

REPORT

**on the investigation into the crash of A310-308,
registration F-OGQS, on 22 March 1994 near the city of Mezhdurechensk**

1. General information

On 22 March 1994, at 17:58 (here and throughout, times will be given in hours and minutes UTC), 00:58 local time, an A310-308 (registration F-OGQS) operated by the state subsidiary Russian Airlines crashed 91 km. from Novokuznetsk Airport while on a scheduled passenger flight from Moscow to Hong Kong. The accident occurred at night in good weather.

The aircraft was owned by the European Bank and registered in France. It had been leased by Aeroflot-Russian International Airlines.

The aircraft was operated by the state subsidiary Russian Airlines (RAL).

The aircraft was carrying three flight crew members, a cabin crew of nine, 63 passengers (including 25 foreigners), and 593 kg of mail and baggage.

The aeroplane took off from Sheremetyeva Airport at 13:39. The mass at take-off was 145 tonnes, c. of g. 26.7%. Thirty-nine minutes after take-off, the aeroplane reached an altitude of 10 100 m (here and throughout, altitudes and flight levels will be given in metres), and until 17:47 it continued on route without deviating from the flight plan at a speed of 530 km/h (here and throughout, IAS will be given in km/h).

Seven minutes and twenty seconds after an exchange of radio messages with the Novokuznetsk controller, the aeroplane banked steeply to the right, stalled and entered a spin. At 17:58 the aeroplane struck the ground.

The accident occurred in the foothills of the Kuznetskii Ala-Tau, on the north-east slope of a 600 m hill with mixed forest cover and a 1.5 m layer of snow. The coordinates of the accident site are: 53°30'N 88°15'E.

The aircraft struck the side of the hill at an elevation of 400 m at a high vertical speed with landing gear, flaps and slats retracted and engines operating. The aeroplane was totally destroyed on impact and partly burned by the fire that broke out on impact with the ground. All crew members and passengers on board perished.

The accident investigation was carried out by a Government Commission appointed under Russian Government order no. 370-P of 23 March 1994 and chaired by V. B. Efimov of the Ministry of Transport of the Russian Federation.

The official investigation into the circumstances and causes of the accident was carried out by a commission appointed under order no. DB-29 issued by the Director of the Air Transport Department of the Russian Ministry of Transport on 22 March 1994. The commission consisted of:

Chairman

I. E. Mashkivsky: head of the Principal Civil Aviation Safety Inspectorate of the Russian Federation and deputy director of the Air Transport Department.

Vice Chairman

V. B. Mikriukov: first deputy head of the Regional Air Transport Administration of Western Siberia (flight operations)

Members of the commission

V. B. Afanasieva: chief specialist of the Principal Civil Aviation Safety Inspectorate of the Russian Federation.

V. A. Karpova: deputy department head of the ATC organization Rosaeronavigatsiia.

L. A. Kashirskovo: head of the aircraft accident investigation department of the Interstate Aviation Committee.

V. D. Mokrinskovo: chief of the certification division of Russian International Airlines.

B. Y. Pechenkina: deputy chief engineer for Russian International Airlines.

Y. F. Pyatanova: deputy general manager for air services of Russian International Airlines.

A. A. Subborina: section chief of the Principal Flight Safety Inspectorate for civil aviation of the Russian Federation.

L. E. Fedotova: deputy chief of the accident investigation section of the Air Transport Department.

Dates of investigation

Commenced: 22 March 1994

Completed:

Also participating in the investigation were representatives of the Ministry of Transport of the Russian Federation (Air Transport Department, "Rosaeronavigatsii"), the Ministry of Internal Affairs of the Russian Federation, the Ministry of Emergencies and Natural Disasters, the Federal Intelligence Service of the Russian Federation, the Interstate Aviation Committee, the Regional Air Transport Administration of Western Siberia, the State Scientific Research Institute of Civil Aviation, the Gromov Flight Test Institute, the fire protection research institute of the Ministry of Internal Affairs, the accident investigation bureau of France, the European consortium Airbus Industrie, and General Electric (USA).

The preliminary investigation was carried out by the Western Siberian transport procurator, with the participation of a representative of the Procurator General of the Russian Federation.

II. ANALYSIS

The analysis was based on an extensive study of digital and aural data from the flight recorders (DFDR and CVR), reproduction of the fatal flight on Airbus Industrie simulators and mock-ups at Toulouse, actual flights on the A310 using a specially developed programme, study and analysis of parts, assemblies and systems from the wrecked aircraft, and examination of the state and actions of the crew when the abnormal situation arose in flight.

On 22 March 1994, the A310-308 F-OGQS was on scheduled flight AFL-593 from Moscow to Hong Kong, piloted by a Russian Airlines crew consisting of pilot in command A. V. Danilov, back-up PIC Y. V. Kudrinsky, and co-pilot I. V. Piskarev (all Class I pilots).

The flight time from Sheremetova Airport (Moscow) was 13 hours 39 minutes.

The crew met the established training requirements. Preflight preparation at Sheremetova Airport was supervised by PIC A. V. Danilov.

The crew received their medical examination at the medical office of Sheremetova Airport. There were no comments on the medical status of the crew members.

The aircraft took off on a heading of 247° with slats deployed at 17°, flaps retracted and autothrottle engaged. Twelve minutes after take-off, the aeroplane reached an altitude of 9,100 m and flew at that altitude for 27 minutes, at a speed of 555 km/h and a magnetic heading of 036°.

At 14:18, the aeroplane climbed to 10 100 m and flew level at that altitude on autopilot ("navigation" submode) at a speed of 530 km/h until 17:47, altering its magnetic heading over successive waypoints. The pitch angle was approximately 1.5°, the true angle of attack 2°, engine speed 87-89% (cruise setting).

When the magnetic tape recording of the cockpit voice recorder (CVR) began at 17:26:52 (the CVR specifications provided for a recording of about 30 minutes of flight), the back-up PIC, Y. V. Kudrinsky, was sitting in the left seat and the co-pilot I. V. Piskarev was in the right seat. the pilot in command, A. V. Danilov, was resting in the passenger cabin.

From 17:40 on, RAL PIC V. E. Makarov, a Class I pilot flying as a passenger on the flight, and PIC Kudrinsky's children, 13-year-old Yana and 15-year-old Eldar, were in the cockpit.

At 17:43:30, Kudrinsky invited his daughter Yana to sit in the left seat ("Come and sit here now, in my seat, would you like that?"). Thus, at 14:43:31 he left his duty station. There was no formal transfer of control to the co-pilot and PIC Kudrinsky continued to be responsible for piloting the aeroplane.

By leaving his station without handing over control to the co-pilot, PIC Kudrinsky violated the provisions of paras. 7.1.4. and 7.1.5 of the civil aviation flight operations manual (NPP GA-85) and para. 4.4.2. of the Annex to the Convention on International Civil Aviation.

Notes:

1. "During the flight, flight crew members must be secured to their seats by means of their safety harnesses when at their stations." (NPP GA-85, para. 7.1.4.)
2. "The pilot in command must remain at his duty station throughout the flight. He may leave his station briefly when flight conditions are favourable. At such times, the co-pilot shall fly the aircraft and other members of the crew must be at their stations. Crew members are forbidden to leave their stations without the permission of the pilot in command." (NPP GA-85, 7.1.5.)

3. "All flight crew members required to be on flight deck duty shall remain at their stations except when their absence is necessary for the performance of duties in connection with the operation of the aeroplane or for physiological needs." (Annex 6 to the Convention on International Civil Aviation, para. 4.4.2. [sic; the paragraph cited is actually 4.4.4.2.- T.N.]

Between 17:43:34 and 17:43:37, Yana sat down in the left seat and asked to have the seat raised (17:44:10: Yana: "Dad, raise me up.") At 17:47:06, Kudrinsky invited his daughter to "fly the aeroplane a bit". ("Hey, Yana, are you going to fly it?" "Go ahead, take the controls.")

Between 17:47:10 and 17:50:44, the aeroplane turned left from a heading of 111° to 102° at the maximum allowable bank angle, 23°, then right to 115° at a bank angle of 15° (the maximum bank angle achievable in "navigation" submode). Two min. 40 sec. after beginning the manoeuvre, the aircraft returned to the planned heading of 102°. After the aircraft rolled out on this heading at 17:51:12, Yana left the captain's seat.

The investigation showed that PIC Kudrinsky carried out "Manoeuvre no. 1" in the following sequence:

- engaged the "heading select" submode (HDG/SEL);
- turned the heading select knob to the left by more than 15° from the initial heading;
- after reaching a left bank of 19-20°, turned the heading select knob to the right to return to the planned flight heading;
- upon reaching a right bank of 6-8°, engaged the "navigation" submode (NAV).

According to the DFDR, the difference in deflection of the right and left ailerons did not exceed one degree during manoeuvre no. 1. This essentially corresponds to the actual stretch and play in the linkage. The force applied to the control column(s) can therefore be considered to be insignificant, no more than 2-4 kg, an assumption that was confirmed in simulation. (Attachment 5).

PIC Kudrinsky thus showed his daughter how to change the aeroplane's heading and bank using the heading select function of the autopilot, while he himself was not at his station.

Notes:

"When the autopilot is engaged in command mode (CMD), the pilot flying shall himself establish the necessary values and select the required mode to obtain the results desired." (FCOM 02.02.03 PAGE 2).

[Translator's note: The original document was unavailable, so the above is a re-translation from Russian and will not correspond word for word to the English-language original.]

It should be noted that manoeuvres of the kind described above, using the heading select and normal autopilot modes, are covered in the Aeroplane Operating Manual. In this case, however, there was no situational need to carry out "Manoeuvre no. 1". It was executed as a demonstration for Yana and could be considered distracting for the crew.

During the 7.5 minutes that Kudrinsky's daughter occupied the captain's seat, father and daughter kept up a conversation that distracted the crew from the monitoring of the flight.

From 17:50:04 to 17:50:46, Piskarov spoke on the radio with Novosibirsk Control and Novokuznetsk Control, reported passing over Novokuznetsk and estimated arrival at waypoint Zakir at 17:59. The investigation established that at this time the co-pilot's seat was in its rearmost position but not pushed sideways.

At 17:51:55, Kudrinsky's son Eldar, with his father's permission, took the left pilot's seat vacated by Yana. V. E. Makarov, who was in the cockpit, took a picture or videotaped the process. This is confirmed by the following phrases on the tape:

17:51:47 Makarov: Let's get a picture of the pilot.

17:52:46 Eldar: You're taking a picture?

17:52:48 Makarov: Yes, I am.

As later events showed, Kudrinsky decided to show his son how to fly the aeroplane using the same manoeuvre he had just executed for his daughter.

At 17:54:25, Eldar asked if he could "turn" the control wheel, and received his father's permission. (Eldar: "Can I turn this? the control?"; Kudrinsky: "Yes".).

After a brief explanation of how the aeroplane was controlled, at 17:54:40 the father and son began to execute what we have called "Manoeuvre no. 2", which is the key to understanding the abnormal situation that arose during this flight.

PIC Kudrinsky carried out the manoeuvre described above following the same scenario and the in same sequence as for "manoeuvre no. 1". This is confirmed by the similarity of the parameters and flight paths during "manoeuvre no. 2" (17:54:44 to 17:55:15) and "manoeuvre no. 1" (17:47:10 to 17:47:40).

At the same time, the permission given Eldar to intervene in the control of the aircraft, which was being flown by the autopilot, made "manoeuvre no. 2" different in the following ways:

1. The beginning of "manoeuvre no. 2" was preceded at 17:54:35 by a recorded comment from PIC Kudrinsky: "OK, watch the ground, where you're going to turn. Go to the left, turn to the left!"

PIC Kudrinsky thus let an unauthorized and unqualified outsider fly the aeroplane.

This and preceding decisions and actions by PIC Kudrinsky and co-pilot Piskarev showed an utterly careless and irresponsible disregard of flight safety, the result of poor discipline and a blatant ignorance of the general rules of flight contained in NPP GA-85.

Note:

1. *"Persons who have no operational duties on the flight are not allowed in the cockpit." (NPP GA-85, para. 7.1.3.)*

2. *"During the flight, one pilot must continuously monitor the aeroplane's attitude and maintenance of flight level (altitude). When flying with the autopilot engaged, the crew member flying the aeroplane must notify the rest of the crew before initiating any manoeuvre."* (NPP GA-85, para. 7.1.6)

Eldar followed his father's instructions, and at 17:54:39 he turned the control wheel to the left 3-4° (the left aileron was deflected upwards by 0.7° from the trimmed position) and held it in that position for 3 seconds. The autopilot, which was functioning normally, reacted to the roll rate by raising the right aileron by about 1°.

At this point, the force on the left control wheel reached about 10 kg (here and throughout, the control forces indicated are reduced to the forces that would be applied when flying with one hand only), and then diminished after Kudrinsky engaged the heading select submode and rotated the knob to turn the aeroplane to the left (at 17:54:44), because the autopilot actuator was moving the aileron linkage in the same direction as the force that Eldar was applying.

2. Beginning at 17:54:58, the autopilot banked and turned the aeroplane on Kudrinsky's command, deflecting the right aileron only. From 17:54:58 to 17:55:35, the left aileron was blocked at the 1° position because either the left or right control wheel (or both) was (were) being held 3-5° to the right.

Resisting the autopilot while the aeroplane was turning with a bank that was changing both in magnitude and direction subjected the control(s) being held to forces that varied in both magnitude and direction. At 17:55:25, when the force on the control wheel (total force on both wheels) increased to 11-13 kg, and the asymmetry in the deflection of the left and right ailerons reached 3-3.2°, the override function triggered the torque-limiting mechanism in the lateral control channel and caused the aileron actuator to declutch without electrically disengaging the autopilot.

Note:

The two columns are mechanically linked by a spring rod with a relatively high elasticity that exceeds the forces applied to the controls in flight. Having only the recording of the aileron deflection, it is not possible to determine whether the forces were being applied to the left column, the right column, or both together, as those forces increased up to the maximum required to cause the aileron actuator to declutch.

Half-scale modelling established that on the fatal flight, force was being applied to both control wheels from the moment the force decreased as the autopilot was being disconnected (from 17:55:25 to 17:55:29) and while the aeroplane was being flown manually (from 17:55:54 to the end of the recording).

The autopilot continued to function in the longitudinal control channel, stabilizing altitude, but the declutching of the aileron actuator meant that no control inputs were being applied to the lateral control channel. The aeroplane had reverted to manual flight in the lateral channel. After the declutching of the actuator, the force on the control wheel (total force on both wheels) decreased to 5-7 kg.

Notes:

1. The Aeroplane Operating Manual for the A310 states:

[Translator's note: The manual was unavailable, so the following is a re-translation from the Russian and will not correspond word for word to the English-language original.]

"...working against the autopilot is defined as an abnormal procedure and should be avoided. (PAGE, REV 20, 2.02.03)

"The autopilot override is a safety mechanism that operates outside the boundaries of normal aircraft operations.

If it is suspected that the aeroplane is not behaving normally when the AP is in CMD mode, disengage the autopilot immediately.

Warning: Do not attempt to correct the flight path by manipulating the controls if the autopilot is not disengaged." [FCOM BULLETIN, n05/1 Page 11 of 14]

2. The aileron actuator declutches when a force of 11-13 kg is applied to the control wheel(s). This is lower than the figure indicated in the Aeroplane Operating Manual and other guidance material (15-17 kg). The accumulation of forces on the controls during an attempt to override the autopilot using one column (by holding it or moving it) enables the pilot to determine the moment of disengagement. If both columns are held, the forces may be divided between them in such a way that the pilot may not perceive the moment of autopilot disengagement.

3. The aeroplane has no warning indicators (lights or aural signals) to inform the pilot that the aileron actuator has declutched. Even after the autopilot has been disengaged, the crew continues to receive information about its operation in the mode selected earlier, although the autopilot has ceased to perform its functions with regard to roll stabilization and control.

According to para. 8.2.7.3 of the Airworthiness Standard NLGS-3:

"The engaging and disengaging of the automatic flight system, as well as any change of mode, must be accompanied by appropriate indications consisting of information about the functioning of the devices in operation, including the mode selected. This indication must be easily distinguished from both pilot stations. If it is possible to change the AFS mode or switch the AFS off involuntarily (for example, by accidental movement of the controls), and also when the AFS mode is changed automatically, the signal must be noticeable enough to enable the pilots to detect the mode change or disengagement in a timely manner."

According to the Airworthiness Technical Manual (International Civil Aviation Organization, Second edition, 1987):

"4.2. The controls, indicators (including monitoring devices) and warning means should be designed to minimize crew errors. Errors or mishandling which can reasonably be expected to occur should not hazard the aeroplane.

4.5. A clear and continuous indication should be given of the selected mode.

Note: It is advisable that the indication should show when the selected mode has been armed and when it is actually in operation.

4.6. An appropriate indication should be given when there is:

a) failure to achieve the selected mode; and

b) inadvertent change or disengagement of a mode."
(Section 4, "Controls, Indicators and Warnings")

Thus, from the commencement of "manoeuvre no. 2", events unfolded in the following sequence:

17:54:39 - 17:54:44. Eldar applied force to the control wheel in an effort to turn the aircraft to the left. The autopilot, "resisting" the interference in the control of the aircraft, deflected the right aileron to counter the roll that was being induced.

17:54:44. Kudrinsky engaged the HDG/S (heading select) submode on the autopilot and turned the heading select knob to the left to a value more than 15° off the initial heading of 105°. The autopilot deflected the ailerons 4°, and the left bank reached 21.5° at 17:54:55.

17:54:52. When the left bank was at 17-19°, Kudrinsky turned the heading select knob to the right to return to the planned heading (the initial heading of 105°). The autopilot responded to that command by deflecting the ailerons to reduce the left bank.

17:54:58. The right aileron, passing through the neutral position, continued to move smoothly (directed by the autopilot) to induce a roll to the right. At the same time, the left aileron was held in the 1° position (also for a right roll) because the control wheel(s) was (were) being held.

17:55:05. The aeroplane rolled from a left to a right bank.

17:55:07. At a right bank of 3-5°, Kudrinsky engaged the NAV (navigation) submode on the autopilot. The autopilot deflected the right aileron and the aeroplane increased its right bank from 6° to 15°, turning right towards the previously assigned heading. The left aileron remained at the 1° position.

17:55:12 - 17:55:36. Yana distracted Kudrinsky from monitoring his son's actions and the flight parameters of the aeroplane.

17:55:25 - 17:55:29. While the aeroplane was turning in a 15° right bank, the control wheel(s) was (were) being held 3-5° to the right, and the autopilot attempted to reduce the bank so as to come out on the assigned course. The forces on the control wheel(s) increased to 11-13 kg, the aileron deflection asymmetry increased to 3-3.2°, and the result was that the properly functioning autopilot was inadvertently disconnected from the roll control system, with no indication from the instruments.

The left aileron may have become stuck in a deflected position for one of the following reasons:

1. Restraining of left control wheel by Eldar.
2. Restraining of right control wheel by the co-pilot, Piskarev.
3. Restraining of both control wheels (the left by Eldar, the right by Piskarev).
4. Jamming of the left aileron linkage (left aileron, left control wheel) without any force being applied to the wheel by the crew.

Eldar, not having flight experience, could not, even theoretically, link the change in force on the wheel with the processes taking place at that moment in the lateral control system of the aeroplane. He not only could not determine that the autopilot had disengaged itself; he could not even know of the possibility.

If Piskarev, an experienced pilot, had been the only one holding the controls, he could not have failed to feel the autopilot disconnect itself.

With both control wheels being handled, the forces could have been divided between them in such a way that the co-pilot would fail to detect the moment of disconnection, since he could attribute the change in force to some action by Eldar.

Simulation demonstrated that the nature of the deflection of the right aileron between 17:55:25 and 17:55:29 while the left aileron was fixed in place corresponded to the type of aileron deflection seen during declutching and could not be explained by the operation of the autopilot in any submode. The recording of the aileron deflections after 17:55:36 bear witness to the fact that the aileron linkage was not jammed during this flight.

The DFDR recording taken during the declutching process (from 17:55:25 to 17:55:29), which was accompanied by reduced aileron asymmetry, shows oscillations in the recorded deflection of the right aileron, while the left aileron position is constant. This reflects a rightward pressure on the control wheel. This was confirmed by simulation in a flight simulator. If either control wheel is held in a constant position while the autopilot is executing a turn, the right aileron moves smoothly, without oscillation, to reduce the amount of "asymmetry".

It can therefore be affirmed that during the declutching process (from 17:55:25 to 17:55:29) both Eldar and Piskarev were holding onto their respective control columns.

Neither the PIC nor the co-pilot noticed that the autopilot had disconnected itself, as demonstrated by the lack of any reference to it in the conversations recorded on the CVR.

The following possible factors could explain why the pilots failed to notice that the autopilot had become disconnected:

- the pilot and co-pilot did not know how the declutching mechanism worked and what to do in such a case, due to lack of appropriate drills in the flight crew training programmes;
- it was difficult for the co-pilot to feel the disengagement of the autopilot, either because of the small forces on his control column or because he attributed changes in force to actions by Eldar;
- the instruments do not provide a disengagement warning;
- it was impossible for Kudrinsky to detect the disengagement visually from the position of the wheel, since at that moment the controls were being held in a near-neutral position.

At 17:55:28, with the autopilot disengaged and the control wheels being held slightly to the right, the right bank began to increase gradually, unnoticed by either Kudrinsky or Piskarev.

By 17:55:36, the aeroplane was in a 20° right bank and was still rolling to the right at an angular velocity of 0.4-1°/sec. The rate of increase in angular velocity was below the threshold at which the acceleration could be sensed (that is, detected without instruments) and was not perceived by the captain, the co-pilot, or any other person in the cockpit.

Beginning at 17:55:36, when the right bank was 20°, the ailerons were deflected an additional 1.5-2° rightwards. Studies have shown that an additional force on the control wheel of 1-2 kg is enough to produce such a deflection with the autopilot disconnected. At this point, total forces on the control columns were 5-7 kg.

Notes:

1. *It was not possible to establish which of the control wheels was moved to produce the additional aileron deflection.*
2. *Analysis of AFS operation showed that in principle such an aileron deflection can be produced in automatic flight only upon simultaneous failure of at least two of the units in an autopilot system. The autopilot must be engaged when this happens. The probability of such simultaneous failures is very small and the event ranks as practically inconceivable. In addition, for the part of the flight following the increase of bank angle past 15°, it was clearly established that the autopilot was disconnected earlier and remained so. This conclusion is supported by the fact that the DFDR recording does not show the aileron deflection typical of the moment of autopilot engagement.*

Because of the additional aileron deflection, the right bank began to increase more quickly (2-2.5°/s), exceeding 30° (the maximum angle of bank for autopilot operation). At 17:55:49, it reached the operating limit of 45° and continued to increase.

Notes:

1. *The 45° bank angle is the operating limitation set by Airbus Industrie for the A310 that was operated by RAL.*
2. *When a 45° bank angle is reached, part of the routine information on the flight director "disappears".*

At 17:55:36, Eldar, sitting in the left seat, was the first to notice "something he didn't understand", and he drew it to the attention of his father, who was busy with Yana.

17:55:36. Eldar: Why is it turning?

17:55:38. Kudrinsky: It's turning by itself?

17:55:40. Eldar: Yes.

The pilots who were in the cockpit at that moment (17:55:36) began to search for an explanation of why the aeroplane was turning. Makarov made a suggestion, supported by Piskarev, that the aeroplane had entered the holding area:

17:55:45. Makarov: It's turning into the area, guys

17:55:46. Piskarev: We've reached the area, the holding area.

17:55:48. Kudrinsky: Have we?

17:55:49. Piskarev: Of course.

The pilots' reference to the "holding area" can be explained by two suppositions:

1. Makarov identified the aeroplane's banking as a holding manoeuvre, although there was no information on the navigation display. Piskarev and Kudrinsky accepted Makarov's suggestion as being true.

2. The navigation display may have unexpectedly produced a new ("false") course line in the form of an arc or circle, this being interpreted by Piskarev as "holding area".

The appearance of "false" course lines on the navigation display has occurred:

- in the simulator during one of the experiments, in the form of a circle to the left;
- on 17 August 1994, in a test flight on an A310, in the form of an arc;
- in RAL A310 operation, in the form of an arc and new course lines.

Furthermore, the designer of the AFS system does not reject the possibility of the appearance of "false" flight paths.

The fact that Kudrinsky and Piskarev were distracted from monitoring the flight parameters could fit the circumstances outlined in either the first or the second supposition.

As a result of the actual aileron deflection, by 17:55:52 the bank angle had reached 50°, but neither the captain nor the co-pilot reacted to the increased bank.

As the bank increased, the autopilot used the autothrottle (which was engaged) to stabilize altitude and airspeed, increasing the angle of attack and the vertical load. However, after the 45° angle was reached, the autopilot could no longer perform its height-keeping function properly and the aeroplane began to descend.

At 17:55:52, with a bank angle of more than 50°, an angle of attack of 4-4.5° and a vertical load factor of 1.6G, buffeting was observed, indicated on the DFDR recording as high-frequency oscillations in lateral and vertical acceleration caused by the stall conditions induced on the wing as higher angles of attack were reached. Similar recordings were produced during certification tests and in experimental flight on 17 August 1994 when angles of attack of 3.4-3.5° were reached at $M = 0.8$.

During the buffeting, the angle of attack went from 4.5° to 10° within a period of two seconds, although the elevator and stabilizer had hardly moved, showing that the aeroplane had pitched up in terms of the angle of attack. At this time, the mass and c. of g. were 122 tonnes and 36%, respectively.

At such angles of attack, unintentional pitch-up was experienced in flight during certification trials and in the test flight on 17 August 1994, using an aircraft with the c. of g. at 36% and a mass of 116 tonnes, but flying manually. During manual flying (using the controls), however, the aeroplane pitched up much more slowly due to the action of the automatic system in improving stability and manoeuvrability and the movement was countered in a timely fashion during the assessment flight.

At 15:55:50, most probably when the vertical load factor exceeded 1.4G and the rate of increase passed the threshold at which acceleration is perceived (0.04G/s), Makarov reacted ("Hey, guys!"), and when the buffeting began, so did Kudrinsky ("Hold on! Hold the column, hold it!").

Notes:

Analysis showed that if the A310 had had a system of noticeable alarms to indicate that the allowable operating bank angle had been exceeded, considering the time needed to recognize the problem, assess the situation and take action, it could in this situation have attracted attention and led to earlier detection of the increased bank angle.

The pilots' "overlooking" the indications that the aeroplane was slipping into a steep bank can be explained by a combination of the following factors:

- at that point in time, the pilots were mainly concentrating on finding out why the aeroplane had left its heading (flight path);
- Kudrinsky, standing behind the left seat, may not even have seen the attitude indicator display, since the flight information on the left panel may have been displayed on the lower screen (indirect evidence of this could be Makarov's comment: "Set the attitude indicator up normally for him") and may thus have been partially obscured by the control column;
- the pilots had become "disconnected" from the flying of the the aeroplane and distracted from monitoring its attitude, and had in fact lost situational awareness.

Note:

Many specialized studies of crew performance have shown that following a brief distraction from monitoring flight instruments, a readaptation time of no less than 3 sec. is required. A lengthy distraction (Kudrinsky's lasted 24 seconds, from 17:55:12 "What do you want, Yana?" to 17:55:36 - Eldar: "Why is it turning?") increases the required perception time to 10-11 sec.

Kudrinsky's command, "Hold it! Hold the column! Hold it!" could have been interpreted literally by Eldar as he held the column close to the neutral position, while the command actually indicated the need to counter the bank and was correctly understood by the co-pilot Piskarev, as confirmed by his subsequent actions.

The increase in the vertical load factor beyond the threshold and the buffeting marked the starting point for sensory-motor activity.

At 17:55:54, when the right bank angle was 63° , there was recorded a strong deflection of the right aileron downward to 14° (the right wheel moved to counter the roll), while the left wheel was "clutched" for 3-4 sec.

Since the left wheel was in a nearly neutral position, the left aileron did not move and neither did three of the five spoilers on the left wing. The increase in the angle of attack and the failure of the left aileron and some of the spoilers to deflect reduced the effectiveness of lateral control and made it impossible to reduce the right bank, which reached 90° 19 sec. after the control wheel was turned to the left.

Analysis showed that at high angles of attack, "blocking" the left control wheel did not have a decisive effect on lateral controllability.

The co-pilot began to counter the roll 6 seconds after the aircraft reached the operating limit of 45° bank (which was indicated on the PFD by the disappearance of some of the routine information) and 2 seconds after the onset of buffeting. These pilot reaction times correspond to statistical averages for the time required to carry out the actions appropriate to the situation, including detection, identification, assessment of the situation and decision-making.

However, under these conditions, the co-pilot could have countered the roll if he had intervened in the piloting 6 seconds after reaching a bank of no more than 40° , when aileron effectiveness was still adequate.

Action to counter the roll was thus taken too late, and one of the reasons for this was the lack of a strong, conspicuous warning that the operating bank limit had been reached.

Furthermore, crew action to counter the roll was in general inappropriate to the situation.

In the situation that had developed, the proper procedure for restoring an operational angle of attack and re-establishing lateral control would have been:

- disengage the autopilot using the button on the control column or override it using forward pressure on the column;
- reduce the angle of attack (pitch) by pushing the control column forward;
- stop the roll and re-establish original flight parameters (stop the descent without allowing buffeting to begin again);
- reduce engine thrust (if necessary).

During the attempt to counter the roll, the computer, reacting to the loss in altitude as the right bank increased, caused the elevator to deflect nose-up to -6.5° . This elevator deflection, taken together with pitching up that had already occurred, induced a high angle of attack and caused the aircraft to stall.

Two to 2.5 seconds after the right control wheel was turned to the left, there followed a short, sharp deflection of the wheel to the right, actually increasing the bank further, then the wheel moved back again to the left to counter the roll.

These actions on the part of the co-pilot can obviously be explained by his failure to understand why the aircraft reacted so sluggishly to full deflection of the ailerons and his need to verify the correctness of his actions.

During the subsequent 21 seconds, Kudrinsky and Makarov in turn commanded: "The other way!", "Turn left!", "Left!". The commands from Piskarev during the same time interval (17:55:56: "The other way", 17:55:58: "The other way", 17:55:59: "Back [also translatable as "The other way"]!") were in all probability directed to Eldar, who, following the orders of Kudrinsky and Makarov, was manipulating the left control wheel and thus interfering with Piskarev's piloting of the aircraft.

Note:

I. V. Piskarev was 160 cm tall, and since his seat was pushed back almost as far as possible (his harness was fastened), his position limited his ability to fly the aeroplane.

Between 17:55:58 and 17:56:11, warnings sounded: "Altitude discrepancy" (twice), "Stall warning", and "Autopilot off". Because the warnings for altitude loss and autopilot disengagement had a higher priority, they turned off the stall warning, with the result that the latter sounded only 5 seconds after passing its activation threshold (10° true angle of attack) and was heard for only 4 seconds. In addition, under the existing conditions, the buffeting was the best indication that a high angle of attack had been reached.

Between 17:56:04 and 17:56:18, the pilots can be considered to have lost lateral spatial orientation. At this time, the bank angle was about $80-90^\circ$ to the right, the aircraft was diving at a pitch angle that increased from -15° to -50° , and speed increased as the vertical load factor reached about 2G.

Note:

Flight crew training does not include drills in recovering from unusual attitudes involving high pitch and bank angles.

The subsequent deflection of the elevator, first from -6.5° to -2.5° , then to -7.5° , evidently reflected an intervention in pitch control and resulted in stick forces exceeding 15 kg, which led the autopilot to disengage at 17:56:11, sounding the appropriate warning. The co-pilot did not confirm the disengagement by pressing the button on the yoke, and the alarm continued to sound every three seconds until the end of the flight.

After the autopilot disengaged itself, the automatic high angle of attack protection system responded, deflecting the stabilizer nose-down from -1° to -0.5° . The elevator was also deflected nose-down, from -7.5° to $+2.5^\circ$. These actions on the part of the automatic systems, the co-pilot and, possibly, Eldar led to a reduction in the angle of attack to 7° , an increase in the average descent rate to 200 m/s, an increase in vertical load factor and a speed that exceeded the maximum allowable limits. Overspeed warnings sounded. At the same time, the engines were operating at high thrust, maintained by the autothrottle (thrust hold mode).

Judging from the audio information, at 17:56:18 (Piskarev: "To the left! There's the ground!"), the co-pilot had re-established lateral orientation, and the deflection of the control wheel to the left (when the autopilot was disconnected 6 seconds earlier) had brought the aeroplane out of the roll.

However, as indicated earlier, the aircraft was by then diving at a pitch angle of up to 40°, and this led to a rapid increase in speed, which at 17:56:28-17:56:29 reached about 740 km/h. According to the data recorder, at 17:56:28 the elevator began to deflect nose-up, and after 10 seconds reached its limit of travel. At this point, vertical acceleration was 4.6-4.7G, exceeding the structural limit.

Two seconds before this, the recording shows a pitch-up movement of the stabilizer from -3.5° to -14°, which is the mechanical limit. During this change, the rate of stabilizer reversal reached 5°/s, which is not technically possible. This reading may have been caused by deformation of the airframe at the location of the stabilizer angle sensor due to the unacceptably high vertical loads. This caused the sensor to give unreliable signals to the data recorder and to the force-limiting computer, which in turn passed that information on to the elevator feel system. The resulting forces in the longitudinal channel, being smaller than in a normally functioning feel system, enabled the co-pilot to pull the control almost completely back, while the actual stabilizer position was about -3° to -1° nose-up. The control column may have been pulled back and the thrust reduced because of the high airspeed and descent rate being experienced at that moment.

Kudrinsky continued to try to get into the left seat, as shown by his repeated cries of "Get out!" addressed to his son. It was, however, very hard for Eldar to leave the left seat because of the significant vertical G-forces and the narrow space between the seat and the left side.

For Piskarev, the principal danger in this situation came from the high indicated airspeed (17:56:34: Piskarev: "Throttle to idle!"). He had unavoidably become fixated under the nervous and emotional stress of the situation, and he found the actual sharp pitching up inadequate; after the command to reduce thrust, the control column was pulled right back to the stop within 7-9 seconds, the aeroplane already being in a nose-up attitude.

Pulling the control column back almost to the stop, together with the reduction in power, led to a sharp drop in indicated airspeed, which at 17:56:41 fell to 185-220 km/h. When the rudder was deflected to about 8°, and the aeroplane banked sharply to the right when the ailerons were deflected leftwards.

At 17:56:41, therefore, the aeroplane was in a classic spin entry position: elevator fully back, low airspeed, ailerons deflected opposite to the spin (that is, towards the left), rudder sharply deflected. The aeroplane responded by rolling uncontrollably into a spin. It has not been possible to establish definitely why the left pedal was pushed forward at that moment. Possible reasons are:

- Eldar may have pushed the left pedal inadvertently as he got out of the left seat;
- Kudrinsky may have pushed the left pedal inadvertently as he got into the left seat;
- Kudrinsky may have extended his left leg in kinetostatic reaction as leftward lateral forces were applied to the control wheel (17:56:40 - 17:56:47).

It can be definitely confirmed only that the pedal was not pushed by Piskarev (his feet did not reach the pedals) or by the autopilot (it was disengaged).

Following the stall and uncontrolled roll, with an angle of attack of about 30-35°, the aeroplane began to rotate to the left in an 80-90° nose-down attitude. The vertical load factor dropped to zero, that is to weightlessness. At 17:56:54, Piskarev noticed the very low airspeed (less than 180 km/h) and ordered in a highly emotional tone: "Full power! Full power! Full power!". At that moment

(17:56:55), Kudrinsky regained his station. The aeroplane had nosed down 10 seconds earlier and when Piskarev issued his order, the aircraft was in an almost vertical dive and the initial phase of acceleration.

Note:

Given Y. Kudrinsky's height of 170 cm, the fact that his seat was pushed back almost to its rearward limit prevented him from controlling the aeroplane in a normal manner.

By 17:57:11, the airspeed had reached 370 km/h, the rotation had slowed (the bank angle stabilized at 20-22° to the left), and the pitch angle had diminished to -20°. There is every reason to believe that if the elevator had been deflected even to the neutral position (or on past neutral), the aeroplane would have become controllable. However, the elevator control was deflected all the way back, and the aeroplane nosed up and lost airspeed.

At 17:57:47-17:57:48, with a left bank angle of 15-20° and a pitch angle of -20°, with ailerons fully deflected against the direction of rotation and the elevator in an almost full nose-up position, following a kick of the foot against the rotation, the aeroplane resumed its rotation at an increased angular velocity.

The alternating pedal deflections indicate that Kudrinsky, in the extremely short time remaining, was trying to find a way to stop the rotation, and at 17:57:56 the aeroplane ceased to rotate, but the speed had once again reached more than 370 km/h. Given the low altitude (about 300-400 m), the nose-up elevator position could not render the aeroplane controllable. At 17:58:01, the aeroplane struck the ground.

Throughout the flight, up to the moment at which the limit load factor had been exceeded, all aircraft systems and engines functioned flawlessly. This is confirmed by the absence of a single failure or fault command on the flight recorders (DFDR and CVR), analysis of voice and aural data recorded on board, as well as examination of the parts, assemblies and systems of the wrecked aeroplane.

III. CONCLUSIONS

The A310 disaster was caused by a stall, spin and impact with the ground resulting from a combination of the following factors:

1. The decision by PIC Kudrinsky to allow an unqualified and unauthorized outsider (his son) to occupy his duty station and intervene in the flying of the aeroplane.
2. The execution of demonstration manoeuvres that were not anticipated in the flight plan or flight situation, with the PIC operating the autopilot while not at his duty station.
3. Application by the outsider and the co-pilot of control forces that interfered with the functioning of the roll channel of the autopilot (and are not recommended in the A310 flight manual), thus overriding the autopilot and disconnecting it from the aileron control linkage.
4. The co-pilot and PIC failed to detect the fact that the autopilot had become disconnected from the aileron control linkage, probably because:

- The A310 instrumentation has no declutch warning. The provision of signals in accordance with the requirements of Airworthiness Standard NLGS-3, para. 8.2.7.3., and international recommended practices, could have enabled the crew to detect the disengaged autopilot in a timely manner.
- The co-pilot and PIC may have been unaware of the peculiarities of the declutching function and the actions to be taken in such a situation because of a lack of appropriate information in the flight manual and crew training programme;
- It was difficult for the co-pilot to detect the disengagement of the autopilot by feel, either because of the small forces on his control column or because he took changing forces to be the result of Eldar's actions;
- The PIC was away from his position and distracted by the conversation with his daughter.

5. A slight, unintentional further turn of the control wheel(s) following disengagement of the autopilot caused a right roll to develop.

6. The PIC and co-pilot failed to detect the excessive right bank angle, which exceeded operating limits, and were late in re-entering the aircraft control loop because their attention was focussed on determining why the aircraft had banked to the right, a manoeuvre they interpreted as entry into a holding area with either no course line or with a new (false) course line generated on the navigational display.

A strong signal indicating that the aeroplane had exceeded the allowable operating bank angle, taking account of the delay in recognizing and assessing the situation and making a decision, could in this situation have attracted the crew's attention and enabled them to detect the bank at an earlier stage.

7. The aeroplane was subjected to buffeting and high angles of attack because the autopilot continued to perform its height-keeping function even after the actuator declutched and as the right roll developed, until the pilot disconnected it by overriding its longitudinal channel.

8. Inappropriate and ineffective action on the part of the co-pilot, who failed to disconnect the autopilot and to push the control column forward when the buffeting occurred and the aeroplane entered an unusual attitude (high angles of attack and pitch). These actions, which caused the aeroplane to stall and spin, could have resulted from:

- the presence of an outsider in the left-hand pilot's seat and the resulting delay before the PIC re-entered the aeroplane control loop;
- the less-than-optimum working posture of the co-pilot, whose seat was pushed back to its rearmost position;
- the occurrence, 2 seconds following the onset of buffeting, of an unintentional pitching up of the aeroplane, which sharply increased the angle of attack and reduced lateral controllability;
- unpreparedness of the crew to act in this situation because of lack of appropriate drills in the training programme;
- temporary loss of spatial orientation in night conditions.

IV. FACTUAL INFORMATION

4.1. Crew/personnel information

The pilot in command, Andrei Viktorovich Danilov, born 1954, Class 1 civil pilot, graduated from Sasov Flight School in 1973 and the Civil Aviation Academy in 1981. Took conversion training as PIC on the A310 in November 1992 in Toulouse (France). Rated for ICAO Cat II operations (30 x 400, takeoff 125 m). He had a total flight time of 9675 hours, of which 950 were on the A320, 895 of those as PIC. Before that, he had accumulated 4700 hours as PIC on the TU134. Total flight time for March 1994 was 38 h 36 min (all on the A310). Training for the Moscow-Hong Kong-Moscow route was conducted on 17 February 1994 under the supervision of deputy flight operations manager Zakharevich of RAL. Check rides were conducted: on simulator - 1 March 1994, piloting and navigation - 19-20 December 1993.

He had had two days off at home before the flight and took regular holidays and days off. He had a three-room apartment. His family consisted of his wife and one child; relations within the family were good. He had had no previous aircraft accidents.

The back-up pilot in command, Yaroslav Vladimirovich Kudrinsky, born 1955, Class 1 civil pilot, graduated from Kremenchug Civil Flight School in 1975, and from the civil aviation academy in 1981. Took conversion training as PIC on the A310 in November 1992 at the training centre in Toronto (Canada). Rated for operations to minima 45 x 700, take-off 200 m. He had a total flying time of 8940 h, 907 of them on the A310, with 735 as PIC. Before that, he was PIC on the Yak-40 (1636 h), AN-12 (500 h), and the IL-76 (2265 h). Total flight time in March 1994 (all on the A310) was 36 h 33 mins.

Training for the Moscow-Hong Kong-Moscow route was conducted under the supervision of deputy flight operations manager Zakharevich of RAL on 21 March 1994. Check rides were conducted: on simulator - 3 February 1994, piloting and navigation - 21-25 December 1993. He had three days' rest at home before the flight and took regular holidays and days off.

He had a comfortable four-room apartment. His family consisted of his wife, his son Eldar (born 1978) and his daughter Yana (born 1981). Relations within the family were good. He had had no previous aviation accidents.

The co-pilot, Igor Vladimirovich Piskarev, born 1961, Class 1 civil pilot, graduated from Aktyubinsk advanced civil aeronautics school in 1982. Trained as PIC on the A310 in April 1993 at the RAL training centre and on simulators belonging to Lufthansa (Frankfurt-am-Main, Germany).

Rated for operations to ICAO Category 2 minima, 30 x 400 m. He had 5855 h total flight time, of which 440 were as co-pilot on the A310 and 3105 as PIC on the TU-134. Flying time for March 1994 was 6 h 57 mins (on the A310). Training for the Moscow-Hong Kong-Moscow route was conducted on 18 January 1994. Check rides were conducted: on simulator - 19 March 1994; piloting and navigation - 21 October 1993.

He had had two days' rest at home before the flight and took regular holidays and days off. He had a comfortable three-room apartment. His wife consisted of his wife and daughter; relations within the family were good. He had had no previous aviation accidents.

All crew members underwent medical examinations at Sheremetyevo-2 airport; there were no comments on their state of health. Crew training met the requirements of the guidance material and provided preparation for the performance of flight duties.

4.2. Information on ground services

The accident was not connected with ground services.

4.3. Aircraft information

The A310-308, bearing registration number F-OGQS and serial number 596, left the factory on 1 November 1991. Since beginning operations, it had flown 5375 hours and done 846 landings. It had not been overhauled. The last scheduled maintenance was done on 23 February 1994 by Lufthansa in Frankfurt. The last operational maintenance was done at Sheremetyevo before departure in accordance with A-check and T-check procedures by Russian specialists working for RAL. The aeroplane was refueled with 54.1 tonnes of TS-1 fuel. The take-off mass of the aircraft was 145.6 tonnes; C. of G. was 26.7%.

Engine no. 1 (N695472), manufactured 16 October 1991, had run 330 hours since commencing operations, and 330 hours since last scheduled maintenance.

Engine no. 2 (N695445), manufactured 9 July 1991, had run 5375 hours since commencing operations, and 330 hours since last scheduled maintenance.

The crew made no comments concerning maintenance or preflight preparations.

The aeroplane, engines and systems had been maintained in accordance with the requirements established by the appropriate documents, with no violations.

4.4. Meteorological information

Synoptic weather report for 18:00 GMT on 22 March 1994 for the region of Maizas (site of the accident):

The region of Maizas is under the influence of a weak low-pressure system, in the area of a warm front, in a stable air mass.

The actual weather from the Mezhdurechensk Hydrometeorological Station (17 km from the crash site):

18 GMT 22 March 1994

calm, visibility 20 km, clear, temperature -5°C, humidity 98%, pressure 10002 mb.

Actual weather from the Tashtagol Civil Aviation Meteorological Station (86 km away):

18 GMT 22 March 1994

calm, visibility 5 km in mist, 2//0 upper [cloud], temperature -6°C, humidity 94%, pressure 735 mm Hg.

Actual weather at the Novokuznetsk Civil Aviation Meteorological Station (98 km away):

17:30 GMT 22 March 1994

31002 m/s, visibility 10 km, 8//0 upper [cloud], average temperature -0.4°C, humidity 80%, pressure 740 mm Hg.

18:00 GMT 22 March 1994

34001 m/s, visibility 10 km, 8//0 upper [cloud], average temperature -0.4°C, humidity 80%, pressure 740 mm Hg.

Weather forecast for Novokuznetsk Airport, 22 March 1994.

1604 variable 03 m/s, good. Time 1904 1000 mist. No storm warnings or storm reports from the nearest Civil Aviation Meteorological Stations or Hydrometeorological Stations.

A weak high pressure area (high-level ridge) at altitudes of 1.5-12.0 km. The head of the ridge is in the vicinity of Obskaya Guba, the ridge line running from the northwest over the territory of Mongolia. Windspeed in the ridge 20-60 km/h. Axis of the high-level frontal zone ran west to the European part of the country, then southwest as it approached the Urals, then south-east from Ekaterinburg. Maximum [wind] speed in the high-level frontal zone 160-200 km/h. Tropopause height 11600 m, temperature at the tropopause -65°.

There were no hazardous phenomena at any altitude. No jet streams were observed.

There was a temperature inversion in the ground layer up to a height of 2 km.

The accident was not linked to meteorological services or weather conditions.

4.5 Communications, navigation, landing and ATC information

ATC units were equipped with radio facilities in accordance with the regulatory documentation of the civil air traffic services. Radio equipment was in proper working order when serving the A310.

4.6 Aerodrome information

The accident occurred outside airport boundaries and was not linked to airport conditions.

4.7. Rescue and firefighting activities

No communication was received from the A310 crew by 17:59, the estimated time of leaving the zone (times in this section are local). The ATC controller called the aircraft repeatedly, beginning at 18:01, but received no response. At 19:48, the air traffic controller at Novokuznetsk airport was informed by the operations duty officer at the Novokuznetsk internal affairs office that an aeroplane had crashed and was burning in the area of the town of Maizas.

At 20:00, a group of 10 persons (led by lieutenant colonel Rybak) arrived at the A310 crash area from the town of Maly Maizas and cordoned off the area. At 20:45, a MI-8 search helicopter located the crash site, determined its coordinates and reported them to the ATC controller. It was impossible to land in the wooded and mountainous area at night. At 23:57, an AN-12 arrived at the

search area. No signal was heard on the emergency frequency, but the aeroplane crew found the crash site visually and confirmed the coordinates reported by the search helicopter. At 00:20 on 23 March 1994, the MI-8 helicopter flew in a group of 16 persons to relieve Lieutenant Colonel Rybak's group, which had carried out the initial cordoning off of the accident site. No emergency work was done at the disaster site until the accident investigation team had arrived. On 22-23 March, an emergency rescue team was formed, consisting of 238 persons and 34 pieces of ground equipment, and between 23 and 26 March it recovered the remains of the crew and passengers and removed them to the morgue at Hospital no. 23 in Novokuznetsk. Search and rescue activities required 34 flights to the crash site, with a total flying time of 21 h 15 min. Between 22 March 1994 and 26 March 1994, the following forces and resources were devoted to the search and rescue effort:

from Joint Stock Company Aerokuznetsk :

- two MI-8 helicopters, a 2-person rescue team and 13 specialists from the emergency rescue team at the maintenance base.

from the Russian Ministry of Emergencies and Natural Disasters:

- 1 IL-76, 166 rescue personnel, 19 pieces of ground equipment

from the Air Defence Forces of the Russian Federation Ministry of Defence:

- 3 MI-8 helicopters, 1 MI-6 helicopter, 1 AN-12 aeroplane.

4.8. Crew and passenger crash survival information

The impact of the A310 with the ground produced trauma inconsistent with survival (massive destruction of tissue), resulting in the deaths of all persons on board the aeroplane (12 crew members and 63 passengers). High temperatures and open flames inflicted post mortem damage on the bodies of some crew members and passengers.

4.9. Other information

In order to determine the cause of the accident and assess crew reactions to the situation, a number of tests and studies were carried out:

4.9.1. Replication of the flight on the full-scale mock-up (the "iron bird") at Airbus Industrie in Toulouse.

4.9.2. Test flights on an A310 at Toulouse, using a programme developed with and agreed to by Airbus Industrie.

4.9.3. The State Scientific Research Institute of Civil Aviation tested the rudder and elevator actuators and the trimmable stabilizer mechanism and examined the left and right pilot's seats to determine their position at the moment of impact, and to assess why and how the seats' structural elements failed. (report no. 7910, 7917-AK/103 of 21 August 1994).

4.9.4. Study of aural and voice data at specialized laboratories of the Russian Ministry of Internal Affairs and the Federal Intelligence Service.

4.9.6. [sic] Autopsies of crew members to determine their positions at the moment of impact.

4.9.7. Blood tests on crew members to detect the presence of alcohol, carboxyhemoglobin or narcotic substances.

V. Shortcomings revealed by the investigation

5.1. The lack of general provisions regarding the procedure for introducing aircraft of foreign manufacture into civil operation in the Russian Federation and for monitoring their operation.

5.2. RAL had insufficient specialized ground equipment to make use of flight recorders in monitoring the operation of aircraft of foreign manufacture.

5.3. A lack of initial and recurrent flight training of civil pilots in establishing spatial orientation and recovering from unusual attitudes.

5.4. Inadequate monitoring of airline operations by the regional air transport administrations and the Air Transport Department.

VI. Recommendations

6.1. In order to improve state oversight of flight safety, proposals should be prepared and submitted to the Government of the Russian Federation concerning the strengthening of state inspection units and the inclusion of highly qualified specialists within them.

6.2. The necessary steps should be taken to increase cockpit discipline in flight and to organize effective monitoring of compliance with flight procedures, using airborne voice and data recorders.

6.3. Flight crew training should be improved to take account of the special factors revealed by the investigation of this accident, including the monitoring of aircraft attitude during instrument flight and methods of recovering from unusual attitudes.

6.5. Review the question of creating, within the Russian civil aviation system, single-type operations centres for aircraft of foreign manufacture.

6.6. Together with the aircraft designers and in cooperation with specialists from the research organizations of the Russian Federation, determine the measures necessary to prevent aeroplanes from exceeding their operating bank and angle of attack limits and to prevent the autopilot from disengaging its aileron control function without warning.

6.7. Make a number of amendments and additions to the A310 flight manual and other regulatory documents in response to the material in the Report and the shortcomings revealed during the accident investigation.

I.E. Mashkivsky
Chairman of the Aircraft Accident Investigation Commission