**Docket No. SA-520**

**Exhibit No. 13-A**

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

# Group Chairman’s Aircraft Performance Study

(18 Pages)

**NATIONAL TRANSPORTATION SAFETY BOARD**
Office of Research and Engineering
Washington, D.C. 20594

December 8, 2000

# Aircraft Performance Study

## Group Chairman's Aircraft Performance Study

## A. ACCIDENT

| | |
|---|---|
| Location: | North of Anacapa Island, CA |
| Date: | January 31, 2000, 1621 PST |
| Aircraft: | Boeing/Douglas MD-83 N963AS |
| NTSB Number: | DCA00MA023 |

## B. GROUP

| | |
|---|---|
| Performance Group Chairman: | Daniel R. Bower, Ph.D.<br>Aerospace Engineer<br>Office of Research and Engineering / RE-60<br>National Transportation Safety Board |
| Member: | Dennis Crider<br>Aerospace Engineer<br>Office of Research and Engineering / RE-60<br>National Transportation Safety Board |
| Member: | David Yingling<br>Aerodynamics Engineer<br>Boeing Company |
| Member: | Gordon Acker<br>Senior Flight Test Engineer / ANM-160L<br>Federal Aviation Administration |
| Member: | Steve Fulton<br>Technical Pilot/ FAA DER<br>Alaska Airlines |

Member: Pierre Huggins
Staff Engineer
Air Line Pilots Association

## C. SUMMARY

On January 31, 2000, at about 1621 PST, Alaska Airlines flight 261, a Boeing MD-83, N963AS, crashed approximately 2.69 miles north of Anacapa Island, California into the Pacific Ocean. The flight, from Puerto Vallarta, Mexico to Seattle, Washington with an intermediate stop in San Francisco, was operating under title 14 CFR part 121. All 83 passengers and 5 crewmembers were fatally injured and the aircraft was destroyed. Visual meteorological conditions prevailed at the time of the accident.

This study examines the motion of Alaska Airlines flight 261 (ASA261) and correlates when various events occurred. Flight Data Recorder (FDR) data, Cockpit Voice Recorder (CVR), Federal Aviation Administration (FAA) radar data, weather data, and Air Traffic Control (ATC) communication data were used to develop the time history of the accident aircraft motion described in this report. Composite plots will graphically show the location and orientation of the airplane when key events occurred. Additional studies were performed at the Safety Board and at Boeing Commercial Airplane Company using aerodynamic data provided by Boeing.

## D. DETAILS OF LABORATORY INVESTIGATION

### Section I - Radar Data

Air Route Surveillance Radar (ARSR) data was obtained from the FAA's Los Angeles Air Route Traffic Control Center (ARTCC), output using the National Track Analysis Program (NTAP). Airport Surveillance Radar (ASR) data was acquired from several airport facilities in the Southern California Terminal Radar Control (SOCAL TRACON) area, and from the United States Air Force 84th Radar Evaluation Squadron (USAF RADES). ASR radar normally records data approximately every 4½ seconds, but NTAP data is only recorded every 12 seconds. Both secondary radar returns and primary[1] radar data were recorded in the various radar data sets. Alaska Airlines flight

---

[1] A "primary" only target is received as a reflection of radar energy only. A "secondary" or "beacon" only target is recorded as a response of the aircraft's transponder to interrogation by the radar system. A "reinforced" target is recorded by the radar system in lieu of a primary or secondary target when transponder information is coincident with and reinforces a reflection of radar energy. Generally, secondary and reinforced returns are referred to as "secondary" targets.

261 was initially recorded using a 4333 beacon code, switched to 2010 as the flight neared the United States - Mexican border, and changed to 7700 beacon code approximately 11 minutes prior to impact with the ocean.

The various radar data sources are listed in table I-1. Listed in this table with each radar source is the antenna location used for each radar source, and approximate distance from the antenna to the location of the wreckage of ASA 261.

Table I-1

| Radar Site | Antenna Location | Radar Type | Approx. Distance | Magnetic Variation |
|---|---|---|---|---|
| Los Angles Airport (LAX) | Los Angeles, CA (2 Antennas) | ASR - 9 | 47 NM | 14° E |
| Burbank Airport | Burbank, CA | ASR - 9 | 50 NM | 15° E |
| Santa Barbara Airport | Santa Barbara, CA | ASR - 8 | 33 NM | 15° E |
| Air Force RADES | San Clemente Island, CA,<br>Paso Robles, CA and<br>Mount Laguna, CA | ARSR | 85 NM<br>92 NM<br>164 NM | N/A |
| LA ARTCC | Los Angeles, CA and<br>Boron, CA | ARSR | 53 NM<br>106 NM | N/A |

The accuracy of the radar returns decreases with increasing distance from the radar sites. Since the relative distances of all the radar sites are different, there is a differing amount of error in the position of the aircraft determined from each radar source. An effort was made to account for the error in each radar data set, such that the best alignment of all radar data sets was achieved. The typical range for the ASR antennas is approximately 60 miles, so ASR information was obtained from those sites that captured the radar returns for the final portion of the flight. The USAF RADES data were obtained to capture the flight from the initial radar contact with the RADES facilities[2] to the final radar return.

The ASR range/azimuth transponder secondary radar data and primary radar data for the accident flight was provided by the FAA. The raw LAX ASR and Santa Barbara ASR data are tabulated in attachments 13B-1 through 13B-8, which shows the radar clock time, range from the respective ASR radar antenna, magnetic azimuth angle, and flight level, and the converted x-y distance and latitude-longitude data. The

---

[2] RADES radar contact with ASA261 begins when the flight is in Mexico airspace, approximately 1 hour and 30 minutes before impact with the ocean. Radar data was not recorded during the flight's departure from Puerto Vallarta.

format supplied by the FAA contains time in hours, minutes, seconds, range from the radar site in nautical miles (NM), azimuth in ACP's (4096 ACP's = 360°), flight level in 100's of feet-msl, and beacon codes (4333[3], 2010 and 7700). The range-azimuth-altitude format for each data set was converted to x-y-altitude format relative to the respective radar antenna using the appropriate magnetic variation for each radar site. In this converted x-y coordinate system, x represents true east and y is true north in nautical miles from the radar antenna. NTAP data and USAF RADES data was obtained in latitude-longitude-altitude format, as shown in attachments 13B-9 through 13B-43, and are similarly converted to the same x-y-altitude coordinates as the ASR data sets.

A plot of the USAF RADES data overlaid on a map of US and Mexico is given in Attachment 13C-1. This plot shows all of the radar data recorded by the USAF RADES faclities, and shows the earliest radar returns recorded of flight 261 while the flight was in Mexican airspace. The entire track corresponds to ASA flight 261 as it was using transponder codes 4333, 2010, and 7700.

Since the transponder altitude data recorded in every data set is obtained from the aircraft, the time of day of the radar data must be adjusted to be consistent in altitude and time. The time of day at the airport ASR facilities is set at each facility, such that each ASR facility could have slightly different time of day. In this study the time of day used as the standard time is from the Los Angeles TRACON ASR data from LAX Airport data, which covers the flight as it enters US airspace to the accident site. Comparison of the altitude data for the LAX ASR's, the Burbank ASR, NTAP, and RADES data showed no offset in time required. An offset of 10.8 seconds was subtracted from the ASR radar data from Santa Barbara airport to align with the time of day from the LAX ASR and NTAP radar data sets.

A plan view of the LAX ASR radar data ground track overlaid on a map of the area, labeled with the altitude and selected ATC transmissions[4] and UTC time of day for several radar data points, is shown in attachment 13C-2. This map and overlay shows the airplane while it was using a 2010 beacon code and crossing into United States airspace to the last recorded radar return. The LAX ASR first records the aircraft at 1545 PST, headed in a northwest direction. At 1610 PST, during the first loss of altitude, the airplane switched to a 7700 beacon code.

A graph of the radar transponder altitude versus time of day is given in attachment 13C-3 from several radar sources is included in this plot. Each radar source interrogates the target and receives altitude information at different times, such that when all transponder altitudes are plotted together, the frequency of recorded

---

[3] This beacon code was used when the RADES radar first recorded the flight. The flight switched to a 2010 beacon code at 2352:09 UTC (1552:09 PST).

[4] For a complete transcript of Air Traffic Control communications, see the Air Traffic Control Group Chairman's Report.

altitude is typically greater than once every two seconds. Between all the radar sources, altitude was recorded during the final descent down to 1600 feet altitude. Attachment 13C-4 shows the altitude data from the LAX ASR versus local time with selected ATC transmissions overlaid on the plot. Noted on this plot are two discernable losses of altitude, or pitchdown events. These events are referred to in this report as the first and second pitchdown.

Shown in Attachment 13C-5 is the final 5 minutes of the ASR radar data plotted in latitude-longitude coordinates, and includes secondary radar data from the LAX ASR, and several primary returns. Primary radar data is included from the the LAX ASR, Burbank Airport ASR, ARTCC NTAP, and USAF RADES. This primary radar data that is recorded after 1619:30 PST in the area of ASA261 is listed in tabular format in Attachments 13B-44 through 13B-46. The initial primary returns shown first appear immediately after the aircraft begins its descent from 17,900 feet, and appear traveling in a south-southeasterly direction, in the opposite direction of the secondary returns. Winds obtained from a sounding in the area at 0000 UTC (1600 PST) showed winds at 16,000 feet to be 30 knots at 335 degrees true, and at 20,000 feet to be 46 knots at 320 degrees true[5]. Additionally, one primary return recorded at 1620:53 PST in the USAF RADES data contained a radar-derived height of 17,800 feet. The RADES system has the capability to estimate the altitude of primary targets with a certain degree of accuracy. This capability is only available from antennas that have been specially modified for this purpose. The published[6] root-mean square accuracy of the height estimated by the radar system is +/- 3000 feet. The RADES primary return at a height of 17,800 feet was recorded at the same time when the secondary radar for ASA261 showed a transponder altitude of 1800 feet. The several other primary returns from the LAX ASR, Burbank ASR, and NTAP were recorded without an estimated height.

## Section II - Time Correlation

A time correlation was made between the ASR radar data sets, NTAP radar data, RADES radar data, FDR data, CVR transcript data, and Air Traffic Control (ATC) radio transmission transcript data. Times indicated with the SOCAL TRACON ASR radar data were used as the reference time, and FDR, CVR, and ATC clocks were adjusted accordingly. Times given in this report are in 24-hour format, in the form HH:MM:SS pacific standard time (PST). The FDR and CVR record information relative to an elapsed time in seconds, and are assigned a time of day correlation using the technique outlined below.

---

[5] See the Meteorological Group Chairman's Factual Report for a complete description of the weather conditions at the time.

[6] Both the FAA and 84th RADES have documented the capabilities of the radar sensing antennas in their respective technical manuals.

## FDR/CVR Time Correlation

To correlate the elapsed time recorded on the FDR with the elapsed time recorded on the CVR, a comparison of the microphone keying on/off times from the FDR data was made with the start/stop times of the radio transmissions recorded on the CVR. The FDR records at one-second intervals whether the aircraft radio microphone is keyed “on” or “off”. Initially, all the microphone keyings are used to get a rough correlation of the FDR and CVR elapsed times. However, since the microphone keying is recorded on the FDR only once per second, the FDR is a less precise determination since the FDR may record a microphone keying (or end of keying) up to 0.99 seconds after the event actually occurred. The CVR recording provides a much more precise reference time for each radio transmission in terms of the CVR elapsed time, typically to within 0.1 second.

The increased accuracy of the CVR microphone interval versus the FDR interval is shown schematically in Figure 1. In this figure, a typical microphone keying recorded on the FDR is shown by the blue triangles. For the same time period, the CVR recording provides a more precise interval of microphone keying (denoted by the red lines). However, for this interval, many other time offsets of the same interval from the CVR also fit the interval defined by the FDR sampled at once per second. An example of another offset of a fraction of a second for the CVR interval, which also matches the FDR indication, is denoted by the red dotted line on the schematic diagram.

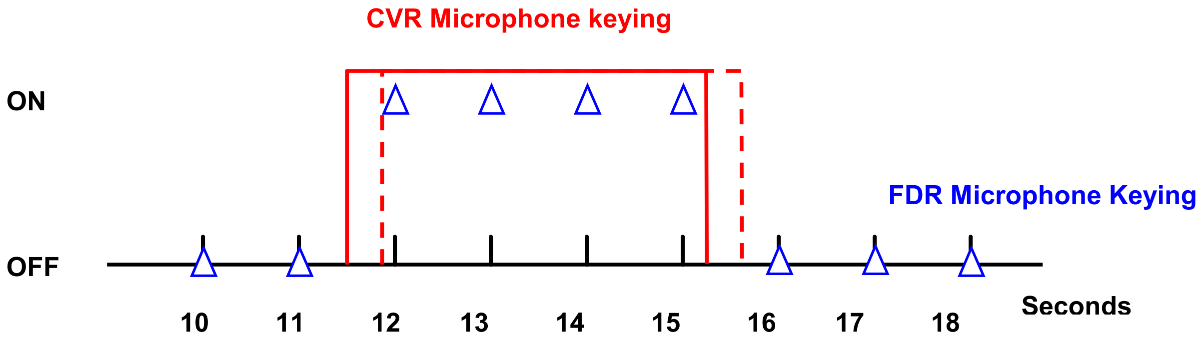

Figure 1

To obtain a correlation and offset which best fits all of the “on” and “off” indications, the earliest FDR time and latest FDR time that could correspond to a keying were determined for several radio calls recorded on the CVR, and the corresponding microphone keying on the FDR. For example, in the schematic shown in figure 1, the FDR time that corresponds to the “off” indication could be as early as 15.01 seconds, and as late as 16.0 seconds. To provide bounds to the correlation, a linear regression was performed using the earliest time and latest time for every keying to find a linear correlation[7] of the “early” and “late” times with the CVR indication. Thus an “early” correlation was determined, and a “late” correlation was determined. The final linear correlation was determined within the bounds defined by the “late” and “early” correlation. Within the bounds, the correlation was adjusted such that the optimum agreements for all microphone keyings were obtained, with particular attention to the events near the end of the recordings. Additional correlation points of the CVR and FDR adjusted time was provided by other common events recorded on both devices such as the indication of autopilot disconnects, flap and speed brake handle movements, and other events. For additional information on the FDR/CVR elapsed time correlation, see Exhibit 12B, Timing and Correlation Study – Cockpit Voice Recorder.

## FDR/Radar Time of Day Correlation

Once the FDR and CVR elapsed times were correlated with each other, the elapsed times were correlated to a time of day clock. A comparison of the radar altitude versus local time for the several radar data sets and FDR altitude versus elapsed time was used to correlate the radar data time of day to the FDR data elapsed time. As discussed in a previous section, transponder altitude data was recorded from several radar facilities. All of the radar systems from the SOCAL TRACON utilized the same time of day clock, and this time of day was also consistent with the NTAP and RADES radar time of day. The comparison of the FDR altitude and radar altitudes yield a correlation of

Subframe reference number on FDR 90667.37 = 0000:00 UTC (1600:00 PST)

With this correlation applied to the FDR and CVR data, the ATC transcript provided an additional check of the correlation for the radio transmissions. Attachment 13C-6 shows FDR derived mean sea level altitude and ASR radar altitude versus local time, using the time correlation given in this section. All the FDR, CVR, and radar data in this report are given in the correlated local time (PST).

---

[7] Depending upon CVR tape speed, the correlation may not be linear. It was determined in this case that the linear correlation was as accurate as any non-linear correlation.

## Section III - Radar/FDR/CVR Overlays

Radar data, certain air traffic communications data, relevant FDR and CVR events are used to graphically depict the flight of ASA261. The FDR data for the final twelve minutes of the flight are shown in Attachment 13C-7. Plots of the data with increased scales to capture the pertinent parameters during the first and second pitchdown are given in attachments 13C-8 through 11. Paraphrasing of selected CVR events[8] are also shown overlaid on plots of the FDR data shown in the attachments for selected portions of flight 261[9]. Parameters shown in these plots are presented versus correlated local time. Attachment 13C-8 shows selected FDR parameters near the time of the first descent from 31,000 feet, as identified in the radar altitude data. Attachment 13C-9 details several FDR parameters in the minute before the second pitchdown from 17,900 feet, and 13C-10 has an expanded time scale for the 15 seconds prior to the second pitchdown to examine the short duration dynamic events during the second pitchdown. Attachment 13C-11 shows the parameters in different scales to capture the larger range behavior after the descent from 17,900 feet described in the next section.

## Section IV - Flight Path Description

Information from the FDR and CVR shows that at 1609:10 the airplane was cruising at 31,000 feet altitude, 304 knots airspeed, with the autopilot engaged and a stabilizer angle of 0.4 degrees. The FDR showed that up to this point in the flight, the stabilizer had not moved for the previous 1 hours and 31 minutes. The stabilizer last moved appreciably[10] during the ascent from Puerto Vallarta when the airplane was climbing through of 23,500 feet altitude at airspeed of 330 knots. At 1609:15 PST, a comment was recorded on the CVR by the captain about moving a switch, and at 1609:16 the autopilot parameter switched from “engaged” to “off”. Also at this instant, the sound of two faint thumps is heard on the CVR. Immediately after this autopilot disconnection, the FDR indicated the stabilizer (also referred to as pitch trim position on the FDR) started to move for the next two seconds to 2.4 degrees[11], slightly higher than the normal operational maximum airplane nose down position of 2.1 degrees. During this time, a sound similar to the stab in motion chime is heard on the CVR. The

---

[8] CVR dialogue will be included in “Supplement I to the Airplane Performance Study”, which will be released at the NTSB Public Hearing scheduled for December 13, 2000.

[9] For details of all the recorded FDR data for the entire flight, see the Group Chairman’s Factual Report – Digital Flight Data Recorder.

[10] There was a slight change in the pitch trim recorded in wordslot 55 at 1353:11, when the autopilot was disconnected. Wordslot location 39 did not record any change in position. For a description of the wordslot locations, see the Exhibit 10A Group Chairman’s Factual Report – Digital Flight Data Recorder.

[11] The normal operational range for the stabilizer is –12.2 to +2.1 degrees. In this report, a positive stabilizer angle corresponds to the airplane nose down direction, and physically corresponds to the leading edge of the stabilizer above horizontal.

stabilizer angle recorded on the FDR remained at 2.4 degrees (2.5 degrees recorded by FDR Word 55) until the last minute of the flight. As soon as the stabilizer began to move, the aircraft began to pitch in the airplane nose down (AND) direction.

Over the next several seconds, there was some oscillation in vertical acceleration between 0.5 and 1.0 g's, and the elevators began to be deflected in the trailing edge up (TEU) direction. At 1609:42, the airplane had descended to 29,450 feet, had accelerated to 323 KIAS, was at a pitch of -7.9 degrees (AND), and the elevators were deflected to -8 degrees TEU[12]. One second later, the speed brakes were deployed, and remained deployed for the next one minute and 30 seconds. At 1609:55, ASA 261 told ATC "…we are uh in a dive here", and the pitch attitude had stopped decreasing, remaining at -7.9 degrees nose-down. The pitch angle increased over the next several seconds as the descent rate reduced. At 1610:02, the sound of the clacker (overspeed) is heard on the CVR, as the maximum allowable airspeed of 343 knots is exceeded in the descent. The maximum airspeed attained in the descent, 353 knots, was reached by approximately 1610:16 and remained nearly constant through 1610:23 as the airplane was passing through 25,000 feet altitude. The pitch had increased to 4.9 degrees nose-up, with the elevators remaining near -11 degrees TEU.

The speed brakes were stowed at approximately 1611:13, when the aircraft had decreased airspeed to 262 KIAS, increased pitch to 4.6 degrees, arrested the descent rate, and was remaining close to 24,500 feet altitude. The aircraft slowed to approximately 250 KIAS over the next 10 seconds. For the next 5 minutes the aircraft remained between 23,000 and 24,000 feet, and the airspeed increased to a maximum of 335 KIAS. During this time the elevators remained between -7 and -9 degrees TEU. At 1614:45, at an airspeed of 312 KIAS, the speed brakes are again deployed as the aircraft slows to approximately 264 KIAS and begins to descend from 22,000 feet. The airspeed remained relatively constant as the airplane descended from 22,000 feet. The elevators had relatively less oscillations in movement during this descent with the speed brakes deployed, as evident in attachment 13C-7 between 1615:00 and 1617:50. The speed brakes are stowed at 1617:50 when the aircraft has leveled off at approximately 18,000 feet, and has slowed to approximately 250 KIAS. The elevators were now operating in the range of approximately –10 to -12 degrees TEU, with the airplane pitch varying slightly between –1.5 and +1.5 degrees and the recorded stabilizer angle remaining constant.

At 1617:57, as the airplane was at 17,800 feet, and 250 KIAS, the leading edge slats parameter changed to "transit", and then "mid" two seconds later. The flaps started to move to 11 degrees approximately 8 seconds after the slats. The elevator deflection reduced slightly to -11 degrees as the flaps reached the extended position. The flaps remained at 11 degrees for approximately 21 seconds, until both the flaps

---

[12] The structurally available range of the elevators is +15 degrees trailing edge down (TED) to -25 degrees TEU.

and slats were returned to the retracted positions over the next few seconds. During this slat/flap extension, the pitch attitude remained close to 0 degrees, with only small perturbations of less than one degree.

Over the next 50 seconds after the slats and flaps were retracted, the airplane increased airspeed from 248 knots to 270 knots, while increasing pitch attitude slightly to over 4 degrees, and rising from 17,400 feet to 17,900 feet altitude. At 1619:09, a slight oscillation began in elevator angle, pitch angle, and vertical acceleration, which lasted approximately 15 seconds. At 1619:21, a sound of faint thump was recorded on the CVR. Also at 1619:21.5, a slight change of stabilizer position of +0.09 degrees is recorded on the FDR, the first change in stabilizer position since the previous change that initiated the descent from 31,000 feet 10 minutes' prior. Within 2 seconds after the slight change in stabilizer position, the oscillations in pitch and elevator angle cease, and vertical acceleration remains close to 1.0 g's.

Table IV-1 shows a chronological sequence of selected key events from the FDR and CVR in the seconds immediately prior to, and the initial seconds of, the second pitchdown. The FDR events described in this table reflect the time the parameters were recorded on the FDR, and for rapidly changing parameters does not capture the behavior between the data samples on the FDR.

At 1619:35.2, with the airplane at 17,900 feet, 270 knots, and pitch angle steady at close to 2 degrees, and rudder near zero, the flap changed to 7 degrees, indicating another deployment of the flaps. The longitudinal acceleration shows a corresponding 0.07 g's change in value corresponding to an increased deceleration as the flaps deploy[13]. At 1619:36.1, the left elevator parameter recorded a value of –12 degrees, the right elevator recorded –11 degrees, consistent with the values over the preceding several seconds. A vertical acceleration of approximately 1.0 g was also recorded at this time.

A loud noise was recorded on the CVR at 1619:36.6. Also at 1619:36.6, the right elevator parameter recorded a value of -25 degrees. All elevator values recorded after this time far exceeded the physical ranges of the elevator system on the airplane, and were considered to be invalid. By the time of the next vertical acceleration recording on the FDR at 1619:36.6 (one-eighth of a second after the previous sample), the vertical acceleration had increased to 1.45 g from 0.99g. The vertical acceleration then dropped to 0.67 g's by 1619:36.9, as the longitudinal acceleration had increased to -0.31[14]. The pitch angle starts to change to the AND direction at the next recorded pitch angle at 1619:36.9.

---

[13] Up to this point, the change in longitudinal acceleration has the same character as the previous flap deployment.

[14] In the coordinate system used, a negative longitudinal acceleration is a decelerating relative to the direction of flight.

**Table IV- 1** Key Events from 1619:20 to 1619:37.5

**Conditions at 1619:20:** 17,950 ft., 266 KIAS, 2.2° pitch, left and right elevators -10°, flaps zero, Word 39[15] pitch trim 2.42°, Word 55 pitch trim 2.51°.

| **Time (PST)** | **Data Source** | **Event** |
|---|---|---|
| 1619:21.1 | CVR | Sound of faint thump |
| 1619:21.49 | FDR | Word 55 Pitch trim changes +0.089 |
| 1619:22.24 | FDR | Word 39 Pitch trim changes +0.119 |
| 1619:27.49 | FDR | Word 55 Pitch trim changes +0.03 |
| 1619:31.49 | FDR | Word 55 Pitch trim changes +0.03 |
| 1619:32.8 | CVR | Sound of two clicks similar to slat/flap handle movement |
| 1619:35 | FDR | Airspeed 270 KIAS, 17,900 ft altitude |
| 1619:35.24 | FDR | FDR Flap position changes to 7.1° |
| 1619:35.63 | FDR | Right elevator position at –11.09° (last recorded position within physical limits of elevator) |
| 1619:36.13 | FDR | Left elevator position at –12.01° (last recorded position within physical limits of elevator) |
| 1619:36.24 | FDR | FDR Flap position changes to 10.6° |
| 1619:36.6 | CVR | Sound of loud noise |
| 1619:36.63 | FDR | Right elevator records -25° |
| 1619:36.66 | FDR | Vertical acceleration increases 0.46g from last sample (0.125 seconds prior) to 1.45g |
| 1619:36.79 | FDR | Vertical acceleration records 1.31g |
| 1619:36.83 | FDR | Longitudinal acceleration changes<br>-0.21g from last sample (0.25 seconds prior) to –0.31g |
| 1619:36.91 | FDR | Vertical acceleration records +0.67g |
| 1619:36.94 | FDR | Pitch attitude records –2.01° |
| 1619:37.08 | FDR | Longitudinal acceleration records<br>–0.23g |
| 1619:37.13 | FDR | Left elevator records +75° |
| 1619:37.43 | FDR | Pitch attitude records –11.05° |
| 1619:37.54 | FDR | Vertical acceleration records<br>–1.05g |

The next several seconds of data show a maximum pitch rate in the nose down

---

[15] Each second of FDR data is divided and recorded in 64 wordslot locations. Some FDR parameters are recorded in more than one wordslot location. The Pitch trim position was recorded in two wordslots, each word recorded once every two seconds. Pitch trim is recorded at 39/64 of one second, the next second at 55/64 of the second, and so on, for an average recording frequency of once per second. For more details, see the Group Chairman's Factual Report – Digital Flight Data Recorder.

direction of close to 25 degrees per second, and the vertical acceleration quickly changes negative and reaches a minimum of –3 g's within 3 seconds. The airplane also begins to roll in the left wing down direction (LWD) by 1619:40, and the rudder had been deflected to +3 degrees to the right by this time. When the airplane reaches its maximum AND pitch attitude of approximately -80 degrees by 1619:42, the roll angle was passing through -76 degrees (LWD) and decreasing rapidly. The vertical acceleration had increased to –1.45 g, and then decreased to –2.1 over the next two seconds. By 1619:45, the lateral acceleration had increased to -0.80 g, as the vertical acceleration now increased to –1.75 g.

The recorded data indicate that the airplane rolled to –180 degrees (inverted) by 1619:45, as the pitch angle increased to –28 degrees. By this time, the airplane had descended to 16,420 feet and airspeed had decreased to 209 KIAS. The recorded left aileron was deflected to over +15 degrees (to command RWD) by 1619:52, then in the opposite direction to –13 degrees (LWD) over the next six seconds. The rudder returned to near 0 degrees by 1619:57, as the flaps were retracted, and as the airplane experienced a lateral acceleration of 0.63 g's, was rolling through –150 degrees, and had a nose down pitch of -8 degrees. The airplane remained near inverted and oscillated in pitch between –30 degrees and 0 degrees over the next minute. Several control parameters, such as rudder and aileron are moved considerably during the final minute. The large-scale deviations and oscillations in the flight parameters are shown in Attachment 13C-11. The airplane also experienced several oscillations in vertical and lateral accelerations until impact with the ocean.

## Section V – Simulation Studies

Safety Board Vehicle Performance Group staff and Boeing conducted several performance studies using six degree of freedom engineering simulator models in support of the Aircraft Performance Group investigation. Boeing and the NTSB staff performed these simulations under the direction of the Performance Group Chairman, and results of these simulations were regularly reviewed with the members of the Performance Group. Boeing utilized their existing engineering simulation for the MD-90 aircraft.

The MD-90 has some physical differences from the MD-80, including a slightly longer fuselage, and larger engine nacelle and pylon. The tail structure of the MD-90 includes a cambered outboard leading edge and hydraulically powered longitudinal control surfaces (control tabs). However, the MD-90 aerodynamic data set a utilized a larger range of dependent parameters such as angle of attack, and consequently produce a larger range of solution validity when deviations from normal flight regimes were encountered. By utilizing the greater range MD-90 aerodynamic data and accounting for the differences in the control tab operation, aerodynamic data similar to the MD-80 was produced. The Aircraft Performance Group determined early in the investigation that, despite these slight differences, the MD-90 aerodynamic data set would be useful for the simulation and kinematic studies. The overall validity of the MD-

90 and MD-80 aerodynamic data used and its applicability to the accident sequence is still under investigation by the Aircraft Performance Group.

The NTSB used a kinematics program incorporating the MD-80 and MD-90 aerodynamic data obtained from Boeing. The NTSB also used its six-degree of freedom engineering simulation program using the MD-80 and MD-90 aerodynamics. Separate simulations with different data sets and differing calculation procedures (simulations vs. kinematics) were used to provide additional validation of the respective aerodynamic data sets, and separate validation of the results obtained.

The respective studies focused on trying to reproduce the FDR flight data parameters such as altitude, airspeed, orientation angles, etc. by using the same control inputs recorded on the FDR (elevator, stabilizer angle, aileron, engine torque, etc.) in the simulation models. The kinematics studies provided a different approach by calculating the control deflections required to match the airplane response on the FDR, and provided an estimate to use for control inputs into the simulations when the control inputs recorded on the FDR did not produce the same response in the simulations as recorded on the FDR.

The results from the simulation and kinematics should not be viewed as exact representations of what occurred on Alaska Airlines flight 261. The results are constrained in their accuracy by the limitations on the aerodynamic data sets used in the simulations and kinematics studies. The aerodynamic data used was originally developed during the initial development and certification of the airplane, and intended to be used in training and flight simulators. The original accuracy of the aerodynamic data, when compared to flight test or wind tunnel results, was only required to be within one degree for most parameters such as stabilizer angle and elevator deflection. Therefore, the simulation and kinematics results for surface positions can contain a certain amounts of inherent error when compared to real world situations, such as the accident scenario. Additionally, the aerodynamic data has bounds on its flight regimes (altitudes, Mach number, local angle of attack, etc.) where it is considered valid to within the original intended accuracy. If the flight parameters used in the simulations and kinematics exceed the bounds of the aerodynamic data sets, the inaccuracy of the results increases. Within the bounds of the aerodynamic data sets, the results should only be considered accurate to within one degree of surface deflection.

The results presented in this section are the results of the initial simulations and kinematics studies performed. As of the date of this report, the studies are continuing and further results will be published in an Addendum to the Group Chairman's Aircraft Performance Study.

## A. Initial Simulations

The initial focus of study was the initial pitch in the airplane nose down direction that occurred at 1609:16 after the autopilot disconnected while the airplane was cruising at 31,000 feet. An initial simulation was performed by Boeing using the MD-90 aerodynamic data bank, the control inputs, and stabilizer angle as recorded on the FDR. The results of the simulation were compared with the FDR time histories of altitude, airspeed, pitch, etc. The flight was examined during the cruise portion, prior to the autopilot disconnect at 1609:16. A reasonable estimate for the weight of the aircraft was obtained from the Operations Group Chairman, and from information on the CVR. Simulations and kinematics results indicated that prior to the autopilot disconnect, the recorded values of stabilizer, elevator position, aileron, and rudder produced the same airplane responses as recorded on the FDR during the cruise condition before 1609:16.

The Boeing and Safety Board simulation results showed a considerable difference from FDR data for airplane response in the seconds after the autopilot disconnect and subsequent pitch-down at 1609:16. Using the stabilizer angle as recorded on the FDR, the simulations were performed using the elevator control inputs evident in the FDR data. These results show that the airplane would have an entirely different response than recorded on the FDR. The simulations showed the airplane would have recovered quickly and climbed considerably using the stabilizer angle and elevator positions and movements indicated on the FDR. This finding indicated that the FDR recorded values of the longitudinal controls (i.e. stabilizer angle and/or elevator angles) were not accurate representations of the actual positions on the accident airplane after the first pitch-down.

The kinematics study was initially performed utilizing two approaches. First, by assuming the stabilizer was accurate and calculating the elevator required, and secondly by assuming the elevator was accurate, and calculating the stabilizer required. The CVR contained information regarding the stabilizer operation and position, and discussions with the System Group, Structures Group and Metallurgy Group chairmen revealed that structural damage indicated that the stabilizer position could have been different than that recorded on the FDR after the autopilot disconnect at 1609:16[16]. Preliminary three degree of freedom simulations for the initial pitchdown found favorable matching with the trends seen in the FDR data by using a constant, increased offset in the stabilizer position and the recorded elevator position. Hence in the further kinematics and simulator studies the elevator position was assumed to be accurate as recorded on the FDR, and the stabilizer angle was assumed to be inaccurate as recorded after 1609:16.

The results from the kinematics study, which directly calculate the control surface positions required to match the FDR angular and position data, are shown in

---

[16] See the Structures Group Chairman's Factual Report, the Systems Group Chairman's Factual report and the Metallurgy Group Chairman's Factual Report for details of the structural damage.

Attachment 13C-12. Also shown is the result from Boeing using their Generic Stability Code (GSC), calculating the stabilizer required to trim the airplane at the flight condition and elevator indicated on the FDR at each point. The GSC trim calculation was performed at several hundred points between the first and second pitchdown, represented by the blue curve on the plot.

The results for the kinematics calculation procedure, utilizing the aerodynamic data tables for both the MD-90 and MD-80, show a slight difference in the calculated stabilizer angle for the entire time range examined. The difference in the results from the two sets of aerodynamic data demonstrates the error that can occur in this type of calculation, considering the MD-80 and MD-90 slightly differing aerodynamic data sets. However, results from both data sets and both calculation procedures are predominantly within the one-degree of accuracy expected from the aerodynamic data.

Data is shown for the flight from the time of the first pitchdown from 31,000 feet, until the second pitchdown from 18,000 feet. Also shown in this plot are FDR recorded parameters for Mach number and speed brake deployment. These are two parameters that have an influence on the calculated results, in that there are terms in the mathematical equation for the airplane pitching moment that are dependent upon Mach number, and there are terms which are added to the equation when the speed brakes are deployed. The pitching moment is dependent on several factors and includes effects of many configuration changes; these two parameters are shown to demonstrate the dependency of the calculated stabilizer angle on other varying parameters. For example the calculated stabilizer angle shows a slight correlation with Mach number, such that calculated stabilizer angle decreases with increasing Mach number, primarily when the speedbrakes are not deployed. The trend is also influenced by several other parameters not shown on this plot.

Attachment 13C-13 shows a finer detailed chart of the GSC and kinematics results for the initial seconds after the first pitchdown. The results show the calculations matching the cruise value for stabilizer angle of 0.4 degrees before the pitchdown. At 1609:16 when the autopilot is disconnected, and the FDR[17] shows the stabilizer starting to move, the calculated values increase also. When the FDR value levels and remains at 2.4 degrees (0.3 degrees greater than the maximum operating value of 2.1 degrees[18]), the calculated values from both methods show the required stabilizer to continue to increase. The calculated value tends not to be converged on a single value as the pitchdown progresses, and should be considered an estimate based on the limitations of the aerodynamic data discussed previously. The kinematics solution does

---

[17] For clarity, only one wordslot location (word 39) is displayed. An additional wordslot location (word 55) for Pitch trim is included in the FDR data

[18] For additional information on tests performed to examine the FDR recording and systemic actions when a MD-80 stabilizer is rotated beyond the operational limit of 2.1 degrees, see Exhibit 9A, the Systems/Powerplants Group Chairman's Factual Report of Investigation, pp 44-46. See also the FDR data plots in Exhibit 9-I, Tulsa Ground Test Data.

not converge between 1609:30 and 1609:35, and for several seconds after 1609:40, when the speedbrakes are deployed in the descent. The trend for all calculation procedures show the required stabilizer angle to be higher than that recorded on the FDR. For the time period examined, the calculated results using the different methods and aerodynamic data are predominantly within one degree.

The effects of configuration parameters are evident in attachment 13C-13. At 1609:43 when the speed brakes were deployed, the kinematics solution could not converge on a solution for several seconds of data. The GSC solution jumps to a higher value and is somewhat oscillatory at this time also, showing the effect of the added terms to the pitching moment equation used to calculate the stabilizer angle.

The kinematics solutions indicate that in order for the airplane to pitch nose down as recorded and utilizing the elevator position recorded on the FDR, the stabilizer must have moved beyond its FDR recorded value of 2.4 degrees. A more precise value of stabilizer angle required is still under investigation by the Aircraft Performance Group[19], and the results shown here should be considered accurate only to within one degree. For example, a kinematics solution of stabilizer angle of 4.0 degrees, could be representative of a stabilizer angle on the accident airplane of anywhere between 3.0 and 5.0 degrees.

Results for the minute preceding the second pitchdown are shown in Attachment 13C-14. The calculations for this maneuver were complicated by the FDR recording of left and right elevator, which both quickly transitioned to values greater than physically possible, at a rate greater than physically possible, immediately after the sound of loud noise at the start of the second pitchdown. Thus, the actual value of elevator position after the last recorded value at 1619:36 was considered to be unknown. To help bound the problem, initial simulations were performed by Boeing. A first study examined the pitch rate that can be developed by a stabilizer in the full operational AND position (+2.1 degrees), and maximum AND elevator input (15 degrees trailing edge down). Using the longitudinal controls in the maximum AND position, the airplane nose down pitch rate would be 18 degrees per second. A second study indicated that in order to generate the pitching moment required to obtain the pitch rate observed in the FDR data (25 degrees/second), with flaps at 11 degrees and elevators in a full nose down position the stabilizer would have to move to 13 degrees. The pitching moment generated from the tail has contributions from both the stabilizer and the elevators. If a single pitching moment and a range of stabilizer position is considered, many combinations of stabilizer angle and elevator angles can produce the pitching moment generated by the tail. Consequently, a calculation using the pitching moment required to match the FDR data at the second pitchdown and elevator angles less than the full airplane nose down position would result in a stabilizer angle higher than 13 degrees.

---

[19] Further results from kinematics studies and simulations will be published in an Addendum to the Group Chairman’s Aircraft Performance Study.

The results in attachment 13C-14 were calculated for the last minute and 45 seconds prior to the sound of the loud noise heard on the CVR at 1619:36.6. During this portion of the flight, the leading edge slats and flaps were extended for approximately 21 seconds. The FDR recorded the flaps reached 11 degrees by 1618:10. The movements of the flaps used in the kinematics solutions are noted on this plot, and are not exactly timed with the movement of the flaps recorded on the FDR. As an approximation, the flaps input to the kinematics were moved to the 11-degree position in the calculations at 1618:08, and fully retracted by 1618:37. The calculated stabilizer angle shows some additional variation as the flaps are moved, detailing the influence of the additional configuration change. The kinematics solution converges on a somewhat more stable solution after the flaps were fully stowed at 1618:39. Also shown on this plot for comparison is one channel of the FDR recorded stabilizer position, which had remained constant since 1609:20. The recorded stabilizer position changes value slightly at about 1619:21. This slight change in position is almost concurrent with the sound of a faint thump heard on the CVR. After this sound of faint thump, a slight trend in higher stabilizer position is noted in all calculations. After 1619:36.6, the time of loud noise heard on the CVR, the calculated value of stabilizer position shows a considerable, sudden increase.

Kinematics results using both data sets, and the results from the Boeing GSC simulation all show a similar trend. The kinematics results and the GSC results all show a relatively steady and consistent stabilizer angle in the minute prior to the second pitchdown, followed by a large increase in stabilizer angle at approximately the time of the loss of elevator data on the FDR, and the loud noise recorded on the CVR.

The kinematic calculations fail to converge soon after the FDR parameters start large variations during the second pitchdown. The Aircraft Performance Group is still as of this date in the process of determining the means by which the calculations fail to converge during the initial stages of the pitchdown. The highly dynamic behavior of the airplane during the pitchdown leads to inaccuracies in the calculations, and the airplane quickly enters flight regimes well beyond normal operational flight regimes for which the aerodynamic data is not validated. Additional factors which hamper the calculation accuracy include: the value of elevator position which cannot be accurately established during the pitchdown; the flaps which had started a flap deployment immediately prior to the large increase in AND pitch rate, and were in transit when the second pitchdown occurred. The flap deployment affected the ability of the kinematics to attain an accurate solution, since this flap deployment is at a higher airspeed than the validation conditions for the flaps 11 degrees aerodynamic data. Due to these factors, the exact value that the stabilizer attained in the initial stages of the second pitchdown is not presently determinable. However, the trend of the calculated stabilizer position shows, along with the static calculations by Boeing mentioned earlier, that the stabilizer had to attain a much higher value than evident prior to the second pitchdown. Additionally, the stabilizer had to move in a relatively quick fashion, attaining the much higher values within fractions of a second of starting to move.

## SIMULATIONS SUMMARY

The kinematics and simulations performed are not yet able to determine the stabilizer angle of ASA 261 during the final eleven minutes of flight to within an accuracy of plus or minus one degree. The studies do show that performance of the airplane is consistent with the stabilizer position moving beyond its recorded value of 2.4 degrees during the first pitchdown at 1609:13. The studies also show that the performance of the airplane during the second pitchdown is consistent with the stabilizer quickly moving to a higher leading edge up position at the second pitchdown by 1619:37, just after the time of the loud noise recorded on the CVR.

[redacted]

Daniel R. Bower, Ph.D.
Aerospace Engineer
Aircraft Performance Group Chairman