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

August 4, 2016

Flight Data Recorder

Group Chairman's Factual Report
By Greg Smith

1. EVENT SUMMARY

Location: Moncks Corner, South Carolina
Date: July 7, 2015
Aircraft: Lockheed-Martin F-16CM
Registration: 96-0085
Operator: US Air Force
NTSB Number: ERA15MA259AB

On July 7, 2015, about 1101 eastern daylight time (EDT), a Cessna 150M, N3601V, and a Lockheed Martin F-16CM, operated by the US Air Force (USAF), collided in midair near Moncks Corner, South Carolina. The private pilot and passenger aboard the Cessna died, and the Cessna was destroyed during the collision. The damaged F-16 continued to fly for about two and a half minutes, during which the pilot activated the airplane's ejection system. The F-16 pilot ejected safely and incurred minor injuries, and the F-16 was destroyed after its subsequent collision with terrain and postimpact fire. Visual meteorological conditions prevailed at the time of the accident. No flight plan was filed for the Cessna, which departed from Berkeley County Airport (MKS), Moncks Corner, South Carolina, about 1057, and was destined for Grand Strand Airport, North Myrtle Beach, South Carolina. The personal flight was conducted under the provisions of *14 Code of Federal Regulations* (CFR) Part 91. The F-16 was operating on an instrument flight rules (IFR) flight plan and had departed from Shaw Air Force Base (SSC), Sumter, South Carolina, about 1020.

2. FLIGHT DATA RECORDER GROUP

A flight data recorder (FDR) group was convened on July 10, 2015.

Chairman: Greg Smith
Aerospace Engineer
National Transportation Safety Board (NTSB)

Member: David A. Vandercook
Flight Safety Engineer, Senior Staff
Lockheed Martin Aeronautics

Member: Robert M. Koehler
Flight Safety Engineer, Senior Staff
Lockheed Martin Aeronautics

Member: Kenneth E. Worrell
Flight Safety Engineer, Principle
Lockheed Martin Aeronautics

Member: Dennis Lasater
Test Engineer, Senior Staff
Lockheed Martin Aeronautics

Member: Jacob Hannusch
Electronics Engineer, Asc.
Lockheed Martin Aeronautics

Member: Steve Green
Lead Equipment Specialist
USAF F-16 System Program Office

Member: Dale Carter
Aerospace Engineer
USAF Mishap Analysis & Animation Facility

3. DETAILS OF FDR INVESTIGATION

A crash-survivable memory unit (CSMU) was recovered from the wreckage of the F-16, and the digital flight control system seat data recorder (SDR) was recovered from the airplane's ejection seat. Both memory units were forwarded to the airframe manufacturer for data extraction under the supervision of a NTSB vehicle recorder specialist. The data were downloaded normally with no anomalies noted.

3.1. Crash-Survivable Memory Unit Recorder Description

The CSMU is the memory module of the Crash-Survivable Flight Data Recorder (CSFDR) system. The CSFDR system consists of two units, a CSMU and a Signal Acquisition Unit (SAU). The SAU interfaces with the aircraft analog, discrete and avionics multiplex (AMUX) bus signals, and processes data for storage in the CSMU.

The CSMU houses non-volatile memory[1] that contains what is called Type 1 data. This data consists of discrete events and analog parameters that have been recorded for the primary purpose of mishap investigation. Recording normally starts when the main generator comes on line after ground engine start. Recording normally stops 90 seconds after weight-on-wheels (WOW) occurs during landing. The CSMU memory capacity is variable depending on how often parameters change. On a normal flight, over 15 minutes of data will be stored. When memory capacity is exceeded, the oldest, unprotected memory data is overwritten. Special event portions of the data are protected from overwrite until the next flight. The baseline special event consists of data for approximately 15 seconds after liftoff. Other special events consist of data associated with the inflight occurrence of specific events. The protected data from non-baseline special events covers at least 15 seconds either side of the event with two exceptions: (a) pilot initiated flight control system (FLCS) reset and (b) an engine data save; which protect at

1 Non-volatile memory is a type of computer memory that has the capability to hold saved data even if the power is turned off.

least 30 seconds of data prior to switch activation. The first five special events of a flight (not including the baseline event) are protected from overwrite until liftoff on the next flight.

A data compression technique is used to store analog data. At liftoff and every 15 seconds thereafter, a data snapshot of all analog parameters is stored. Between snapshots, the analog parameters are sampled and a new value is stored only if the parameter has changed by its pre-determined amount (minimum change to record). The value recorded is a truncated value determined by the resolution associated with the parameter. For example, altitude has a resolution of 40 ft and airspeed has a resolution of 4 knots. A recorded altitude of 13,920 ft means that altitude was in the 13,920 ft to, but not including, 13,960 ft range. Similarly, a recorded airspeed of 220 means that airspeed was in the 220 to, but not including, 224 knot range. The status of each discrete parameter is updated at liftoff and at each 15 second interval thereafter. In addition, discrete parameters are sampled 16 times per second and a recording is made if a discrete parameter changes state.

3.1.1. Recorder Condition

The recorder suffered minor impact and thermal damaged in the event. The extent of the damage is shown in figure 1.

Figure 1. Damaged exterior of CSMU.

The non-hardened interface portion of the CSMU was removed from the armored memory housing which was then connected to a specialized interface assembly for downloading as shown in figure 2.

Figure 2. CSMU memory connected to specialized interface.

3.1.2. Recording Description

The downloaded data file was processed by both the airframe manufacturer and USAF Mishap Analysis & Animation Facility (MAAF) to convert the raw data file into engineering units data. The resulting data are provided in compressed (zipped) electronic comma separated value (*.csv) format as attachments 1 through 3 to this report.

The CSMU recording contained approximately 20.5 minutes of data. Timing of the CSMU data is measured in time since the start of recording. The data contains a baseline special event of approximately 15 seconds and the last 20.25 minutes of the accident flight. The gap between the end of the baseline event and the last recorded data is approximately 20 minutes.

3.1.3. Engineering Units Conversions

The CSMU data contained in this report were converted to engineering units by the airframe manufacturer and the MAAF as described above.

3.2. Seat Data Recorder Description

The digital flight control system seat data recorder (SDR) memory is recorded in two different formats. The flight profile (FP) memory records airspeed, altitude and true heading every 15 seconds after takeoff, and is stored on the P2 circuit card; this data is referred to as either “Flight Profile” or “P2” data. The FP memory can store 1320 records (5 hours and 30 minutes) before it fills the register, wraps-around, and starts to overwrite the oldest data. The system status (SS) memory records airspeed, altitude, heading, attitude, radar altitude (truncated), normal acceleration, angle-of-attack, surface positions (flaperons, horizontal tails and rudder), stick force (pitch and roll), and data bits (relating to

switch positions, control law changes and system failures). The SS data is stored on the P3 circuit card and is referred to as either “System Status” or “P3” data. The SS recording is event driven and only records at the end of a half second time period, when any one of these data bits (with exception of a few bits[2]) changes state during that time period. The SS memory can store 132 records (events) before it fills the register, wraps-around and starts to overwrite the oldest data.

3.2.1. Recorder Condition

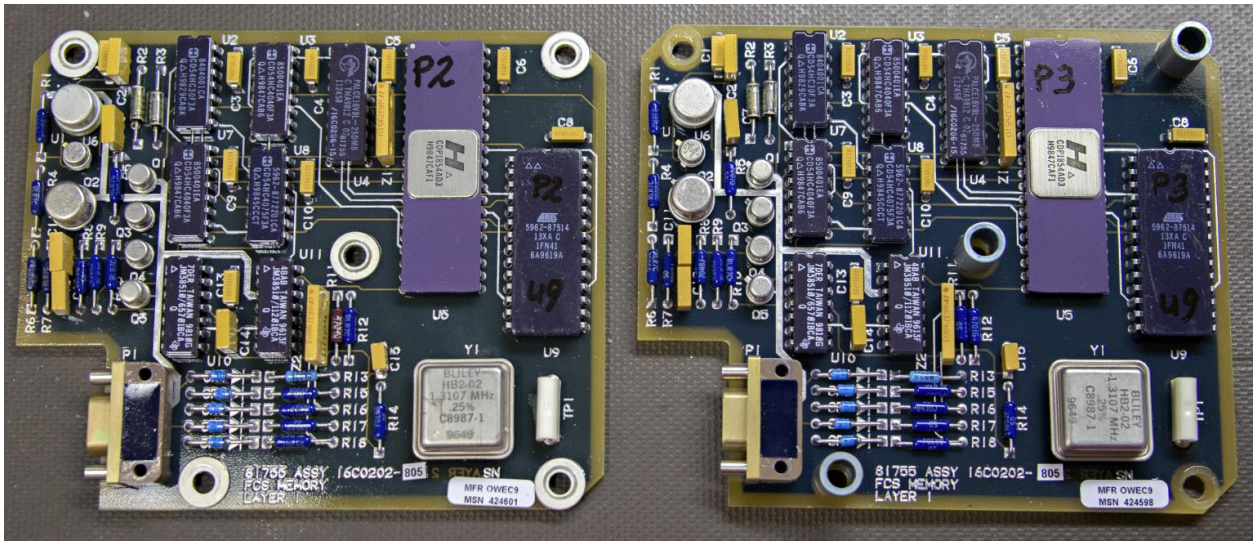
The recorder suffered minor impact damage during the event. The extent of the damage is shown in figure 3.

Figure 3. Damaged exterior of SDR.

The P2 and P3 memory boards were removed from the damaged housing and connector (figure 4) and inspected.

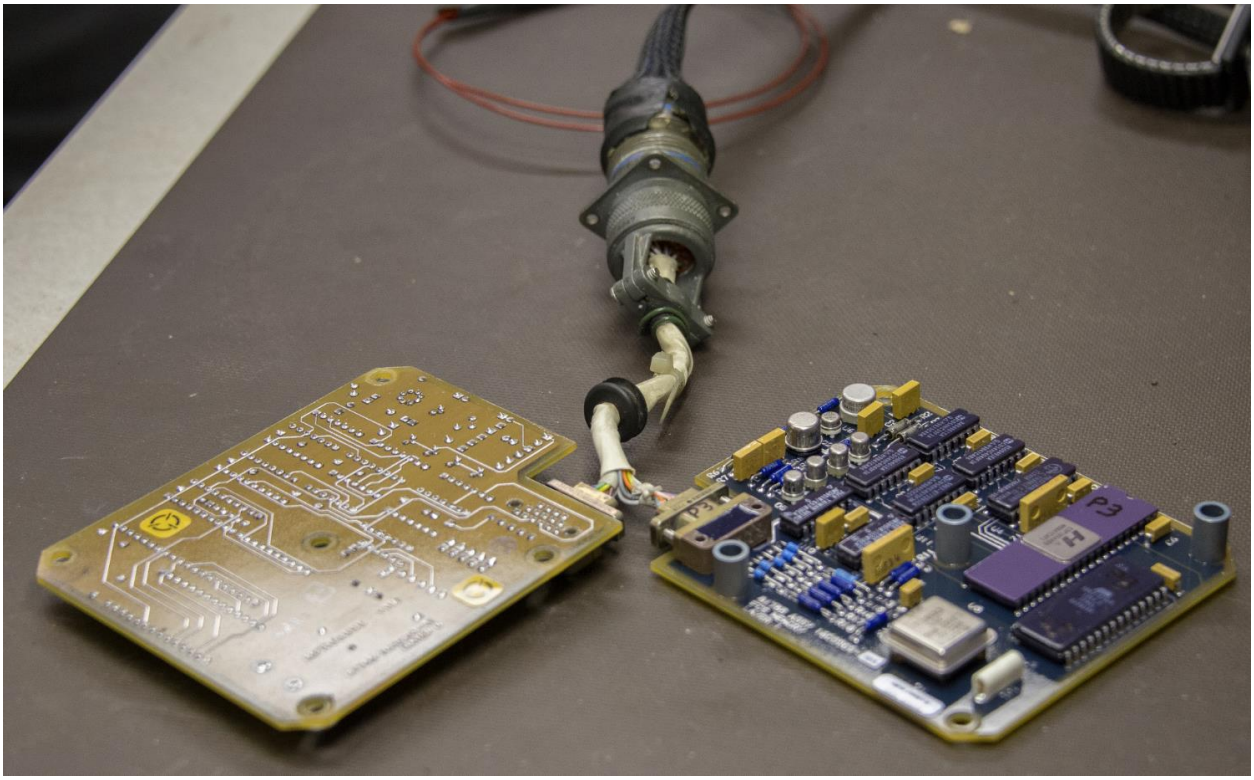
[2] Data bits that do not trigger the recording of an SS record are indicated in the bit assignment listing on the FP and SS data listings of attachment 4. Note that although the listings in attachment 4 are labeled as FP and SS, there are some SS data mixed into the FP listing. FP records do not contain any discrete data. See the notes on the FP listing regarding 15 second records.

Figure 4. P2 and P3 boards from SDR.



No damage to the boards was found. They were then connected to an undamaged interface cable and downloaded as shown in figure 5.

Figure 5. P2 and P3 boards connected for downloading.



3.2.2. Recording Description

The downloaded data file was processed by airframe manufacturer software applications to convert the raw data file into engineering units data. The resulting data are provided in the airframe manufacturer's SDR analysis report as attachment 4 to this report.

The SDR recording contained the complete event flight, the duration of which was approximately 42.75 minutes of data. Timing of the SDR data is measured in seconds after takeoff.

3.2.3. Engineering Units Conversions

The SDR data contained in this report were converted to engineering units by the airframe manufacturer as described above.

3.3. Time Correlation

Correlation of the SDR data to the CSMU data was established using the CSMU's baseline special event, which is triggered by WOW changing to Air at takeoff. The change in state of WOW also triggers the SDR to start recording. Therefore, the resulting conversion from SDR relative time to CSMU relative time is the following: CSMU time = SDR time + 1383.9375

Correlation of the CSMU data to the event local time, EDT, was established with an offset provided by the MAAF plus an additional 4 hour offset to convert UTC to EDT.

Accordingly, the time offset for the event flight data from CSMU time to local EDT is the following: EDT = CSMU time +35833.027. Therefore, for the rest of this report, all times are referenced as EDT.

3.4. FDR Plots and Corresponding Tabular Data

Figures 6 to 9 contain FDR data recorded during the July 7, 2015 event. The tabular data used to create figures 6 to 9 are provided in attachments 1 through 4 to this report.

In the following plots, data from the SDR are annotated with _SDR at the end of the parameter name. Data from the CSMU has no annotation.

Due to the non-constant recording rates used in the CSMU and SDR recorders, simply connecting the recorded data points with straight lines may result in misleading plots. Therefore, in some of the following plots data points may be shown without connecting lines. For CSMU data, where the recorded data rates are based on fixed sample rate data being passed through a compression filter, lines are drawn based on the sampling interval of the data before it was passed through the filter. The legends on figures 7 through 9 show these "filled" parameters with "(f)" appended onto the end of the parameter name. For example, the legend of figure 7 lists the CSMU parameter CalibratedAirspeed as being a black open square with no line and its filled counterpart, CalibratedAirspeed (f), as being a black line with no symbol. When plotted together, these two parameters provide a more accurate representation of the recorded data than simply connecting the recorded data points of CalibratedAirspeed.

These figures are configured such that right turns are indicated by the trace moving toward the bottom of the page, left turns towards the top of the page, and nose up attitudes towards the top of the page.

Figure 6 is a plot showing the timing relationship between the CSMU and SDR data. The SDR FP parameters are plotted along with the corresponding CSMU parameters. Data from both the CSMU baseline special event (takeoff event) and the main CSMU recording session are plotted showing the approximately 20 minute gap when only the SDR data was recorded.

Figure 7 is a plot of parameters that provide a general overview of the F-16 flight for the time period leading up to and immediately following the collision. The recorded data indicates that in the two minutes prior to the collision, the F-16 was flying generally straight and level between 1560 and 1639[3] feet corrected altitude at an average calibrated airspeed of approximately 244 knots. Approximately 20 seconds before the end of the CSMU recording, the F-16 rolled into a left bank of about 32 degrees which was maintained until the end of the recording. The true heading data indicates that the F-16 began turning left and was continuing the left turn when the recording ended. The last recorded altitude value was 1520 indicating that the altitude at that time, 12 seconds before the end of the recording, was between 1520 and 1559 ft[4].

Figure 8 is a plot showing control inputs and surface deflections with the pitch axis parameters. It also includes the auto pilot status discretes which indicate that the auto-pilot was engaged and in the pitch altitude hold mode.

Figure 9 is a plot showing control inputs and surface deflections with the roll and yaw axes related parameters. It also includes the auto pilot status discretes which indicate that the auto-pilot was engaged and in the roll heading select mode. The data also show that three radio transmissions were made in the last 35 seconds of the recording, two prior to and one during the banking maneuver.

[3] The recorded altitude data points fluctuate between 1560 and 1600. The resolution of the corrected altitude parameter is 40 ft so the actual altitude could be as much a 39 ft higher than the recorded value at that point.

[4] The minimum change to record value for altitude is 200 ft. Therefore, the lack of an additional altitude data point in the last 12 seconds of the recording indicates that the altitude for that period, which was sampled once per second, was between 1320 and 1759 feet.

Figure 6. Plot of common CSMU and SDR parameters during entire flight.

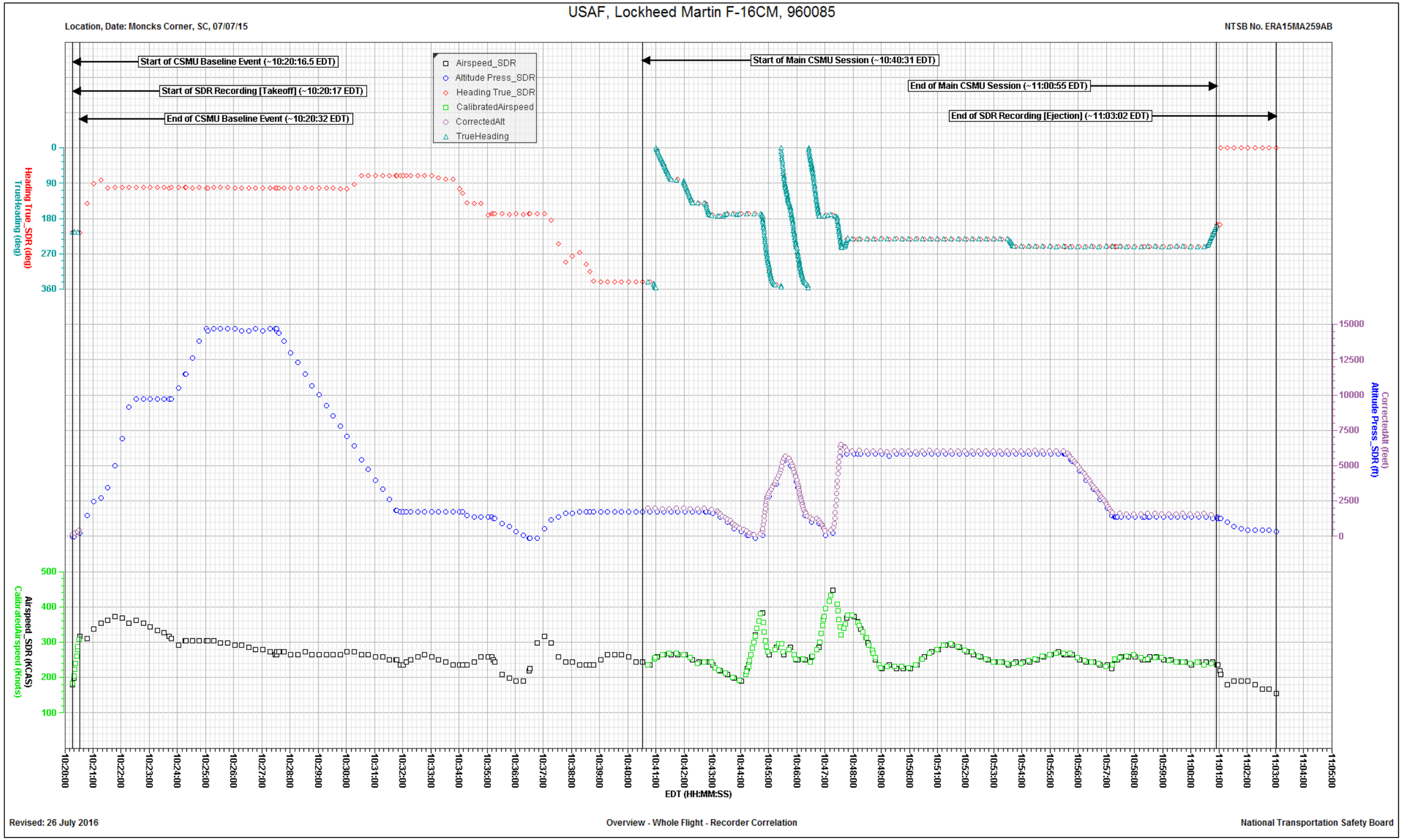


Figure 7. Plot of general overview parameters for the time period leading up to and after the collision.

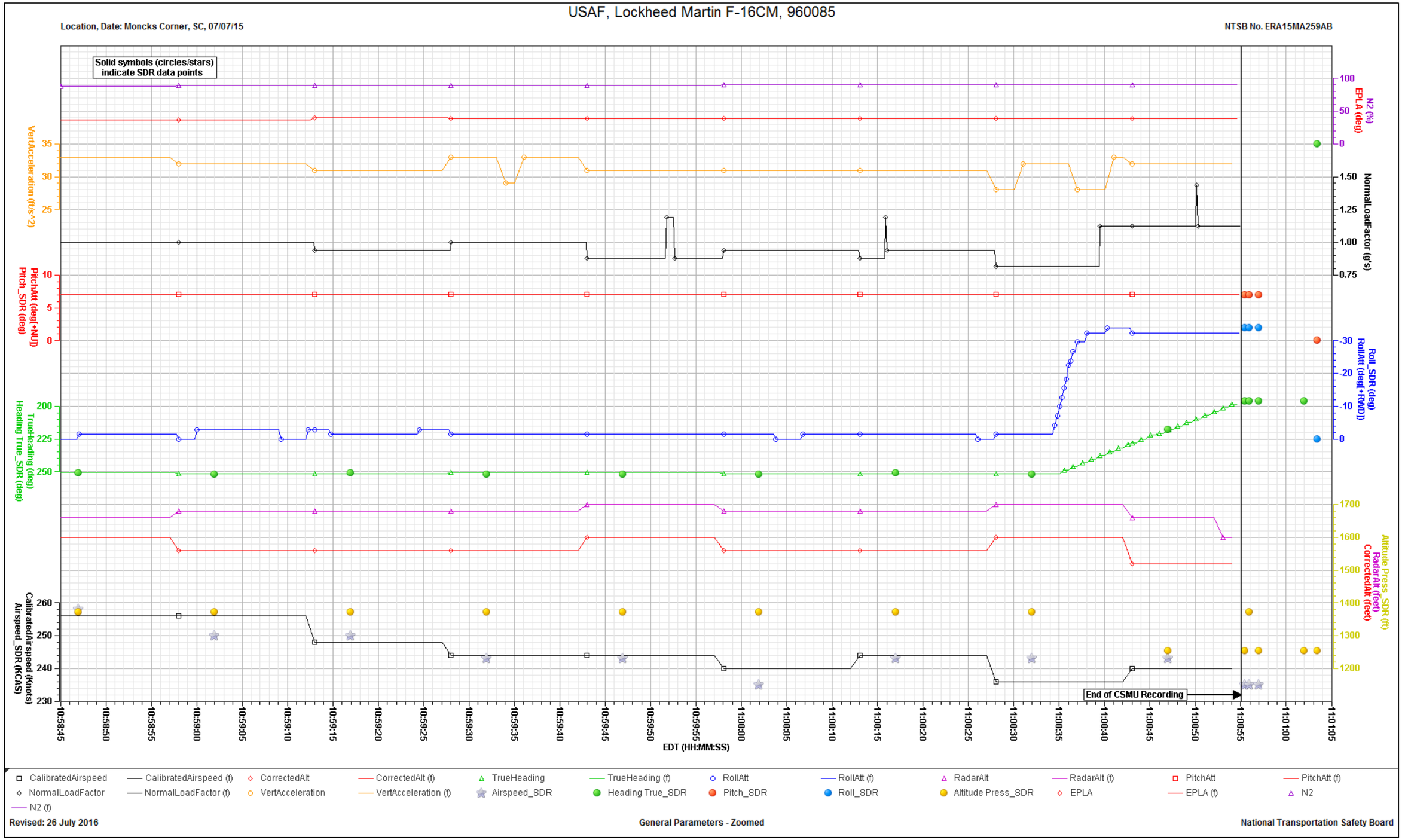


Figure 8. Plot of pitch related parameters for the time period leading up to and after the collision.

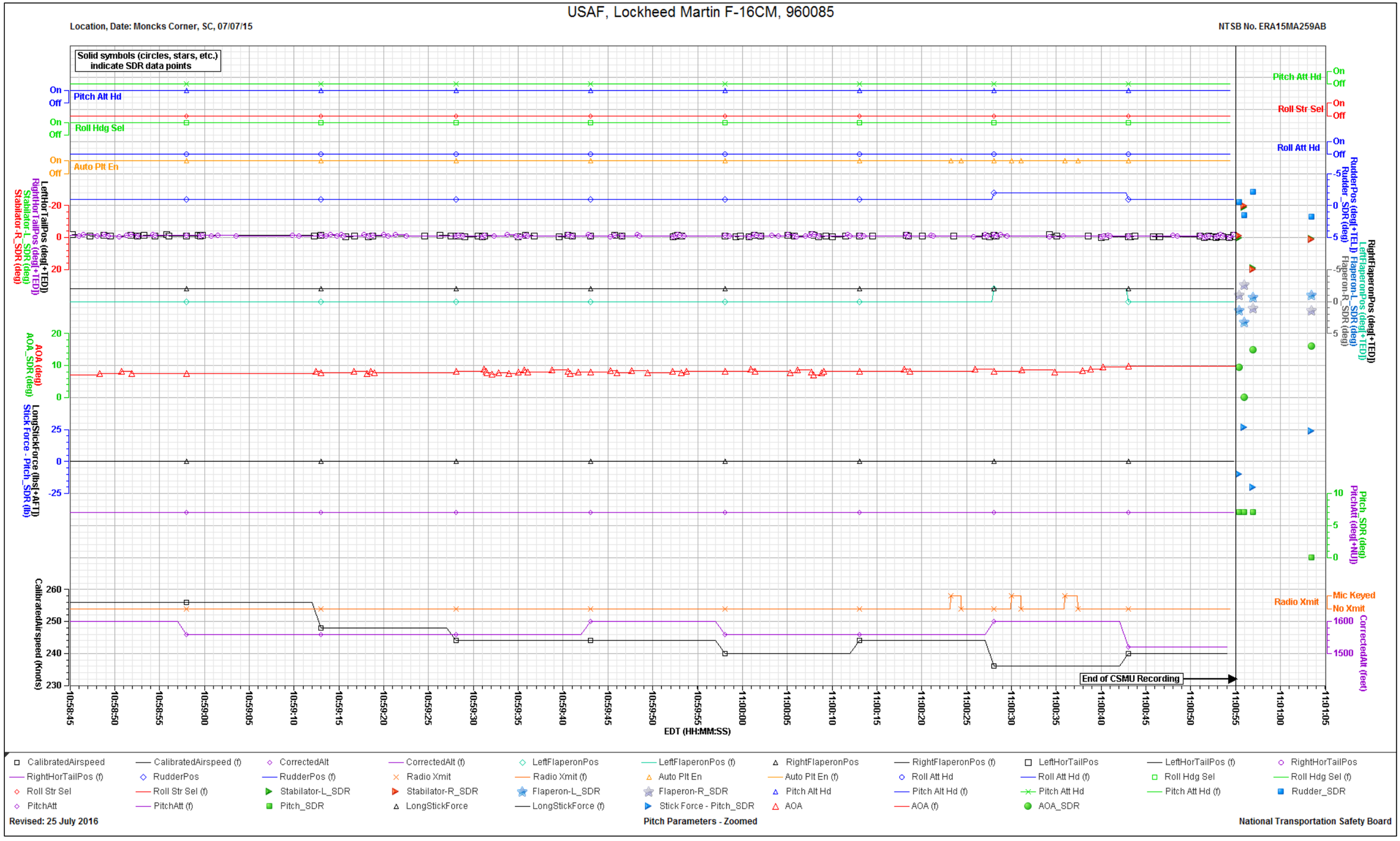


Figure 9. Plot of roll and yaw parameters for the time period leading up to and after the collision.