

NATIONAL TRANSPORTATION SAFETY BOARD

Vehicle Recorder Division
Washington, D.C. 20594

October 12, 2021

**Global Positioning System (GPS) & Attitude Heading
Reference System (AHRS) Device**

**Specialist's Factual Report
By Sean Payne**

1. EVENT

Location: Rockford, Illinois
Date: August 20, 2020
Aircraft: Beech 200
Registration: N198DM
Operator: Private
NTSB Number: CEN20LA352

2. DETAILS OF INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following device:

Device Manufacturer/Model: **Appareo Stratus PRX V2**
Serial Number: **223772**

2.1. Device 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 the acquired information. The pilot needs to have a particular software application called

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).

ForeFlight installed on their iOS Device to view the Stratus data.⁴ In addition to communicating with the iOS Device, the Stratus 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.

2.2. Device Condition

Upon arrival at the Vehicle Recorder Laboratory, an examination revealed the unit had sustained both impact and fire damage. The device did not turn on. The device is pictured in figure 1.



Figure 1. Photo of fire damaged Appareo Stratus unit, as received.

2.3. Data Recovery

The device was both fire and impact damaged and did not power. The device was deconstructed, and the NVM chip was located and removed from the unit's board. Figure 2 shows the device's NVM chip that contains the flight data indicated with a tool.

This device is capable of storing data in NVM. This feature can be activated or deactivated by the user within the device's associated software. The flight data recording option was found to be enabled, and a tracklog consistent with the accident flight was recovered after a chip-off read and subsequent binary conversion was performed. The binary conversion

⁴ iOS Device app (program) that communicates wirelessly with the Appareo Status unit to display aircraft's attitude, navigation, weather, and traffic information.

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

to flight data was executed using NTSB laboratory tools with documentation from the manufacturer.



Figure 2. Photo of the device's internal NVM memory prior to being removed and read.

2.4. Data Description

The unit contained recorded data from a number of flights. Only one set of converted data was determined to be pertinent to the accident investigation and was found to be associated with the accident flight. Only these data are discussed in the report.

The Appareo Stratus PRX V2 is an externally mounted device and is not necessarily fixed to the aircraft's instrument panel in a rigid mounted position. As such, the device is subject to movement under extreme pitch and roll conditions. In such cases where the device is detached from its resting location, the device will continue to record. This means that in an extreme pitch, roll or acceleration scenario, the device may move out of correlation with the aircraft, and the device will continue to record data based on the orientation of the unit itself, which is not necessarily reflective of the aircraft's pitch, roll or acceleration condition. The validity of certain portions of the data set is discussed further below.

All times are expressed as central daylight time (CDT).

Figure 3 is a north-up Google Earth overlay of the accident tracklog recording. The data show the device began recording around 15:35:45 in a ramp area in the northeast corner of the airport. Around 15:38, the aircraft began taxiing to runway 19. Around 15:40:34, the aircraft crossed the hold short line for runway 19. Around 15:41:19, the aircraft began a takeoff roll on runway 19. Around 15:41:42, the aircraft began to depart runway centerline to the left of the runway. Subsequent tracklog points show the aircraft gaining some

altitude and the tracklog terminating adjacent to a taxiway in a grassy area. Note that the weather and lighting conditions depicted in Google Earth are not necessarily representative of the weather conditions at the time of the accident.

Figure 4 is a Google Earth overlay oriented in such a way to highlight the aircraft's taxi toward runway 19. Note that the weather and lighting conditions depicted in Google Earth are not necessarily representative of the weather conditions at the time of the accident.

Figure 5 is a Google Earth overlay oriented in such a way to highlight the aircraft's takeoff roll and subsequent departure from the centerline of runway 19. Note that the weather and lighting conditions depicted in Google Earth are not necessarily representative of the weather conditions at the time of the accident.

Figure 6 is a plot of recorded flight data for the entire recorded tracklog session encompassing the accident flight. Note that the data for groundtrack and heading is likely invalid prior to approximately 15:38:10 CDT. Also note that altitude data is likely invalid prior to approximately 15:39:00. The dataset shows the aircraft increased groundspeed on a heading of roughly 185 degrees true around 15:41 CDT. Pitch began to increase positive around 15:41:41 as the groundspeed was recorded around 104 knots. Groundspeed increased to 107 knots within the next two seconds and the pitch angle reached around 4 degrees at this time. In the next few seconds, pitch lowered to around 0 degrees as the groundspeed decayed to around 98 knots. Pitch then became 15 degrees nose up as groundspeed continued to decay to approximately 95 knots. A right roll occurred of about 13 degrees, changing to a rapidly increasing left roll over the next five seconds. Left roll reached a maximum of about 86 degrees left, as the pitch angle increasingly became negative (aircraft became nose down). Pitch angle reached a maximum nose down condition of -73 degrees. Data then became invalid after 15:41:53.4, which could indicate that the Appareo Stratus device became detached from its mounting location.

Figure 7 is a plot of recorded flight data for the time period between 15:41:00 to 15:41:30. The plot shows in greater detail the accident portion of the recorded information.

Figure 8 is a plot of recorded flight data for the time period between 15:41:00 to the end of valid flight data at 15:41:53.4. The plot shows in greater detail the accident portion of the recorded information.

Figure 9 is a plot of recorded flight data for the time period between 15:41:35 to the end of valid flight data at 15:41:53.4. The plot shows in greater detail the final portion of the recorded valid information.

Attachment 1 is a record of all recorded data discussed in this report from the Appareo Stratus PRX V2 Device. The data are provided in electronic comma separated value format (.CSV).



Figure 3. A north-up Google Earth overlay of the entire accident flight tracklog.



Figure 4. A Google Earth overlay that highlights the aircraft's location at the start of the recording and its subsequent taxi to the active runway.

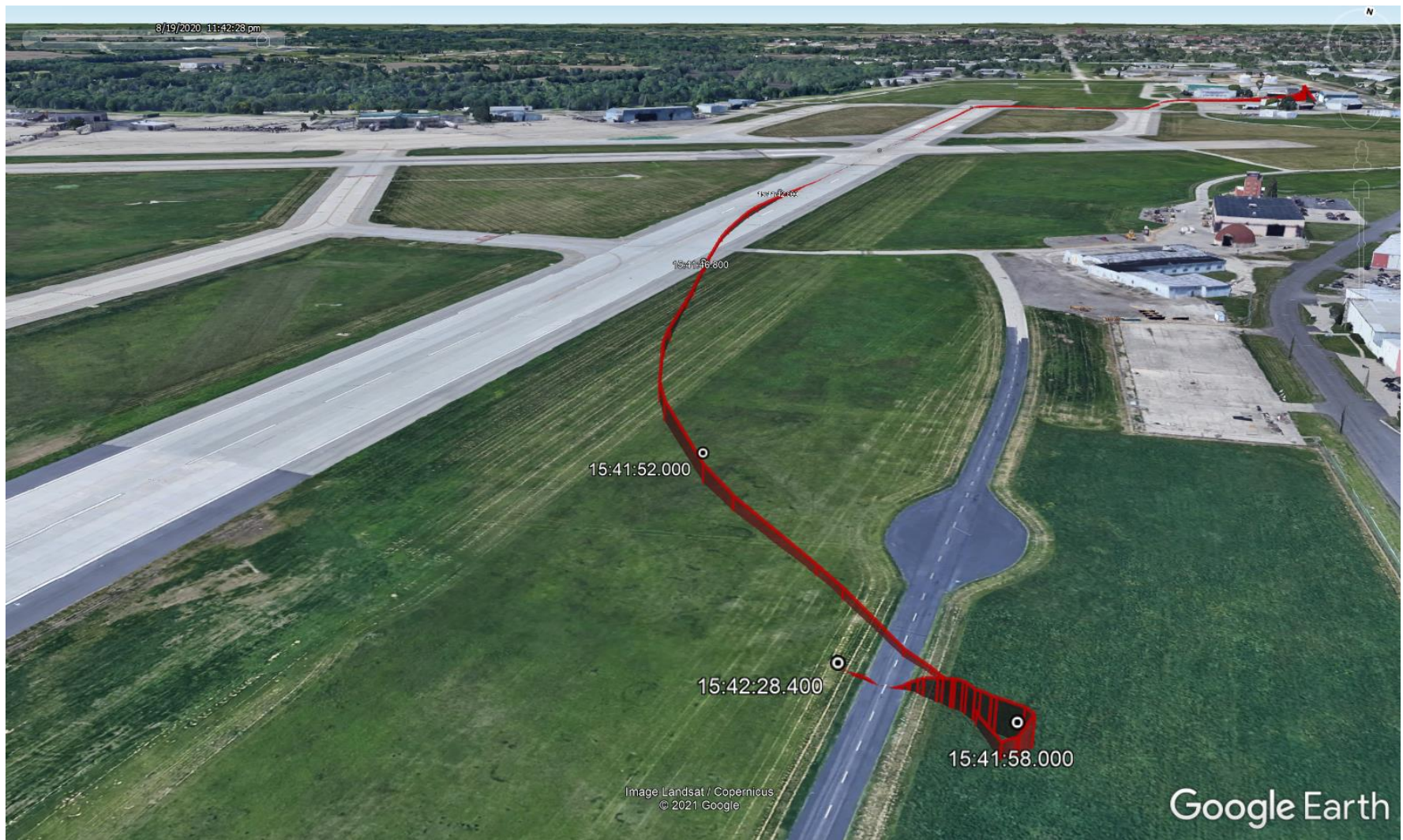


Figure 5. A Google Earth overlay that highlights the aircraft's departure from the runway and subsequent final tracklog points.

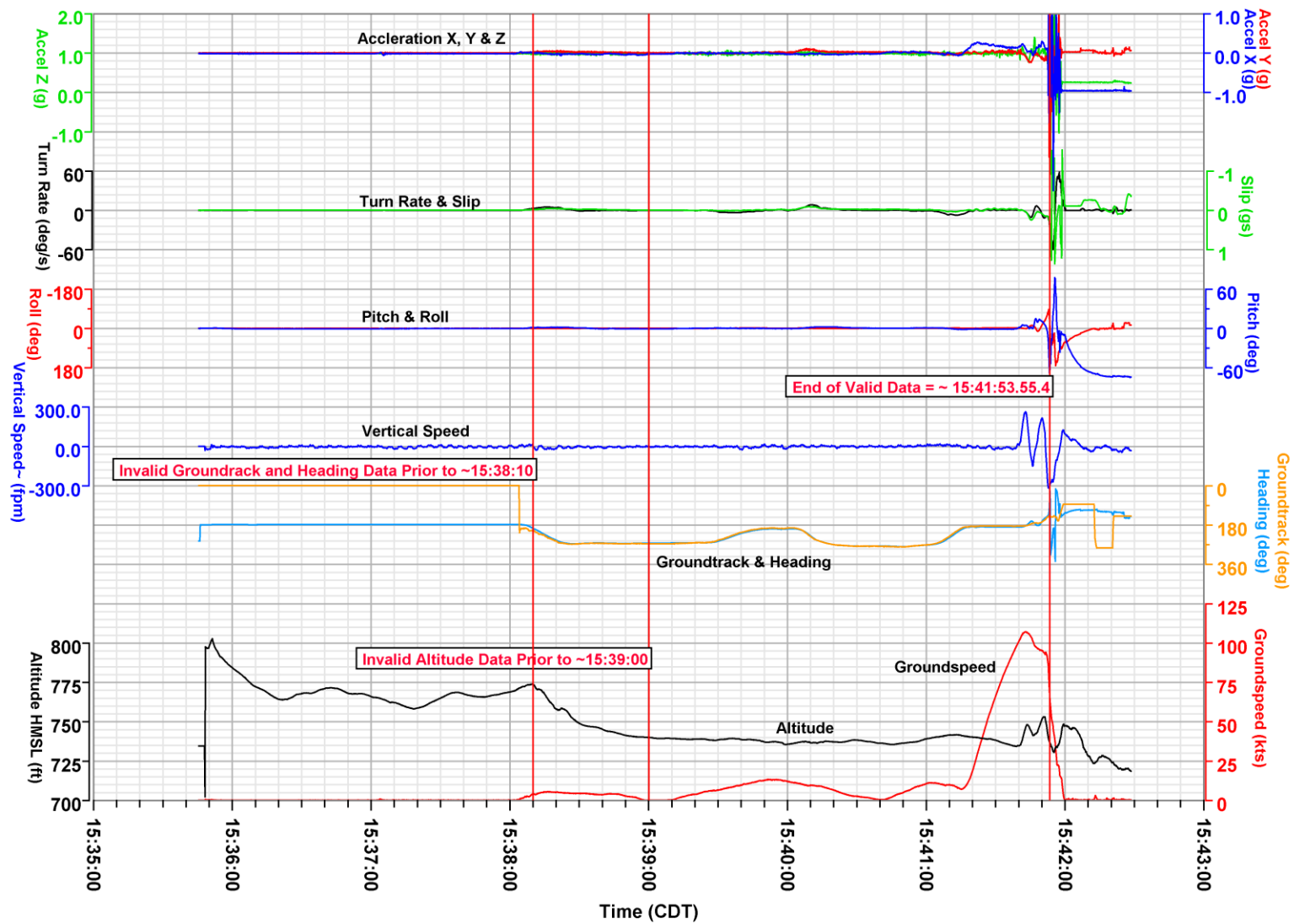


Figure 6. A plot of recorded data from the Stratus device encompassing the entire recorded session for the accident flight.

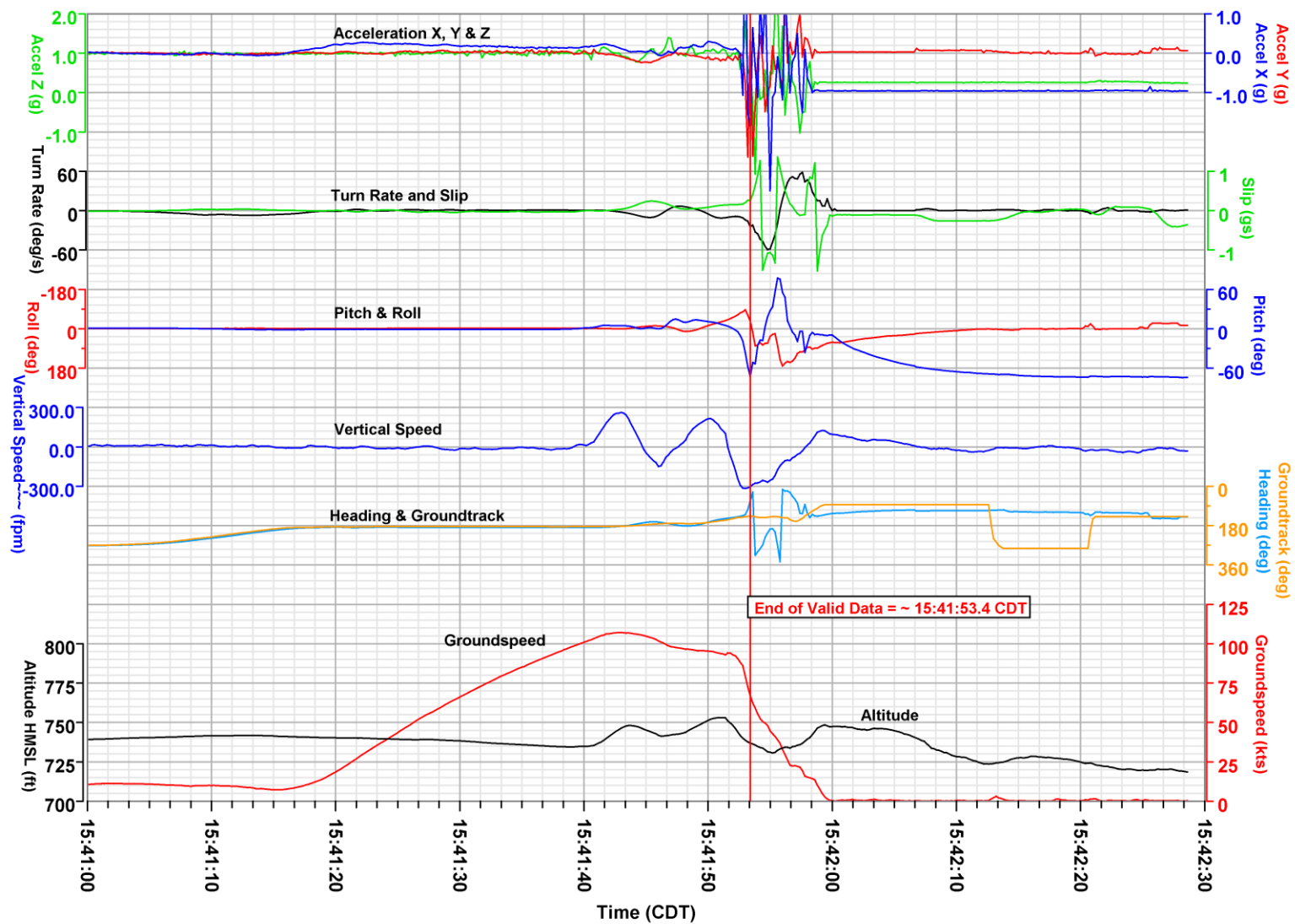


Figure 7. A plot of recorded data from the Stratus device highlighting the portion of the recording session that captured the aircraft's takeoff roll and subsequent crash. Note that data likely became invalid at 15:41:53.4 CDT.

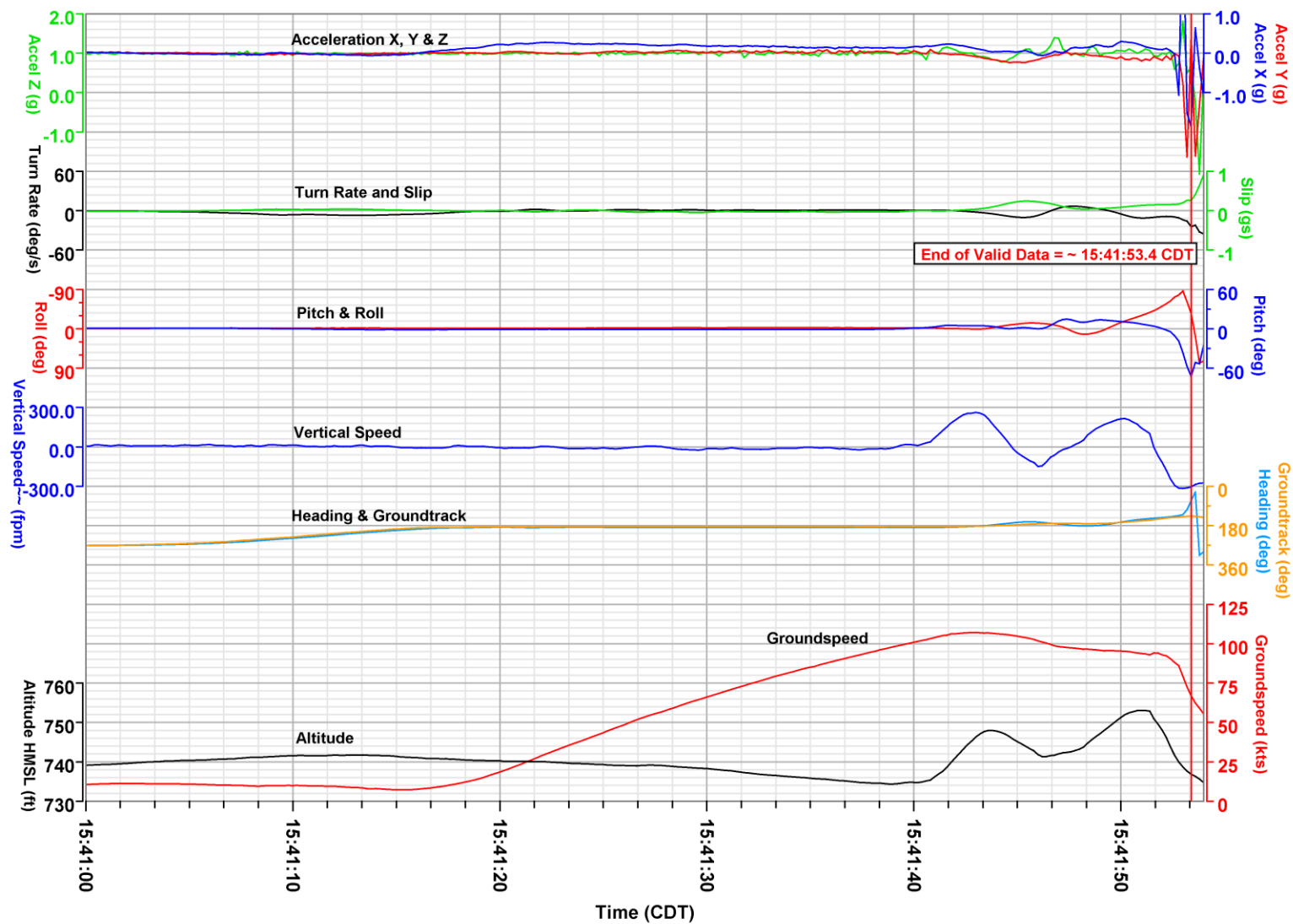


Figure 8. A fine detailed plot of recorded data from the Stratus device highlighting the portion of the recording session that captured the aircraft's takeoff roll and subsequent crash. Note that data likely became invalid at 15:41:53.4 CDT.

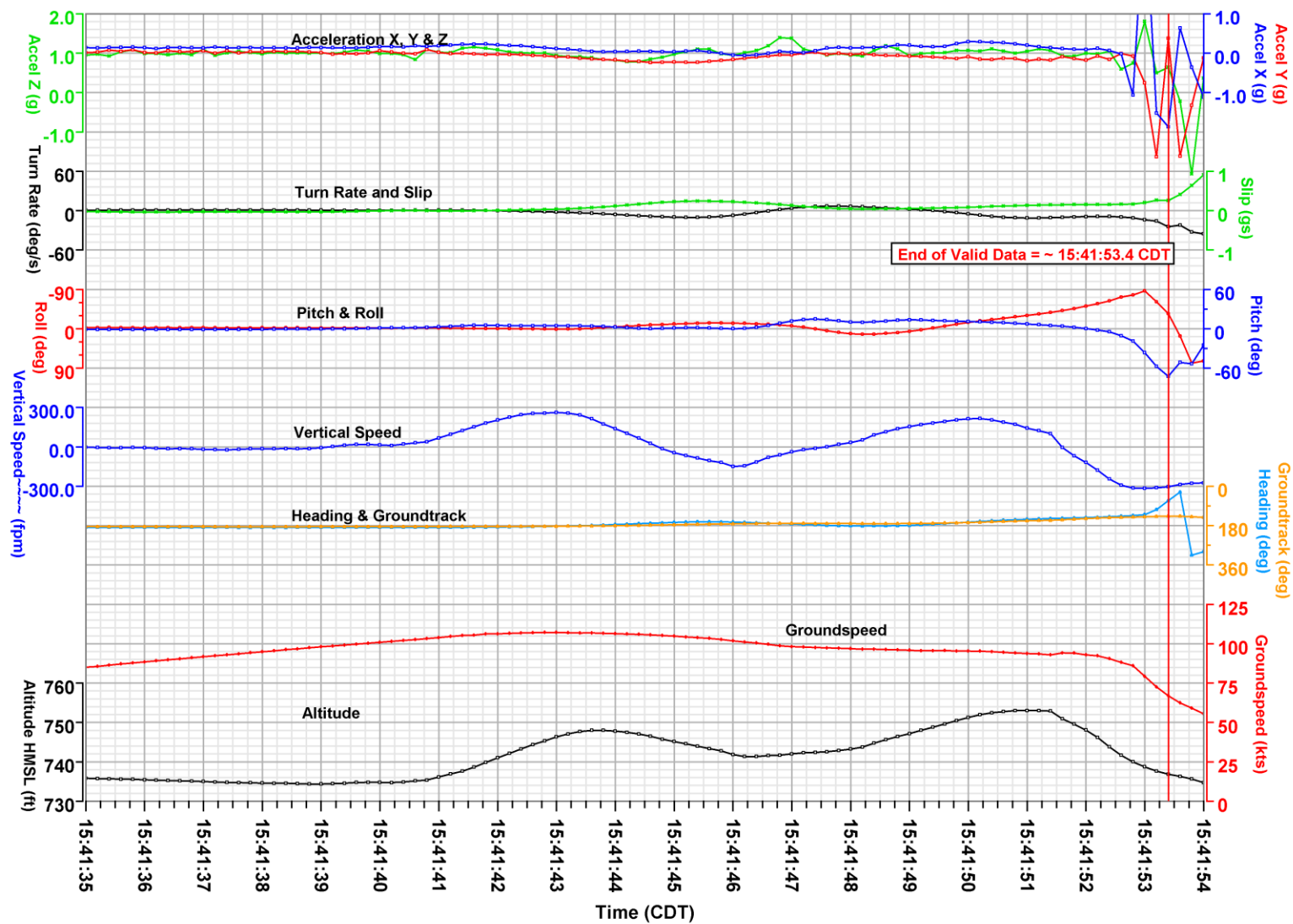


Figure 9. A fine detailed plot of recorded data from the Stratus device highlighting the portion of the recording session that captured the accident portion of the recording. Note that data likely became invalid at 15:41:53.4 CDT.