

DOCKET NO. SA-542

EXHIBIT NO. 17-C

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

TIMELINE STUDY
(32 pages)

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

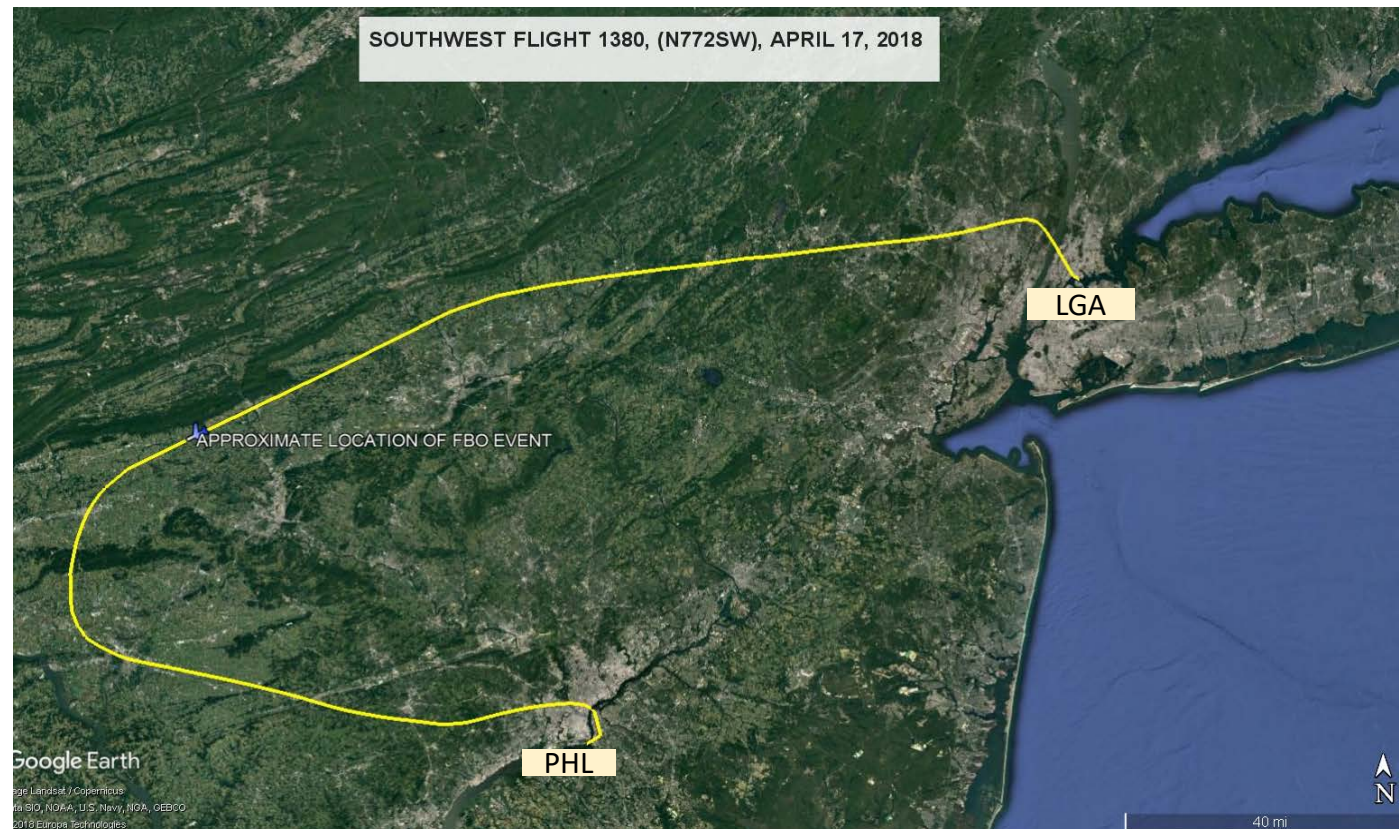
NTSB ID No. DCA18MA142

TIMELINE STUDY

NOVEMBER 6, 2018

SUMMARY

On April 17, 2018, at 1103 eastern daylight time, Southwest Airlines flight 1380, a Boeing 737-7H4, N772SW, experienced a left engine failure and loss of engine inlet and cowling during climb at about flight level 320. Fragments from the engine inlet and cowling struck the wing, fuselage, and one cabin window, resulting in a depressurization. The flight crew conducted an emergency descent and diverted into Philadelphia International Airport (KPHL), Philadelphia, PA. Of the 144 passengers and five crewmembers onboard, one passenger received fatal injuries and eight passengers received minor injuries. The airplane sustained substantial damage. The regularly scheduled domestic passenger flight was operating under 14 Code of Federal Regulations Part 121 from LaGuardia Airport (KLGA), Queens, New York, to Dallas Love Field (KDAL), Dallas, Texas.



UNEXPECTED FAILURE EFFECTS

Findings:

Examination of the left engine revealed that one of its fan blades had separated at its root with the dovetail remaining in the disk¹. As a result of the fan blade failure, or commonly referred to as fan-blade-out (FBO), the following unexpected events occurred:

- Portions of the inlet departed the engine
- Portions of the fan cowl departed the engine
- Passenger cabin window departed the airplane

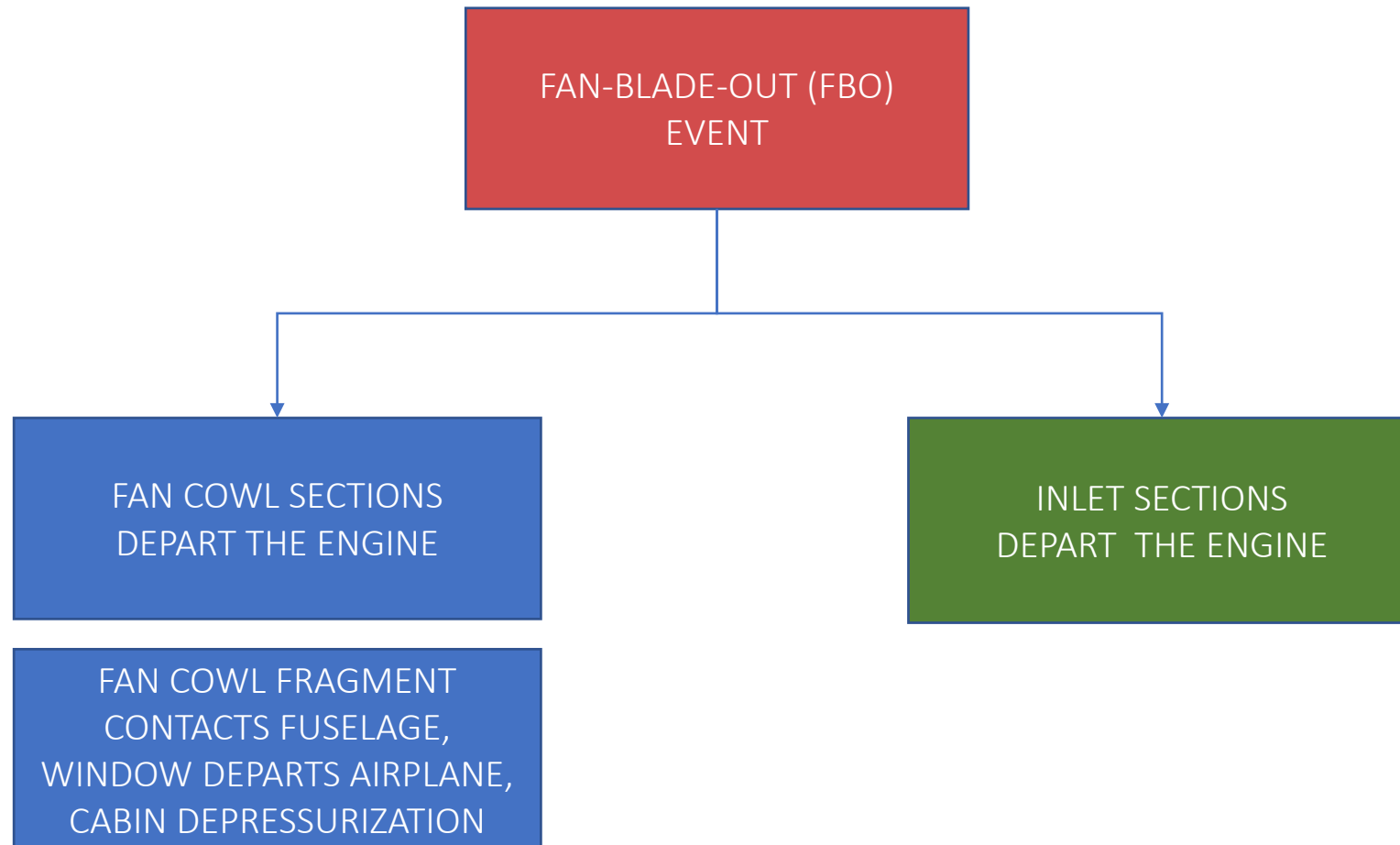


1. Reference the Powerplant Group Chairman's Factual Report for accident DCA18MA142

KEY EVENTS:

Diagram of Key Events:

Based on a review of the events that occurred during the flight, the following “Key Events” were identified for further analysis to determine (as best as possible) the time that they occurred with respect to the fan-blade-out event.



FAN BLADE-OUT – TIMING STUDY

On-Scene Findings:

Examination of the left engine revealed that all of the fan blades were present and remained installed in the fan disk except for one; identified as blade No. 13. The fan blade had separated at the root with the dovetail remaining installed in the fan disk. Two pieces of fan blade No. 13 were recovered within the engine between the fan blades and the outlet guide vanes (OGVs). One piece was part of the blade root that mates with the dovetail that remained in the fan disk, measured about 12-inch spanwise, was full width, and weighed approximately 6.825 pounds. The other piece was identified as part of the airfoil, measured about 2-inch spanwise, appeared to be full width, twisted, and weighed approximately 0.650 pounds. (*Ref. Powerplants Group Chairman's Factual Report*)

Analysis Objective:

1. Conduct a study to determine as best as possible the most likely time that the FBO event occurred.



FAN BLADE-OUT – TIMING STUDY

Engine Fan Speed – Left Engine:

The engine fan speed (N1) and the position of the throttles before and after the fan-blade-out event were determined by reviewing flight data recorder (FDR) data (Figure 1). The data revealed that the left engine's fan speed was 5,149 rpm just prior to the event and then rapidly decreased between times 96837.42 and 96838.42.

SOE Objective:

Because the FDR only records the N1 parameter at a rate of one sample per second, the objective of this analysis is to review the FDR acceleration data for the purpose of trying to get a better understanding for the time when the FBO occurred between the two data points.

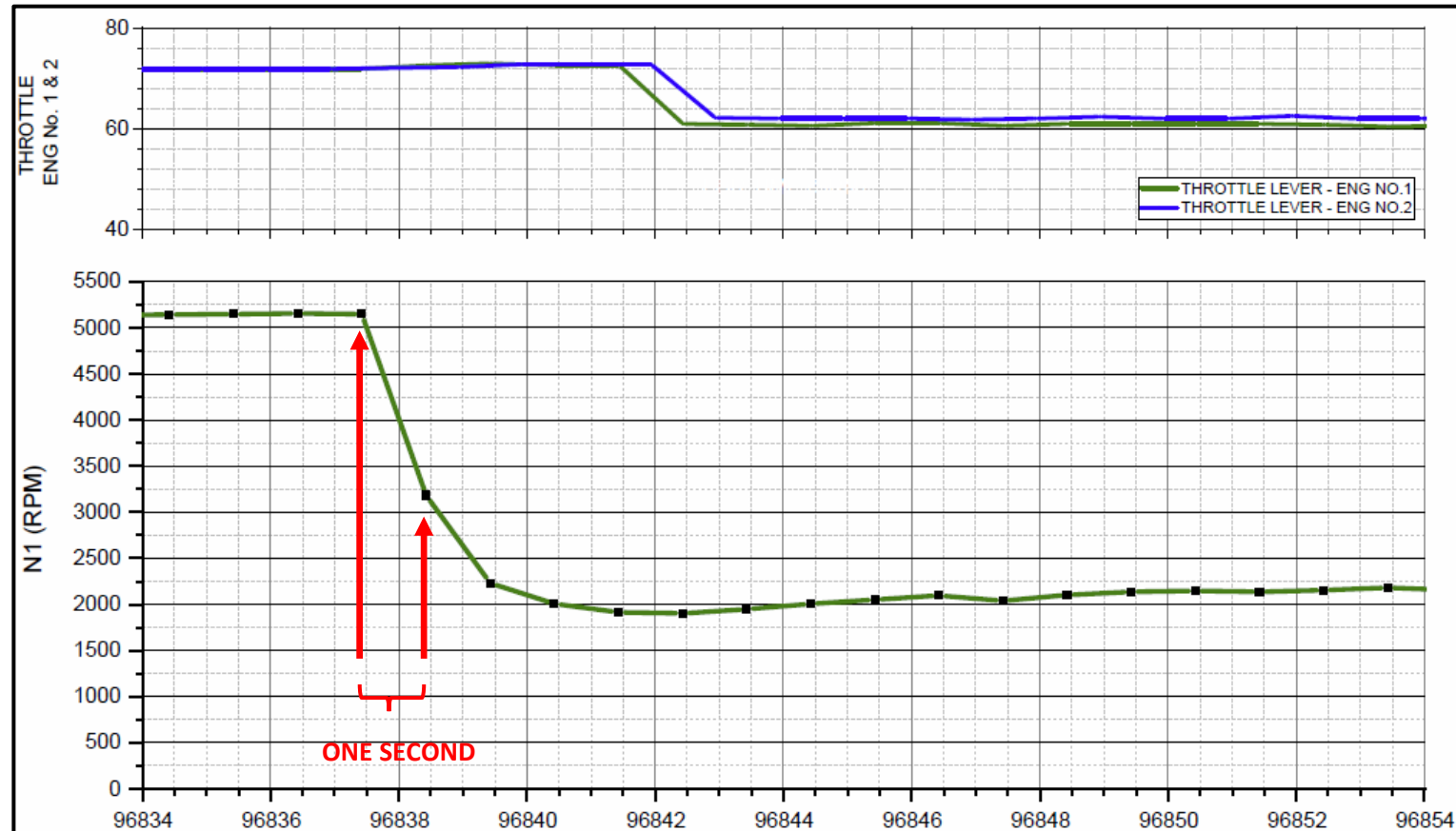


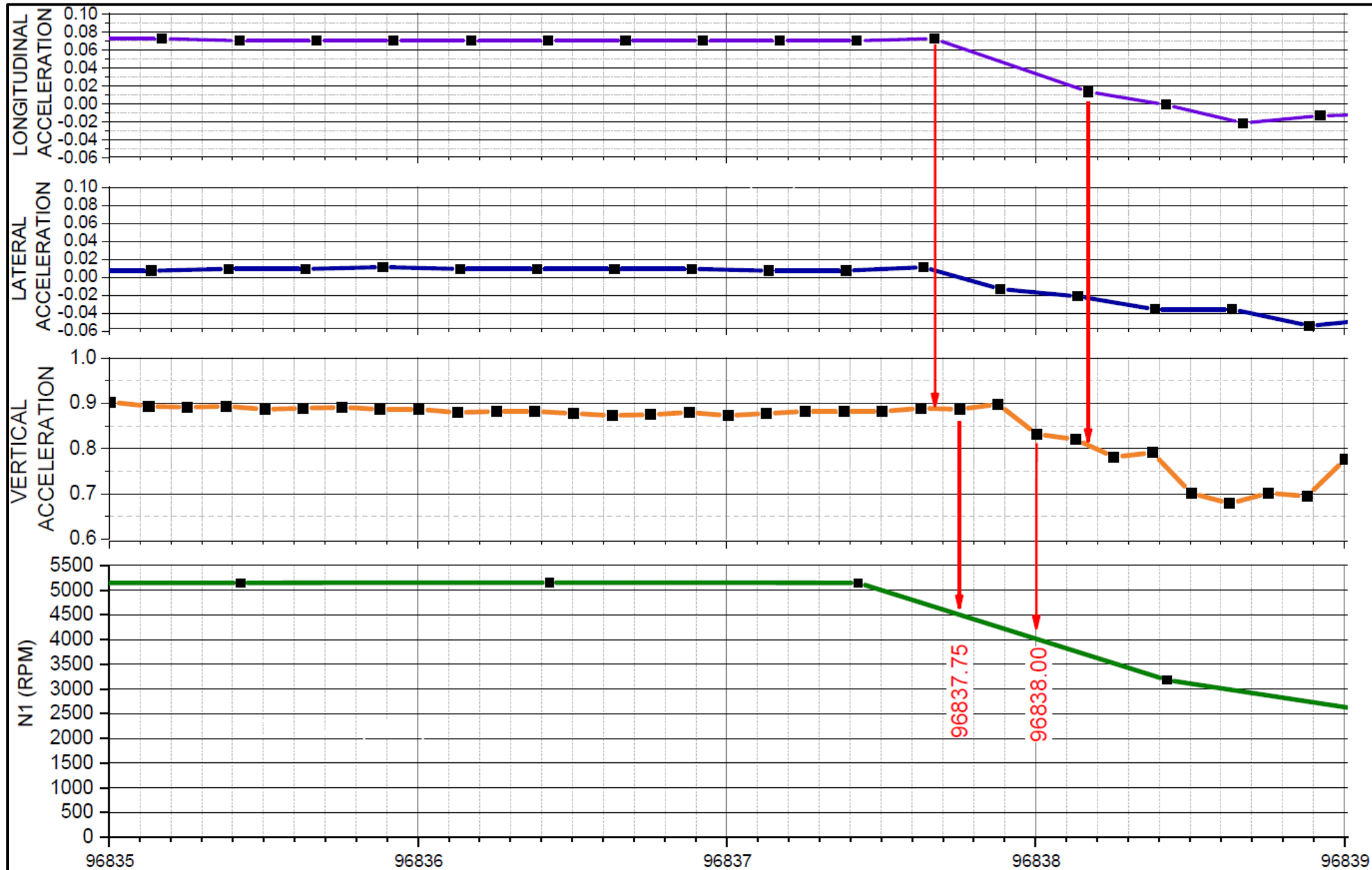
FIGURE 1 - Data showing the reduction of N1 after the FBO event

Note:

The FDR recorded N1 as a percent. To convert this to RPM, the following was used: 100% N1 = 5,175 RPM

FAN BLADE-OUT – TIMING STUDY

FIGURE 2 - FDR Data showing acceleration data and left engine speed (N1)



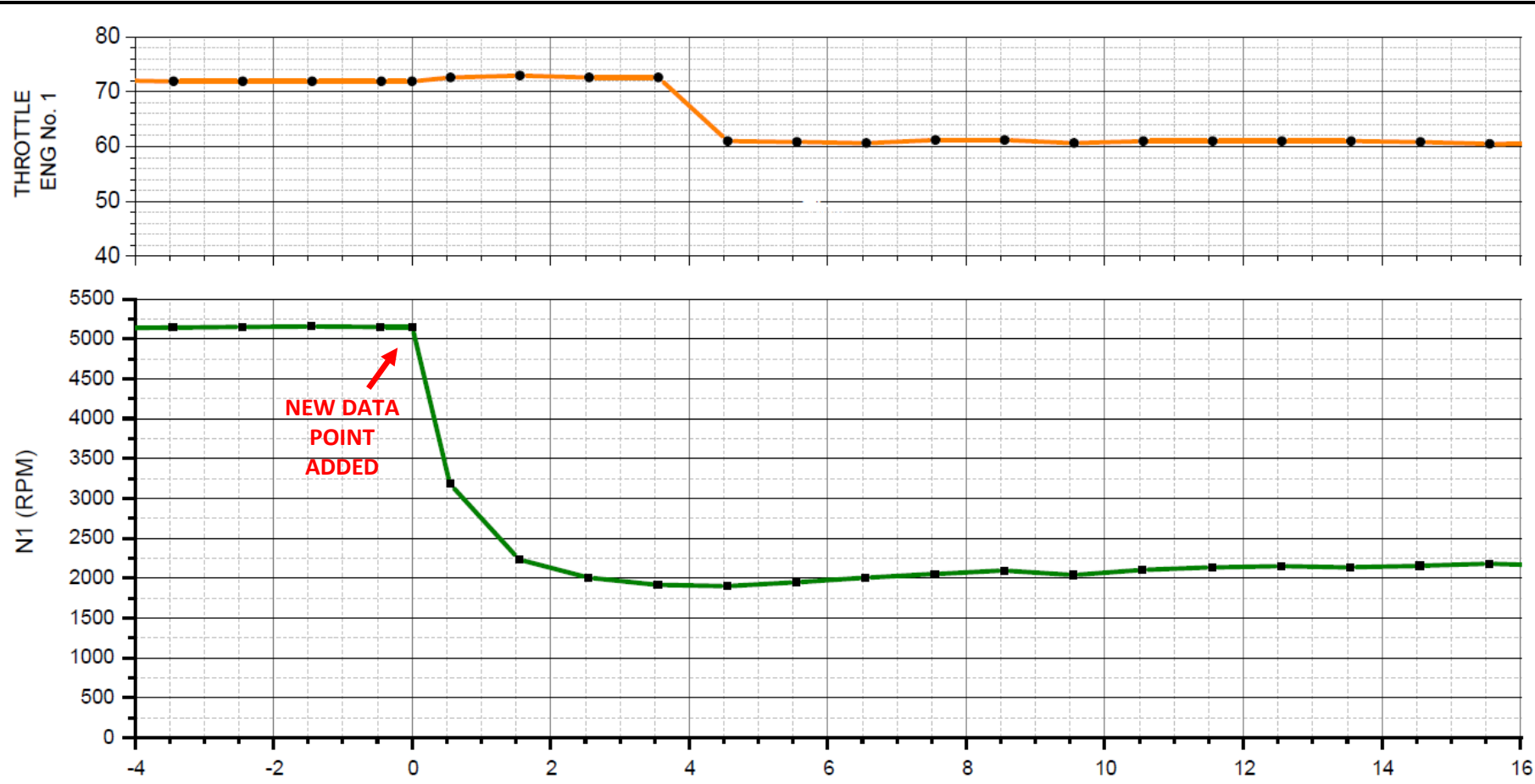
FBO
TIMING ANALYSIS:
Based on the acceleration data, the FBO likely occurred between SRN 96837.75 & 96838.00

FAN BLADE-OUT – TIMING STUDY

SOE Conclusion:

1. Based on the position changes of the acceleration data, the FBO likely occurred sometime within the range of SRN 96837.75 & 96838.00 (see previous slide).
2. For further SOE analysis, it will be assumed that the FBO occurred at the midpoint between the time range (96837.88). And as such, this point will become the new time = 0 point.
3. A data point was inserted into the engine fan speed (N1) plot (Figure 3) to represent the calculated time of the FBO

FIGURE 3 - FDR Data showing left throttle position (%) and left engine speed (N1)



Analysis Objective:

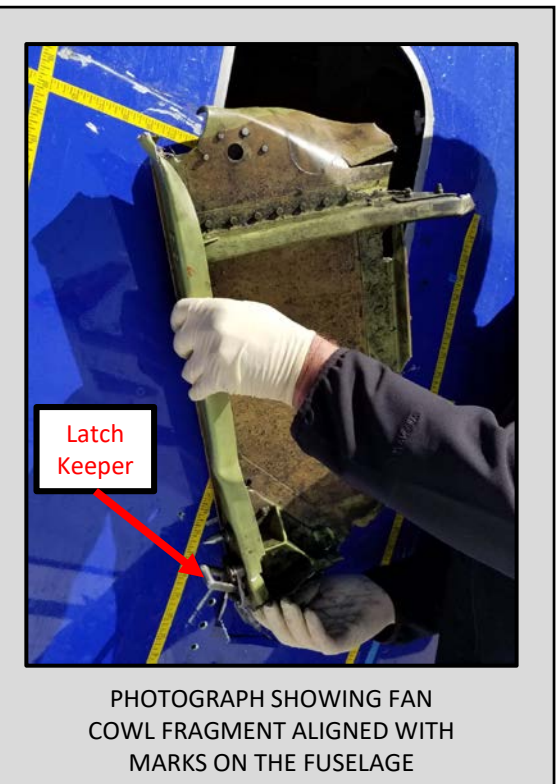
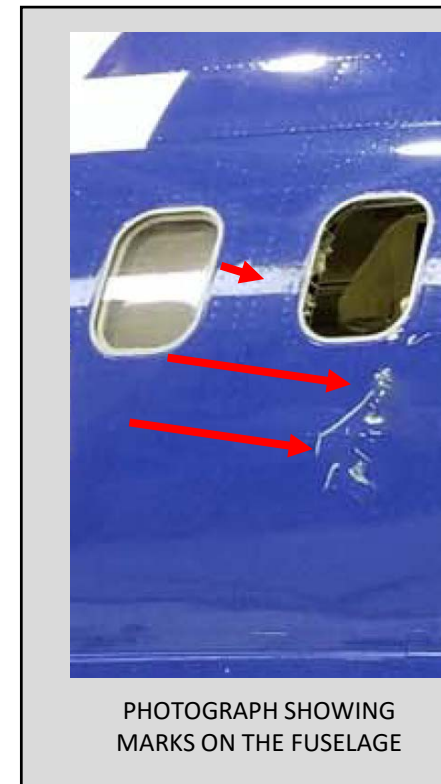
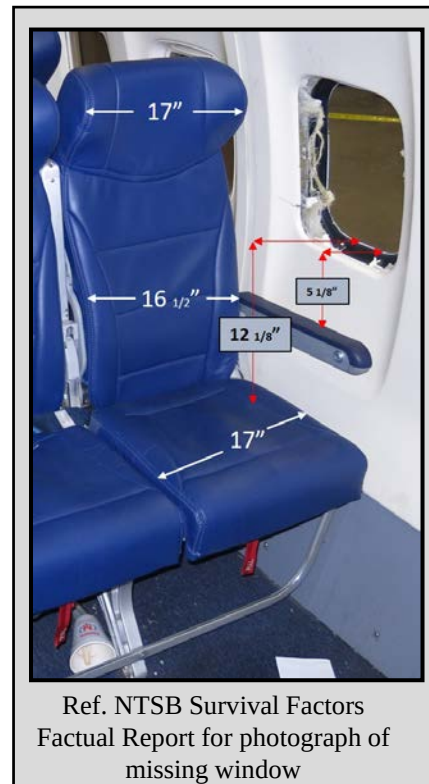
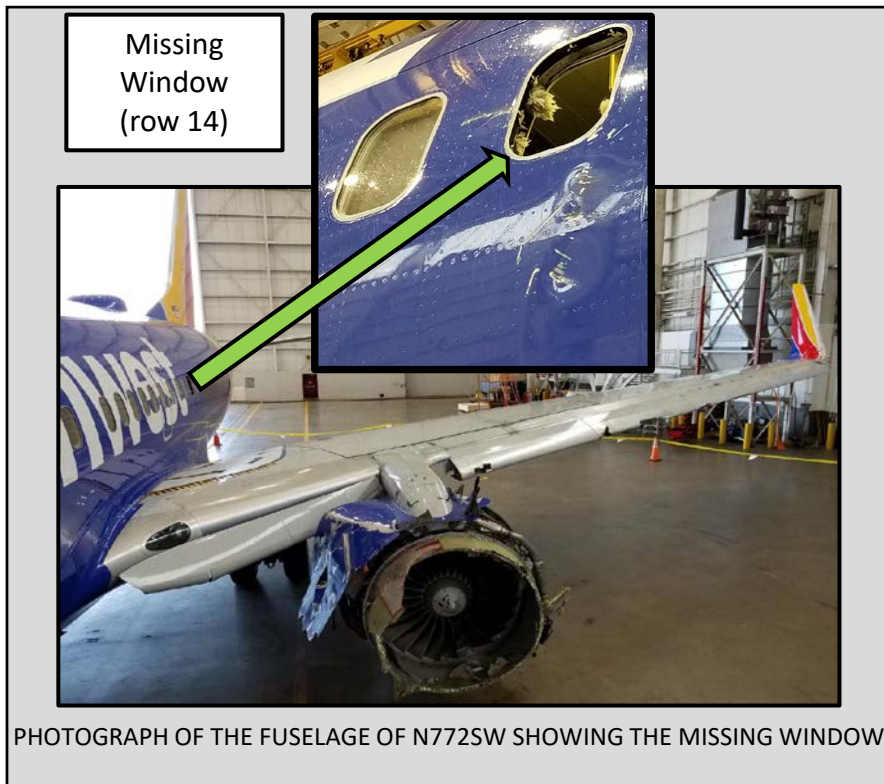
1. Conduct a study to determine the most likely time that the fan cowl fragment impacted the fuselage and also the timing for when the passenger cabin window departed the airplane.

Analysis Details:

1. Provide a brief description of the on-scene findings
2. Plan to determine timing for when the window was compromised.
 - A. Determine the timing of the cabin altitude warning in relation to the FBO.
 - B. Describe what faults were captured on the cabin pressure controller.
 - C. Determine what the pressure inside the passenger cabin was prior the FBO.
 - D. Determine the area of the window that was open to the outside air.
 - E. Calculate how long it takes to depressurize the cabin in order to trigger the 10,000 foot message.
 - F. Conclusion - Calculate the timing for when the window was compromised in relation to the FBO.

On-Scene Findings:

Examination of the fuselage (exterior and interior) revealed that the window at row 14 was not present. Neither the window assembly or any remnants of the assembly were found. Examination of the area near the window revealed impact marks on the exterior of the fuselage forward and below the window. The characteristics of some of the marks on the fuselage were consistent with the characteristics of a fragment of the inboard fan cowl.

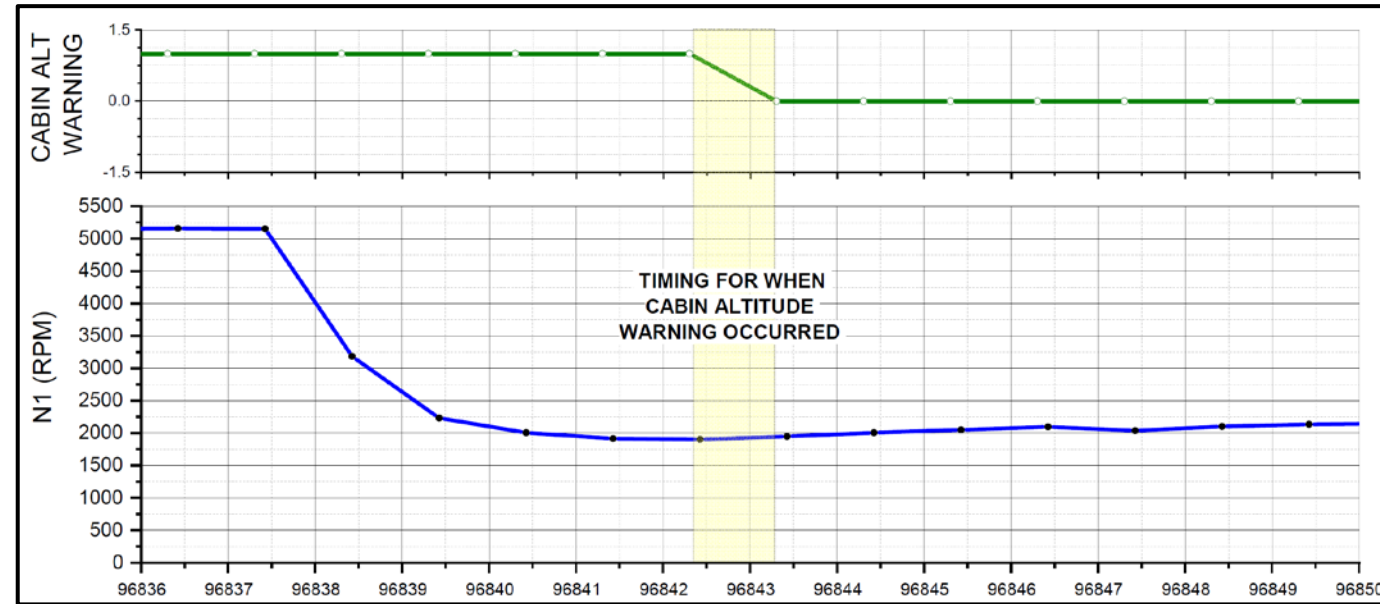


DEPRESSURIZATION / PASSENGER WINDOW STUDY

STEP A. DETERMINE THE TIMING OF THE CABIN ALTITUDE WARNING IN RELATION TO THE FBO

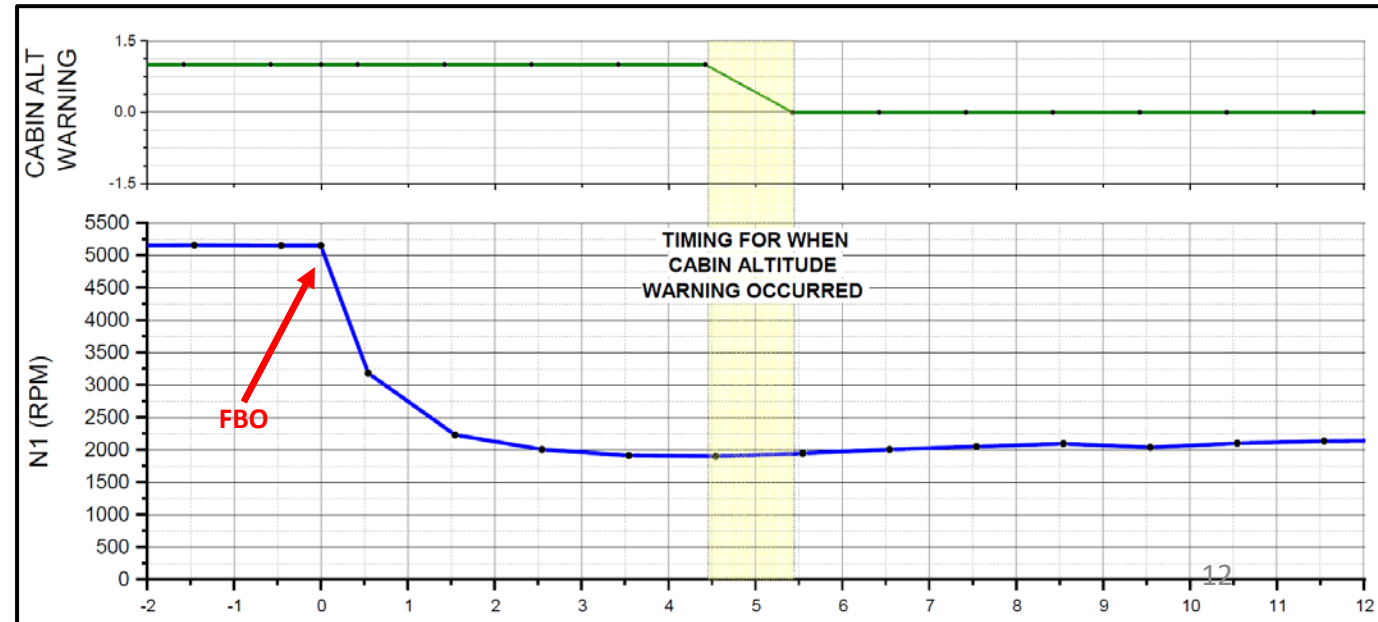
FDR DATA:

The FDR recorded the Cabin Altitude Warning discrete at a rate of one sample per second. A review of the data revealed that discrete transitioned from 1 (no warning) to 0 (warning) between the times of 96842.3 and 96843.3



STUDY:

Aligning the timing of the Cabin Altitude Warning discrete with the calculated timing of the FBO indicates that the warning occurred between 4.4 and 5.4 seconds after the FBO



DEPRESSURIZATION / PASSENGER WINDOW STUDY

STEP B. WHAT FAULTS WERE CAPTURED ON THE CABIN PRESSURE CONTROLLER

- THE OPERATIONAL & THE STANDBY CABIN PRESSURIZATION CONTROLLERS (CPC) BOTH LOGGED THE FOLLOWING
 - A 10,000 FOOT MESSAGE AT 32,610 FEET
 - A 13,500 FOOT MESSAGE AT 32,554 FEET
- ACCORDING TO BOEING, THE TOLERANCE BAND FOR THE CABIN ALTITUDE PRESSURE SWITCH IS +/- 1,000 FEET

STEP C. DETERMINE THE PRESSURE INSIDE THE CABIN PRIOR TO THE EVENT

ACCORDING TO BOEING, THE STARTING CABIN ALTITUDE IS NOT A MEASURED VALUE AND THEREFORE IT WAS CALCULATED, BY BOEING, TO BE 5,773 FEET WHILE CLIMBING THROUGH 32,600 FEET HEADING TO FL380.

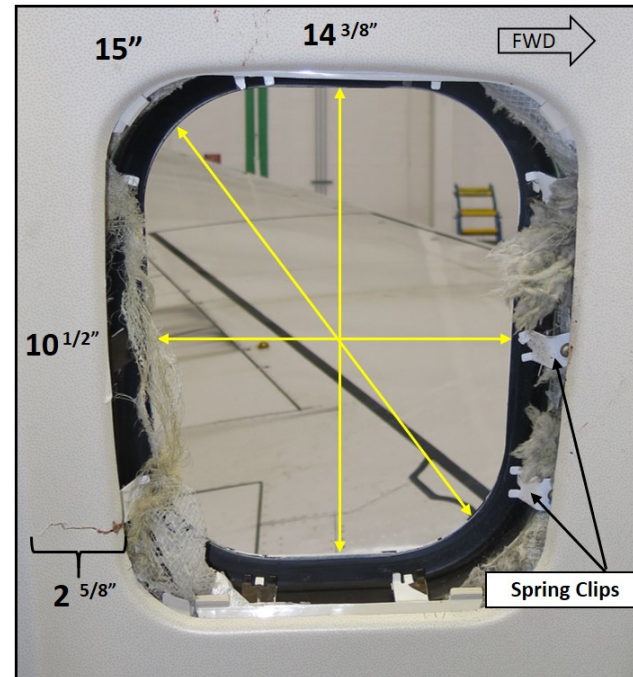
DEPRESSURIZATION / PASSENGER WINDOW STUDY

STEP D. DETERMINE THE AREA OF THE WINDOW OPEN TO THE OUTSIDE

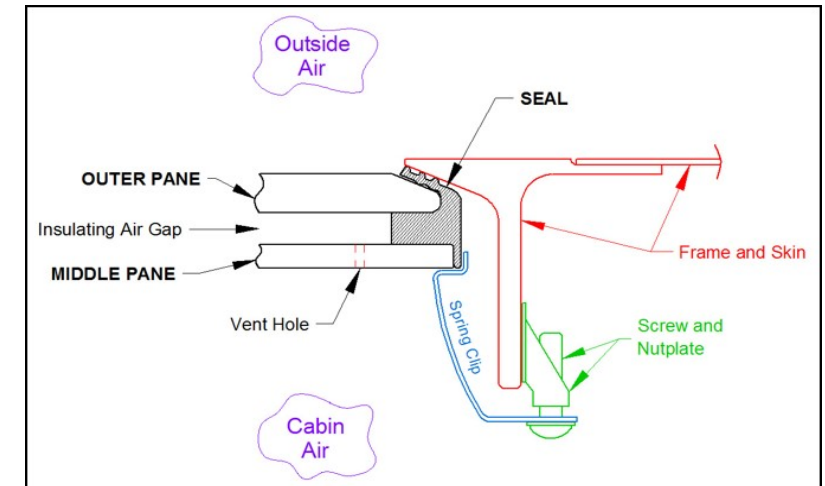
- THE AMOUNT OF WINDOW AREA THAT WAS OPEN TO THE OUTSIDE AIR IS NOT KNOWN AND CANNOT ACCURRATELY BE DETERMINED BY THE INVESTIGATION.
- TO BE CONSERVATIVE, THIS STUDY WILL ASSUME THAT THE AREA OF THE WINDOW WAS UNOBSTRUCTED AND THEREFORE AN AREA OF 167.6 in^2 WILL BE USED.



Ref. NTSB Survival Factors Factual Report for photograph of missing window



Ref. NTSB Survival Factors Factual Report. The window has an approximate area of 167.6 in^2



Ref. NTSB Survival Factors Factual Report. The aircraft window is installed with a rubber seal and 10 spring clips

DEPRESSURIZATION / PASSENGER WINDOW STUDY

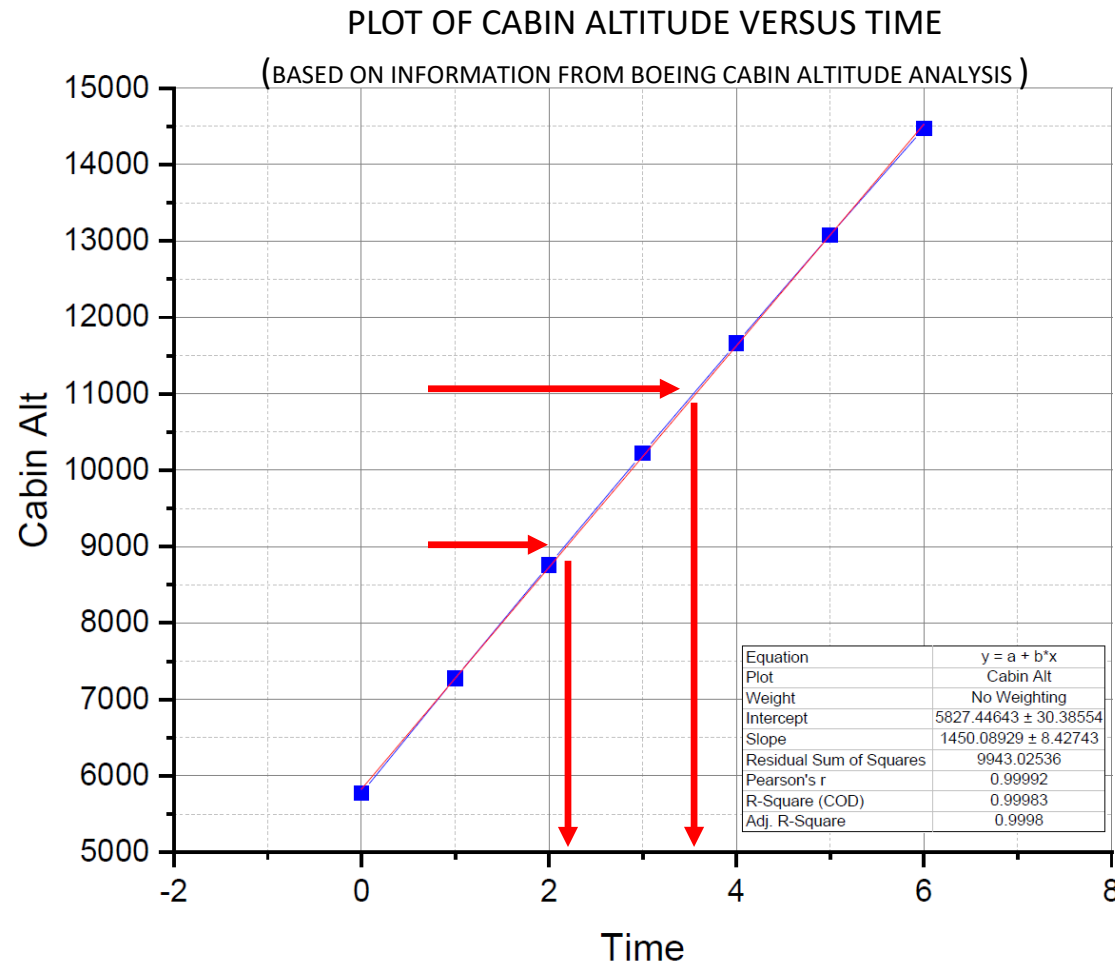
STEP E. CALCULATE HOW LONG IT TAKES TO DEPRESSURIZE THE CABIN TO GET THE 10,000 FT MESSAGE

Assumptions:

- STARTING CABIN ALTITUDE ASSUMED TO BE 5,773 FEET
- ASSUMED A HOLE SIZE OF 167.6 in ² (unobstructed window)
- TOLERANCE BAND FOR THE PRESSURE SWITCH IS +/- 1000 FEET

ANALYSIS USING THE SLOPE OF THE CURVE TO DETERMINE RANGE OF TIMES DUE TO A TOLERANCE BAND ON THE PRESSURE SWITCH OF +/- 1,000 FEET

CABIN ALTITUDE	TIME (SEC)
5773	0.00
6000	0.16
7000	0.85
8000	1.54
9000	2.23
10000	2.92
10221	3.07
11000	3.60
13500	5.33



CONCLUSION:

FOR AN UNOBSTRUCTED WINDOW, IT COULD TAKE BETWEEN 2.23 AND 3.60 SECONDS FOR THE CABIN TO DEPRESSURIZE ENOUGH TO TRIGGER THE PRESSURE SWITCH

DEPRESSURIZATION / PASSENGER WINDOW STUDY

STEP F. CALCULATE THE TIMING FOR WHEN THE WINDOW LIKELY “DEPARTED” THE AIRPLANE IN RELATION TO THE FBO

ANALYSIS:

- For an unobstructed window, it could take between 2.23 to 3.6 seconds to depressurize the cabin enough to trigger the Cabin Altitude Warning.
- The Cabin Altitude Warning occurred between 4.4 to 5.4 seconds after the FBO
- Minimum time that the window could have departed:
 - $(4.4 \text{ to } 5.4) - (3.6) = (0.8 \text{ to } 1.8 \text{ seconds})$ after the FBO
- Maximum time that the window could have departed:
 - $(4.4 \text{ to } 5.4) - (2.23) = (2.17 \text{ to } 3.17 \text{ seconds})$ after the FBO

CONCLUSION:

With the conservative assumption that the area of the window was unobstructed, analysis indicates that the window could have departed the airplane anywhere between 0.8 and 3.17 seconds after the FBO in order for the cabin altitude warning to be recorded on the FDR. However, because the window was unlikely to be fully open during the event, this analysis will shift the minimum time from 0.8 seconds to 0.0 seconds. Therefore, the window could have departed the airplane anywhere between 0.0 and 3.17 seconds after the FBO in order for the cabin altitude warning to be recorded on the FDR.

PORTIONS OF INLET DEPART ENGINE - STUDY

Analysis Objective:

1. The exact time for when the inlet (or portions of the inlet) departed the engine is not known because the airplane was not equipped with recording devices (computers) that recorded the position of the inlet and there were no video recordings of the event. However, a temperature sensor (T12) is mechanically connected to the inlet's inner barrel at 1:00 and two electrical wires attach to a connector panel at the inlet aft bulkhead. The health (in-range or out-of-range) of this sensor is monitored by the engine's electronic engine control (EEC). Therefore, the following study will present the most likely time that the T12 sensor wires were severed.

Analysis Details:

1. Provide a description of the engine inlet
2. Provide a brief description of the on-scene findings
3. Plan to determine timing for when T12 Sensor wires were severed
 - A. Describe the known facts regarding the T12 sensor
 - B. List the "out-of-range" faults that were downloaded from the EEC
 - C. Describe the analysis, performed by Boeing EQA, on the T12 sensor
 - D. Provide an analysis showing when the EEC took the snapshot of the engine data
 - E. Provide an analysis showing when the EEC first detected the T12 sensor fault
4. Conclusion

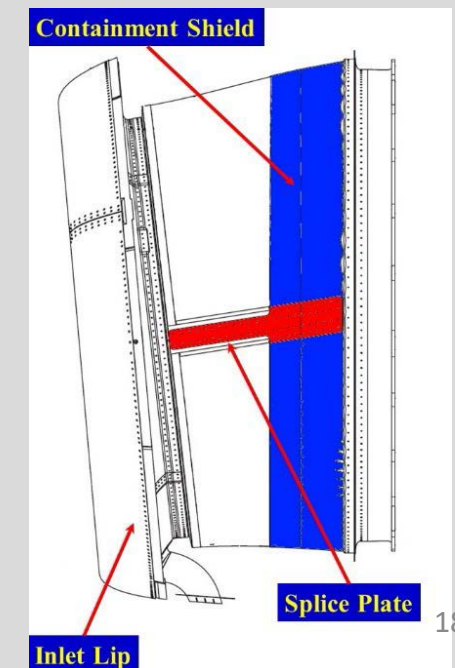
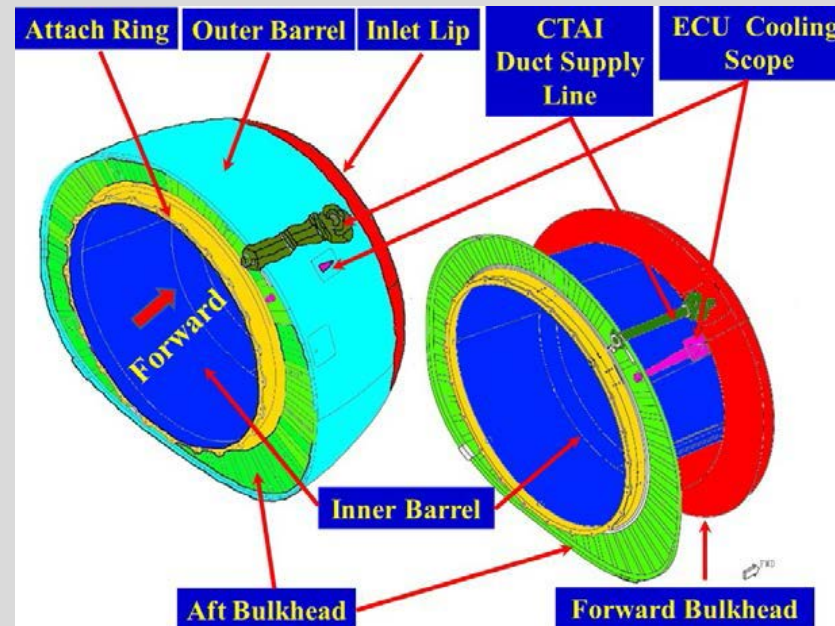
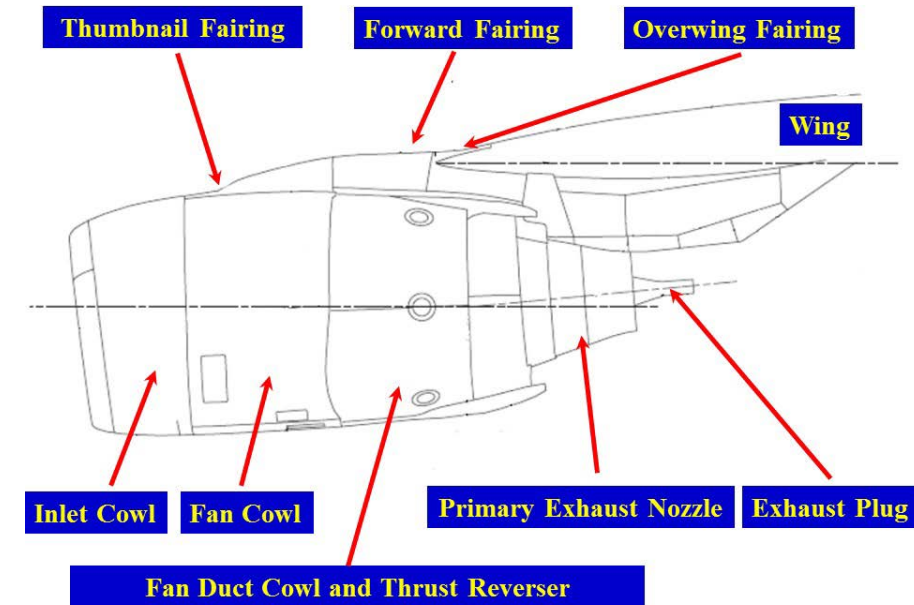
PORTIONS OF INLET DEPART ENGINE - STUDY

Inlet Description - (Basic):

The inlet directs air into the engine and permits smooth air flow over the fan cowl doors. The inlet is comprised of the inner barrel, inlet lip, forward and aft bulkheads, outer barrel skin panels, and attach ring. The inner barrel is attached to the inlet lip at the forward end and the engine attach ring at the aft end. On the backside of the inner barrel outer face sheet, an aluminum doubler is attached over the aft 11-inches of the panel.

Note:

The above description and all of the images on this slide were obtained from the *Powerplant Group Chairman's Factual Report for accident DCA18MA042*



PORTIONS OF INLET DEPART ENGINE - STUDY

On-Scene Findings:

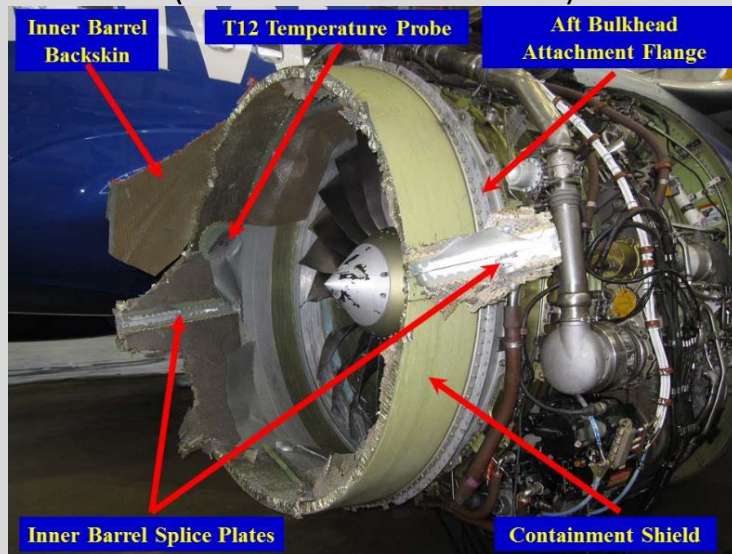
The inlet containment shield was intact and exhibited no penetrations. The entire inner barrel separated from the rest of the inlet except for a remnant of the inner barrel back-skin from the 1:00-3:00 o'clock position and at the 5:00 o'clock position.

Note:

The above description was obtained from the *Powerplant Group Chairman's Factual Report for accident DCA18MA042*



PHOTOGRAPH OF THE ENGINE
(REF. PP FACTUAL REPORT)



PHOTOGRAPH OF THE UPPER LIPSKIN
AND OUTER BARREL IN A FIELD



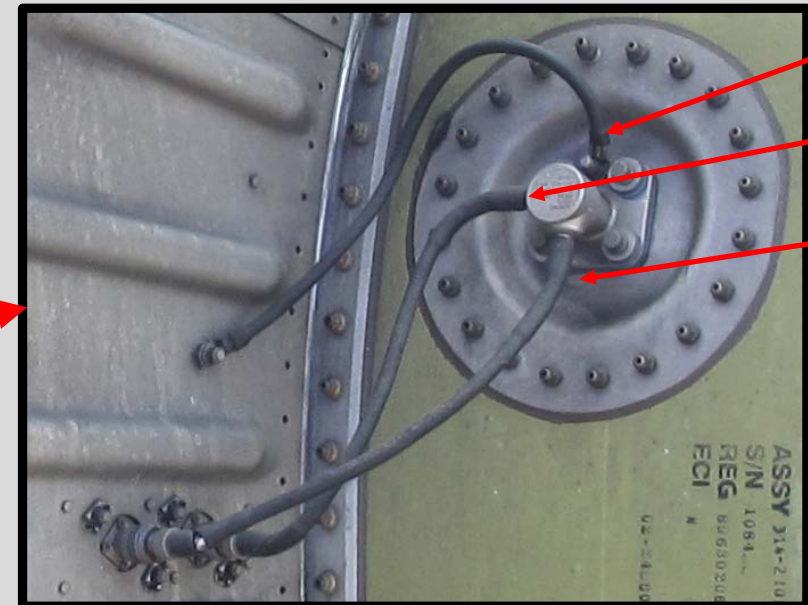
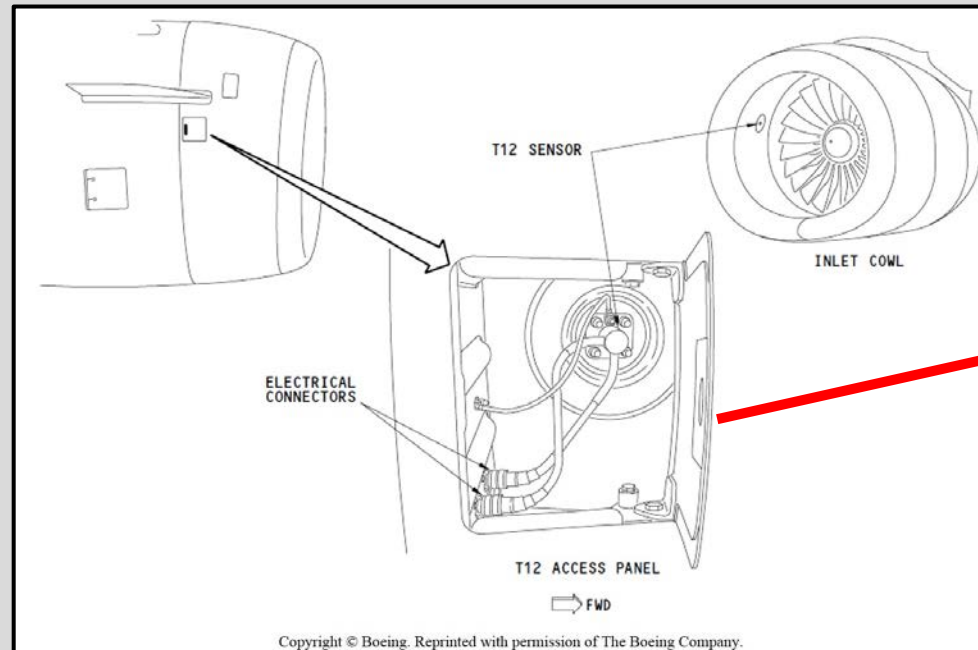
PHOTOGRAPH OF THE LOWER LIPSKIN
AND OUTER BARREL IN A DITCH



PORTIONS OF INLET DEPART ENGINE - STUDY

STEP 1. FACTS:

- The T12 is mechanically connected to the inlet's inner barrel and electrically connected to the inlets aft bulkhead (See images below)
- The event EEC, PN 1853M78P39, SN LMDN5148, contained software version 7BA5.
- The EEC is a dual channel (Channel A and Channel B) digital controller containing two independent computers.
- The EEC was shipped to the BAE Systems facility in Fort Wayne, Indiana for FAULT download of its non-volatile memory (NVM)
- A download of the EEC's Non-volatile (NMV) memory provide the following data:
 - o The Active Channel for the event flight was Channel B
 - o Channel A had a total of 3 faults recorded;
 1. "No Dispatch Fault" ('T12 signal is out of range'),
 2. "Short Time Dispatch Mode Faults" ('FMV position signal is out of range'),
 3. "Long Time Dispatch Fault" ('T12 signal is out of range').
 - o Channel B had 1 fault,
 1. a "No Dispatch Faults" ('T12 signal is out of range').



GROUND

CHANNEL "A"

CHANNEL "B"

PHOTOGRAPH OF T12 FROM N766SW LEFT ENGINE (PENSACOLA EVENT)

PORTIONS OF INLET DEPART ENGINE - STUDY

STEP 2. FAULTS CAPTURED ON EEC

- The EEC monitors certain engine parameters
- When the EEC detects that a parameter has exceeded the built-in test criteria (for example “out of range”) it will start a timer and monitor the parameter.
- If the fault condition still exists for a defined minimum persistence time (for example 4.8 seconds, but can be different for different faults) the EEC will take a “Snapshot” of the selected engine data¹.

CHANNEL “A” SNAPSHOT

Independent Snapshot Data

Fault Location (1-10)	= 0x01
Fault Storage NVM Zone Number	= 0x01
Fault_History	= 0100000000000000
SET Fault occurred in current leg	= Bit 14
Selected Fan Rotational Speed	= 2141.5000 RPM
Selected Core Rotational Speed	= 12048 RPM
Sel. Exhaust Gas Total Temp.	= 782.5000 DEG_C
Selected TRA Position	= 60.8828 DEGREES
Selected Amb. Static Pressure	= 3.8867E+00 PSIA
Sel. Comp. Deliv. Static Pres.	= 36.1875 PSIA
Selected ECU Temperature	= 2.7195E+01 DEG_C
N1 Command	= 4447.0000 RPM
Sel. Fan Inlet Total Temp.	= -1.3375E+01 DEG_C
Est. T25 Inlet Total Temp.	= 37.7344 DEG_C
Selected FMV Position	= 1.0902E+01 PERCENT
Selected VSV Position	= 2.1973E+00 INCHES
Selected VBV Position	= 2.2938E+01 DEGREES
Controlling Regulator	= 7
EDL_CHSTSWRD	= x0xxxxxxxxxxxxxx
CLEAR Local Channel Active	= Bit 14

CHANNEL “B” SNAPSHOT

Independent Snapshot Data

Fault Location (1-10)	= 0x01
Fault Storage NVM Zone Number	= 0x01
Fault_History	= 0100000000000000
SET Fault occurred in current leg	= Bit 14
Selected Fan Rotational Speed	= 2167.0000 RPM
Selected Core Rotational Speed	= 11958 RPM
Sel. Exhaust Gas Total Temp.	= 772.3750 DEG_C
Selected TRA Position	= 61.0156 DEGREES
Selected Amb. Static Pressure	= 3.9141E+00 PSIA
Sel. Comp. Deliv. Static Pres.	= 2.7688E+01 PSIA
Selected ECU Temperature	= 2.7148E+01 DEG_C
N1 Command	= 4444.0000 RPM
Sel. Fan Inlet Total Temp.	= -1.3375E+01 DEG_C
Est. T25 Inlet Total Temp.	= 32.9688 DEG_C
Selected FMV Position	= 1.0738E+01 PERCENT

Note:

The above description regarding the EEC was obtained from the *Powerplant Group Chairman’s Factual Report for accident DCA18MA042*

PORTIONS OF INLET DEPART ENGINE - STUDY

Step 3. Analysis of the T12 sensor

➤ Initial Observations:

- EEC was intact and attached to engine
- T12 Sensor was intact and in-place
- SENSOR wiring was damaged
- Aft bulkhead was not present

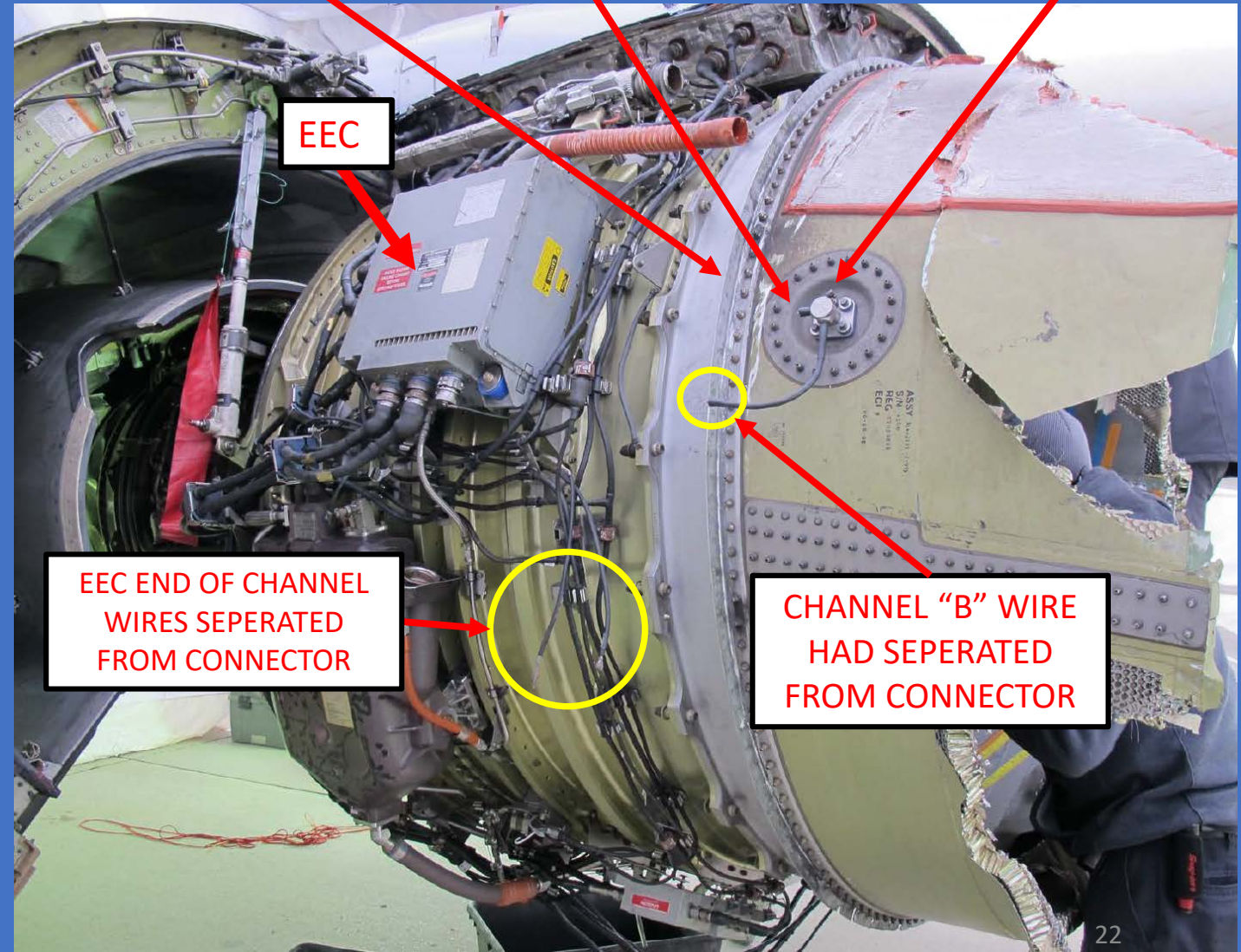
➤ Action:

- T12 Sensor was removed from inlet
- Sensor was sent to Boeing for examination

AFT BULKHEAD
NOT PRESENT 360°

CHANNEL "A" WIRE
FRACTURED AT SENSOR

GROUND WIRE
FRACTURED AT SENSOR



PORTIONS OF INLET DEPART ENGINE - STUDY

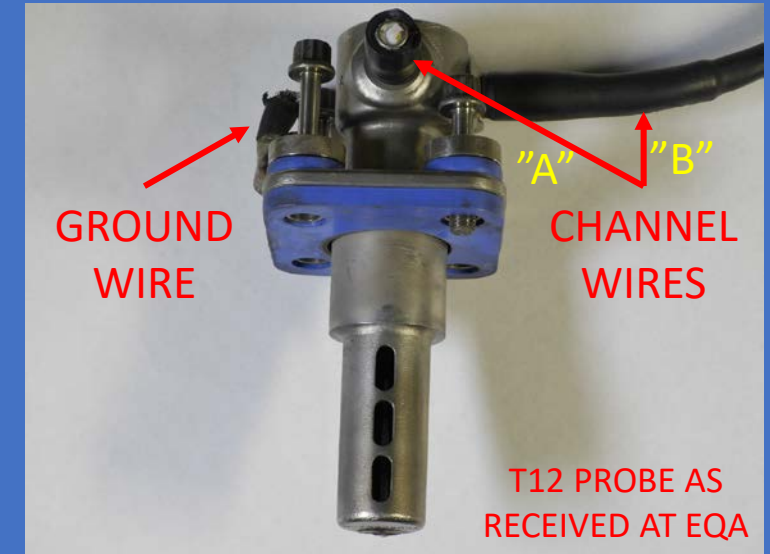
Step 3. Analysis of the T12 sensor – cont.

- Examination:

- T12 Sensor wiring examined by Boeing EQA on July 18, 2018
- Objective was to determine the mode of fracture of the wires leading to the sensor

- Results:

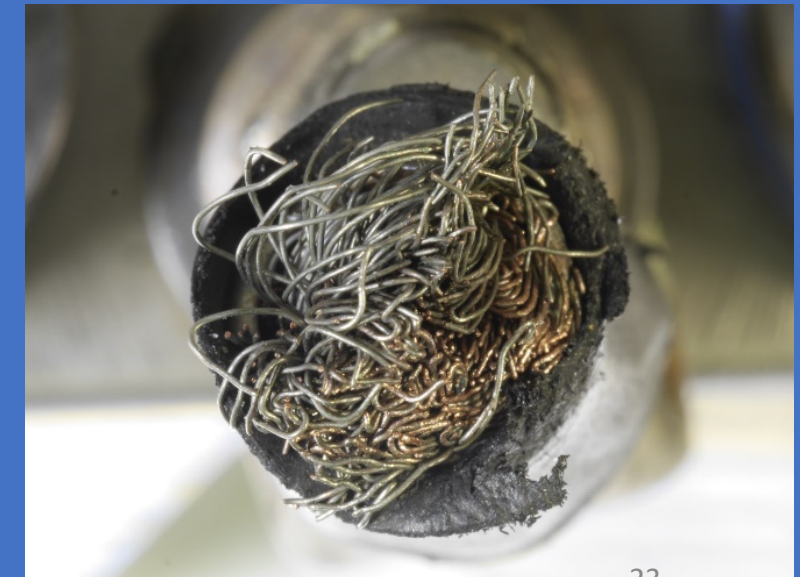
- T12 Probe was in good condition
- All examined wire fractures are consistent with tension overload
- Observed 'pull' direction for 'A' channel wire was consistent with a 'downward' (airplane sense) direction.



CHANNEL "A" FRACTURED AT PROBE



CHANNEL "B"



GROUND WIRE

PORTIONS OF INLET DEPART ENGINE - STUDY

Step 4. Determine the timing of the EEC T12 faults

THE VALUES OF THE CHANNEL "A" & "B" ENGINE PARAMETERS THAT WERE RECORDED BY THE EEC WERE LOCATED (AND HIGHLIGHTED) ON A TABLE OF THE FDR DATA. (SEE BELOW)

• EEC Channel "A" Data to Match:

- N1 = 2,141 RPM
- N2 = 12,048 RPM
- EGT = 782.5 C

Time FDR SRN	N1 RPM	Time FDR SRN	N2 RPM	Time FDR SRN	EGT
0	5149.125	0	14134.65	0	797
0.54578	3182.625	0.57313	12977.85	0.55359	797
1.54578	2231.7188	1.57313	12562.13	1.55359	806
2.54578	2005.3125	2.57313	12399.45	2.55359	810
3.54578	1914.75	3.57313	12254.85	3.55359	812
4.54578	1901.8125	4.57313	12236.78	4.55359	813
5.54578	1947.0938	5.57313	12254.85	5.55359	810
6.54578	2005.3125	6.57313	12236.78	6.55359	806
7.54578	2050.5938	7.57313	12236.78	7.55359	802
8.54578	2095.875	8.57313	12182.55	8.55359	798
9.54578	2037.6563	9.57313	12110.25	9.55359	793
10.54578	2102.3438	10.57313	12074.1	10.55359	788
11.54578	2134.6875	11.57313	12037.95	11.55359	784
12.54578	2147.625	12.57313	12001.8	12.55359	779
13.54578	2134.6875	13.57313	11947.58	13.55359	775
14.54578	2154.0938	14.57313	11929.5	14.55359	771
15.54578	2179.9688	15.57313	11911.43	15.55359	767
16.54578	2154.0938	16.57313	11857.2	16.55359	764
17.54578	2160.5625	17.57313	11821.05	17.55359	759
18.54578	2218.7813	18.57313	11857.2	18.55359	755
19.54578	2205.8438	19.57313	11802.98	19.55359	751

• EEC Channel "B" Data to Match:

- N1 = 2,167 RPM
- N2 = 11,958 RPM
- EGT = 772.375 C

Time FDR SRN	N1 RPM	Time FDR SRN	N2 RPM	Time FDR SRN	EGT
0	5149.125	0	14134.65	0	797
0.54578	3182.625	0.57313	12977.85	0.55359	797
1.54578	2231.7188	1.57313	12562.13	1.55359	806
2.54578	2005.3125	2.57313	12399.45	2.55359	810
3.54578	1914.75	3.57313	12254.85	3.55359	812
4.54578	1901.8125	4.57313	12236.78	4.55359	813
5.54578	1947.0938	5.57313	12254.85	5.55359	810
6.54578	2005.3125	6.57313	12236.78	6.55359	806
7.54578	2050.5938	7.57313	12236.78	7.55359	802
8.54578	2095.875	8.57313	12182.55	8.55359	798
9.54578	2037.6563	9.57313	12110.25	9.55359	793
10.54578	2102.3438	10.57313	12074.1	10.55359	788
11.54578	2134.6875	11.57313	12037.95	11.55359	784
12.54578	2147.625	12.57313	12001.8	12.55359	779
13.54578	2134.6875	13.57313	11947.58	13.55359	775
14.54578	2154.0938	14.57313	11929.5	14.55359	771
15.54578	2179.9688	15.57313	11911.43	15.55359	767
16.54578	2154.0938	16.57313	11857.2	16.55359	764
17.54578	2160.5625	17.57313	11821.05	17.55359	759
18.54578	2218.7813	18.57313	11857.2	18.55359	755
19.54578	2205.8438	19.57313	11802.98	19.55359	751

- Did not match percent

PORTIONS OF INLET DEPART ENGINE - STUDY

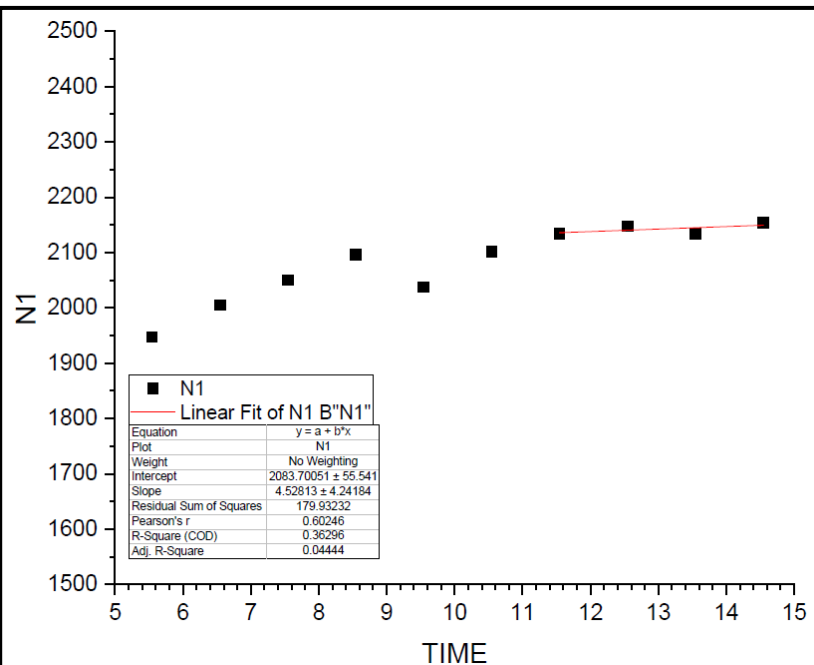
BECAUSE THE VALUES OF THE CHANNEL "A" & "B" ENGINE PARAMETERS RECORDED BY THE EEC OCCURRED BETWEEN THE FDR DATA POINTS, ANALYSIS USING THE SLOPE OF THE FDR DATA (FOR EACH PARAMETER) WAS USED TO DETERMINE, AS BEST AS POSSIBLE, THE TIMING FOR WHEN THE SNAPSHOTS WERE TAKEN.

- EEC Channel "A" Data to Match:

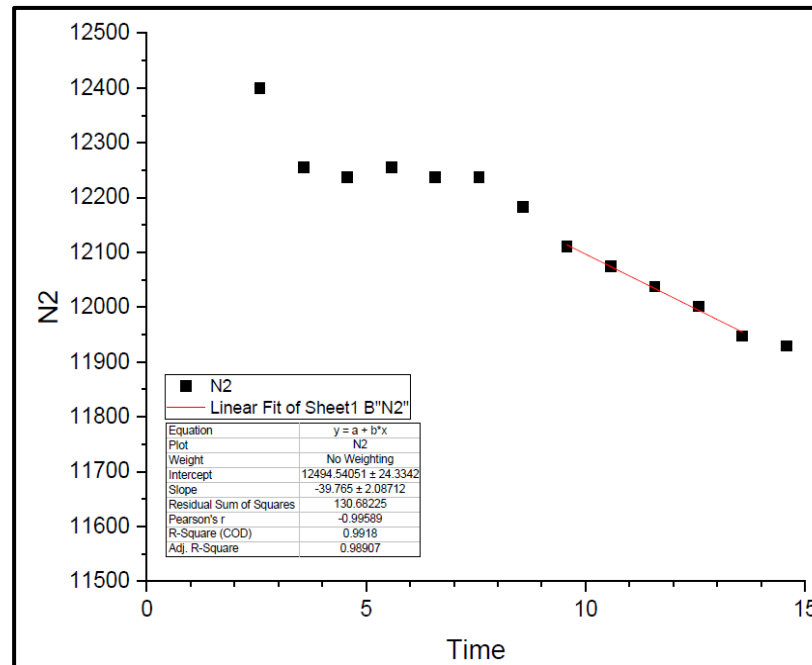
- N1 = 2,141 RPM
- N2 = 12,048 RPM
- EGT = 782.5 C

- EEC Channel "B" Data to Match:

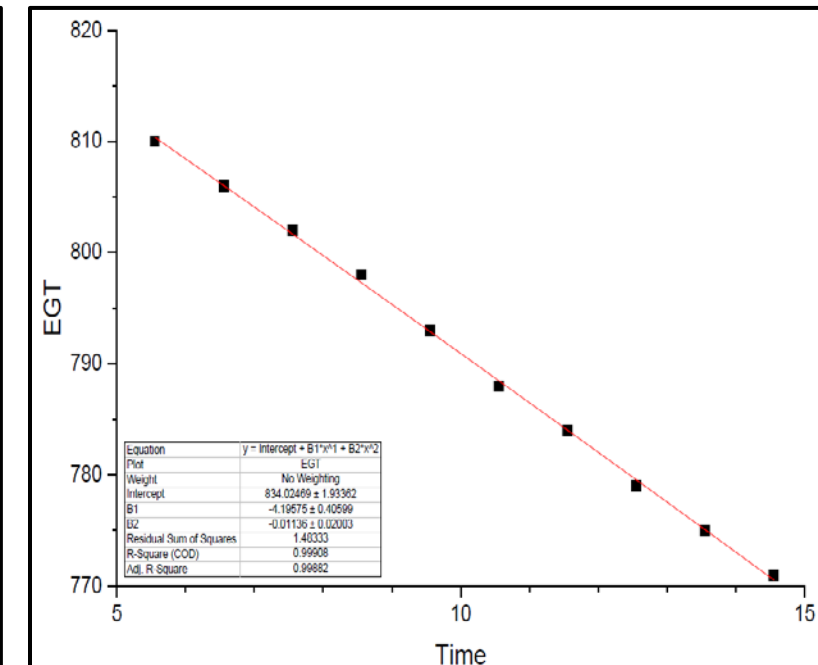
- N1 = 2,167 RPM
- N2 = 11,958 RPM
- EGT = 772.375 C



- Channel A: N1=2141.5 rpm @ 12.764 sec
- Channel B: N1 = 2167 rpm @ 18.963 sec



- Channel A: N2 = 12,048 rpm @ 11.229 sec
- Channel B: N2 = 11,958 rpm @ 13.49 sec



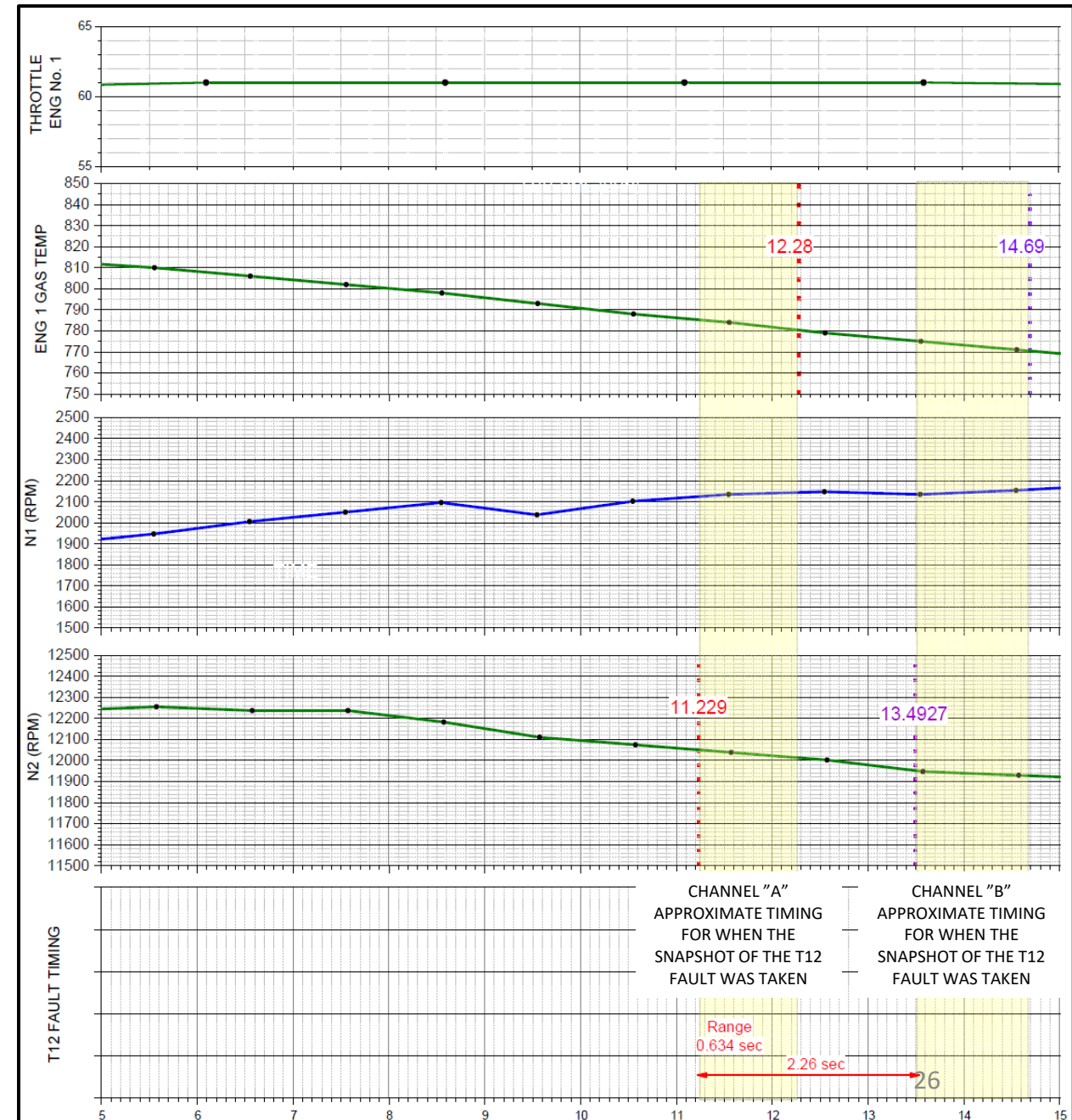
- Channel A: EGT = 782.5 C @ 12.28 sec
- Channel B: EGT = 772.5 C @ 14.69²⁵ sec

PORTIONS OF INLET DEPART ENGINE - STUDY

Step 4. DETERMINE THE TIMING OF WHEN THE EEC TOOK THE SNAPSHOT

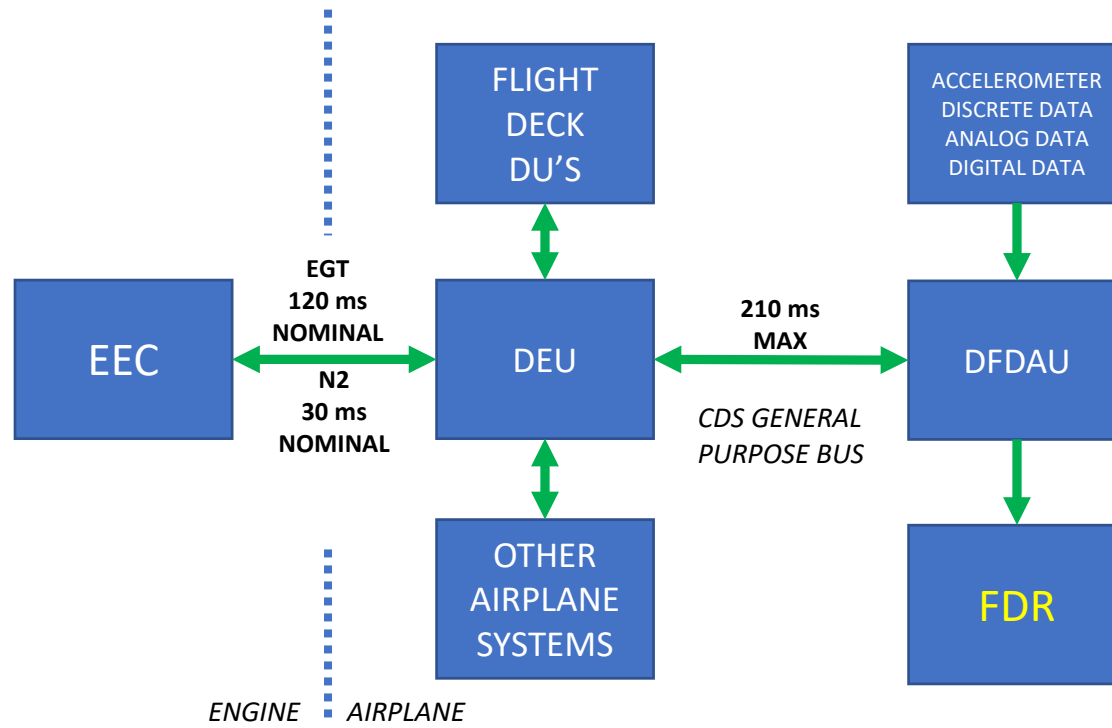
Aligning the EEC “Snapshot” data with the FDR data shows the following:

- Snapshot of engine data for the Channel “A” likely occurred between 11.23 and 12.28 sec after FBO
- Snapshot of engine data for the Channel “B” likely occurred between 13.49 and 14.69 sec after FBO



PORTIONS OF INLET DEPART ENGINE - STUDY

5. CALCULATE WHEN THE EEC FIRST DETECTED THE T12 FAULTS IN RELATION TO THE FBO



NOTE:
REF. FLIGHT RECORDER SPECIALIST
REPORT FOR THIS FIGURE

Analysis:

1. EGT:

Subtract 5.13 seconds (120ms + 210ms + 4.8 sec) from the FDR time to determine the time when the EEC first detected the T12 signal out of range:

2. N2

Subtract 5.04 seconds (30ms + 210ms + 4.8 sec) from the FDR time to determine the time when the EEC first detected the T12 signal out of range:

PORTIONS OF INLET DEPART ENGINE

5. CALCULATE WHEN THE EEC FIRST DETECTED THE T12 FAULTS IN RELATION TO THE FBO

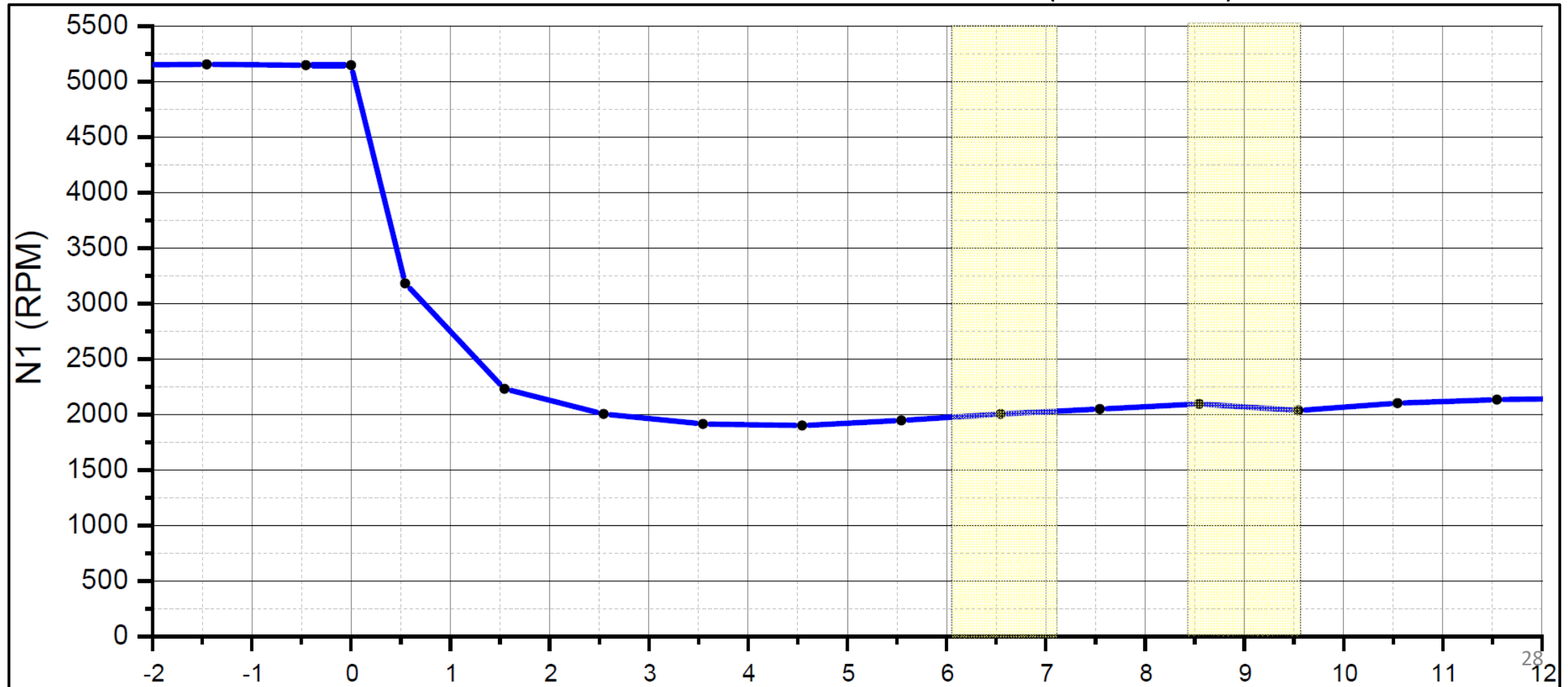
Analysis for when EEC first detected the T12 fault:

- Channel A:

- $(11.23 - 5.13) = 6.2 \text{ Seconds}$
- $(12.28 - 5.13) = 7.15 \text{ Seconds}$

- Channel B:

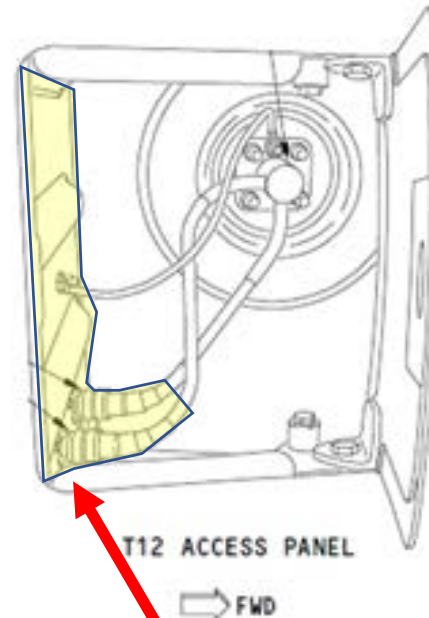
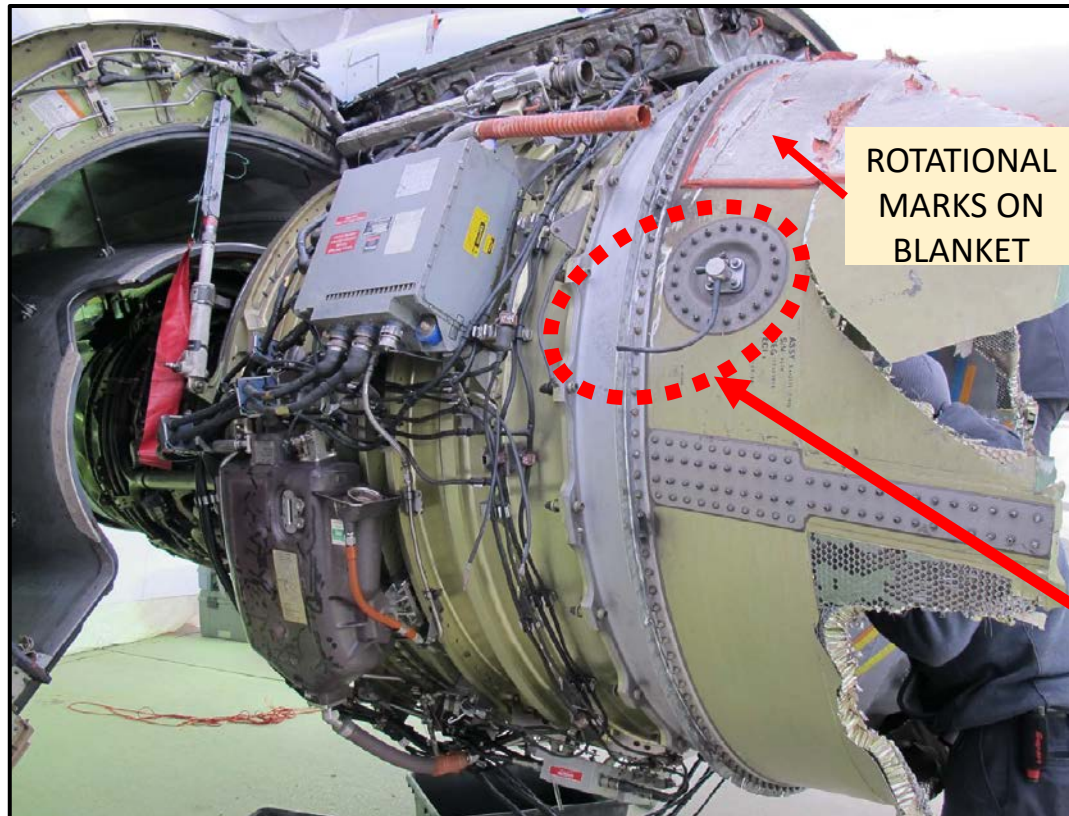
- $(13.49 - 5.13) = 8.45 \text{ Seconds}$
- $(14.69 - 5.13) = 9.56 \text{ Seconds}$



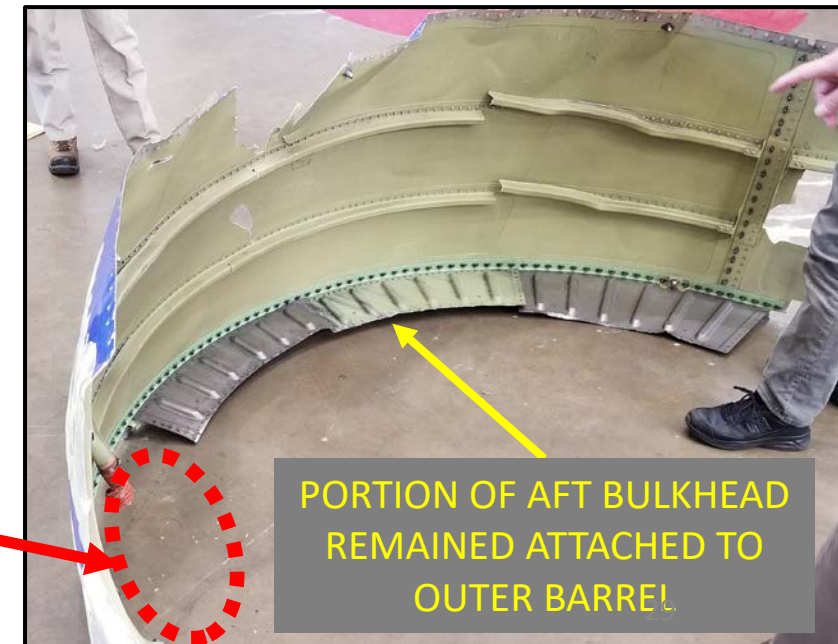
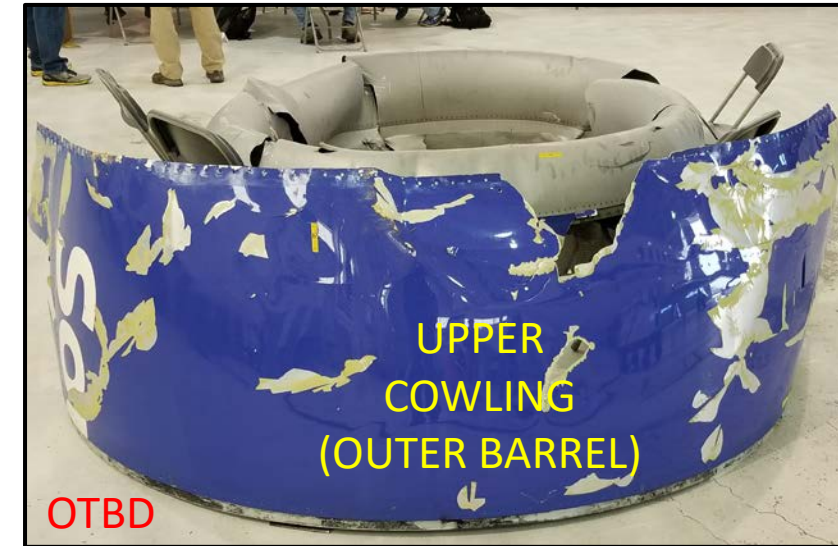
PORTIONS OF INLET DEPART ENGINE

• CONCLUSION:

- EXACT TIMING FOR WHEN THE INLET (OR PORTIONS OF THE INLET) DEPARTED THE ENGINE IS NOT KNOWN AT THIS TIME.
- THE T12 SENSOR WIRING WAS LIKELY DAMAGED WHEN THE AFT BULKHEAD (SECTION WHERE WIRES WERE ATTACHED) MOVED SUFFICIENTLY.
- THE T12 CHANNEL "A" SENSOR WIRING WAS SEVERED BETWEEN 6.2 AND 7.15 SECONDS AFTER THE FBO



PORTION OF AFT BULKHEAD NOT FOUND



ENGINE FUEL CUTOFF - STUDY

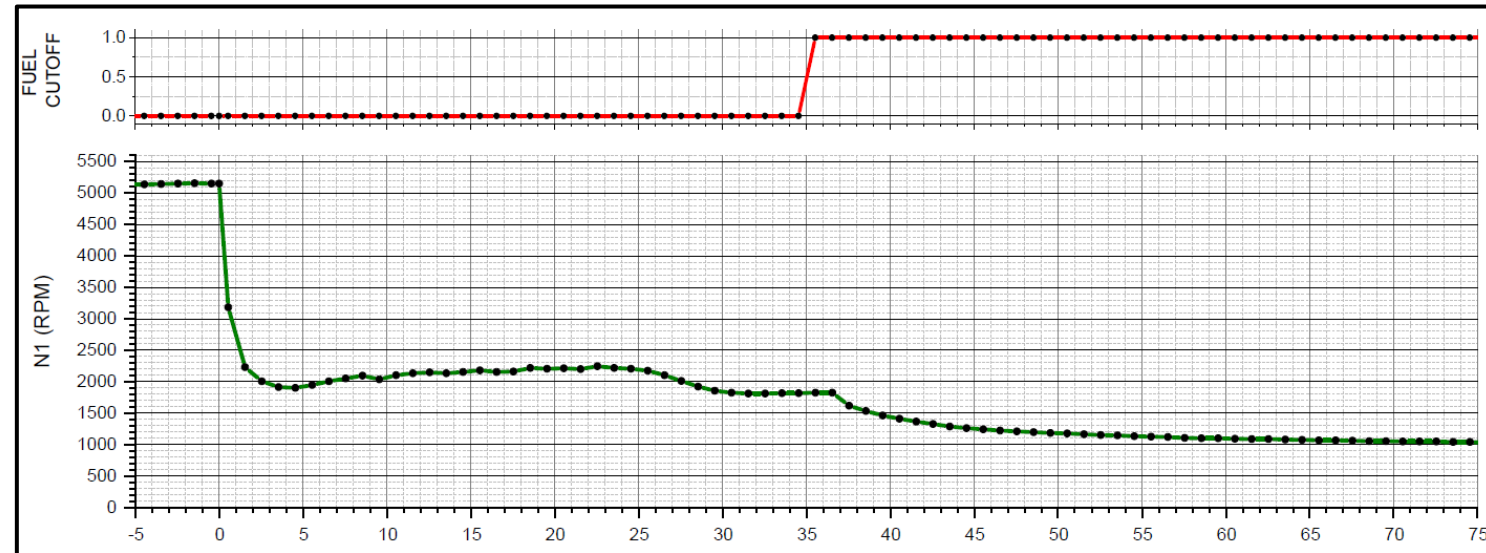
Engine Continued to Run:

A review of the flight data recorder (FDR) data revealed that the left engine continued to operate, “Run-On” until the fuel was cutoff approximately 35 seconds after the FBO.

Engine Fuel Cutoff– Left Engine:

The timing for when the fuel was cutoff to the left engine was determined by reviewing flight data recorder (FDR) data. The data revealed that the Eng1 Cutoff discrete (left engine fuel cutoff) transitioned from 0 (run) to 1 (Cutoff) between times 96872.41 and 96873.41. Aligning the timing of the fuel was cutoff discrete with the calculated timing of the FBO indicates that the fuel to the left engine was cutoff between 34.41 and 35.41 seconds after the FBO

FIGURE 1 – N772SW Fuel Cutoff to Left Engine



TIMING SUMMARY

TIMELINE – SUMMARY (0 to 45 seconds)

1.
FAN BLADE FAILURE
T = 0.0 SECONDS

2.
IMPACT PHASE
(0.0 – 0.02 SECONDS)

3.
ENGINE RUN-DOWN
(0.2 – 2.0 SECONDS)

4.
ENGINE RUN-ON
(2.0 – 35 SECONDS)

5.
ENGINE WINDMILLING
(35+ SECONDS)

FAN BLADE
FAILURE
(LEFT ENGINE)

T = 0 SEC

PASSENGER
WINDOW DEPARTED
THE AIRPLANE

0 > T < 3.2 SEC

CABIN ALTITUDE
WARNING
RECORDED ON
FDR

4.4 TO 5.4

TEMPERATURE
SENSOR WIRES
SEVERED

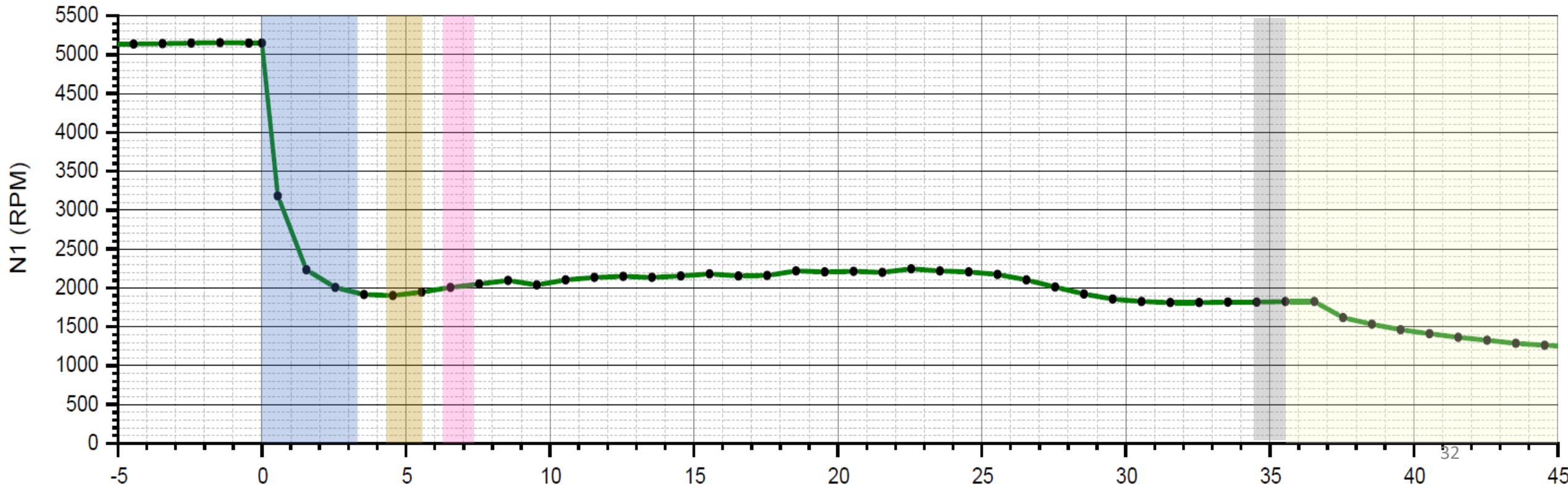
6.2 TO 7.2 SEC

FUEL
CUTOFF
TO THE
ENGINE

34.5 TO 35.5

ENGINE
ENTERS
WINDMILLING
PHASE

T = + 35 SEC



WINDOW TIMELINE – SUMMARY (0 to 6 seconds)

