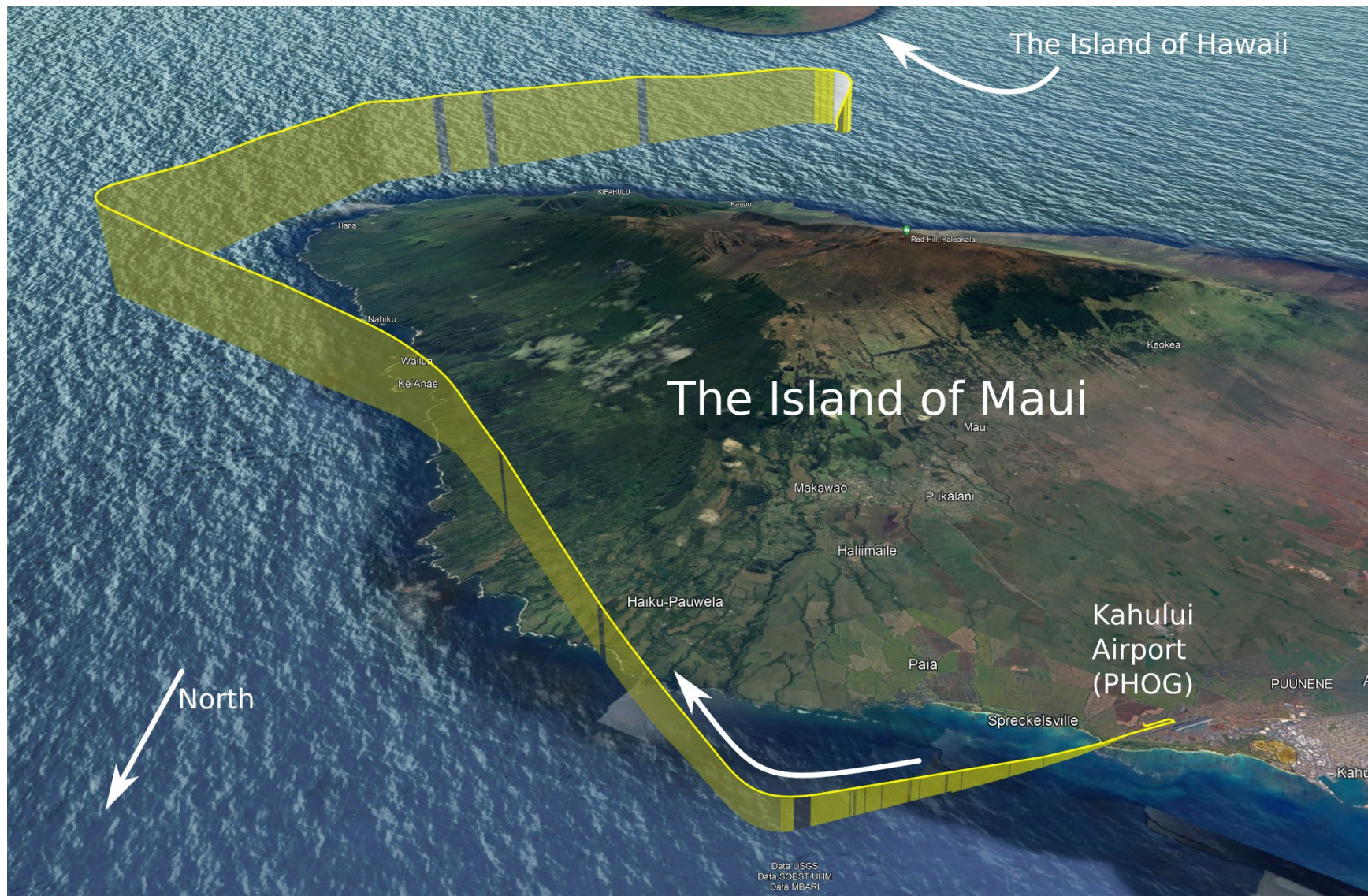


Figure 12. Overview Map of entire flight.

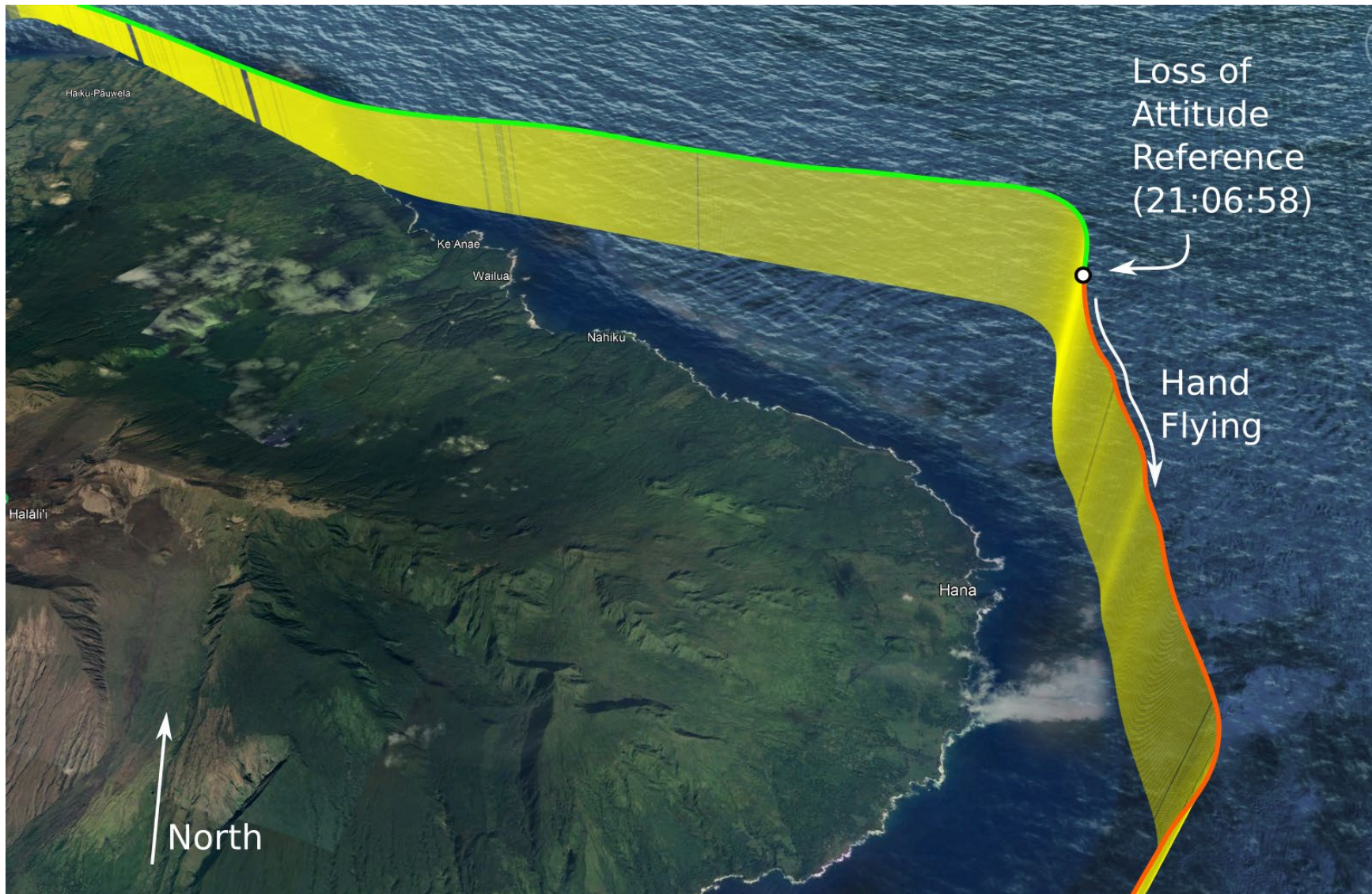


Figure 13. Mid-flight Map showing the middle portion of the flight before and after the loss of attitude reference at 21:06:58 HST.

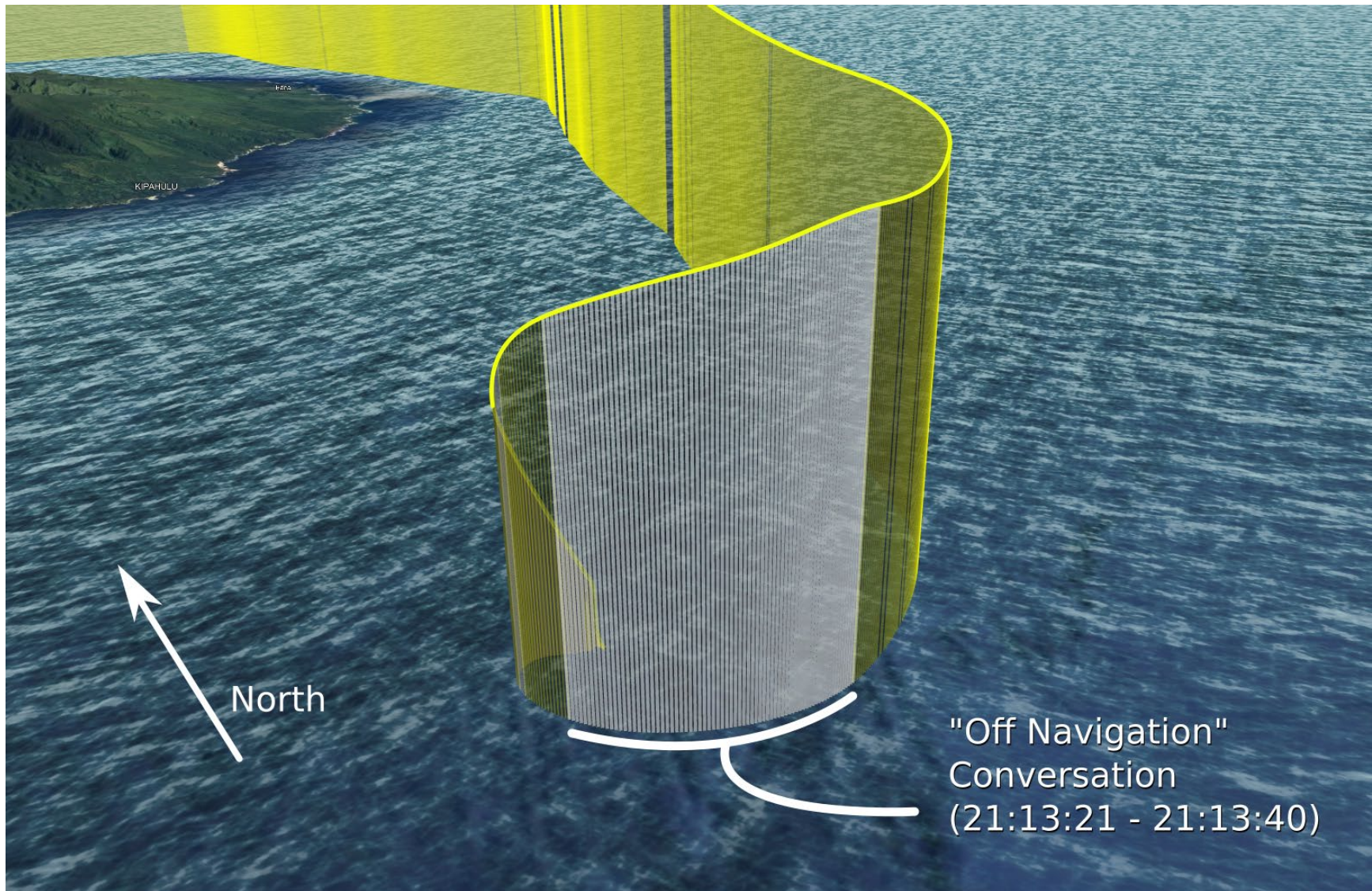


Figure 14. Aircraft track during the "Off Navigation" conversation, between 21:13:21 and 21:13:40 HST.

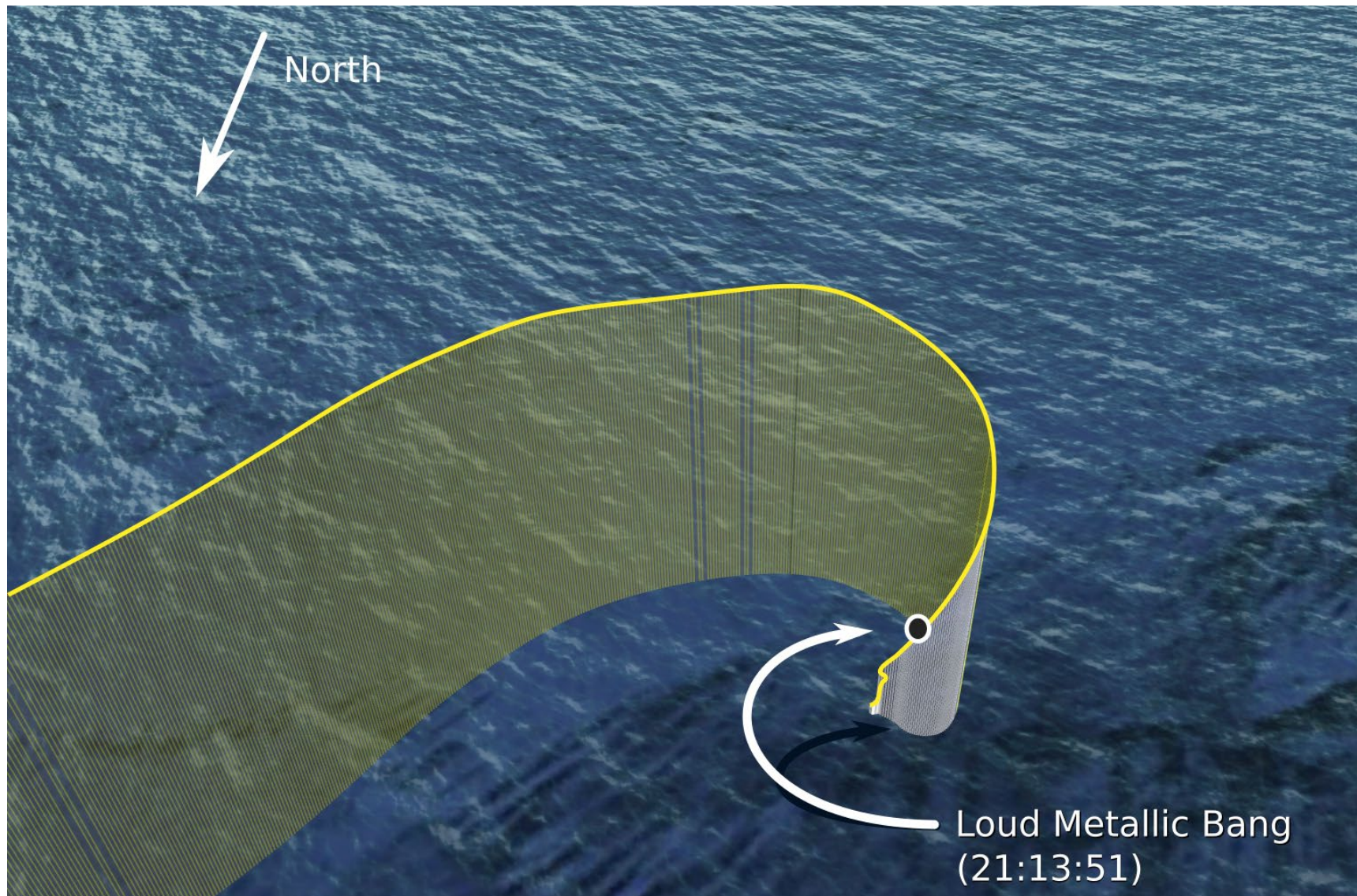


Figure 15. Aircraft track during the final moments of the flight.

APPENDIX A. VERIFIED AND PROVIDED PARAMETERS FROM THE VISION 1000

This appendix describes the flight data parameters provided and verified in this report. Table 1 lists the parameters from the Vision 1000, and table 2 describes the unit abbreviations used in this report.

Table 1. Verified and provided parameters

Parameter Name (units)	Parameter Description
GroundSpeed (kts)	GPS Ground Speed
Elevation (ft)	GPS Elevation (altitude)
VerticalSpeed (fpm)	Vertical Speed (derived, from GPS location)
Heading (deg)	Heading (derived, from GPS location)
Pitch (deg)	Aircraft Pitch
Roll (deg)	Aircraft Roll
LongitudinalAccel (g)	Longitudinal Acceleration (force felt while speeding up, or slowing down)
LateralAccel (g)	Lateral Acceleration (force felt left to right)
NormalAccel (g)	Normal Acceleration (force felt as being pulled up or down)
Slip (g)	Slip (force felt as being rotated side to side)
PitchRate (deg/sec)	Pitch Rate
YawRate (deg/sec)	Yaw Rate
RollRate (deg/sec)	Roll Rate

Table 2. Unit abbreviations

Unit Abbreviations	Descriptions
Deg	degrees
Ft	feet
Fpm	feet per minute
Kts	knots
g	Acceleration in terms of gravity at sea level on the Earth's surface; 9.8 meters per second per second
Deg/sec	Degrees per second