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

July 19, 2016

Multiple Electronic Devices

Specialist's Factual Report
by Bill Tuccio, Ph.D.

1. EVENT

Location:	Santa Rosa, California
Date:	January 28, 2016
Aircraft:	Piper PA-24-260C
Registration:	N9362P
Operator:	Tango Charlie Aviation LLC
NTSB Number:	WPR16FA059

On January 28, 2016, about 1900 Pacific standard time, a Piper PA-24-260C, N9362P, was destroyed when it impacted terrain during an instrument landing system (ILS) approach into Charles M. Schulz Airport – Sonoma County Airport (STS), Santa Rosa, California. The commercial pilot and passenger were fatally injured. The airplane was registered to and operated by Tango Charlie Aviation LLC as a 14 *Code of Federal Regulations* Part 91 flight. Night instrument meteorological conditions prevailed about the time of the accident, and a visual flight rules (VFR) flight plan was filed for the cross country flight. The personal flight departed Palm Springs International Airport (PSP), Palm Springs, California at 1535.

2. DETAILS OF INVESTIGATION

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

Devices with no data recovered:

Device 1:	Garmin GTN 650
Device 1 Serial Number:	1Z8015336
Device 2:	Apple iPad Mini
Device 2 Serial Number:	F4KLV1WJFCM9
Device 3:	Apple iPad Mini
Device 3 Serial Number:	DLXLVAG3FCM7

Devices with data recovered:

Device 4:	Appareo Stratus
Device 4 Serial Number:	228139
Device 5:	JPI EDM-800
Device 5 Serial Number:	unknown

2.1. Devices With No Data Recovered

A Garmin GTN 650 and two Apple iPad Minis were recovered as shown in figures 1, 2, and 3, respectively. None of the devices yielded any data.

Regarding the Garmin GTN 650 (figure 1), the device does not record any historical data and only retains last communication and navigation frequency information in non-volatile memory. This information was deemed non-pertinent to this investigation and no effort was made to recover the last frequency information.

Regarding the iPad Mini (serial number F4KLV1WJFCM9, figure 2), the internal board was removed from the unit and installed in an operable unit; however, the unit would not start. No further recovery efforts were attempted.

Regarding the iPad Mini (serial number DLXLVAG3FCM7, figure 3), the internal board was damaged and could not be installed in an operable unit. No further recovery efforts were attempted.

Figure 1. Garmin GTN 650.

Figure 2. Apple iPad Mini (serial number F4KLV1WJFCM9) with internal board inset.

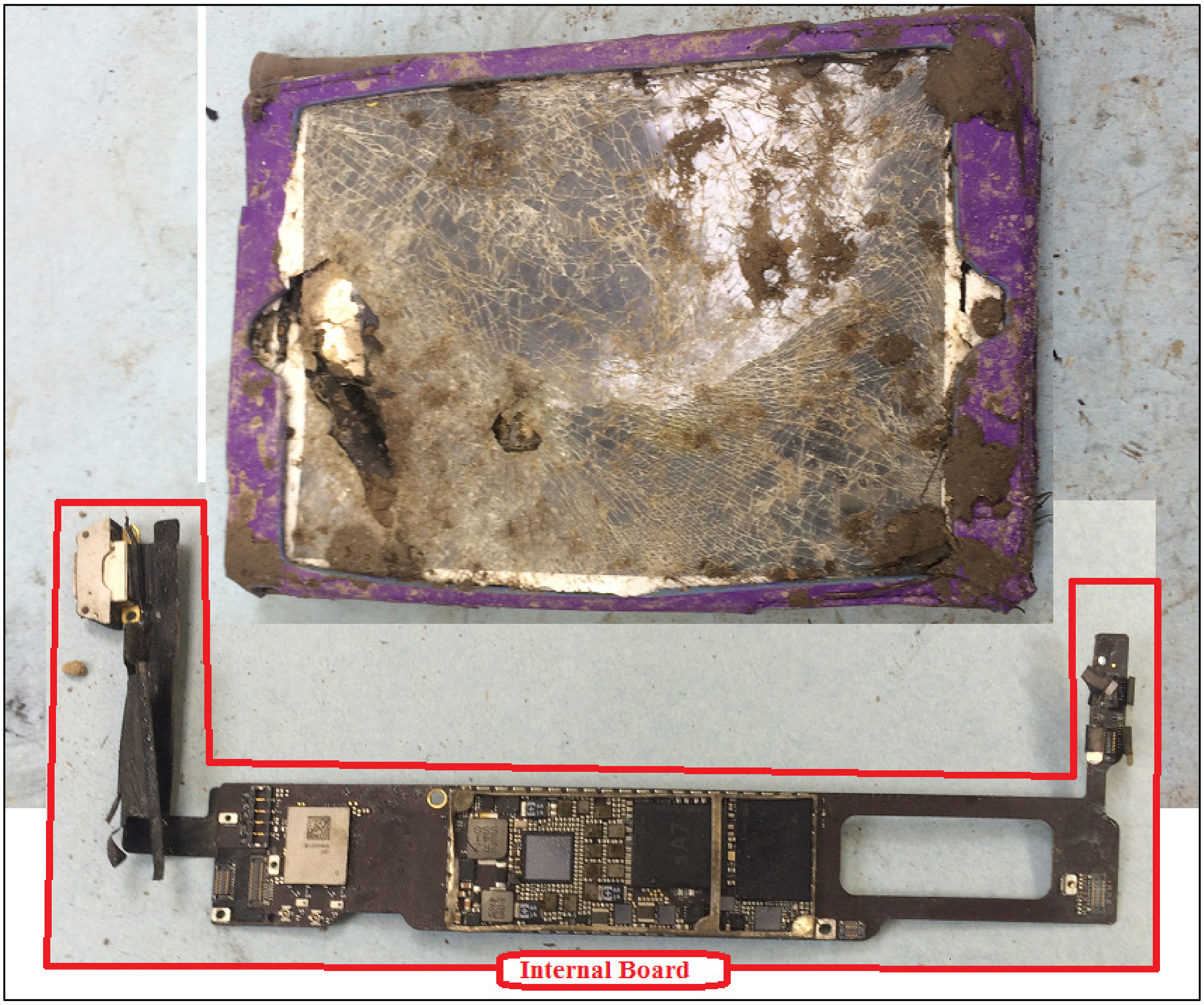


Figure 3. Apple iPad Mini (serial number DLXLVAG3FCM7) with internal board inset.

2.2. Devices With Data Recovered

The Appareo Stratus 2 and JPI EDM-800 yielded accident-pertinent data, as follows.

2.2.1. Time Alignment Between Devices

All times in this report are as recorded by each device and are not aligned between devices. See the Electronic Devices Study Report in the public docket for time alignment.

2.2.2. Appareo Stratus 2 Device Description

The Appareo Status 2 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

[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

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[4] 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-volatile[5] flash memory chip. Internal memory has the space to store over 13 hours of flight data that is sampled at a rate of 5 data records per second (5 Hz).

2.2.2.1. Appareo Stratus 2 Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained minor impact damage, as shown in figure 4. An internal inspection revealed minor damage to the internal components, as shown in figure 5. When power was applied to the unit, it would not start. The unit was repaired and data logs downloaded using the ForeFlight application.

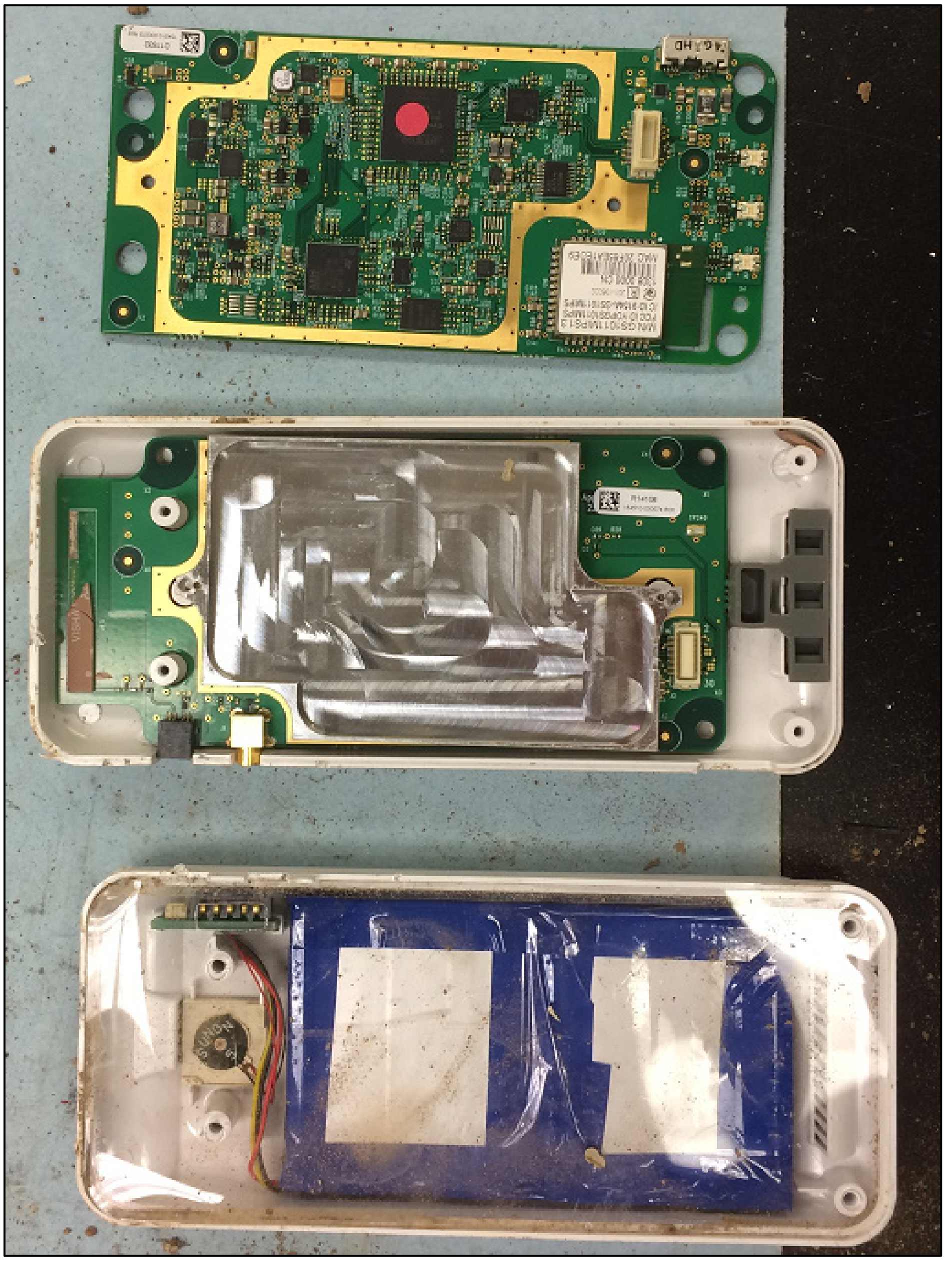
Figure 4. Appareo Stratus 2 as received.

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.

Figure 5. Appareo Stratus 2 internal components.



2.2.2.2. Appareo Stratus 2 Data Description

Downloaded data included the accident flight from January 28, 2016, starting at 23:17:00 UTC through January 29, 2016, at 02:57:03 UTC. Additionally, a near stationary series of points at about longitude -122.7869378, latitude 38.4789967, were recorded on January 29, 2016, from 02:57:03 to 13:22:18 UTC.

While the Stratus 2 recorded vertical and horizontal acceleration data, the acceleration entries in the download appeared to report only the integer portion of the acceleration data. Based on prior Stratus 2 investigations, it is likely higher resolution acceleration data existed on the non-volatile memory chip in the Stratus 2; however, for this investigation the chip was not accessed directly and acceleration data were omitted from this report.

2.2.2.3. Appareo Stratus 2 Parameters Provided

Table 1 describes data parameters provided by the Stratus 2. All parameters were as recorded by the Stratus 2 unit (that is, none were derived).

Table 1. Appareo Stratus 2 Data Parameters

Parameter Name	Parameter Description
Date	Date (UTC) for recorded data point (MM/DD/YYYY)
Time	Time (UTC) for recorded data point (HH:MM:SS)
Latitude	Latitude (degrees)
Longitude	Longitude (degrees)
GPS Alt	GPS Altitude (feet (ft), MSL)
Groundspeed	Groundspeed (knots (kts))
Track	True track (degrees)
Pitch	Pitch angle (degrees) (- down, + up)
Roll	Roll angle (degrees) (- left, + right)

Note: MSL means altitude above mean sea level

2.2.2.4. Appareo Stratus 2 Plots and Tabular Data

Figures 6 through 16 were generated using data extracted from the Stratus 2 and overlaid using Google Earth. The weather and lighting depicted in Google Earth are not necessarily representative of the weather and lighting conditions experienced during the accident flight. Figures 11 through 16 use the Jeppesen "STS ILS or LOC Rwy 32" chart, revision April 24, 2015.[6]

Figure 6 provides an overview of the accident flight recording. The recording began at 23:17:00 UTC on January 28, 2016, and ended at 02:57:03 on January 29, 2016; a duration of 3 hours, 40 minutes, 3 seconds.

Figure 7 shows the start of the recording at PSP. The recording began on the ramp at 23:17:00 UTC, and the aircraft began movement at about 23:26:53 UTC. The aircraft stopped short of the runway at 23:28:10 UTC, and then began the takeoff roll at about 23:29:47 UTC.

Figures 8 through 10 show the enroute flight path overlaid on an aviation sectional chart.

[6] The chart is for reference only in this report; refer to other investigative information for what chart may have been used on the accident flight.

Collectively, figures 11 through 16 show the flight path overlaid on the ILS 32 instrument approach chart, as follows (narrative values are approximate):

- At 02:37:57 UTC, the aircraft passed the SGD VOR at about 6,400 feet.
- Between 02:37:57 UTC and 02:40:44 UTC, the aircraft path was consistent with the 281° feeder route from SGD to DACER intersection (with a minimum published altitude of 3,900 feet). On this segment the recorded GPS altitude was 6,500 feet.
- At 02:40:44 UTC, the aircraft path turned towards the southwest.
- At 02:45:52 UTC, at a GPS altitude of 4,800 feet, the aircraft path turned towards the northeast.
- At 02:49:11 UTC, at a GPS altitude of 4,900 feet, the aircraft path turned towards the west and the path was consistent with the feeder route from SGD to DACER to LUSEE.
- At 02:51:07 UTC, at a GPS altitude of 4,200 feet, the aircraft passed near the LUSEE intersection (the minimum published altitude at LUSEE was 3,000 feet).
- At 02:52:46 UTC, at a GPS altitude of 4,000 feet, the aircraft passed near the EDOVE intersection (the minimum published altitude at EDOVE was 2,700 feet).
- At 02:54:47 UTC, at a GPS altitude of 3,000 feet, the aircraft passed near the PIGPN intersection (the ILS intercept altitude published at PIGPN was 2,000 feet).
- At 02:55:48 UTC, at a GPS altitude of 1,700 feet, the aircraft crossed the localizer tracking slightly west of the localizer.
- At 02:56:43 UTC, at a GPS altitude of 810 feet, the aircraft crossed the localizer, tracking east of the localizer.
- The last recorded point was 02:57:03 UTC at a GPS altitude of 203 feet, east of the localizer. AHRS data showed the aircraft in left bank of about 50 degrees with a pitch down attitude (the decision altitude for the approach was 377 feet).

Figures 17 through 21 show plots of the accident flight data, including Stratus 2 recorded groundspeed, track, pitch, and roll. The plots may be summarized as follows (narrative values are approximate):

- In the first 12 minutes after takeoff, until 23:42:23 UTC, the aircraft climbed to a GPS altitude of 8,500 feet.
- For the 43 minutes, until 00:25:28 UTC, the aircraft remained at a GPS altitude of 8,500 feet.
- Between 00:25:28 UTC and 00:37:10 UTC, the aircraft climbed to a GPS altitude of 12,500 feet and remained at this altitude until 00:41:00 UTC.
- By 00:46:32 UTC, the aircraft descended to 10,500 feet and remained at that altitude until 01:35:00 UTC.
    - Note: Between 00:28:02 UTC and 00:47:21 UTC, there were four large excursions of pitch and roll. Given the track, groundspeed, and altitude trends during this same period, it is possible the excursions were an anomaly (for example, the Stratus 2 unit may have been moved from its reference location, disturbing the AHRS accelerometers).

- Between 01:35:00 UTC and 2:07:53 UTC, the aircraft descended from 10,500 feet to 6,500 feet and remained at 6,500 feet until passing the SGD VOR on the approach.

Figure 21 details the approach period with approach events/positions annotated. After 02:49:00 UTC, oscillations in roll and pitch were also observed in track and altitude/groundspeed, respectively.

Tabular data used to generate figures 6 through 21 are included as attachment 1 in electronic comma-delimited (.CSV) format.

Figure 6. Entire flight, satellite overlay with select points.

Figure 7. Start of recording at PSP, select points.

Figure 8. First portion of recording, aviation sectional chart overlay, select points.

Figure 9. Enroute portion of accident flight, select points.

Figure 10. Arrival portion of recording, select points.

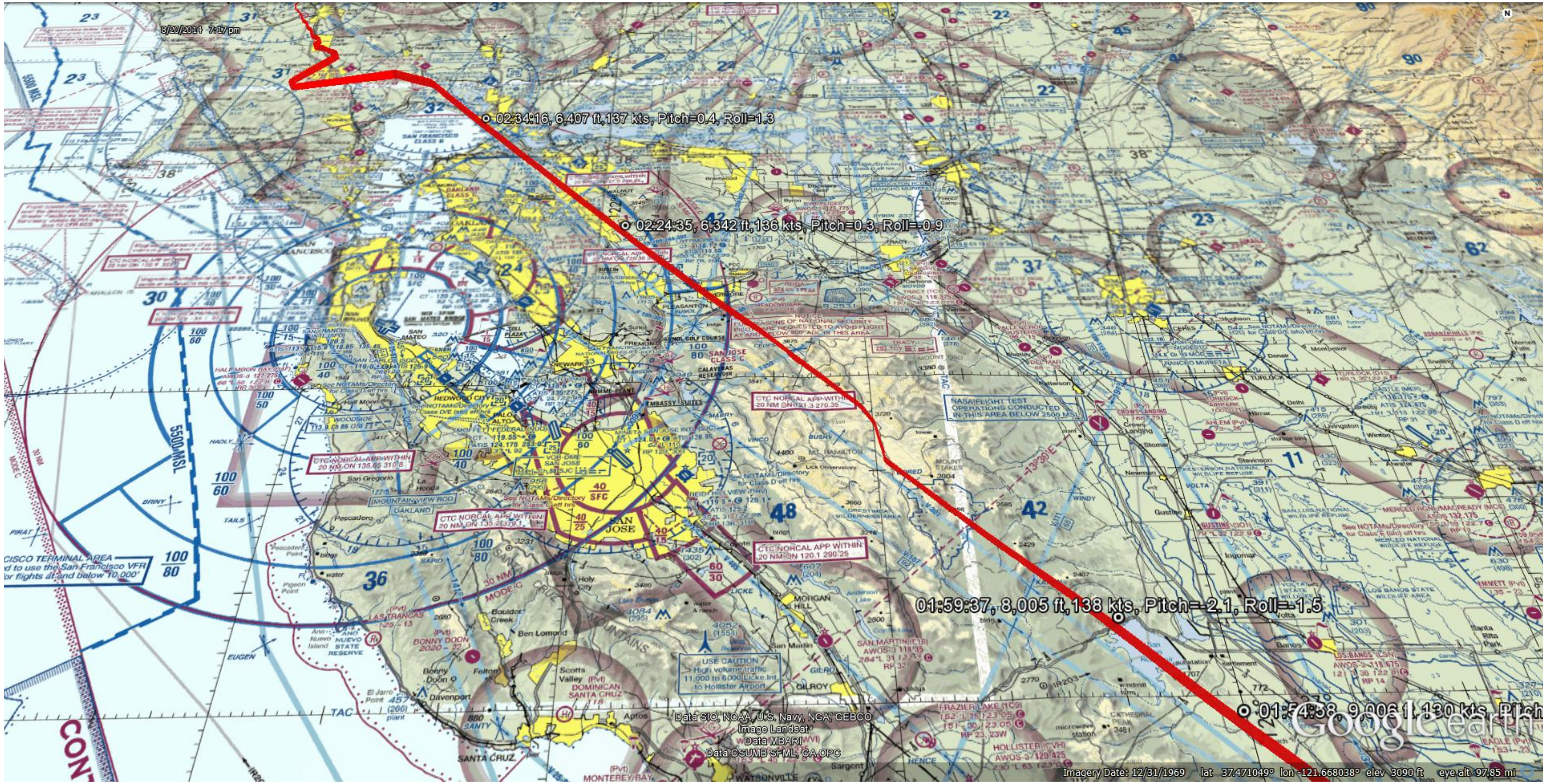


Figure 11. ILS32 chart overlay with satellite imagery (overview).

Figure 12. ILS32 chart overlay with sectional imagery (overview).

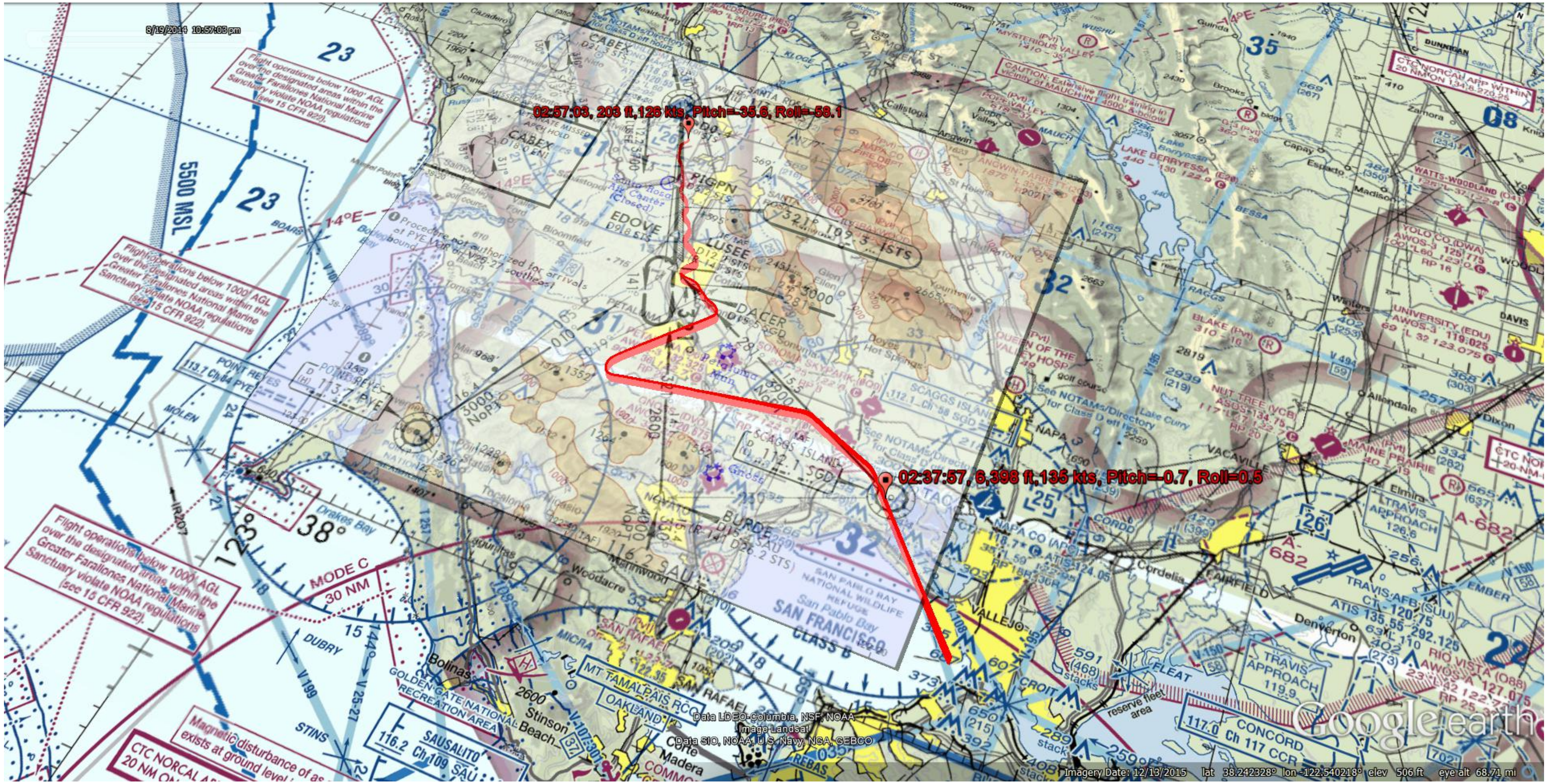


Figure 13. ILS32 chart overlay, entire approach, select points.

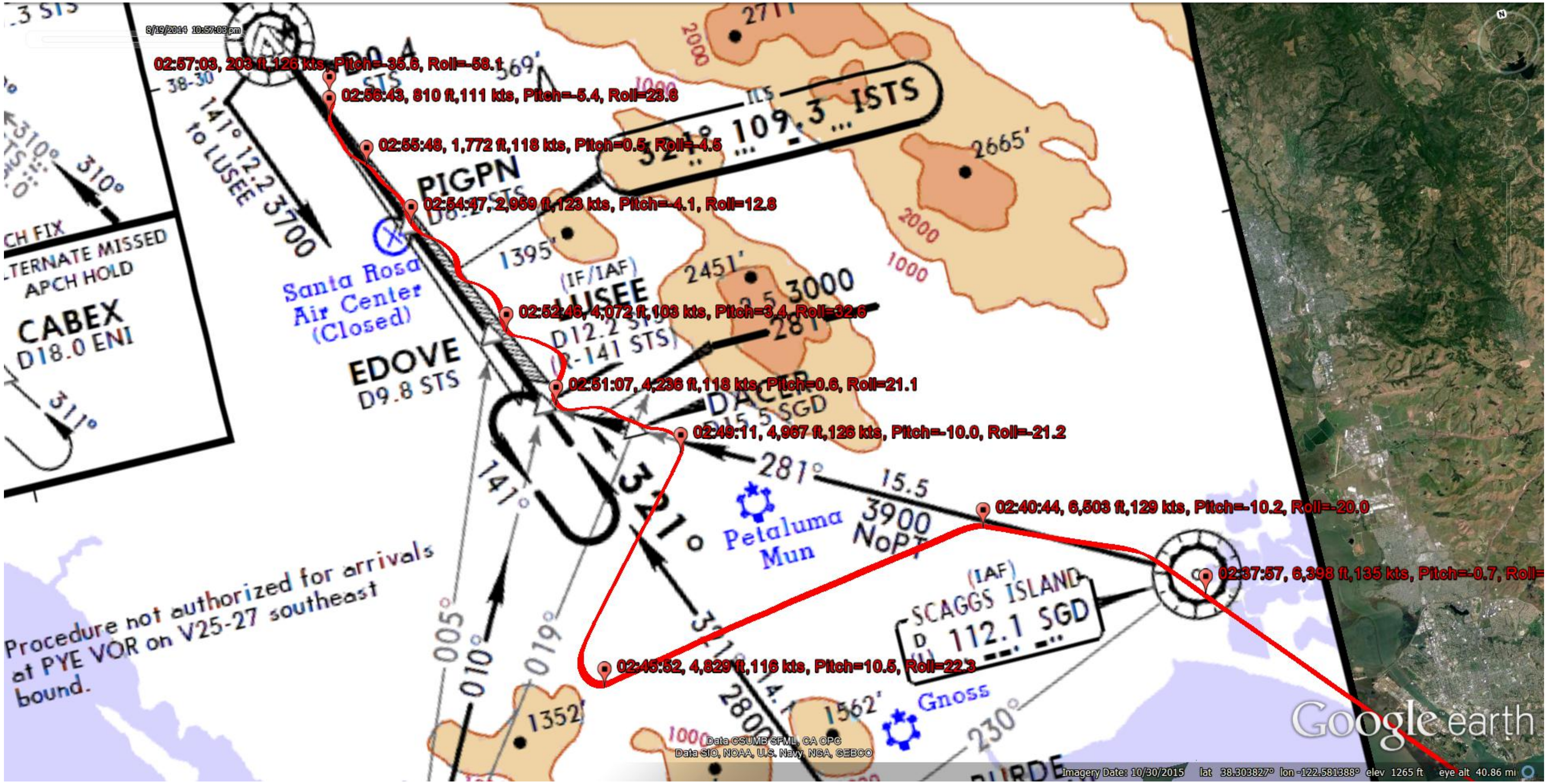


Figure 14. ILS32 chart overlay, start of approach, select points.

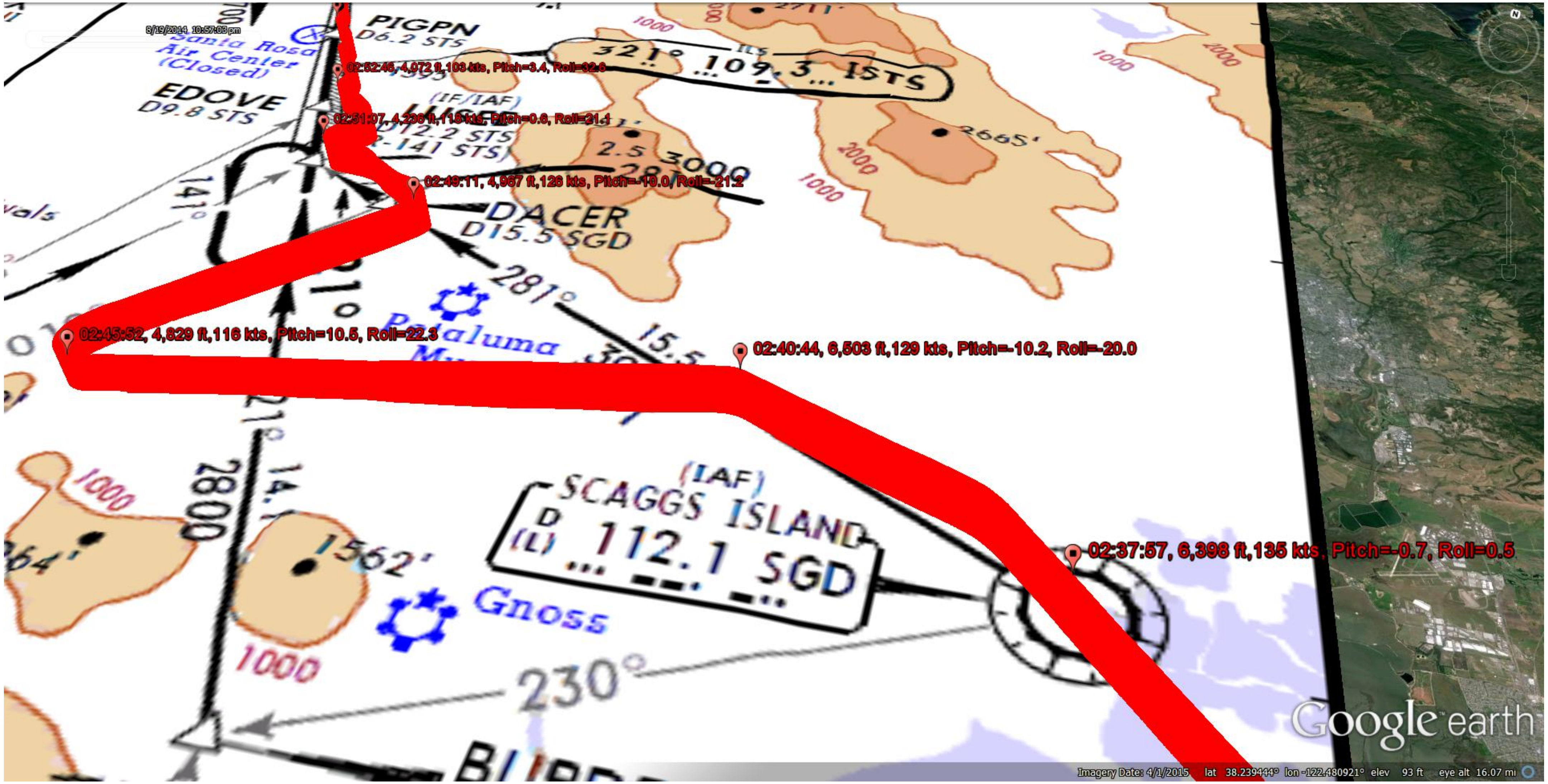


Figure 15. ILS32 chart overlay, LUSEE to PIGPN, select points.

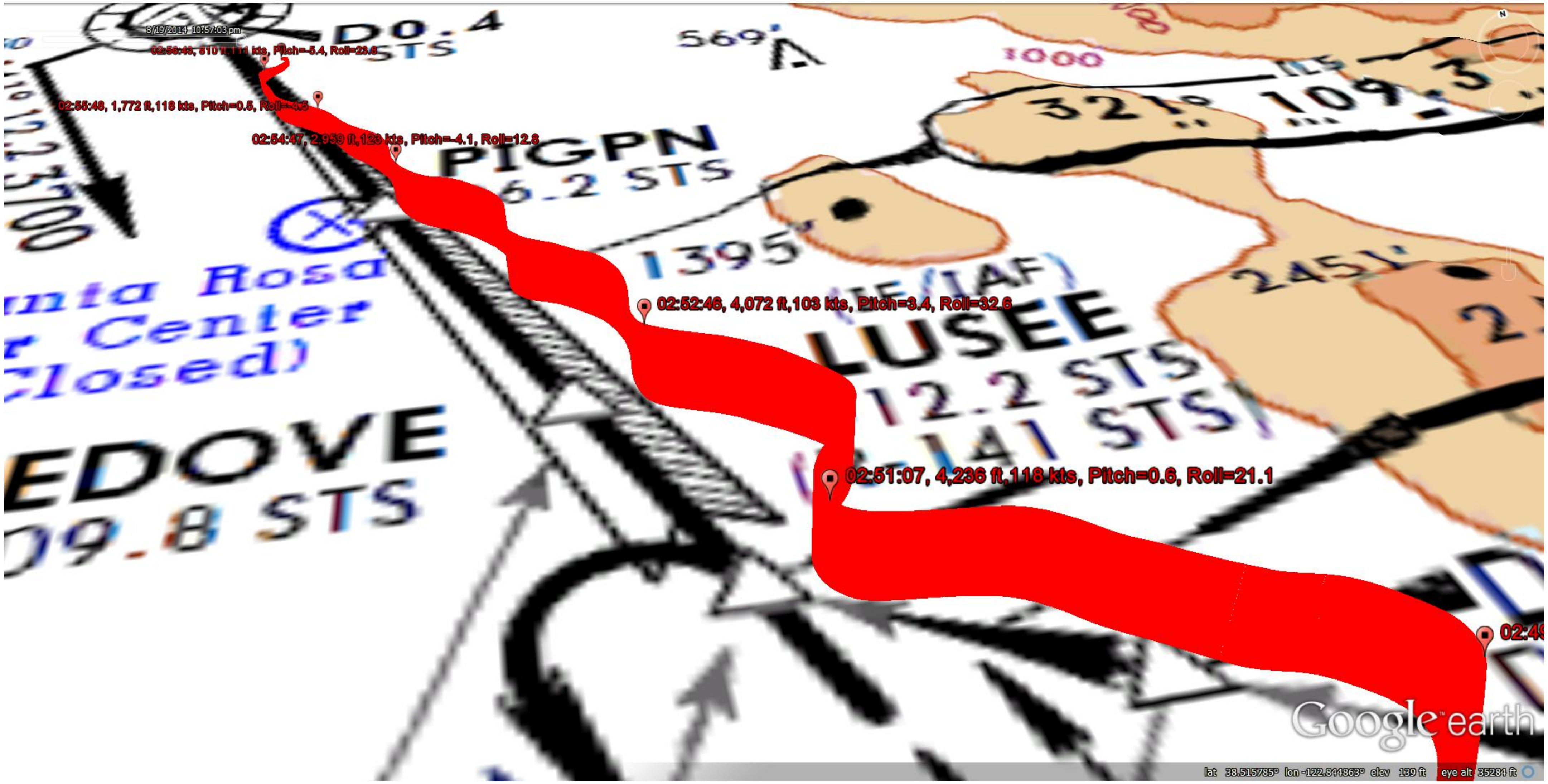


Figure 16. ILS32 chart overlay, PIGPN to end of recording, select points.

Figure 17. Plot of entire accident flight.

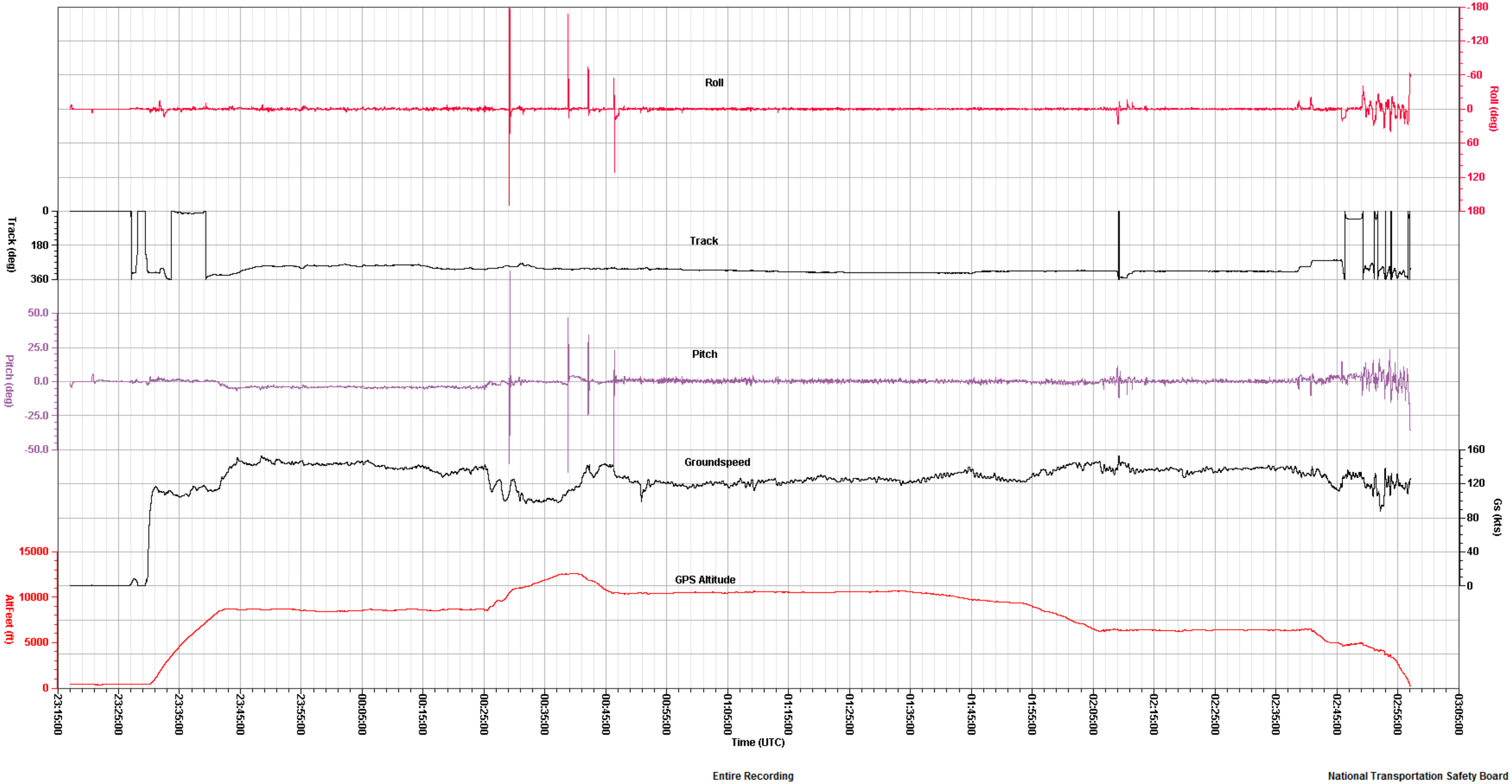


Figure 18. Plot of start of recording.

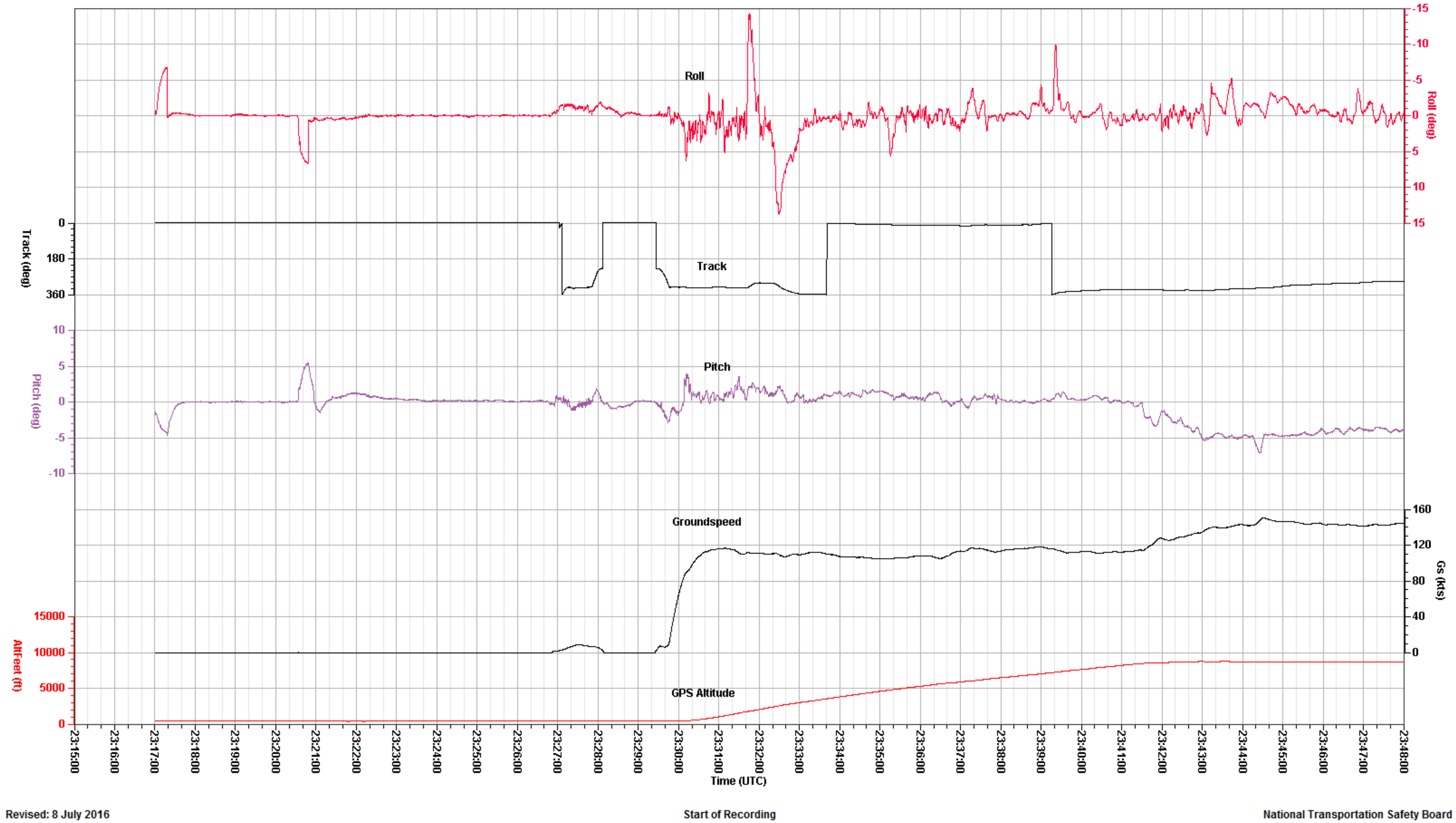


Figure 19. Plot of pitch and roll excursions enroute.

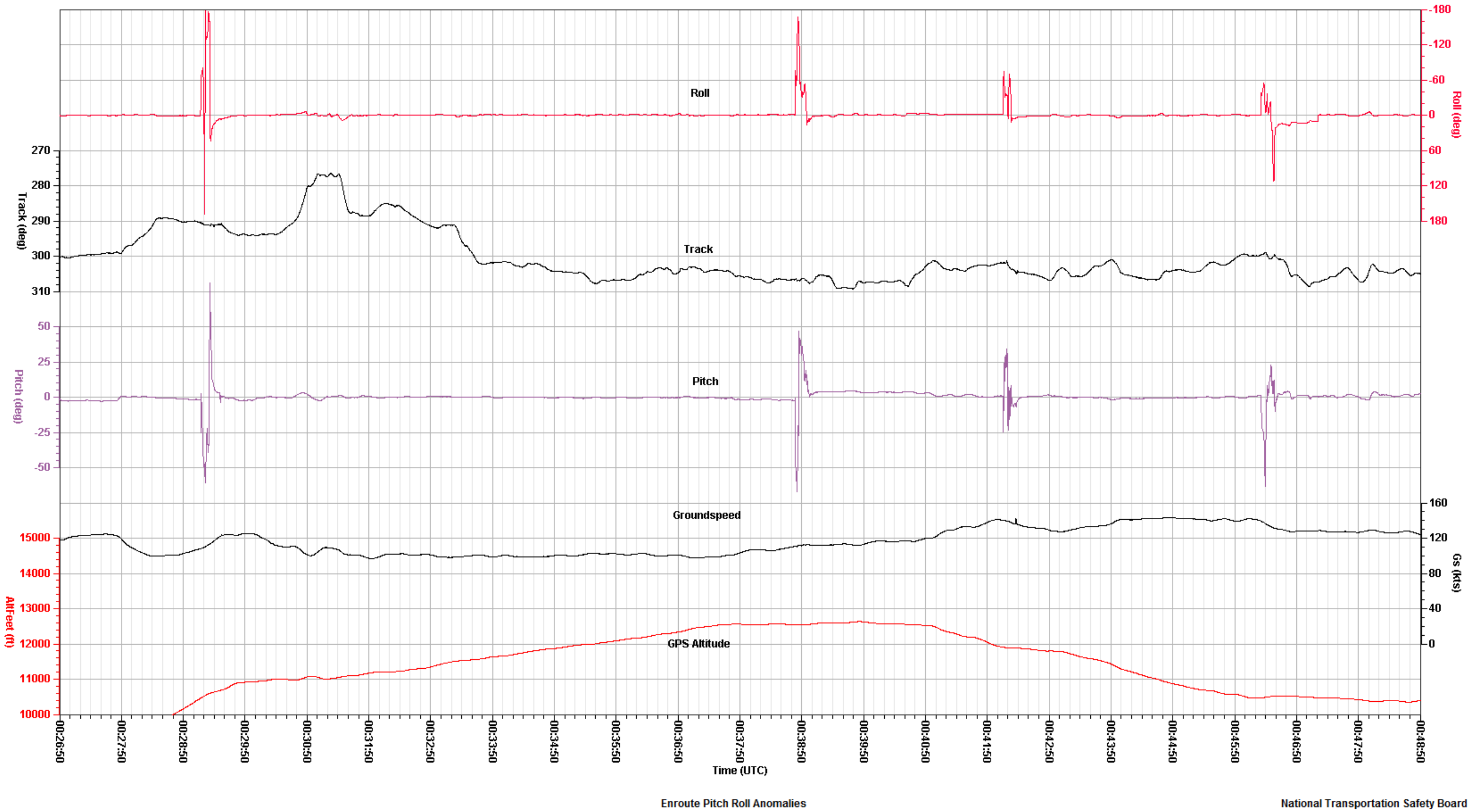


Figure 20. Plot of groundspeed excursion enroute.

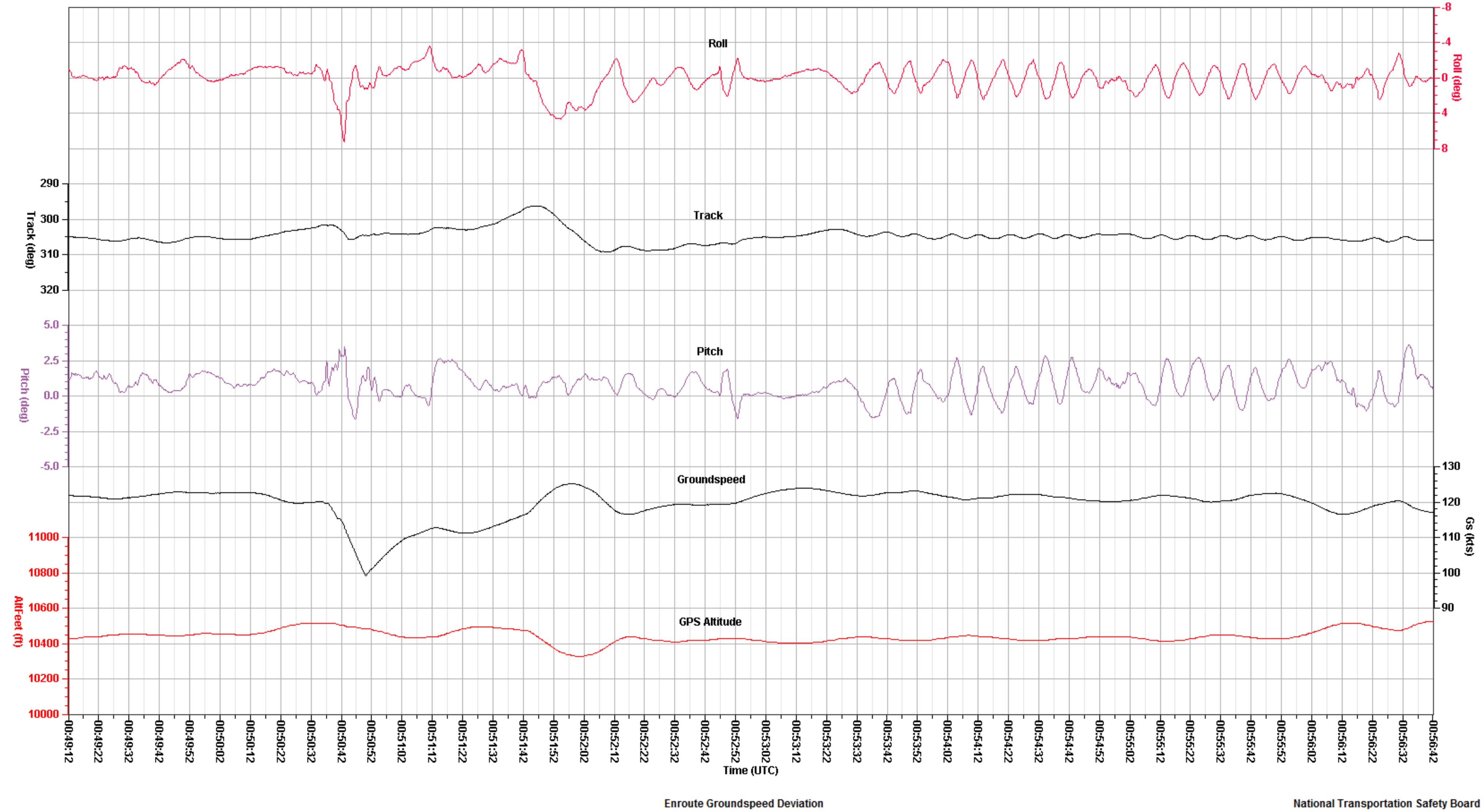
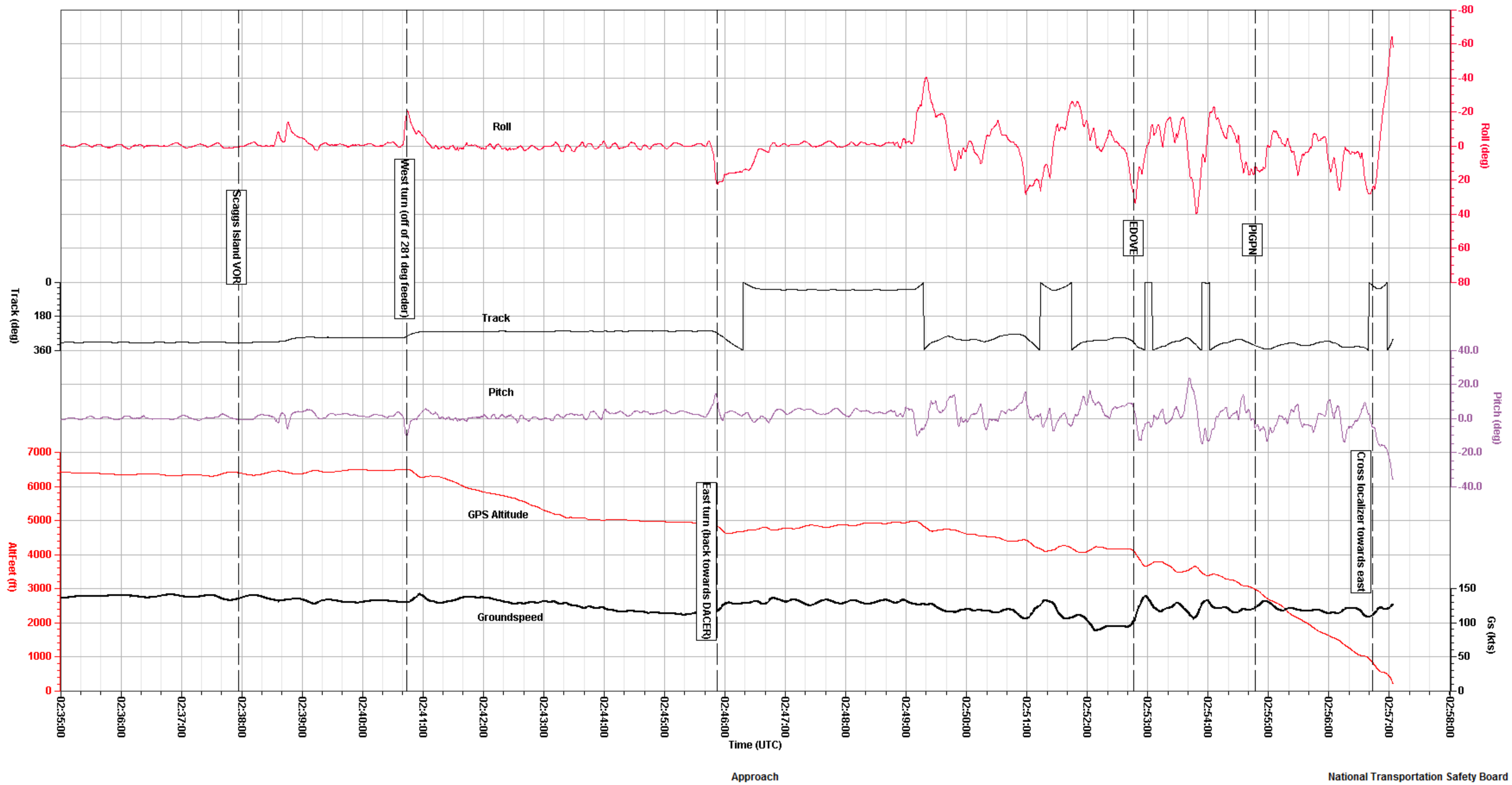


Figure 21. Plot of approach segment of flight until end of recording.



2.2.3. JPI EDM-800 Device Description

The JPI EDM-800 is a panel mounted instrument enabling 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 (TIT), engine revolutions per minute, compressor discharge temperature, fuel flow, carburetor temperature, and battery voltage.

The unit can also calculate, in real-time, horsepower, fuel used, fuel remaining, shock cooling rate, and EGT differentials between the highest and lowest cylinder temperatures. The calculations are also based on the aircraft installation. Some parameters, such as fuel used and fuel remaining, require the operator to set initial values.

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 sample rate. The data can then be downloaded by the operator using the JPI software.

2.2.3.1. JPI EDM-800 Data Recovery

Upon arrival at the NTSB Vehicle Recorder Division, an exterior examination revealed the unit had sustained significant structural damage, as shown in figure 22. The dataplate from the unit is shown in figure 23, with marks next to the letters: C, OT, OP, A, F, and R/M. An internal inspection revealed that non-volatile memory chips containing recorded information were intact, as shown in figure 24.

The non-volatile memory chips were removed from the printed circuit board (PCB) using a soldering iron and a hot air re-work station. While removing the U14 chip, one of the 8 connector pins was damaged. X-ray images showed the chip was intact and revealed the location of the bonding wire, as shown in figure 25. The chip packaging was etched away to expose the bonding wire and a probing station was used to connect to the chip, as shown in figure 26.

A raw-data binary readout of each chip was obtained using a Xeltek SP-6000u EEPROM programmer. Recorded data was identified and converted to engineering units using an in-house software program.

Figure 22. JPI EDM-800 as received.

Figure 23. JPI EDM-800 dataplate.

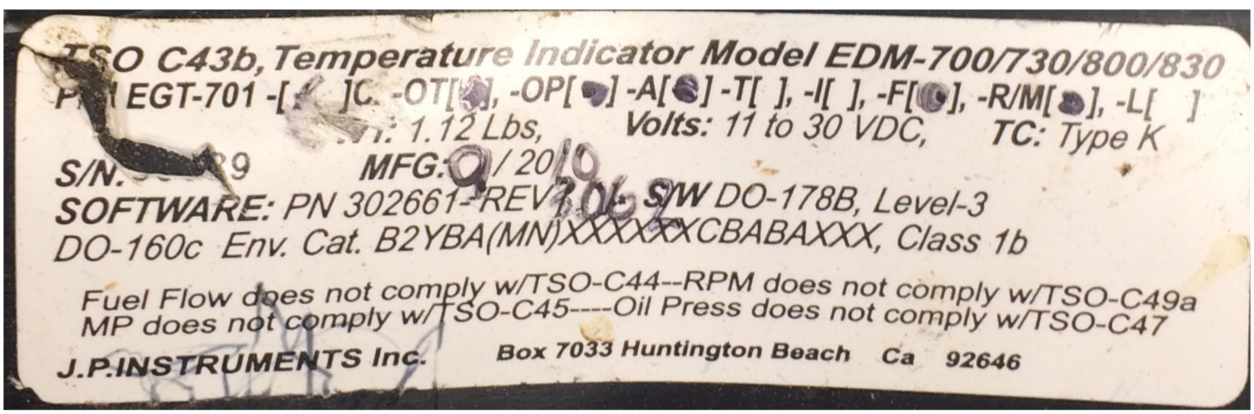


Figure 24. Non-volatile memory chips.

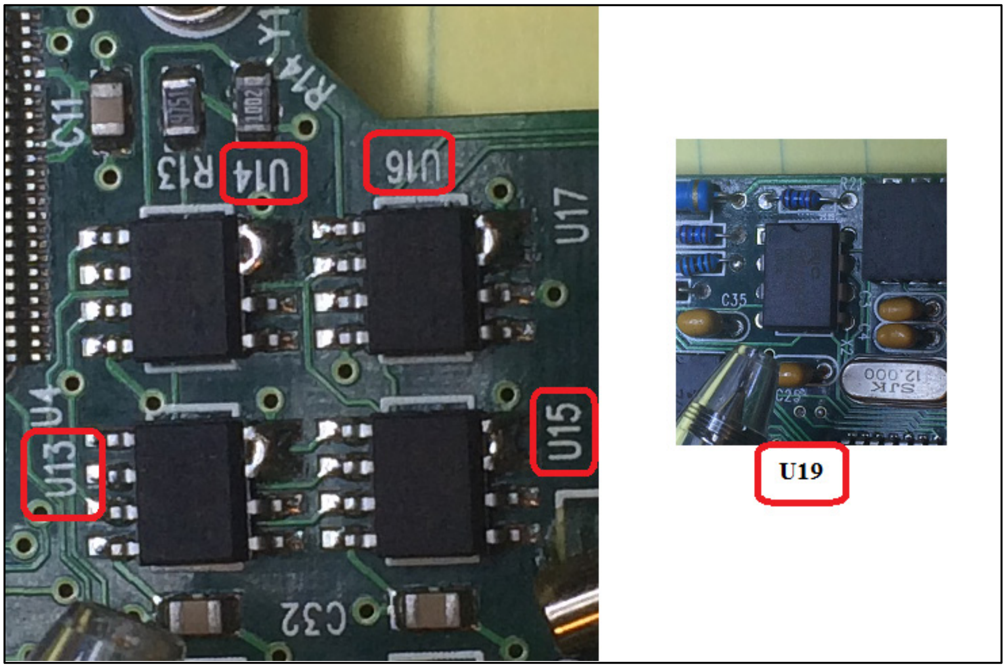


Figure 25. X-ray image of U14 chip.

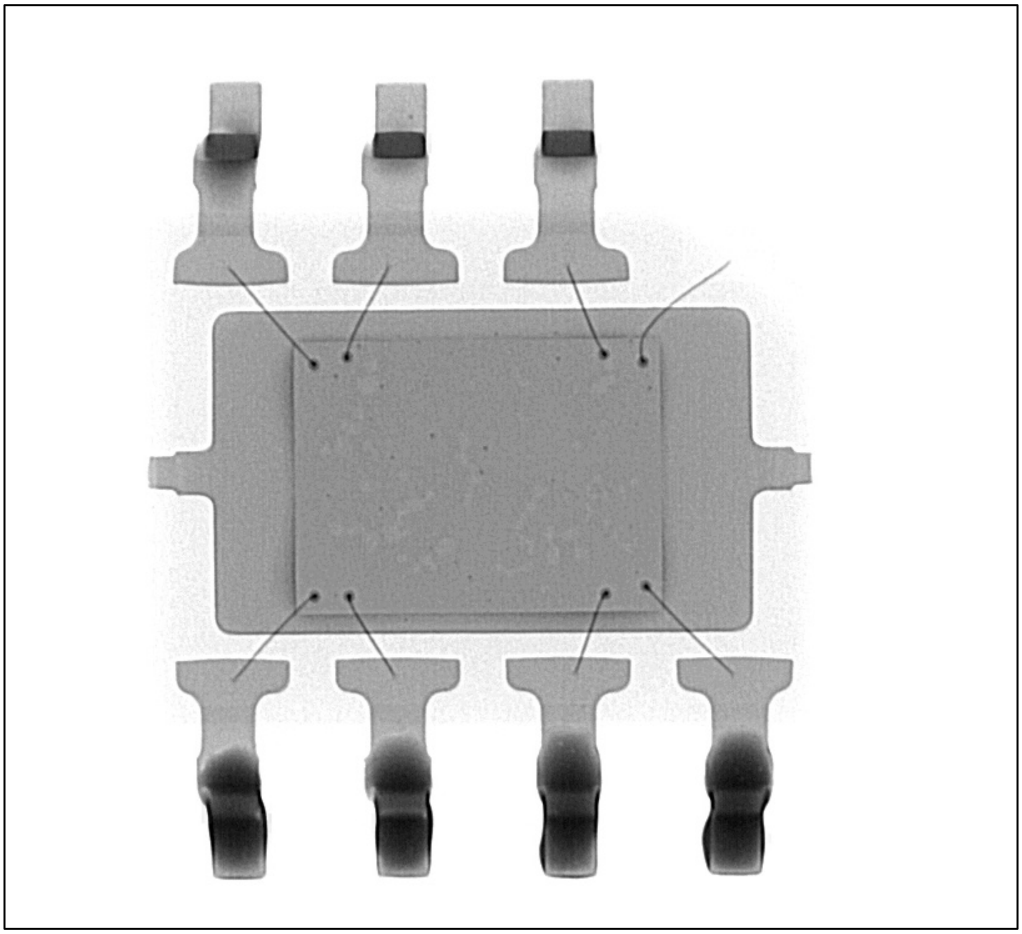
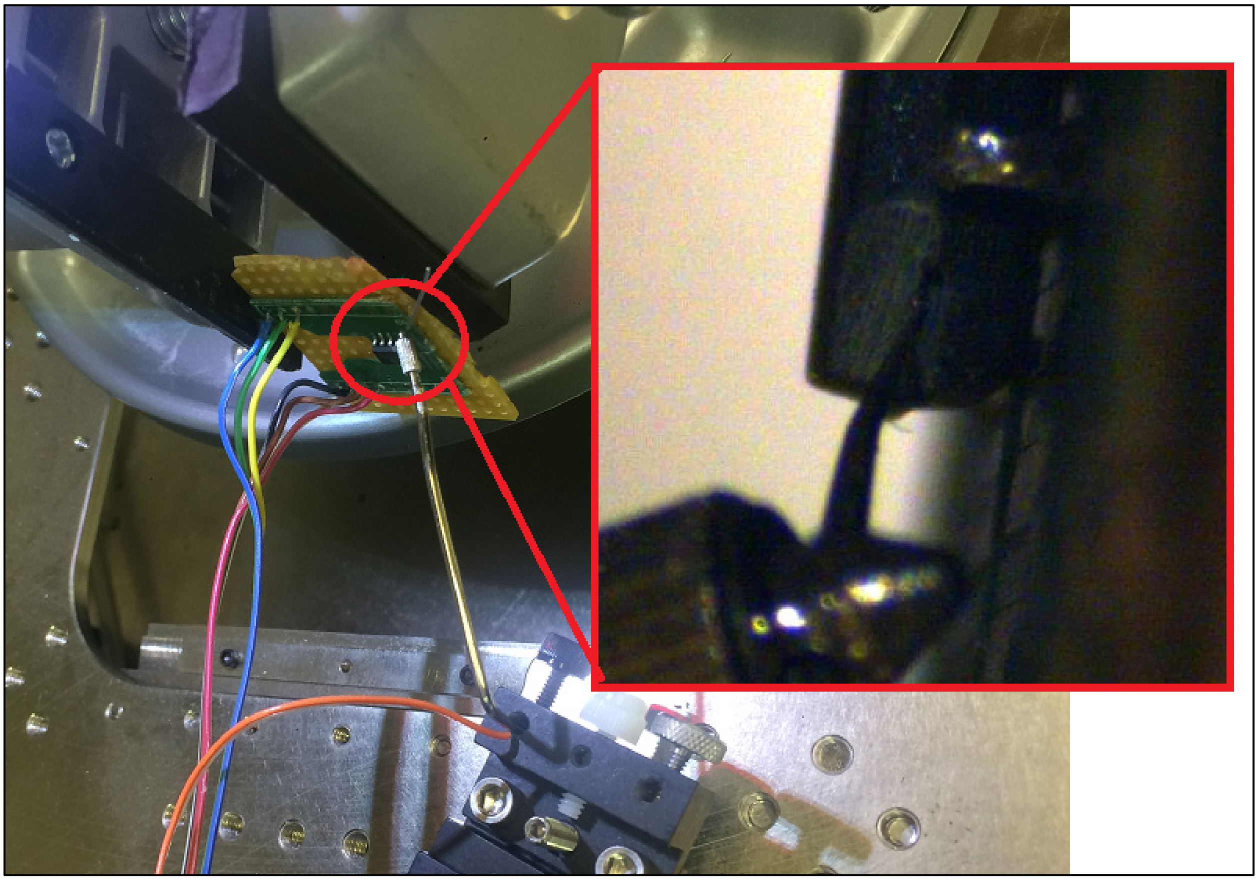


Figure 26. Connection to U14 chip with probing station.



2.2.3.2. JPI EDM-800 Data Description

Downloaded and converted data contained spanned from January 2, 2016 through January 29, 2016 at 03:05:00 in an unknown time zone. The accident flight recording was identified starting on January 28, 2016, at 23:36:38 and ending on January 29, 2016, at 03:05:00. Data was sampled once every 2 seconds.

2.2.3.3. JPI EDM-800 Parameters Provided

Table 2 describes data parameters provided by the JPI EDM-800.

Table 2. JPI EDM-800 Data Parameters

Parameter Name	Parameter Description
Time	Time (unknown time zone) for recorded data point (HH:MM:SS)
Eng1 EGT-#	Exhaust Gas Temperature (EGT) (degrees Fahrenheit (degF))
Eng1 CHT-#	Cylinder Head Temperature (CHT) (degrees Fahrenheit (degF))
Eng1 Fuel Flow	Fuel Flow (gallons per hour (gph))
Eng1 Fuel Used	Total Fuel Used (gallons (gal))

Parameter Name	Parameter Description
Eng1 MAP	Manifold Pressure (inches of Mercury (in Hg))
Eng1 RPM	Propeller Revolutions per Minute (RPM)
Temp OAT	Outside Air Temperature (degrees Fahrenheit (degF))
Eng1 Oil Temp	Oil Temperature (degrees Fahrenheit (degF))
Eng1 Oil Press	Oil Pressure (pounds per square inch (psi))

Note: # is a number from 1 to 6, indicating the cylinder.

2.2.3.4. JPI EDM-800 Plots and Tabular Data

Figures 27 through 30 show plots of the accident flight recording with timespans focusing on the entire accident flight, the start of the recording, an enroute power anomaly, and the end of the recording, respectively. Collectively, the recordings show (all narrative values are approximate and time zone/accuracy is unknown):

- The recording began at 23:36:38 and ended at 03:05:12; a duration of 3 hours, 28 minutes, 34 seconds.
- At 23:37:54, the manifold pressure, rpm, and fuel flow increased, consistent with takeoff; this occurred 1 minute and 16 seconds after the recording began.
- Between 00:58:42 and 00:59:00, the EGTs, CHTs, fuel flow, and RPM fluctuated.
- In the last 20 seconds of the recording, the manifold pressure, fuel flow, and RPM increased.

Tabular data used to generate figures 27 through 30 are included as attachment 2 in electronic comma-delimited (.CSV) format.

Figure 27. JPI EDM-800 entire accident flight recording.

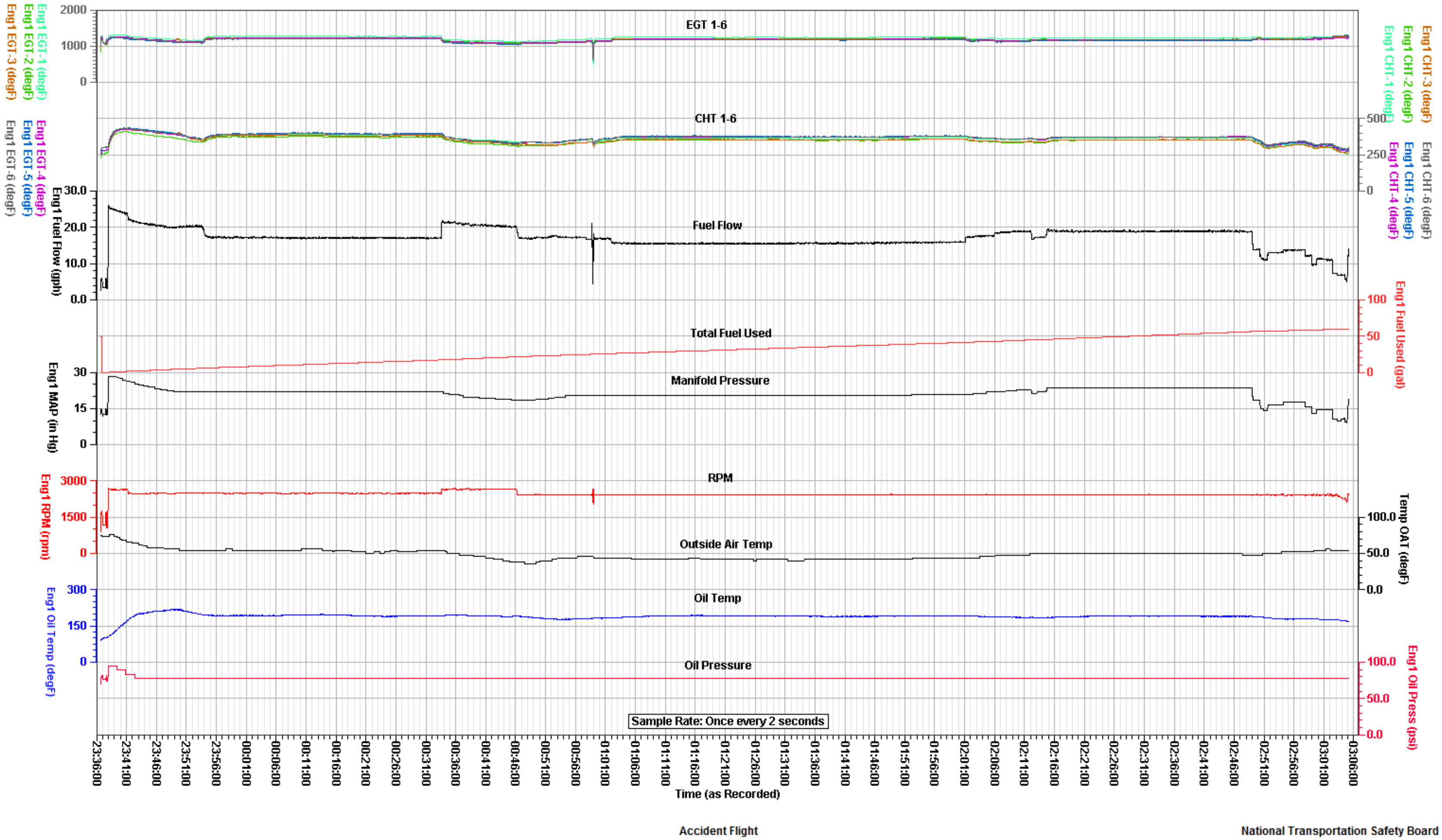


Figure 28. JPI EDM-800 start of accident flight recording.

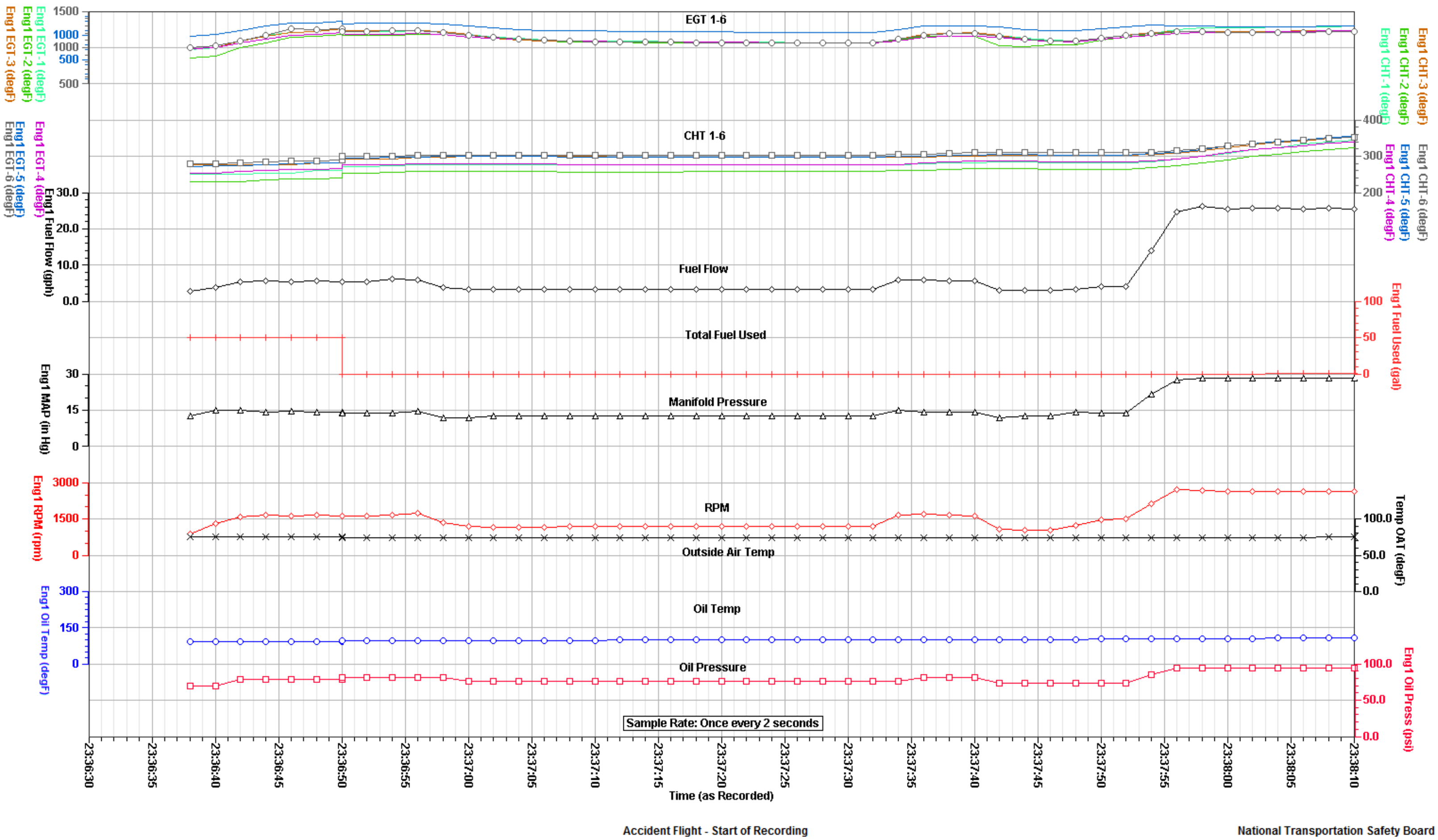


Figure 29. JPI EDM-800 enroute power anomaly.

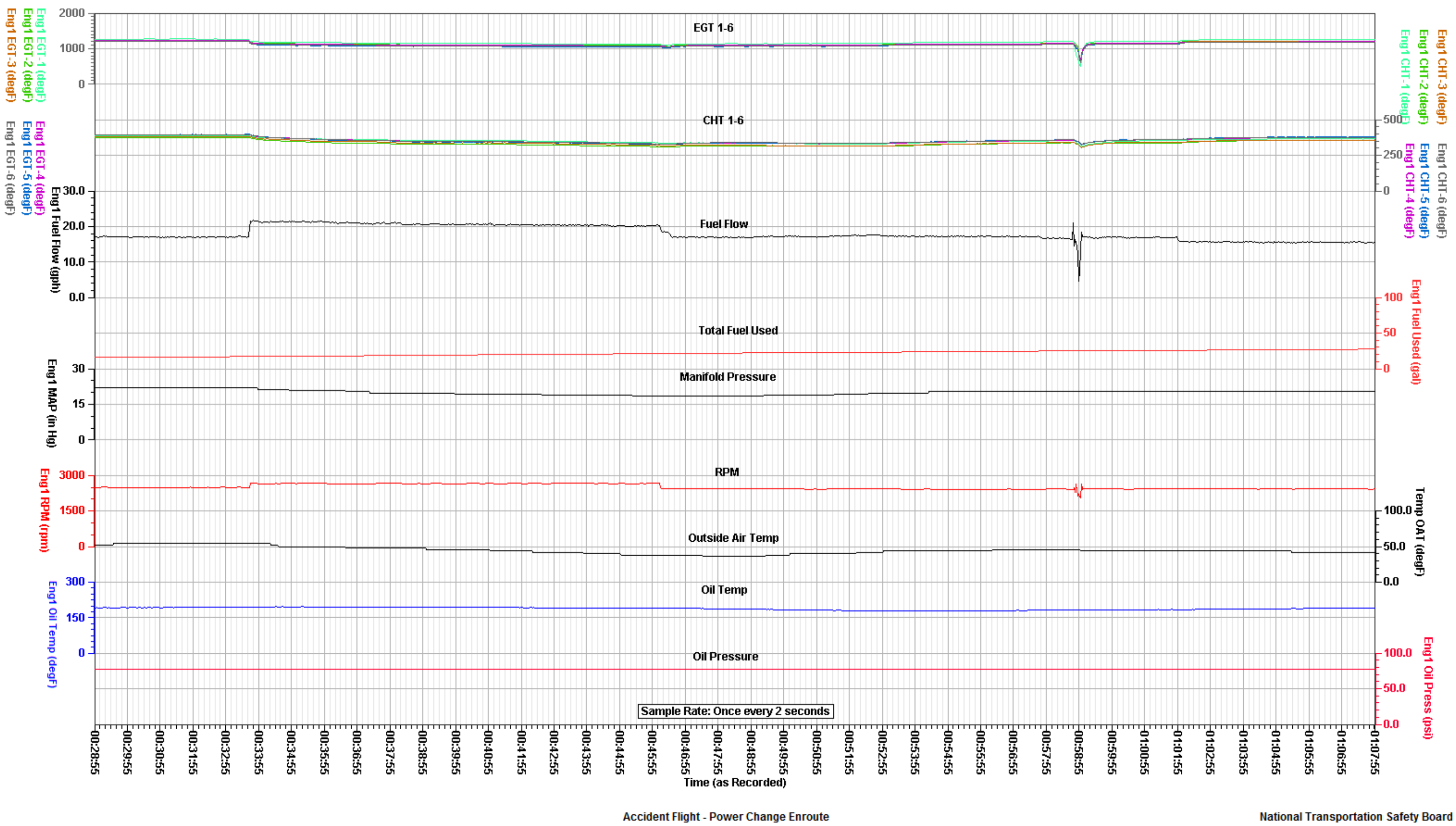


Figure 30. JPI EDM-800 end of accident flight recording.