

NATIONAL TRANSPORTATION SAFETY BOARD

Vehicle Recorder Division

Washington, D.C. 20594

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

Specialist's Factual Report

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1. EVENT

Location: Fort Lauderdale, FL
Date: December 1, 2018
Aircraft: Cessna 335
Registration: N79HP
Operator: Private
NTSB Number: ERA19FA060

2. Summary

On December 1, 2018, about 1327 eastern standard time (EST), a privately owned and operated Cessna 335, N79HP, impacted the ground and a building during a forced landing shortly after takeoff from Fort Lauderdale Executive Airport (FXE), Fort Lauderdale, Florida. The commercial pilot and pilot-rated passenger were fatally injured and one occupant of the building sustained minor injuries. The airplane was destroyed by a post-crash fire, and the building sustained structural and fire damage. The airplane was being operated under the provisions of Title 14 *Code of Federal Regulations* Part 91 as a personal flight. Visual meteorological conditions prevailed at the time and visual flight rules flight following was obtained for the flight that originated about 3 minutes earlier. The flight was destined for Hilliard Airpark (01J), Hilliard, Florida.

3. DETAILS OF INVESTIGATION

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

Device Manufacturer/Model:	Appareo Stratus 2S
Serial Number:	023546

3.1. Device Description

The Appareo Status device is a self-contained battery powered unit that contains an internal AHRS,¹ GPS/WAAS receiver,² and ADS-B³ receiver in one compact unit. 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 ForeFlight⁴ installed on their iOS Device to view the Stratus data. In addition to communicating with the iOS Device, the Stratus device records GPS position and AHRS information internally on a non-volatile⁵ flash memory chip. Internal memory has the space to store over 13 hours of data.

3.2. Device Condition

Upon arrival at the Vehicle Recorder Laboratory, an examination revealed the unit had sustained impact and fire damage. The unit is shown in figure 1.



Figure 1. Photo of unit.

3.3. Data Recovery

The device was unable to be powered normally and was disassembled.

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.

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

This device is capable of storing data in non-volatile memory (NVM). This feature can be activated or deactivated by the user within the device's associated software on an iOS device. After the unit was disassembled, the NVM chip associated with storing flight data was removed. During the removal process, one of the chip's eight connection pins was damaged. An x-ray revealed the chip's wirebonds were intact, but the pad associated with that wirebond had broken. Figure 2 is a stereoscopic image of the area of damage. Figure 3 is an X-ray image of the affected area.

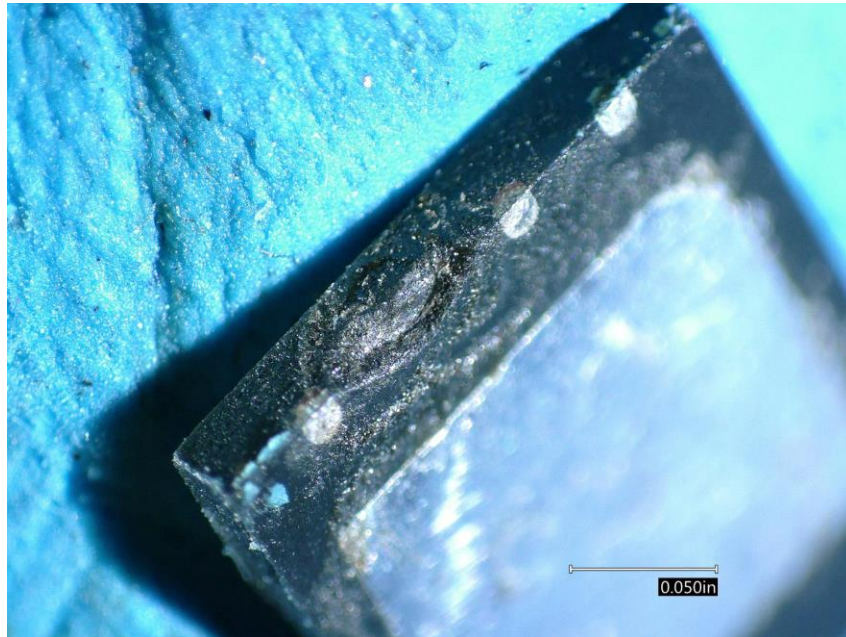


Figure 2. Stereoscopic image of the affected area.

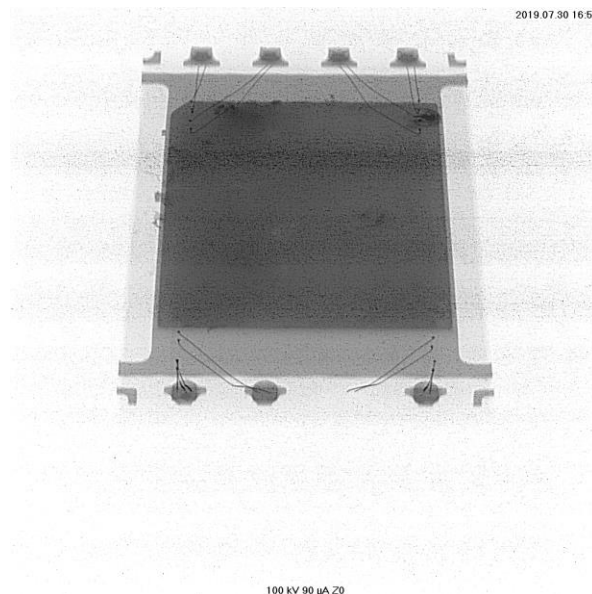


Figure 3. X-ray image of the affected area.

This chip was sent to the Integrated Electronics Engineering Center (IEEC) at SUNY Binghamton to undergo an experimental repair procedure. Engineers at IEEC first removed part of the chip's overmold to expose more surface area of the wirebond connection, then used an aerosol printer capable of printing conductive material to rebuild a pad connection to the exposed wirebond. Figure 4 shows the area printed with the conductive material.

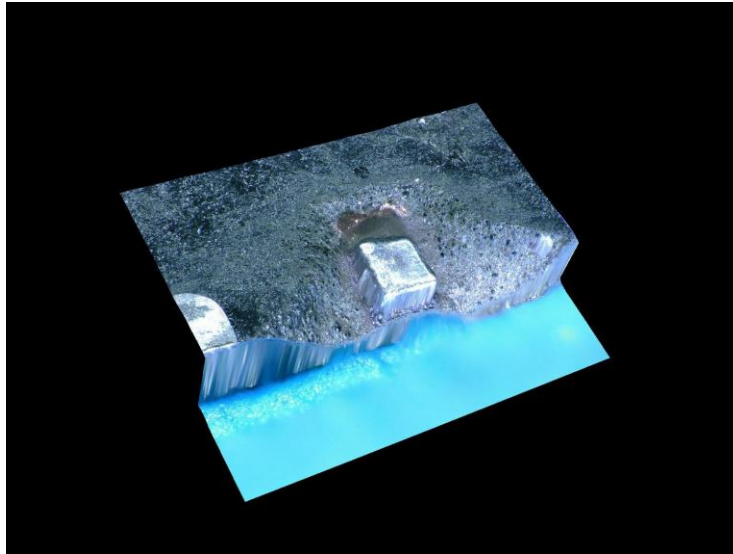


Figure 4. The repaired portion of the chip after undergoing the aerosol printer process.

This chip was then interfaced with the appropriate model socket reader for this device and data was read in binary via a PC. Using known conversions, the binary data was converted to engineering units.

3.4. Data Description

Raw data conversion to engineering units revealed the device had recorded a number of flights. Only one set of converted data was associated with the accident flight and was recorded on December 1, 2018.

Data records showed the device began recording AHRS data before valid GPS records became apparent. For this device, the unit first begins recording AHRS records, and GPS records are not recorded correctly until the device achieves a reliable GPS lock. In a typical installation, this device sits on the aircraft's glareshield and is activated manually by the pilot. It is unclear if this data indicates whether or not the pilot turned on the device in flight. As such, the entire set of data for the accident flight is described as follows:

Figure 5 describes the entirety of the recorded flight data. Initial AHRS data showed the aircraft on a northerly heading in a descending left turn. The data continued to indicate the aircraft was in a left turn, changing from roughly 360 degrees until approximately 230 degrees when the bank angled lessened. When GPS data became valid, the aircraft had a ground speed of approximately 110 knots with a decreasing trend and an altitude of 301 feet mean sea level (MSL) with a decreasing trend. Bank angle and heading

stabilized and the aircraft continued to descend at a ground speed of around 75 knots. Final recorded data showed the aircraft's last ground speed was about 67 knots on a heading of roughly 190 degrees.

Acceleration for the Z axis appeared to be recorded in reverse and was offset by a constant multiplier of -1 to obtain baseline values. Data labeled for Z axis acceleration was initially recorded with a Y-axis label. As such, it is uncertain if the other sets of data for acceleration represent either the X-axis or Y-axis. According to the manufacturer, the device has the capability to self-offset the data if the device is turned on in an orientation other than upright. During this calibration process, the device assumes level flight for the preceding 20 to 30 seconds, then calibrates offsets based on this information. It is possible that these offsets may not be reflected in the raw binary data, which is what was used for this investigation. The plot in figure 5 seems to describe a flight with a valid roll parameter, however, for the reasons stated above, values for pitch attitude may be incorrect or incorrectly referencing a zero pitch attitude.

Figure 6 is a Google Earth plot of the aircraft's position in relation to the wreckage location and the departure airport.

Figure 7 is a detailed view of the overall flight path.

Figure 8 is a close-in detail view of the final portion of the flight path near the wreckage location.

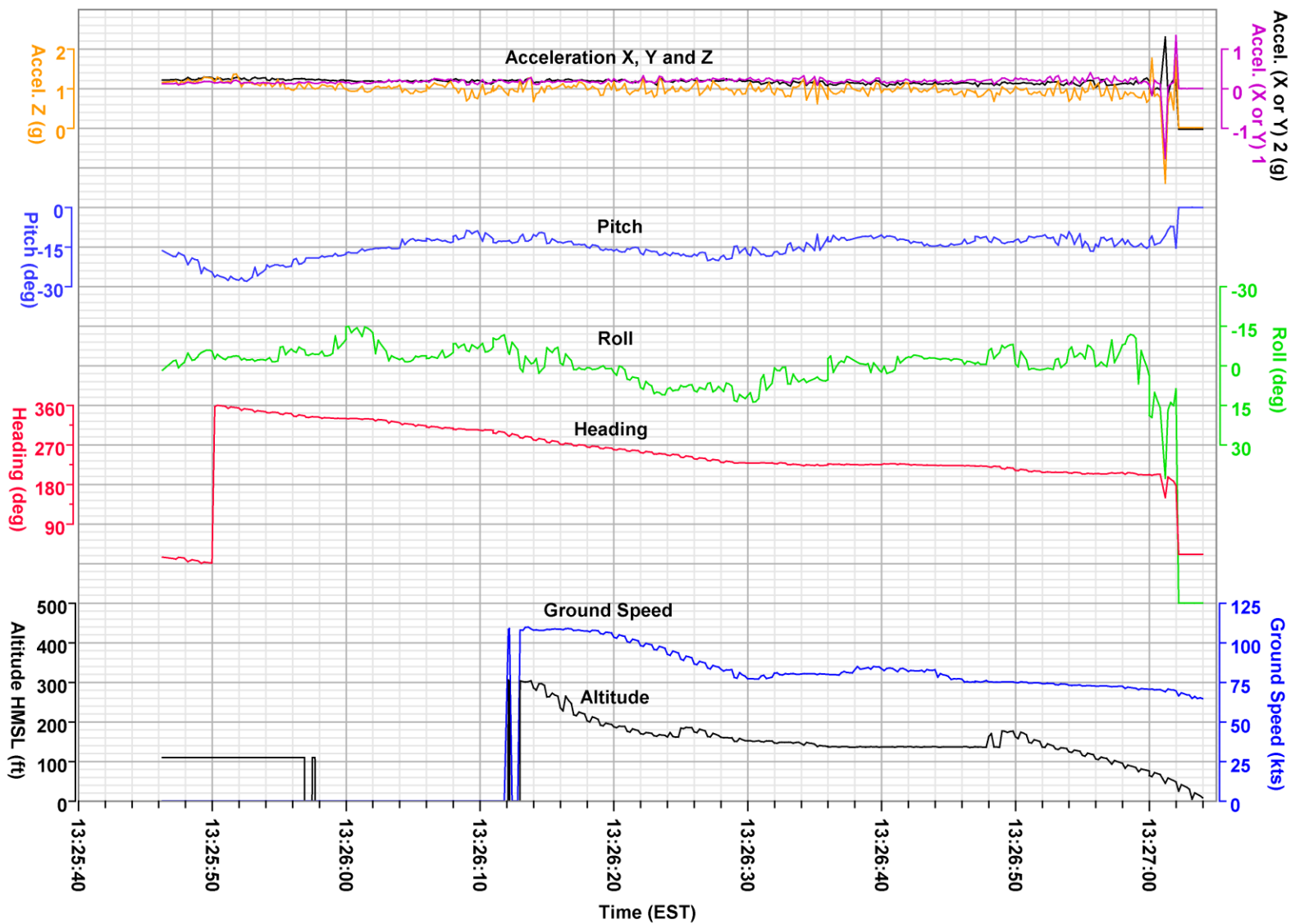


Figure 5. A plot of all the recorded data associated with the accident flight.

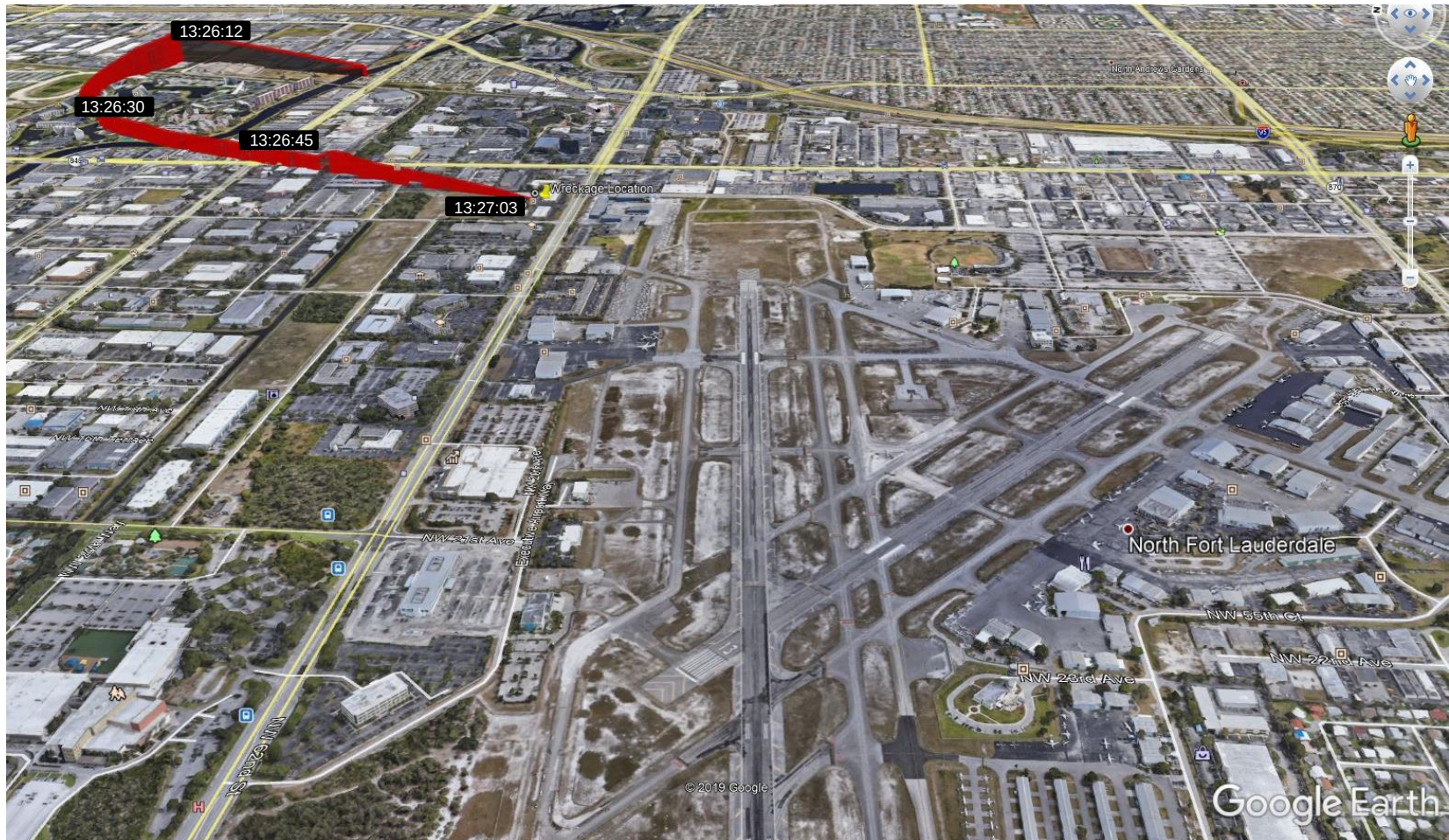


Figure 6. An overall view of the recorded flight data in relation to the departure airport.



Figure 7. A detailed overall view of the recorded flight data.

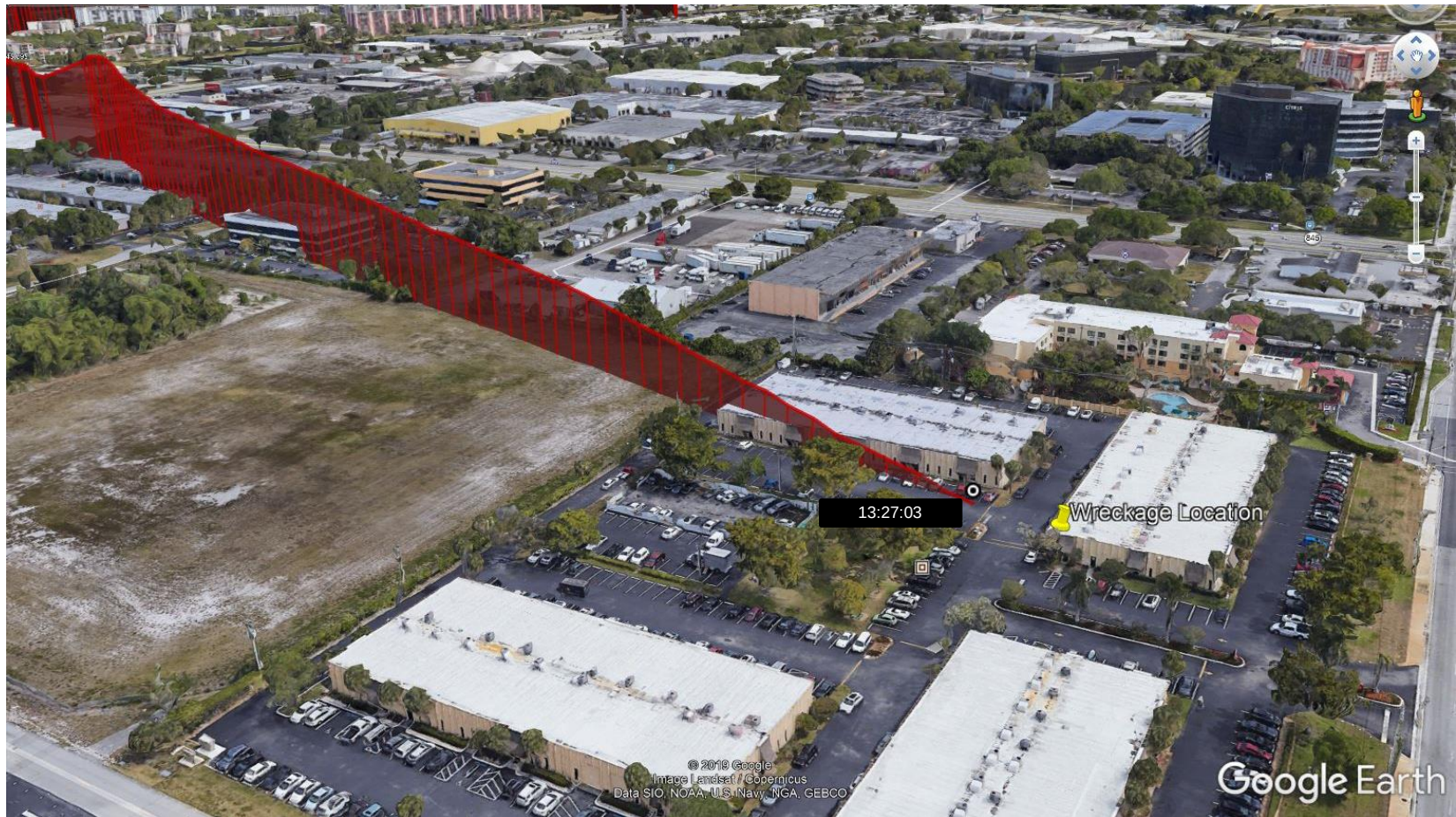


Figure 8. A close-in view of the flight path in relation to the wreckage location.