NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC
January 28, 2004

Colgan Air Flight 9446 Airplane Performance Study

Dennis Crider

A. Accident: NYC03MA183 (key 57787)

LOCATION:	Yarmouth, MA
DATE:	August 26, 2003
TIME:	Approximately 15:40 EST
AIRCRAFT:	Raytheon (Beech) 1900D, N240CJ
OPERATOR:	Colgan Air (d.b.a. US Airways Express)

B. Group

No group was formed for this activity.

C. Summary

On August 26, 2003, at 1540 eastern daylight time, a Beech 1900D, N240CJ, operated by Colgan Air Inc. as flight 9446 (d.b.a. US Airways Express), was substantially damaged when it impacted water near Yarmouth, Massachusetts. The certificated airline transport pilot and certificated commercial pilot were fatally injured. Visual meteorological conditions prevailed for the flight that departed Barnstable Municipal Airport (HYA), Hyannis, Massachusetts; destined for Albany International Airport (ALB), Albany, New York. An instrument flight rules flight plan was filed for the repositioning flight conducted under 14 CFR Part 91.

D. Details of Investigation

Aircraft Loading

According to the load manifest, the aircraft weight at takeoff was 13907 lbs. This included the basic operating weight of the aircraft (which includes the crew), and 3200 lbs of loaded fuel less 50 lbs burned in taxi. The center of gravity (c.g.) is calculated in the following table.

Item	Comments	Weight(lbs)	Arm(in)	Moment (in-lbs)
Basic Operating Weight	From 12/20/2002 supplemental weight & balance	10757.6	277.0	2979750
Fuel	Arm from Pilot's operation handbook for 3150 lb fuel	3150	295.8	931800
Total		13906.6		3911550

The c.g. is found by dividing the moment by the weight. This yields 281.27 inches, which is 13.19% mean aerodynamic chord (mac).

Radar Data

Radar beacon data was obtained from the FAA for the Falmouth-Otis AFB ASR-8 radar site and the Nantucket Memorial Airport ASR-9 radar site. The accident aircraft used a transponder code of 0015.

The Falmouth-Otis AFB ASR-8 radar is located at 41: 39: 30.384 N, 70: 31: 17.112 W at a ground elevation of 123 ft and a magnetic variation of 16 deg W. The Nantucket Memorial ASR-9 is located at 41: 14: 54.5 N, 70: 03: 38.5 W at a ground elevation of 48 ft. These airport locations were then converted to distances East and North of the airport reference point (41:40:09.611 N, 070:16:49.281 W).

The azimuth, range and altitude data from the Falmouth-Otis and Nantucket Memorial radar sites were converted to distance East and North of the airport reference point using the following steps.

1. The magnetic north oriented radar azimuths were rotated 16 degree west to get true azimuths.
2. The polar radar coordinates were converted to rectangular (East-North) coordinates centered on the radar sites.
3. The radar site origin radar coordinates were translated to airport reference point origin coordinates.

In addition to the FAA radar information, Hyannis Barnstable Municipal Airport was equipped with a Rannoch Corporation AirScene multilateration flight tracking system that was installed as part of an integrated airport management and environmental monitoring system. This system receives aircraft transponder response to radar signals and triangulates on the signal to determine the aircraft's location. The altitude encoded within the transponder response is recorded to complete a three-dimensional time history of the aircraft's departure from the airfield. At the request of the Barnstable Municipal Airport manager, Rannoch Corporation extracted the identification and time history of the accident aircraft's flight and provided it to the Safety Board. The ground track of the accident aircraft derived from the Falmouth-Otis and Nantucket Memorial radars and the AirScene system is shown in figure 1.

Figure 1: The accident flight track.

Altitude information from the accident aircraft's radar transponder was available in both the radar and AirScene data. The flight data recorder (FDR) also recorded altitude. This provided the opportunity to synchronize elapsed FDR time to clock time from the radar.

Pressure altitude is based on a standard altimeter setting of 29.92 (in. Hg.) Mean sea level altitude (MSL) can be derived from pressure altitude by adjusting the altitude to the accident altimeter setting of 29.87 (in. Hg.). After this barometric correction was applied, it was found that, while the radar altitudes were brought to field elevation when the aircraft was on the ground, the FDR recorded altitudes that were 100 ft higher. Accordingly, 100 ft was subtracted from the FDR altitude.

Radar data were synchronized with the flight data recorder (FDR) data by aligning the pressure altitude from each source. This resulted in the following time correction with time recorded by the radar converted to seconds past midnight.

$$\text{UTC Time}_{\text{radar}} = \text{FDR elapsed time} - 280426 \text{ sec}$$

Since local time is 4 hr from UTC (daylight savings time), then

$$\text{Local Time}_{\text{radar}} = \text{FDR elapsed time} - 294826 \text{ sec}$$

The resulting synchronized corrected mean sea level (MSL) altitude from the FDR is compared to MSL altitude from the radar sources in figure 2.

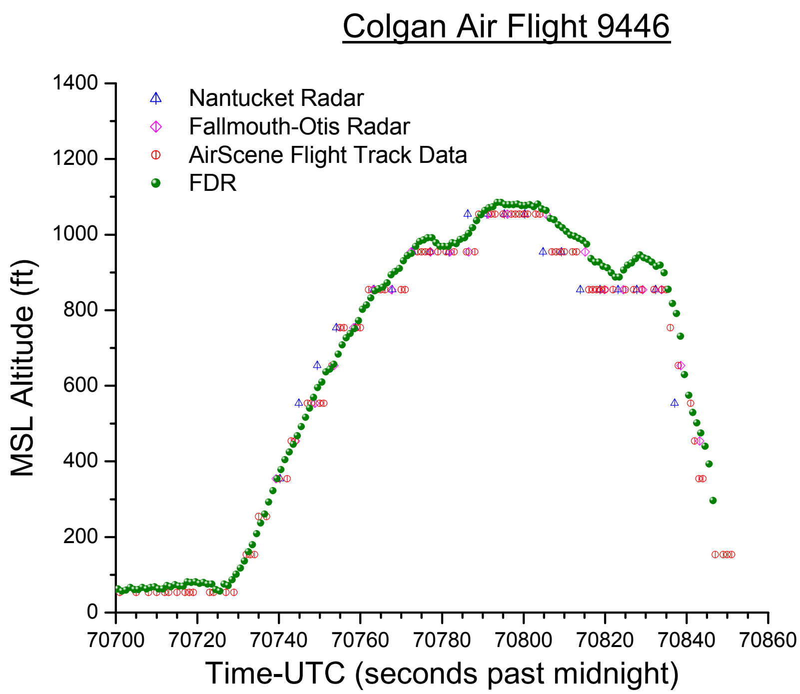

Figure 2: Radar/FDR altitude time synchronization.

FDR Data

Selected flight data recorder (FDR) parameters[1] are presented in figures 3 to 10. With the exception of side load N_y, which is included for completeness and the control deflections, these parameters are the inputs to the kinematics parameter extraction to be described later. The recorded control deflections are actually control cable positions measured near the wing of the aircraft calibrated to degrees of control surface deflection.

[1] See the Flight Data Recorder factual report by Dennis Grossi.

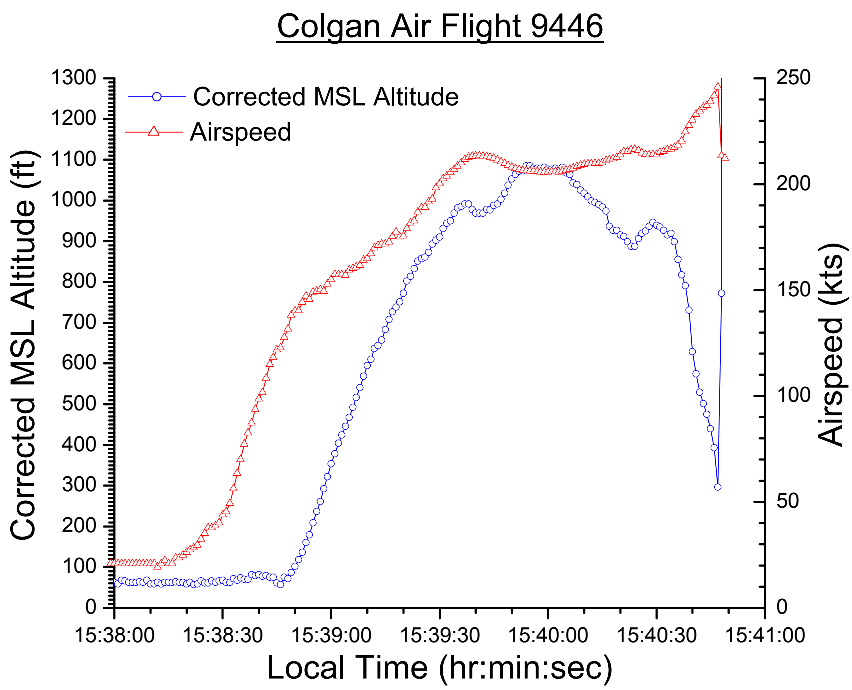

Figure 3: Corrected MSL altitude and airspeed.

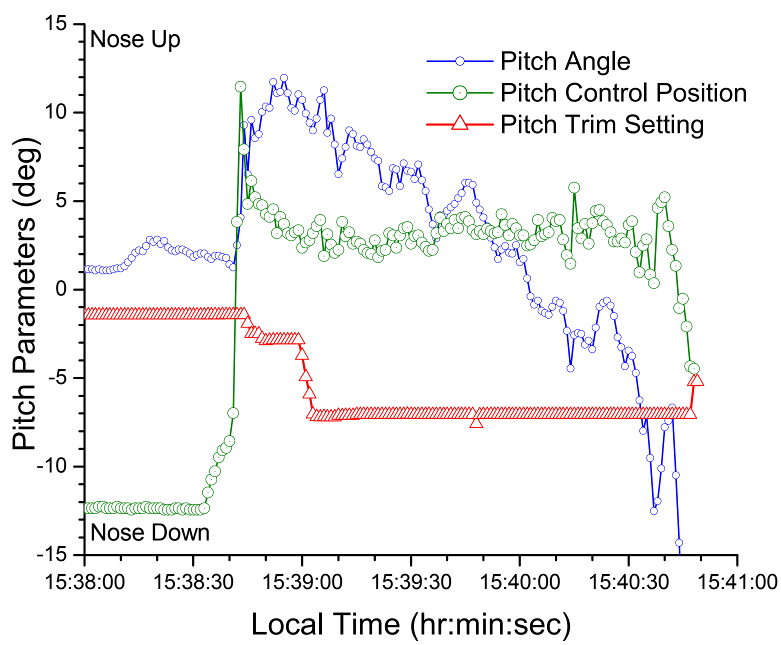

Figure 4: Pitch, pitch control and pitch trim.

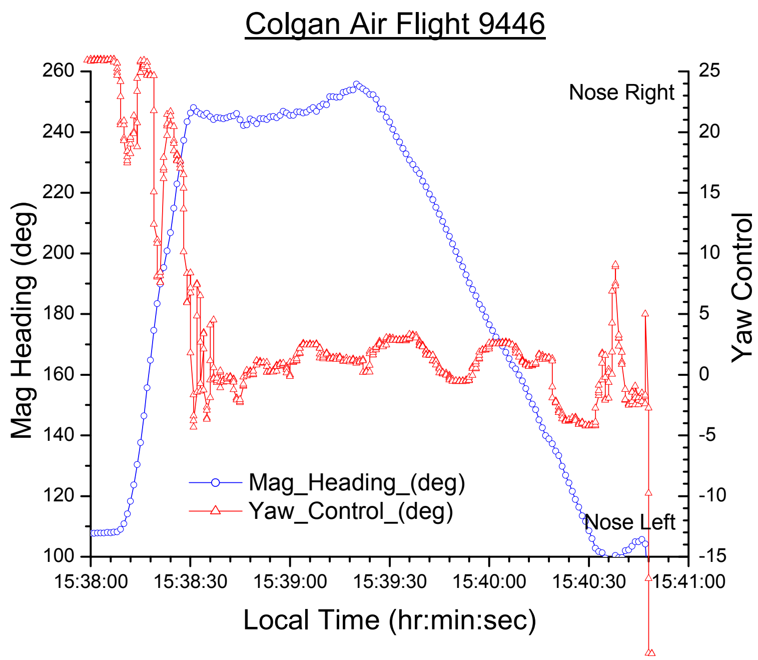

Figure 5: Heading and yaw control.

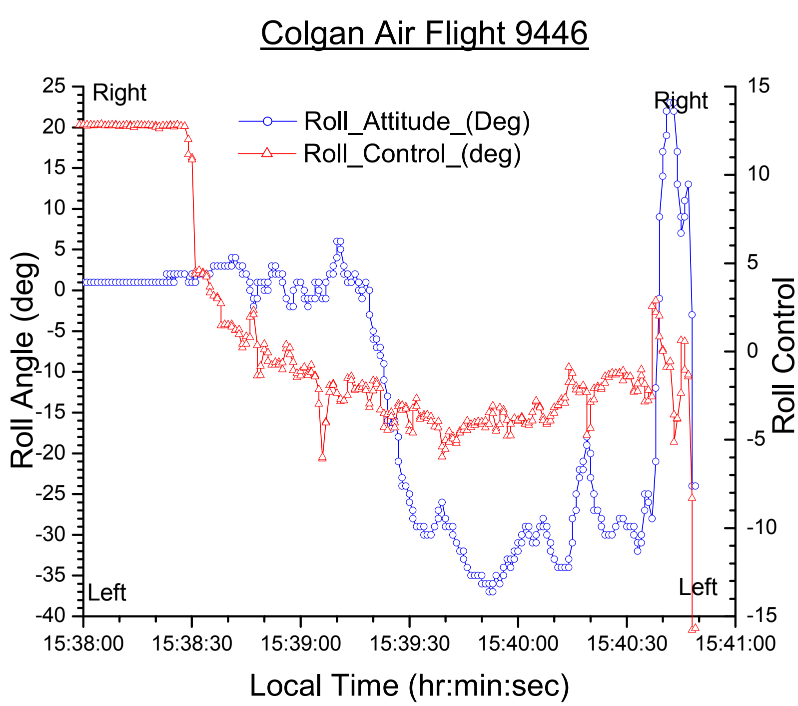

Figure 6: Roll and roll control.

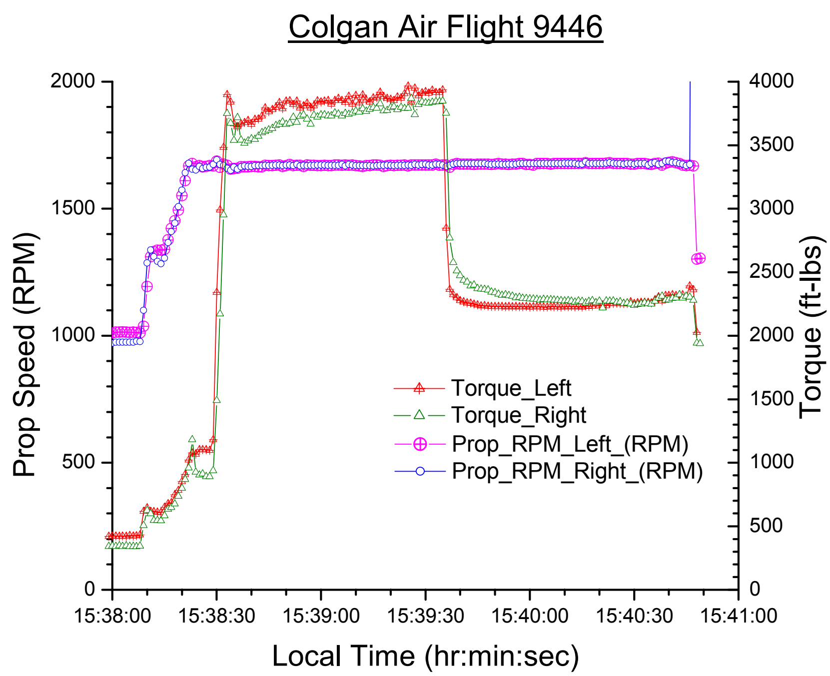

Figure 7: Power parameters.

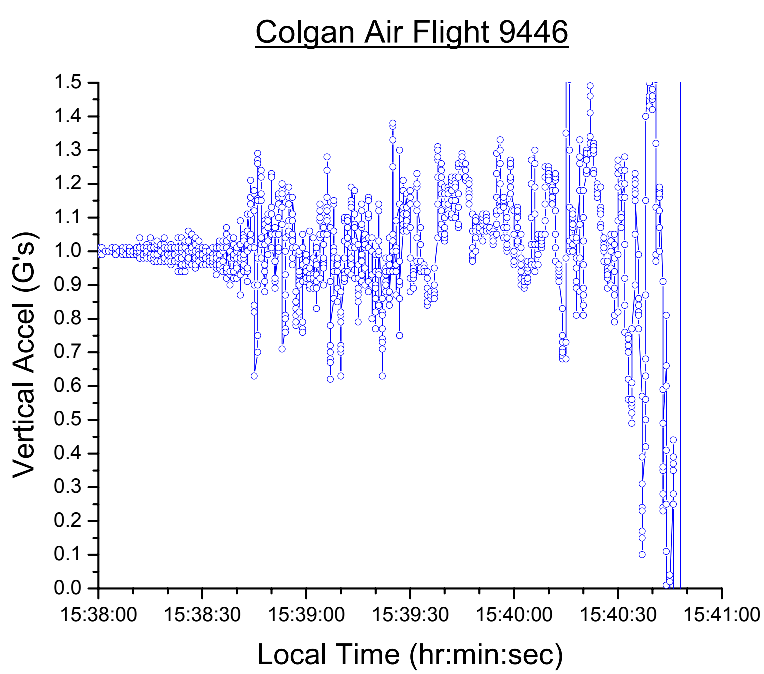

Figure 8: Vertical load factor.

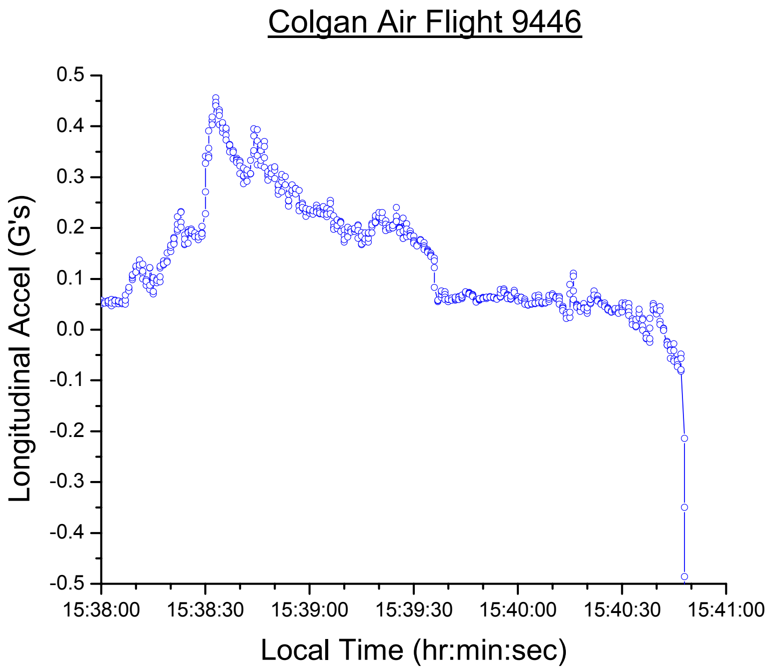

Figure 9: Longitudinal load factor.

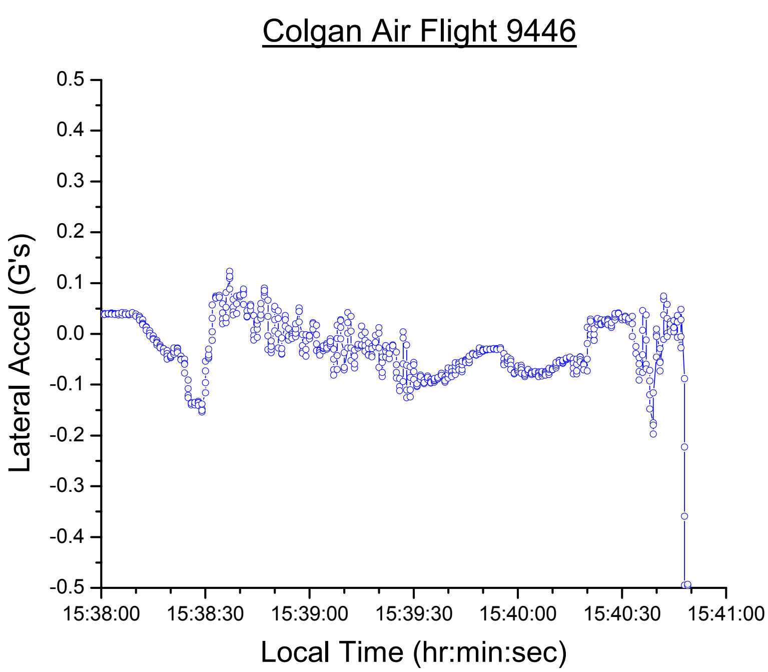

Figure 10: Lateral load factor.

FDR parameters may be offset from their true values. For this case, the FDR shows approximately a 1.1 degree pitch angle for ground operations before power comes up for the takeoff run. However, the pitch angle of a 1900D at this loading should be slightly less than 0.0 degrees. Accordingly a -1.25 deg offset was applied to the pitch data for the kinematics extraction. Similarly the FDR roll angle is 1 degree during taxi and remained constant as the airplane turned onto the runway. Accordingly, a -1.0 degree offset was applied to the roll data for the kinematics extraction. The FDR longitudinal load factor (N_x) value remains 0.05 during taxi operations. Accordingly a -0.05 offset was applied to the roll data for the kinematics extraction.

Kinematics Extraction

A kinematics controls extraction determines the effective control inputs required to produce the aircraft motion as recorded by the FDR. Column force can be an additional product of a kinematics control extraction. Since column force was not recorded on the FDR and the recorded elevator deflections was more trailing edge up than expected for takeoff at this loading[2], a kinematics extraction was done to determine the column force and elevator deflection. This extraction began shortly after liftoff since ground reaction forces would contaminate the extraction.

Neither the landing gear nor flap setting was available from the FDR for use in the kinematics parameter extraction. Per CVR evidence, flaps were set at zero for the entire flight. The landing gear was raised at the time indicated on the CVR.

The accident flight was the first flight after maintenance. As a result of this maintenance, the elevator trim parameter on the FDR was listed as inoperative since it was not re-calibrated after work on the trim system that would have taken the elevator trim out of calibration[3]. The recorded trim is presented together with the trim limits in figure 11. Note that this recorded elevator trim represents degrees of trim commanded at the elevator trim tab but, since the measurement is actually on the cable, it does not include the gearing to the elevator. Since the FDR pitch trim was not calibrated after maintenance, the "zero point" for the trim was not known. The slope however should not have been affected by the maintenance.

[2] See the Flight Data Recorder factual report by Dennis Grossi.

[3] For more details see the Flight Data Recorder factual report by Dennis Grossi.

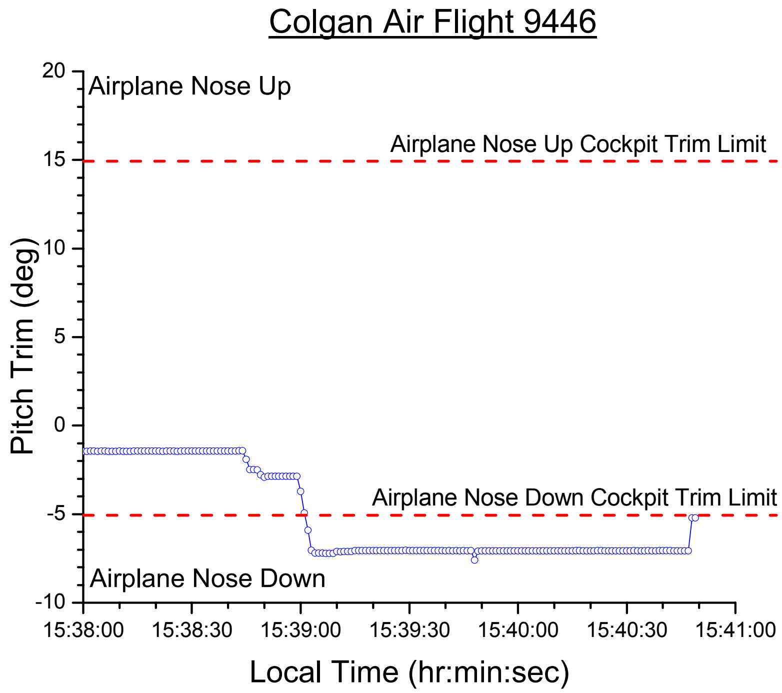

Figure 11: Pitch trim command.

The possibility of a reversal in trim calibration, that is a nose up trim change, was explored. The input trim derived by reversing the sign of the FDR trim is shown together with the column force from a kinematics extraction in figure 12. The extracted elevator for this case is compared to the FDR elevator in figure 13. As previously discussed the FDR elevator is known to be calibrated incorrectly being shifted trailing edge up from the true elevator. The push force shown in figure 12 is inconsistent with CVR evidence and the pitch down to water impact shown in FDR and radar data. A shift of the trim command trace to the nose up stop would have resulted in even more extreme push forces.

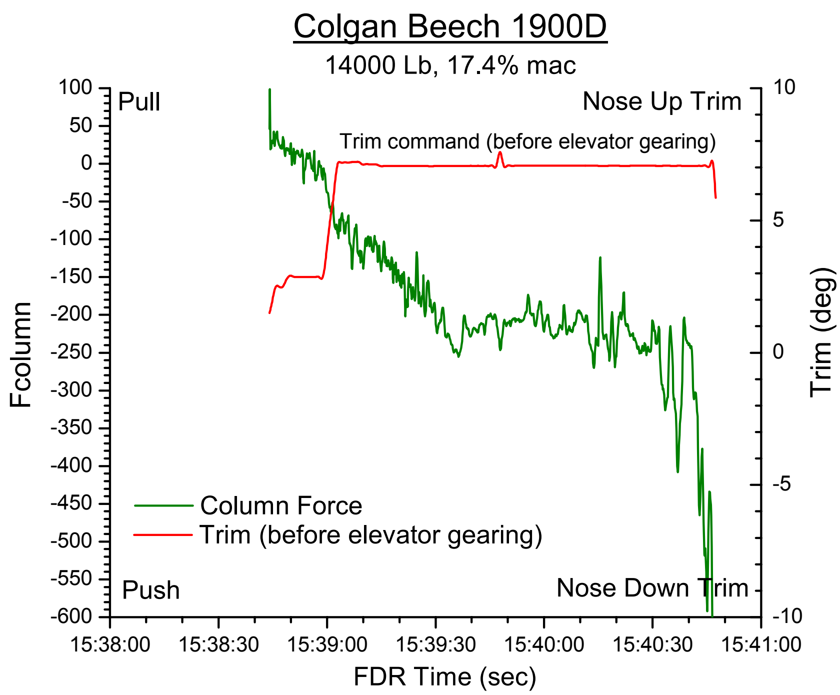

Figure 12: Column force with reversed trim input.

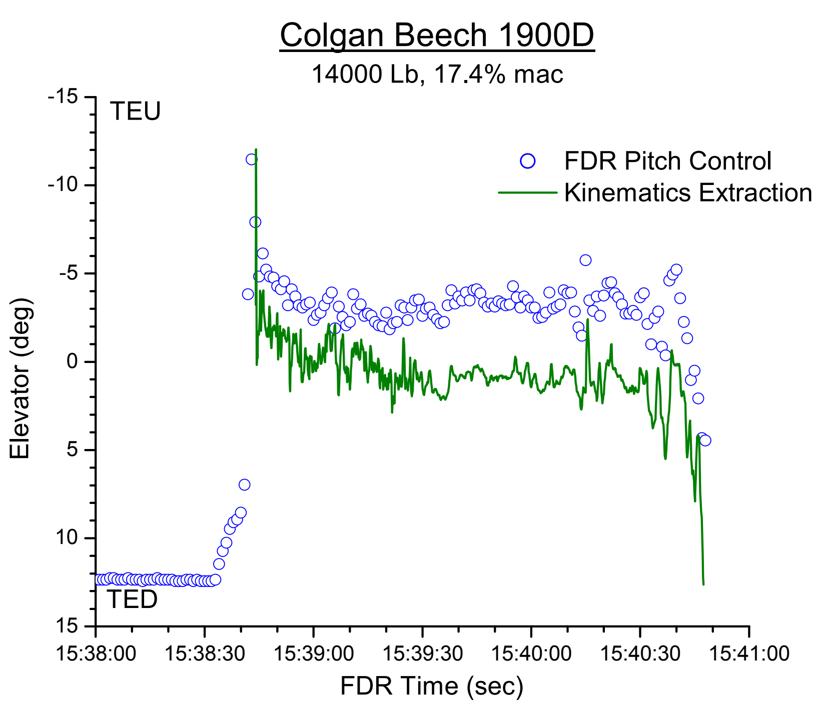

Figure 13: Extracted elevator with reversed trim input.

As discussed previously, since the FDR pitch trim was not calibrated after maintenance, the "zero point" for the trim was not known. However CVR evidence and the constant nature of the trim trace beginning about 14:39:02 indicate that trim was at its stop during this period providing a reference for establishing the "zero point". Accordingly, the FDR pitch trim was shifted 2.07 degrees airplane nose up (tab trailing edge down) for input into the kinematics extraction. The shifted pitch trim is shown together with the column force from a kinematics extraction in figure 14. The extracted elevator for this case is compared to the FDR elevator in figure 15. The pull force shown in figure 14 is consistent with CVR evidence and the pitch down to water impact shown in FDR and radar data.

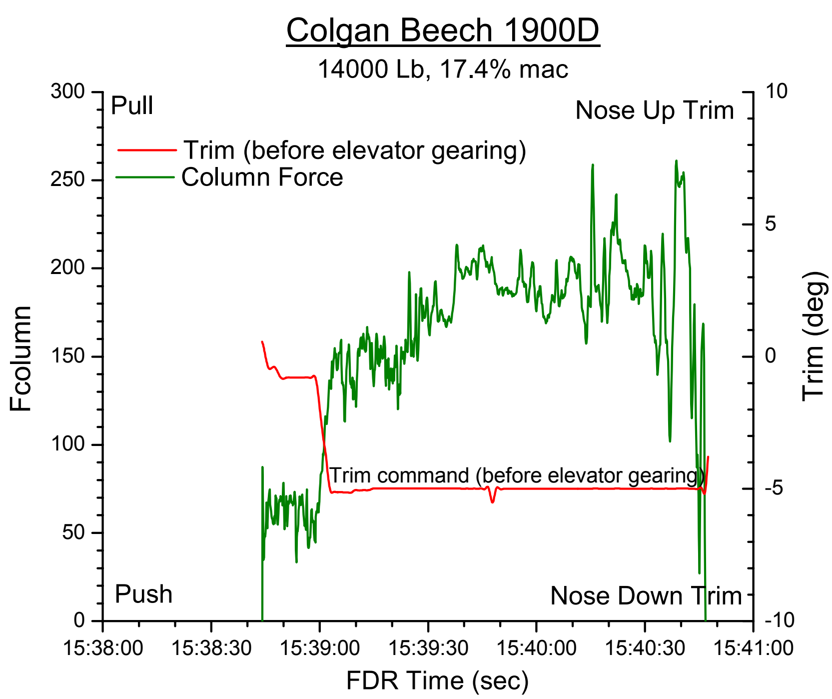

Figure 14: Column force with trim shifted to nose down stop.

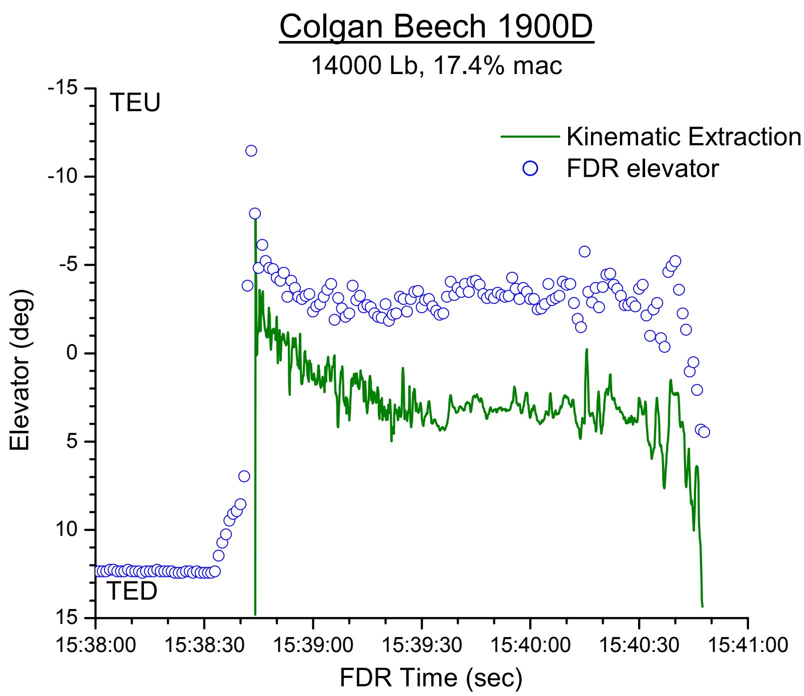

Figure 15: Extracted elevator with trim shifted to nose down stop.

Elevator Float

As shown in the Flight Data Recorder Study[4], the elevator deflection during the takeoff run prior to rotation did not leave the trailing edge down stop as soon and did not move in the trailing edge up direction as rapidly as during other takeoffs. Prior to the pull back at rotation, the pilot would be expected to be exerting very light forces on the column. The aircraft is equipped with a downspring and bobweight which will hold the elevator at its trailing edge down stop until sufficient airspeed has been obtained for the elevator aerodynamic hinge moment to lift the elevator trailing edge or the pilot pulls back with sufficient force.

It is not possible to definitively match the accident profile with the pilot input forces unknown. However, trends can be examined for the zero column force case. The elevator angle with zero pilot input force is called the float angle. This angle was determined with the simulator for the accident takeoff. Figure 16 shows the float angle with the accident trim tab command, a 4 degree trim tab command (the average takeoff tab found in the Flight Data Recorder Study) and a more nose up trim tab command. As can be seen, the simulation with the accident trim begins to float later and moves less from the stop than the more representative 4-degree trim command. This is very consistent with the flight data in the Flight Data Recorder Study. The 4-degree trim command results in a more trailing edge down elevator tab than the accident trim command. The trailing edge down elevator tab lifts the elevator sooner than a less trailing edge down tab.

[4] See the Flight Data Recorder Study by Dennis Grossi.

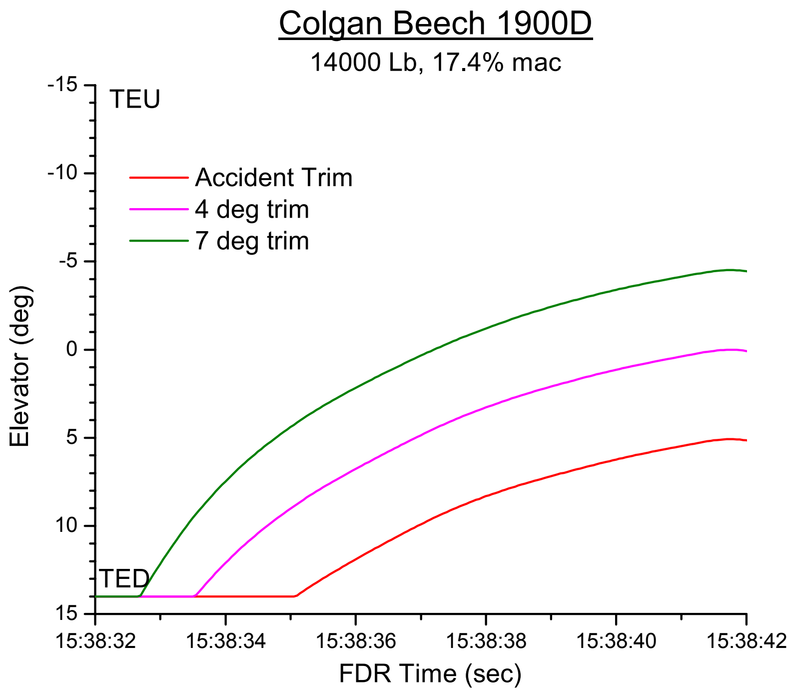

Figure 16: Elevator tab float.

Conclusions

The elevator extracted from the aircraft motion reflects the features (movements) of the offset FDR elevator. This indicates that the elevator was free to move and that the airplane responded properly to elevator movement.

A direction of tab motion opposite that recorded by the FDR would require a large push force to produce the recorded motion of the aircraft. This is inconsistent with CVR evidence and other data. The recorded direction of tab motion is consistent with the rest of the data.

The kinematics extraction (figure 14) shows approximately 60 lbs of column pull force were required until the tab movement to the airplane nose down stop. This tab movement increased the column force to 150 lbs pull. The required column force increased further to approximately 200 lbs as speed increased and remained at that level until reducing just prior to impact.

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