NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

February 21, 2020

Electronic Devices

Specialist's Factual Report
by Gerald Kawamoto

1. EVENT

Location:	Woodbine, New Jersey
Date:	October 23, 2018
Aircraft:	Mooney M20C
Registration:	N9667M
Operator:	Private
NTSB Number:	ERA19FA023

On October 23, 2018, about 1400 eastern daylight time, a privately owned and operated Mooney M20C, N9667M, impacted the ground during the initial climb after takeoff from the Woodbine Municipal Airport (OBI), Woodbine, New Jersey. The commercial pilot was fatally injured, and the airplane was destroyed. 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 no flight plan was filed. The flight was originating at the time of the accident.

2. DETAILS OF INVESTIGATION

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

Device 1:	**Appareo Stratus 2S**
Device 1 Serial Number:	**002714**
Device 2:	**JPI EDM-700**
Device 2 Serial Number:	**17501**
Device 3:	**JPI FS-450**
Device 3 Serial Number:	**N/A**
Device 4:	**Garmin GPSMAP 396**
Device 4 Serial Number:	**28213816**
Device 5:	**Apple iPhone 6S**
Device 5 Serial Number:	**356135090890454**
Device 6:	**Apple iPhone SE**
Device 6 Serial Number:	**355437078922148**
Device 7:	**Apple iPad**
Device 7 Serial Number:	**DMQHTJC9CDVGH**

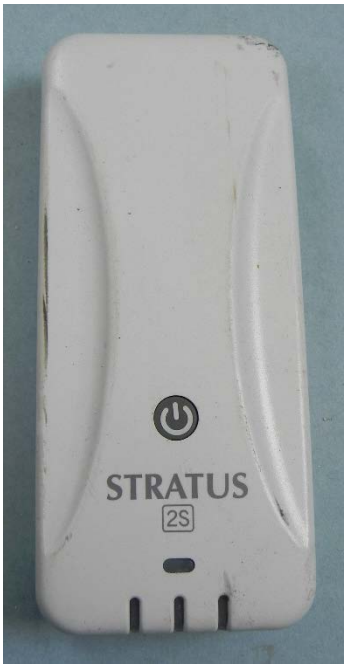
2.1. Appareo Stratus 2S Device Description

The Appareo Status 2S device is a self-contained battery powered unit that contains an internal AHRS,[1] GPS/WAAS receiver,[2] and ADS-B[3] receiver in one compact unit. The unit communicates wirelessly with compatible devices to display all the acquired information. In addition to communicating with compatible devices, the Stratus device records GPS position and AHRS information internally on a non-volatile flash[4] memory chip. Internal memory has the space to store over 13 hours of flight data that is sampled at approximately 5 data records per second (5 Hz).

2.1.1. Appareo Stratus 2S Data Recovery

The device was in good condition upon arrival at the Vehicle Recorder Division, as shown in Figure 1, and the NVM was downloaded normally using laboratory tools.

Figure 1. Appareo Stratus 2S as received.



[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 GPS and transmit its position along with additional information about the aircraft to ground stations for use by air traffic control (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] Non-volatile memory (NVM) is semiconductor memory that does not require external power for data retention.

2.1.2. Appareo Stratus 2S Data Description

The data extracted included sessions from May 27, 2017[5], through October 23, 2018. The last session recorded on the device was determined to be relevant to the accident event was parsed out. This was the only session recorded on the accident date. The recording started at 17:49:04 UTC and ended at 17:59:32 UTC on October 23, 2018. The session recorded prior to the accident event was recorded on October 10, 2018. The flight originated and returned to OBI and data is included in this report.

2.1.3. Appareo Stratus 2S Parameters Provided

Table 1 describes data parameters recorded and derived by the device.

Table 1: Appareo Stratus 2S Parameters

Parameter Name	Parameter Description
Date	Date for recorded data point (MM/DD/YYYY)
Time	Time (UTC) for recorded data point (HH:MM:SS)
Latitude	Recorded Latitude (degrees)
Longitude	Recorded Longitude (degrees)
MSL Altitude	Recorded MSL Altitude (feet)
Ground Speed	Averaged derived ground speed (knots)
Course	Averaged derived true course (degrees)
Pitch	Pitch Angle (degrees)
Bank	Bank Angle (degrees)

2.2. JPI EDM-700 Description

The JPI EDM-700 is a panel-mounted gauge that allows the operator to monitor and record up to 24 parameters related to engine operations. Depending on the installation, engine parameters monitored can include: Exhaust Gas Temperature (EGT), Cylinder Head Temperature (CHT), Oil Pressure and Temperature, Manifold Pressure, Outside Air Temperature, Turbine Inlet Temperature, Engine Revolutions Per Minute (RPM), Compressor Discharge Temperature, Fuel Flow, Carburetor Temperature, and Battery Voltage.

The unit can also calculate in real time, percent of maximum horsepower, fuel used, shock cooling rate, and EGT differentials between highest and lowest cylinder temperatures. The calculations are also based on the aircraft installation.

The unit contains non-volatile memory for data storage of the parameters recorded and calculated. The rate at which the data is stored is selectable by the operator from 2 to 500 seconds per sample. The memory can store up to 20 hours of data at a 6 second-per-sample rate. The data can then be downloaded by the operator using the J.P. Instruments software.

[5]Coordinated Universal Time (UTC).

2.2.1. JPI EDM-700 Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained impact damage, as shown in Figure 2, rendering the unit inoperable. The NVM chips were removed, readout, and converted to engineering units using laboratory tools.

Figure 2. JPI EDM-700 as received.

2.2.2. JPI EDM-700 Data Description

The data extracted included 34 sessions from February 13, 2018, through October 23, 2018. The recorded time is based on the unit's internal clock, which is set and updated by the user. The device begins recording data when power is applied and stops when power is disconnected. Due to the condition of the device, the user set time was unable to be verified and is referred to as JPI Time in this report. The last two sessions were recorded on the date of the accident and are included in this report. The data was recorded at a 6 second-per-sample rate.

2.2.3. JPI EDM-700 Parameters Provided

Table 2 describes data parameters recorded by the device.

Table 2: JPI EDM-700 Data Parameters

Parameter Name	Parameter Description
Time	Time (Device Calculated PST) for recorded data point (HH:MM:SS)
EGT 1-4 (degF)	Exhaust Gas Temperature Cylinder # (degrees Fahrenheit)
CHT 1-4 (degF)	Cylinder Head Temperature Cylinder # (degrees Fahrenheit)
CLD (degF/min)	Shock Cooling Rate (degrees Fahrenheit per minute)
Oil Temp (degF)	Oil Temperature (degrees Fahrenheit)
Voltage (V)	Battery Voltage (Volts)

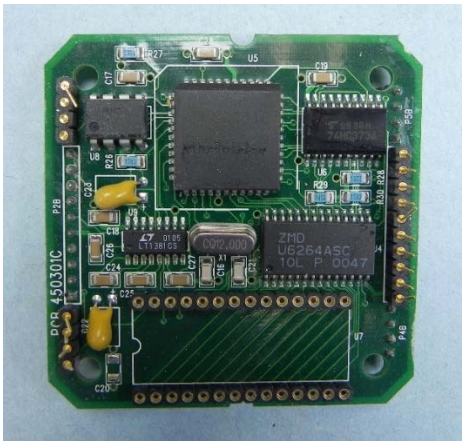
2.3. JPI FS-450 Description

The JPI FS-450 is a panel mounted gauge capable of displaying fuel information to the operator. The fuel status is dependent on the user to properly program the amount of fuel onboard the aircrarft prior to each flight. The device stores the last remaining record of fuel used and fuel remaining in gallons.

2.3.1. JPI FS-450 Data Recovery

The circuit board from the JPI FS-450 was received without the display, as shown in Figure 3. The non-volatile memory chip was removed, readout and a binary image was created using laboratory tools.

Figure 3. JPI FS-450 as received.



2.3.2. JPI FS-450 Data Description

The binary data was decoded with instruction from the manufacturer. The following settings were decoded from the binary image:

- **Twin/single:** “single”
- **Units:** “gallons”
- **Tanks size:** “54”
- **Fuel trip total (single):** “182”
- **Fuel remaining:** “358”

2.4. Garmin GPSMAP 396 Description

The Garmin GPSMAP 396 is a battery-powered portable 12-channel GPS receiver with a 256-color TFT LCD display screen. The unit includes a built-in Jeppesen database and is capable of receiving XM satellite radio for flight information including NEXTRAD radar, lightning, METARs, TAFs, and TFRs. The unit stores date, route-of-flight, and flight-time information for up to 50 flights. A flight record is triggered when groundspeed exceeds 30 knots and altitude exceeds 500 feet, and ends when groundspeed drops below 30 knots for 10 minutes or more. A detailed tracklog including latitude, longitude, date, time, and GPS altitude information is stored within the unit whenever the receiver has a lock on the

GPS navigation signal. Position is updated within the tracklog as a function of time or distance moved, depending on how the unit has been configured. Once the current tracklog memory becomes full, new information either overwrites the oldest information or recording stops, depending on how the unit is configured. The current tracklog can be saved to long-term memory and 15 saved tracklogs can be maintained in addition to the current tracklog. Tracklog storage may be activated or de-activated at user discretion. All recorded data is stored in non-volatile memory. The unit contains hardware and software permitting the download of recorded waypoint, route, and tracklog information to a PC via a built-in serial port using the NMEA 0183 version 2.0 protocol. The unit can also communicate with external devices such as a computer using a built in USB port. An internal button-battery is used to back-up power to the internal memory and real-time clock during those periods when main power is removed.

2.4.1. Garmin GPSMAP 396 Data Recovery

The device arrived at the Vehicle Recorder Laboratory in good condition and powered on normally. No track logs were recorded to the non-volatile memory, as shown in Figure 4, therefore no data were recovered.

Figure 4. Garmin GPSMAP 396 "Track" screen showing that no track logs were recorded to NVM.

2.5. Personal Electronic Devices (PEDs) Description

PEDs are a category of devices comprised primarily of portable computing devices and mobile phones. Portable computing devices are typically capable of internet access, email, messaging services, and can run user-installed applications to perform specific tasks. PED user and system data is typically stored on non-volatile memory and can be accessed through manufacturer-provided interfaces.

2.5.1. Apple iPad Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained impact damage as shown in Figure 5. The extent of the damage precluded normal recovery procedures and additional attempts were unsuccessful in yielding usable data.

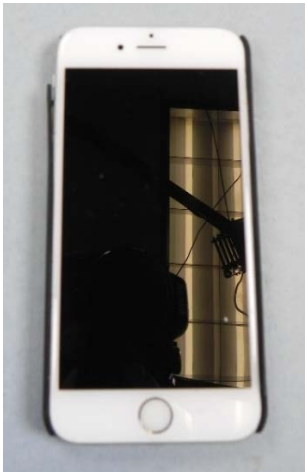
Figure 5. Apple iPad as received.

2.5.2. Apple iPhone SE Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained impact damage as shown in Figure 6. The logic board was removed and installed in a functioning surrogate unit. The surrogate powered on normally but the device was passcode protected. Potential passcodes provided by the Investigator-In-Charge (IIC) were unable to unlock the device and no further data recovery was pursued.

Figure 6. iPhone SE as received.

Figure 7. iPhone 6S as received.



2.5.3. Apple iPhone 6S Data Recovery

The iPhone 6S was in good condition upon arrival at the Vehicle Recorder Laboratory, as shown in Figure 7, and turned on normally. The device was passcode protected. Potential passcodes provided by the Investigator-In-Charge (IIC) were unable to unlock the device and no further data recovery was pursued.

2.6. Plots and Corresponding Tabular Data

Figure 8 is a graphical overlay generated using Google Earth showing the entire accident flight. Data from the Appareo Stratus 2S was used to create the flight track. The weather and lighting conditions in Google Earth are not necessarily the weather and lighting conditions present at the time of the recording.

The device started recorded data at 17:49:04 UTC. The flight departed Woodbine Municipal Airport (OBI) about 17:59 UTC and the last recorded parameter was at 17:59:32 UTC.

Figure 9 is a graphical overlay generated using Google Earth zoomed in on the end of the recording and the main wreckage location.

Figure 10 is a plot of parameters from the Appareo Stratus 2S for the entire accident flight. The time interval is 17:49:00 to 18:00:00 UTC.

Figure 11 is a plot of parameters from the Appareo Stratus 2S at the end of the accident flight. The time interval is 17:58:20 to 17:59:40 UTC.

Figure 12 is a graphical overlay generated using Google Earth for the takeoff portion of the flight recorded on October 10, 2018.

Figure 13 is a plot of parameters from the Appareo Stratus 2S for the takeoff portion of the flight recorded on October 10, 2018. The time interval is 22:15:35 to 22:17:05 UTC.

Figure 14 is a plot of the 1st Session of data recorded on the JPI EDM-700 on October 23, 2018. The recording started at 18:08:40 JPI Time and ended at 18:11:52 JPI Time. The time interval displayed is 18:08:30 to 18:12:00 JPI Time.

Figure 15 is a plot of the 2nd Session of data recorded on the JPI EDM-700 on October 23, 2018 JPI Time. The recording started at 18:36:44 JPI Time and ended at 20:10:08 JPI Time. The time interval displayed is 18:36:00 to 20:11:00 JPI Time.

The corresponding tabular data used to create Figures 8 through 11 are provided in electronic comma separated value (.CSV) format as Attachment 1 to this report. The corresponding tabular data used to create Figures 14 and 15 are provided in electronic .CSV format as Attachment 2 to this report. The corresponding tabular data used to create Figures 12 and 13 are provided in electronic .CSV format as Attachment 3 to this report.

Figure 8. Google Earth overlay showing the entire accident flight.

Figure 9. Google Earth overlay showing the end of the accident flight and the main wreckage location.

Figure 10. Plot of parameters from the Appareo Stratus 2S for the entire accident flight.

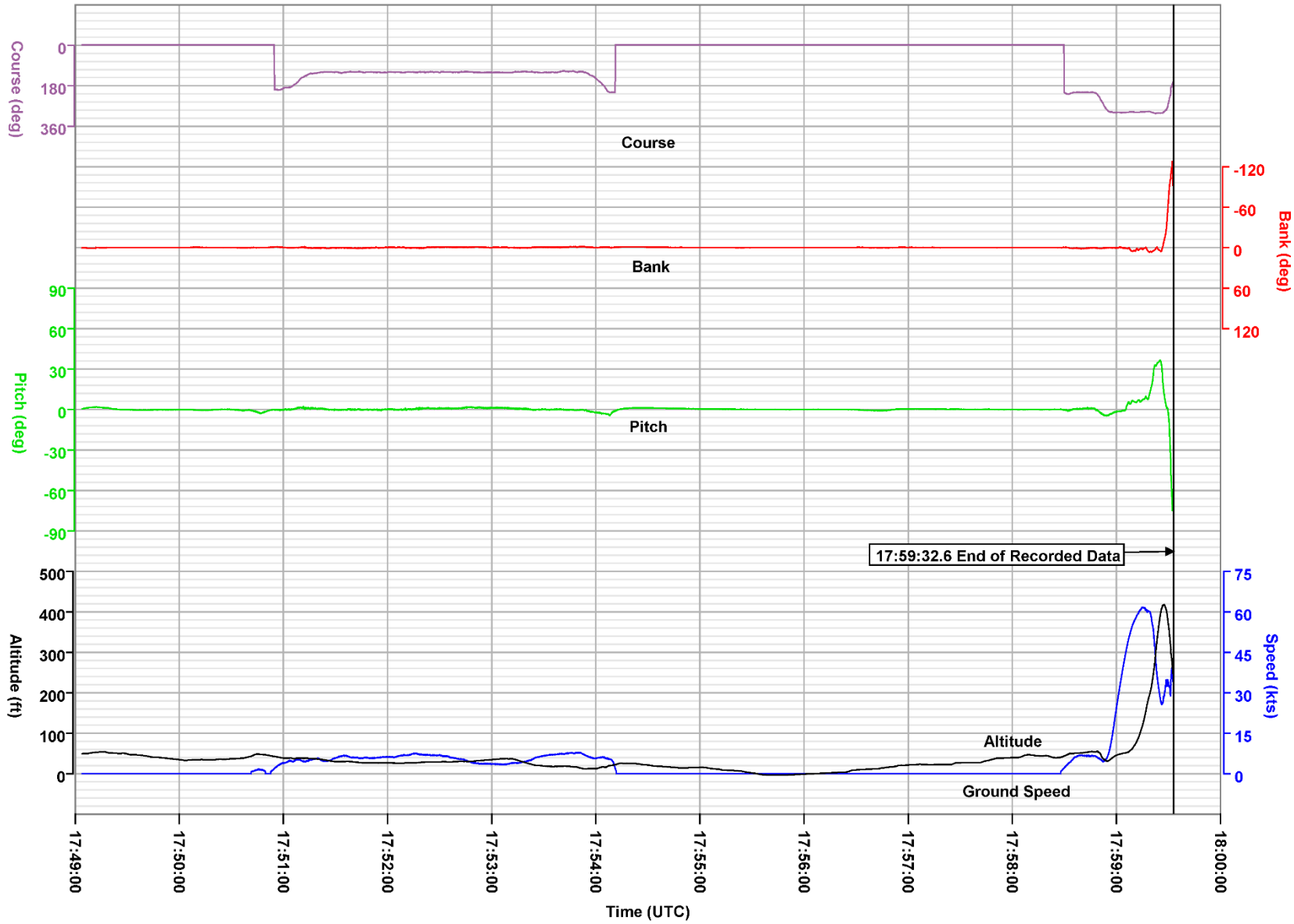


Figure 11. Plot of parameters from the Appareo Stratus 2S at the end of the accident flight.

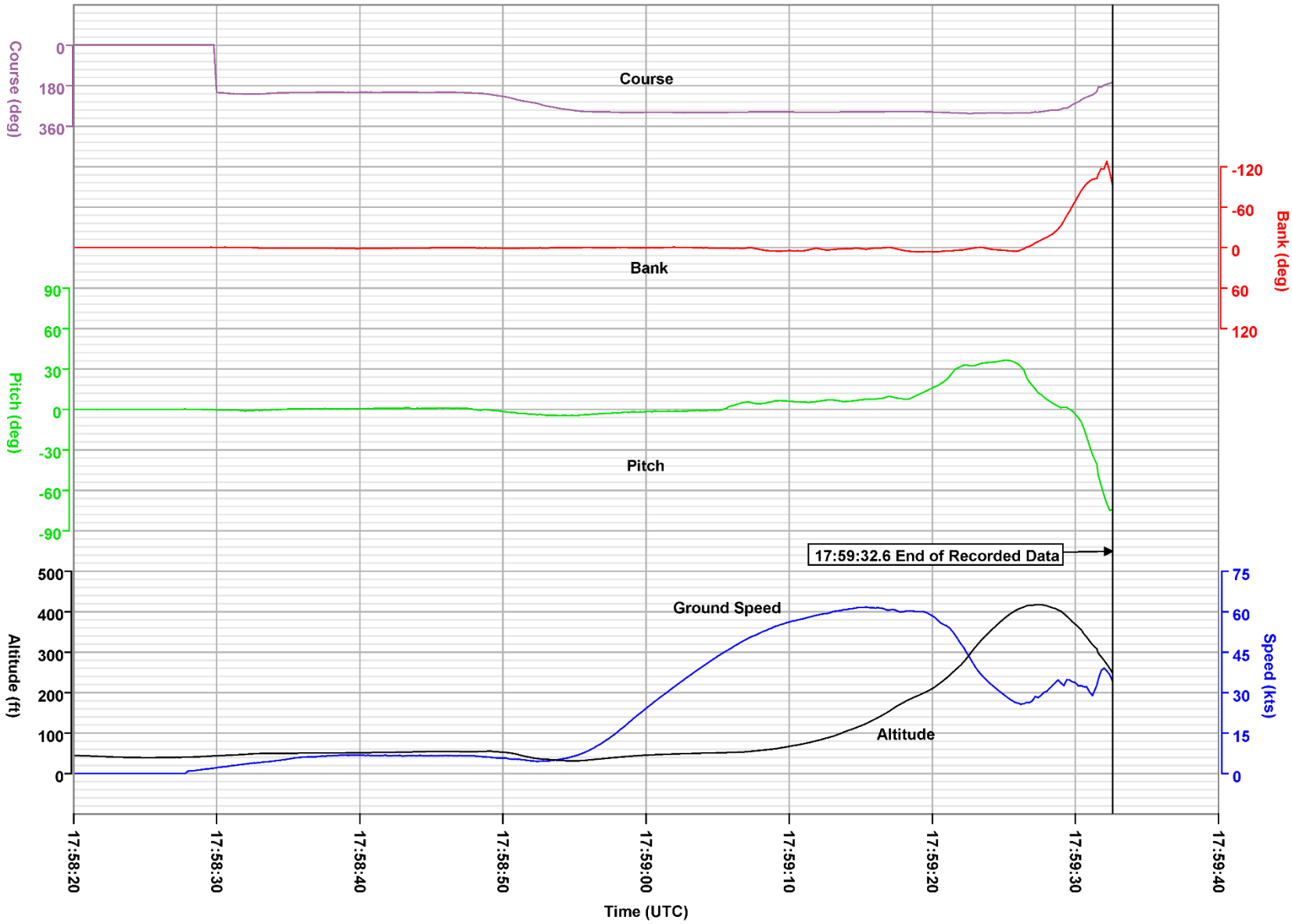


Figure 12. Google Earth overlay showing the takeoff portion of the flight recorded on October 10, 2018.

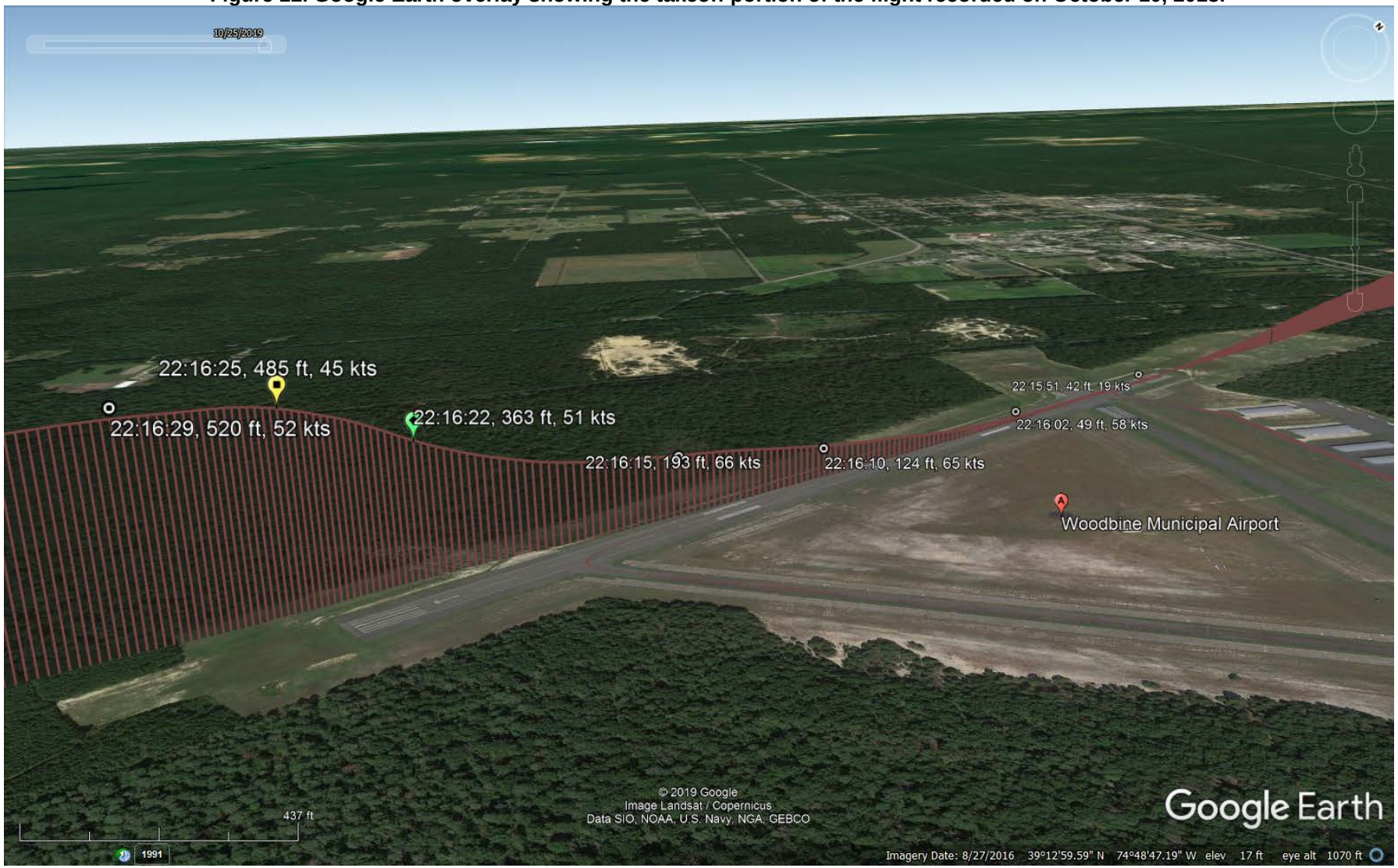


Figure 13. Plot of parameters from the Appareo Stratus 2S showing the takeoff portion of the flight recorded on October 10, 2018.

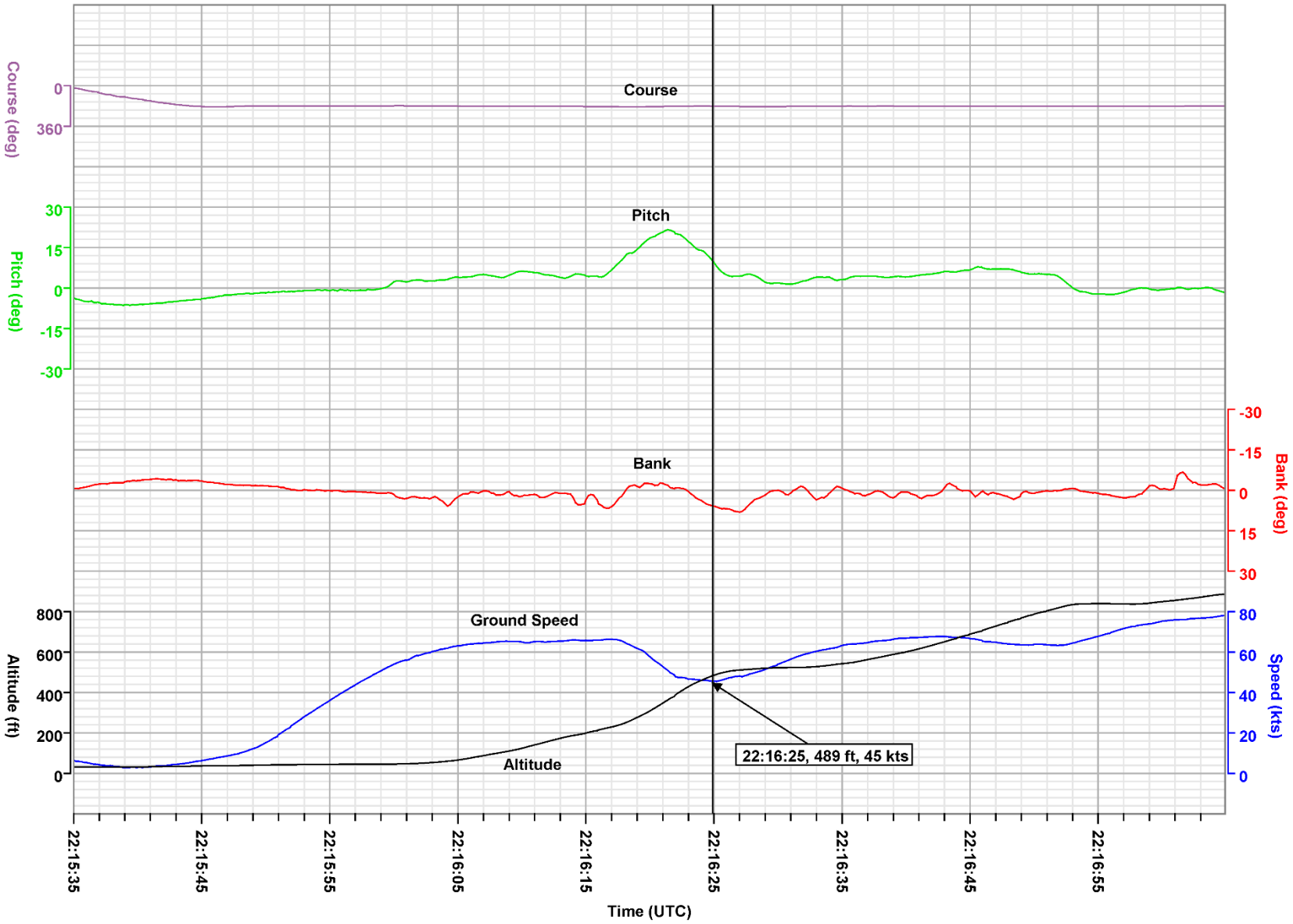


Figure 14. Plot of the 1st Session of data recorded on October 23, 2018 from the JPI EDM-700.

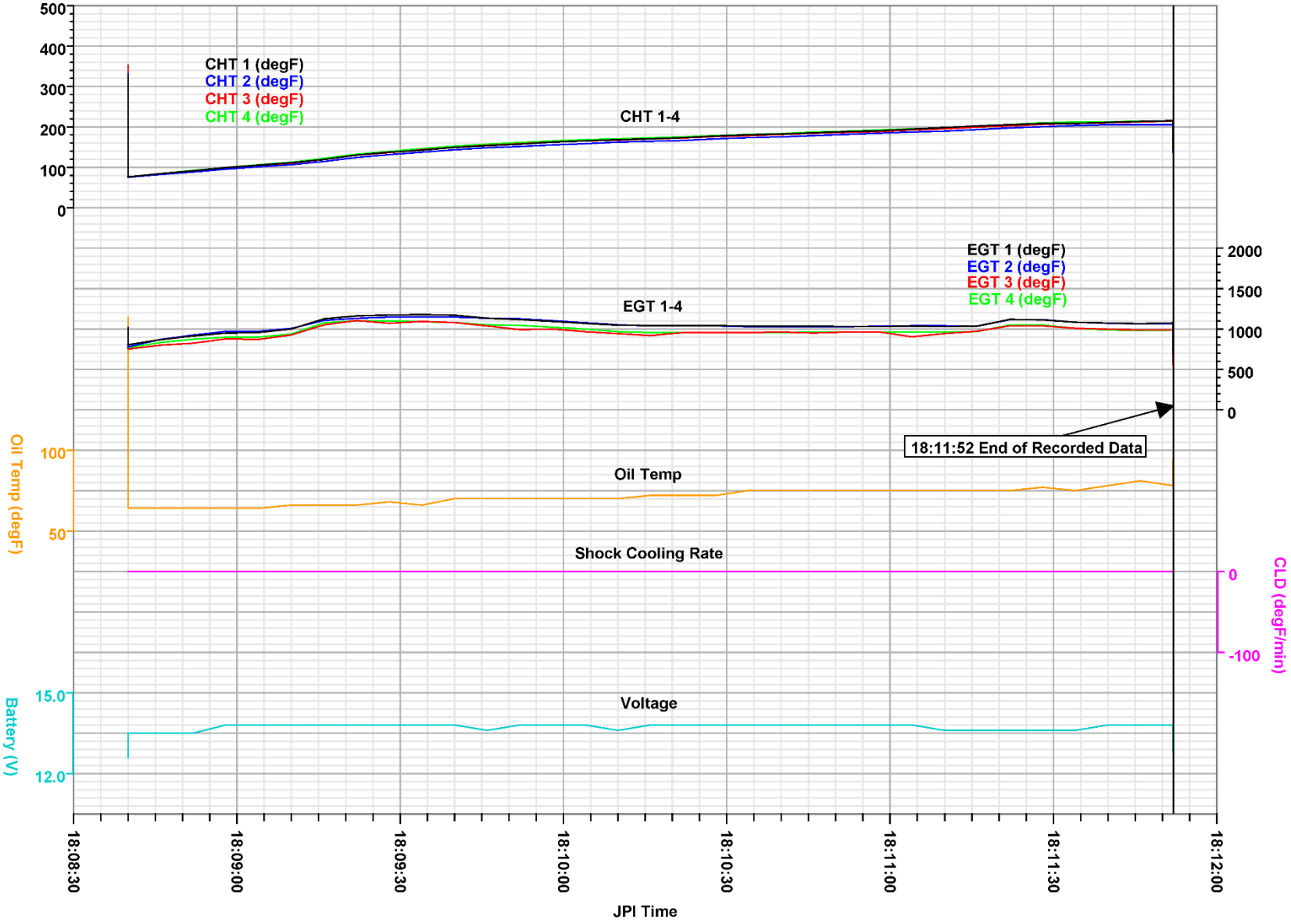


Figure 15. Plot of the 2nd Session of data recorded on October 23, 2018 from the JPI EDM-700.