DUTCH
SAFETY BOARD

Hard landing after automatic approach

at Amsterdam Airport Schiphol

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The Hague, May 2016

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Dutch Safety Board

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NB: This report is published in the Dutch and English languages. If there is a difference in interpretation between the Dutch and English versions, the Dutch text will prevail.

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GENERAL INFORMATION

Occurrence number:	2014119
Classification:	Accident
Date and time of occurrence:	1 October 2014, 07:45 hours [1]
Location of occurrence:	Amsterdam Airport Schiphol [2]
Aircraft registration number:	PH-EZV
Aircraft model:	Embraer ERJ190-100 STD
Aircraft type:	Passenger aeroplane
Flight type:	Scheduled flight
Flight phase:	Landing
Damage to the aircraft:	Operating rods of the left-hand main landing gear door and of the innermost right-hand flap damaged
Number of crew members:	Two flight crew, two cabin crew
Number of passengers:	86
Injuries:	None
Other damage:	None
Light conditions:	Daylight

1 All times in this report are local times unless stated otherwise.
2 Amsterdam Airport Schiphol (AAS) will be referred to as Schiphol Airport throughout the rest of this report.

SUMMARY

The pilots prepared for an automatic landing at Schiphol Airport. At a low altitude, the captain realised that the aircraft was not going to perform the intended automatic landing. He pulled back on the control column to reduce the rate of descent. The aircraft made a hard landing. An inspection after the occurrence found that the aircraft was damaged. No one on board was injured.

An automatic landing was not possible in the selected configuration. In accordance with the selected system settings, the aircraft did not perform a landing flare and maintained a constant rate of descent in the direction of the runway.

The indications of the automatic pilot did not lead the pilots to suspect that the aircraft was actually configured for a manual landing. The system indications received by the pilots were the same as what they were used to seeing, as they had previously performed mostly manual landings. Moreover, the aircraft was in a valid configuration, which meant that no error messages were generated and the pilots had no reason to think that the aircraft was not flying in the correct configuration.

The procedures for reporting occurrences described in the airline's operations manual leave room for interpretation. The airline ultimately reported the occurrence to the Dutch Safety Board 20 days after it took place. As a result, at the start of the investigation various information sources were no longer available and the crew's recollections were possibly not as sharp.

1 FACTUAL INFORMATION

1.1 The flight

An Embraer 190 passenger aeroplane, registration PH-EZV, was making a scheduled flight from Prague's Vacláv Havel airport (LKPR) to Schiphol Airport. The planned departure time was 06:25 hours. On board were 86 passengers, two flight attendants, the Captain and the First Officer.

The crew were collected from their hotel in Prague at 05:00 hours and taken to the airport. The reporting time at the airport was 05:30 hours. This was the crew's last day in a four-day pairing. The reporting times on the second and third day were also early.[3] The Captain and First Officer stated that they started the working day fully rested.

Flight preparation
After arrival at the aeroplane the crew started preparations for the flight. The aeroplane had no known defects that could have affected flight operation.

According to the Captain's statement the weather forecast for the expected landing time at Schiphol Airport indicated that horizontal visibility would be 800 metres. Limited visibility conditions, phase A, were in force.[4]

The crew decided to anticipate these conditions by taking extra fuel on board at the departure airport so that any delay in the vicinity of Schiphol Airport could be compensated before having to decide to divert to a different aerodrome. In addition to this, account was taken of the need to conduct a low visibility approach followed by an automatic landing at Schiphol Airport. The Captain would be the person who would fly the aeroplane (Pilot Flying, PF).[5]

Take-off, climb and cruise flight
The flight departed from Prague at 06:20 hours, five minutes before the planned departure time. According to the crew nothing of note occurred during the take-off, climb or cruise flight.

3 An early flight is when the reporting time is between 00:00 and 07:29 hours.
4 Limited Visibility Conditions (LVC) at Schiphol are in place when the runway visual range (RVR) is equal to or less than 1500 metres and/or the cloud ceiling is at or below 300 feet (approx. 90 metres). The RVR is the measured visible distance along the centreline of a runway. The RVR is usually measured using three transmissometers along the runway; at the start (section A), halfway (section B) and at the end of the runway (section C). LVC phase A is a reduced visibility procedure which has only impact on ground operations regarding departing traffic (source: AIP AD 2.22-3 Low Visibility Procedures).
5 The tasks during the flight are shared between the two pilots. One pilot flies the aircraft (Pilot Flying, PF) and the other pilot (Pilot Monitoring, PM) monitors the PF and is responsible for communication with air traffic control and for paperwork.

According to the Captain, approach and landing at Schiphol Airport were prepared prior to top of descent. At that time the current weather at Schiphol Airport had been received via ATIS.[6] The weather indicated the need to perform an ILS (Instrument Landing System) CAT I approach. The ILS is a navigation aid for precision approaches.[7]

ILS approach procedures are divided into three categories (CAT I, II and III). The conditions that must be satisfied before initiating a particular ILS approach category are expressed in terms of horizontal flight visibility. A runway visual range (RVR) of at least 550 metres is required for a Category I approach. With this type of approach, the aircraft may not descend below the internationally adopted 'decision altitude' (DA), unless it is possible to observe the landing environment at this altitude.

The Captain stated that the aeroplane was prepared for an ILS CAT I approach followed by an automatic landing. This procedure is seldom flown in operational practice and was therefore comprehensively discussed by the two pilots prior to the descent. Both pilots stated that this briefing was clear and that there was no need to consult the manuals. The First Officer stated that during the briefing it was emphasised that this would be the first ILS CAT I approach followed by an automatic landing in limited visibility conditions for both pilots since completing conversion training on the Embraer 190.

Descent

Top of descent was at 113 kilometres before passing the Dutch border. Once air traffic control (Amsterdam Radar) had been contacted, runway 36R (Aalsmeerbaan) was assigned as the runway for landing.

Data from the Quick Access Recorder (QAR)[8] show that during descent the DA was set to 190 feet around the passage of FL290 and that when passing FL255 it was changed from 190 to 230 feet. That day, a NOTAM[9] had been published in which the obstacle clearance altitude[10] for ILS CAT I approaches to runway 36R for Category C aircraft (which includes the Embraer 190) was increased to 225 feet due to the presence of an obstacle.[11]

6 Automatic Terminal Information Service (ATIS) is a continuous transmission of aeronautical information and contains essential information such as runways in use, weather information and special procedures such as low visibility operations. Pilots listen to the available ATIS transmission before contacting air traffic control. This eases the workload for the air traffic controllers and eases congestion on the communications channel. See the 'Meteorological information' paragraph for the ATIS content.

7 A precision approach is an approach with guidance in both the horizontal and vertical planes. This is unlike a non-precision approach, where guidance is only given in the horizontal plane.

8 The Embraer 190 is equipped with a Quick Access Recorder (QAR) for recording flight data for the engineering department and the Flight Data Monitoring (FDM) programme.

9 A NOtice To AirMen (NOTAM) is a message containing critical information about an aerodrome or airspace, which is of a temporary nature or was not yet known when the national aeronautical publication (AIP) was compiled.

10 The obstacle clearance altitude is the lowest altitude that still provides a sufficiently safe margin in relation to obstacles in the final approach path. The decision altitude for an approach procedure must be at least equal to the obstacle clearance altitude.

11 The crew set the altitude to 230 feet; this is the closest value above 225 feet that can be set using the BARO/RA setting knob. This knob uses 10 feet steps.

The QAR data show that the final approach speeds were programmed at about the passage of FL160. With the estimated landing weight of 39,000 kilograms, a reference speed[12] of 119 knots and an approach speed[13] of 124 knots were entered into the Flight Management System.

Approach

Having contacted air traffic control (Schiphol Approach) the PF flew the aeroplane to final approach based on radar vectors. According to the QAR data the final approach path towards runway 36R was approached from the standard altitude of 2,000 feet. The autopilot was set to follow the final approach path and the speed was controlled by autothrottle.[14] While the aeroplane was flying on the final approach course and upon intercepting the glide slope, the landing gear was lowered and flaps were set to position 3.[15] At 1,400 feet, the flaps were set to the FULL position. At 1,100 feet, speed was reduced to the calculated approach speed of 124 knots. At 1,000 feet the aeroplane was prepared for landing.

The crew stated that no incorrect or abnormal indications about the aeroplane's configuration were observed during the final approach. If that had been the case then, according to the Captain, one or both pilots would certainly have commented on this. The crew assumed that the aeroplane was correctly configured for the intended automatic landing.

The Captain stated that he saw the runway from a distance of approximately 4 NM (7.4 kilometres). At that time the aeroplane was flying at an altitude of approximately 1,200 feet. The First Officer, in turn, stated that he could see the runway before the aircraft had passed an altitude of more than 500 feet. At that time the aeroplane was flying slightly to the left of the final approach path. Soon after, this was corrected by the autopilot. At low altitude, the First Officer again noticed a slight leftward displacement.

Landing

The Captain stated that at approximately 50 feet above the runway he noticed that the aeroplane was continuing to fly towards the runway at a constant rate of descent and did not perform a flare.[16] This was confirmed by the QAR data which indicated that the aeroplane's pitch remained at a constant 1.6 degrees above the horizon.

In an attempt to reduce the aeroplane's rate of descent the Captain pulled back on the control column at a low altitude. The Captain stated that he cannot remember whether or not he disengaged the autopilot.

12 The reference speed (V_{REF}) is the minimum safe airspeed at 50 feet above the runway threshold, which is used as a reference for calculating landing performance.

13 The approach speed (V_{AP}) is the reference speed with an added speed margin for wind (minimum 5 and maximum 20 knots).

14 The autothrottle controls the thrust from the engines by moving the thrust levers. In some modes a constant thrust is selected, in other modes the thrust levers are adjusted as required to control the airspeed.

15 The possible flap positions on the Embraer 190 are 0, 1, 2, 3, 4, 5 and FULL. Positions 5 and FULL are the landing positions.

16 A flare is the transition from horizontal flight close to the ground to the actual landing. In a flare the aircraft's nose is raised which reduces the rate of descent.

The QAR data shows that the autopilot disengaged at a height less than 9 feet (3 metres) above the runway. The tractive force on the control column at that moment was twice as high as during a normal manual landing. The aeroplane made a hard landing. After the main landing gear touched the ground the aeroplane's pitch increased further to 8.6 degrees before the nose wheel was landed. The First Officer stated that he was concerned that the aeroplane had sustained damage as a result of how hard the landing was. Therefore, while rolling-out on the runway he asked the Captain if he could still steer the aeroplane; the Captain replied in the affirmative. After the landing the Captain informed the passengers and taxied to the aircraft stand.

After the flight arrived at the aircraft stand and the engines were shut down, the central maintenance computer on board the Embraer 190 printed a warning that the aeroplane had touched down with a vertical acceleration that was 2.78 times the gravitational acceleration (g).[17] The printed warning was left in the maintenance records (AML)[18] along with a comment that a hard landing had been made. At the same time, an Engine-Indicating and Crew-Alerting System (EICAS) message was generated for the hard landing and an Aircraft Communications Addressing and Reporting System (ACARS) message was automatically sent to the airline's fleet controller. The First Officer stated that he informed engineering personnel about the hard landing so that the aeroplane could be inspected.

Subsequently, the crew then flew a scheduled flight to Nuremberg and back to Schiphol Airport with a different aeroplane to PH-EZV. After returning to Schiphol Airport (12 hours after the hard landing) the Captain submitted an Air Safety Report (ASR)[19] explaining that the aeroplane had made a hard landing. The ASR reported that the flaps were in position 5. Apart from the weather details the report did not contain any additional background information.

1.2 Injuries

The hard landing did not lead to any injured passengers or crew.

1.3 Damage to the aircraft

The inspection by engineering personnel revealed that the aeroplane had been damaged. An operating rod of the left-hand main landing gear door was damaged and an operating rod of the innermost right-hand wing flap was bent. Following on from these findings the damaged parts were replaced and the work was reported in the maintenance records.[20] Due to the replacement of components the aeroplane was not available for commercial operations for more than 24 hours.

17 The QAR had recorded a value of 2.54 g.
18 The Aircraft Maintenance Log (AML) is a register in which faults and the corrective actions by the Engineering Department and maintenance work are noted.
19 An Air Safety Report (ASR) is a form for reporting occurrences during the flight that relate to flight safety matters such as technical defects, losses of separation and bird strikes.
20 Maintenance Service Report (MSR).

1.4 Crew particulars

In 2014 both pilots had successfully completed conversion training on the Embraer 190 without notable points for attention. According to the airline's guidelines the crew was experienced on the Embraer 190 and available for assignment to this flight without restrictions. Table 1 presents a summary of the relevant crew particulars.

Crew member	Age	Type of licence	Total flying experience	Flying experience on Embraer 190	Completed conversion training	Previous position and aircraft model
Captain	40 years	ATPL(A)	3,667 hours	157 hours	17/08/2014	F/O F70/F100
First Officer (F/O)	32 years	CPL(A)	4,939 hours	317 hours	22/03/2014	S/O B777

Table 1: Crew particulars as per 1 October 2014.

1.5 Aircraft information

The PH-EZV is an Embraer ERJ 190-100 STD aeroplane which was built by the aircraft manufacturer Embraer in 2012 in Brazil with serial number 9000528. The aircraft is registered in the Dutch Civil Aircraft Register under number 7895.

Prior to the flight no technical defects had been reported and there were no items on the Hold Item List (HIL).

According to the loadsheet, which was compiled prior to the flight, the aeroplane had been loaded in such a way that the aeroplane's centre of gravity was within the limits set by the manufacturer for the entire flight.

According to the aircraft manual the aeroplane is capable of flying ILS CAT I, II and IIIA approaches. Given sufficient visual reference, ILS CAT I and II approaches may be followed by either a manual or automatic landing. Given sufficient visual reference, ILS CAT IIIA approaches must be followed by an automatic landing. If there is insufficient visual reference, a missed approach must be initiated for all categories.

The reference for altitude measurement is set using the BARO/RA[21] selection knob (see Figure 1). The outer ring is used to set RA (radio altitude) or BARO (barometric altitude) and the inner ring allows the decision altitude or height (DA or DH) to be set for the intended approach. The Enhanced Ground Proximity Warning System (EGPWS)[22] uses

21 Barometric altitude (BARO)/radio altitude (RA). BARO is the measured static air pressure that is converted to an altitude using the International Standard Atmosphere (ISA). With RA the height above the ground is determined with the aid of radio waves.

22 The EGPWS is a warning system on board the aircraft that issues warnings to prevent collisions with terrain ('TERRAIN', 'PULL UP', 'TOO LOW TERRAIN') and when windshear is detected ('CAUTION WINDSHEAR', 'WINDSHEAR'). In addition, advisory messages are given, including the announcement of 'MINIMUMS' at the set decision altitude or height.

this value for announcing the call 'minimums'. Setting the altitude/height to zero suppresses the announcement of 'minimums' by the EGPWS. The setting for the minima is displayed on the primary flight displays in the cockpit.

Figure 1: Location of the BARO/RA selection knob on the instrument panel (see red arrow). (Photo: Embraer)

When set to BARO prior to the start of the final approach, the autopilot will be able to perform an ILS CAT I approach up to the minima. When the intention is to make a manual landing, the automatic pilot on the Embraer 190 must be switched off at no lower than a radio altitude of 50 feet, regardless of the type of approach. If the latter is not done, the aeroplane will fly into the runway. If upon reaching the minima there is insufficient visual reference, a missed approach should be initiated.

To perform an automatic landing, the reference must be set to radio altitude (RA) and the flaps to position 5 before the start of the automatic ILS approach. Only after the AUTOLAND function has been activated (when the aeroplane is at an altitude of between 1,500 and 800 feet on the ILS glide slope) the pilot should set the BARO/RA selection knob to BARO in order to make the correct 'minimums' call.

The status of the autopilot and autothrottle are displayed as indications on the Flight Mode Annunciator (FMA) panel above the primary flight instruments (see Figure 2).

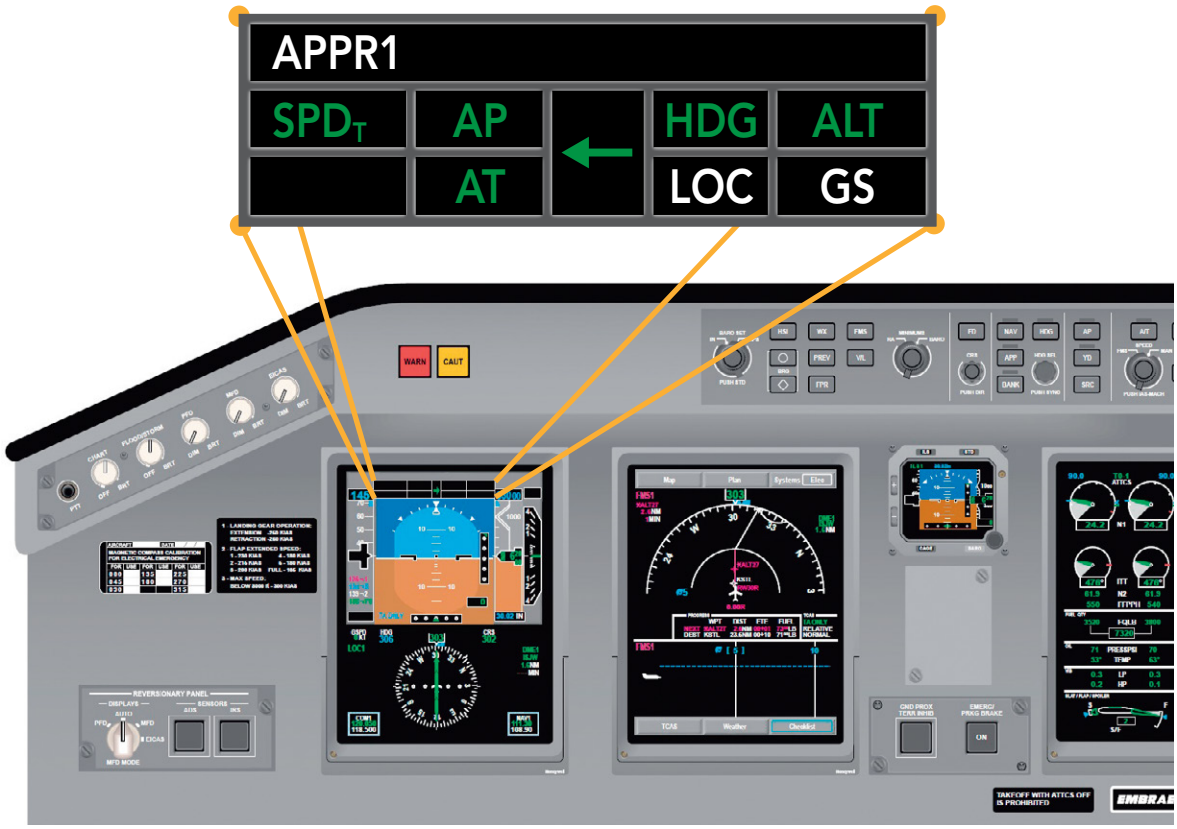


Figure 2: Location of and indications on the Flight Mode Annunciator (FMA) on the instrument panel. (Photo: Embraer)

The FMA indications for an ILS CAT I approach followed by a manual or automatic landing, respectively, are shown in Appendix C. The FMA indications are shown for nine different moments during approach and landing. These indications are explained.

1.6 Meteorological information

Prior to the flight the weather forecast for Schiphol Airport indicated (see box below[23]) that the wind would be coming from a southerly direction at 4 knots at the expected landing time of 07:55 hours. Visibility was expected to be 3,000 metres with a temporary reduction in visibility to 1,200 metres in fog banks with a 30% chance of a further temporary reduction in visibility to 600 metres and vertical visibility of 100 feet. Visibility would start to improve from 08:00 hours.

23 The times in this weather forecast are UTC times.The local time at Schiphol Airport when the occurrence happened was equal to UTC + 2 hours.

Weather forecast which was in possession of the flight crew prior to the flight:

FT 302256 0100/0206 18004KT 5000 BR SCT012
BECMG 0100/0102 3000
TEMPO 0101/0107 1200 BCFG NSC
PROB30 TEMPO 0101/0107 0600 FG VV001
BECMG 0106/0109 6000 NSW BKN005
BECMG 0109/0111 23010KT 9999 SCT020
PROB30 TEMP 0113/0122 7000 -RA BKN020
BECMG 0116/0119 VRB03KT
BECMG 0121/0124 4000 BR
PROB30 TEMPO 0202/0206 BKN006=

At the time the aeroplane entered the area under control of Schiphol Approach, ATIS message India was active. This stated that runway 18C (Zwanenburg runway) and 36R (Aalsmeer runway) were being used for landings. The wind on runway 18C came from a direction of 190 degrees at 6 knots and the wind on runway 36R from a direction of 190 degrees at 4 knots. Visibility was 1,400 meters in fog and the values for the actual runway visibility (RVR) were reported to the pilots on the ATC tower frequency during the last phase of the flight (see Table 2). There were clouds at 1,300 feet with a 1/8 coverage. The air and dew point temperature was 12 °C and the air pressure was 1024 hectopascal. Visibility would reduce further to 700 metres temporarily.

Time to landing	Runway Visual Range (RVR)		
	Section A (> 550 m)	Section B (> 125 m)	Section C (> 75 m)
8 minutes	750 m	550 m	375 m
4 minutes	1,100 m	650 m	400 m
2 minutes	2,000 m	1,300 m	550 m

Table 2: Runway Visual Range (RVR) for ILS CAT I approach (values designated 'Section A, B and C') and visibility reported by air traffic control at various times.

From the actual weather reports published (METAR) for Schiphol Airport (see Table 3) it appears that the visibility continued to decrease further until half an hour after sunrise.[24] It then started to increase again.

The last wind that air traffic control reported to the crew was 190/07. This resulted in a tailwind of approximately 7 knots.

24 On 1 October 2014 sunrise was at 07:25 hours.

Time	Wind	Visibility	Significant weather	Lowest RVR and runway indicator	Clouds	Change
05:25	170/05	3,200 m	Fog banks	500 m (18R)	None	Visibility 2,000 m
05:55	180/06	2,400 m	Fog banks	350 m (18R)	None	Visibility 1,200 m
06:25	160/06	2,200 m	Fog banks	300 m (18R)	None	Visibility 1,000 m
06:55	160/05	2,400 m	Fog banks	350 m (18R)	None	Visibility 1,400 m
07:25	180/06	1,400 m	Fog banks	275 m (27)	1/8 at 1,300'	Visibility 700 m
07:55	180/06	1,000 m	Fog	1100 m (27)	None	Visibility 3,000 m
08:25	180/05	1,900 m	Fog	Not reported	1/8 at 1,800'	Visibility 3,000 m

Table 3: Actual weather reports for Schiphol Airport.

1.7 Aerodrome information and navigation aids

Runway 36R (Aalsmeerbaan) is equipped with an Instrument Landing System (ILS). Further information on this is included in Appendix B. According to the Aeronautical Information Publication (AIP) this ground equipment supports ILS CAT IIIB approaches and automatic landings. Air Traffic Control the Netherlands stated that no anomalous behaviour by the ILS equipment on runway 36R was observed during the approach.

1.8 Flight recorders

The Embraer 190 is equipped with two digital Voice Data Recorders. This type of recorder is a combined Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR). The information from these recorders was overwritten by data from later flights and was not retained for the investigation.

The aeroplane was also equipped with a Quick Access Recorder (QAR) for recording flight data for the engineering department and the Flight Data Monitoring (FDM)[25] programme. The QAR information is comparable with the information from the FDR in terms of both quantity and quality and was suitable for the investigation.

1.9 Training

The training to convert the pilots to the Embraer 190 was provided by the airline. The training programme is described in the type rating course handbook and is based on national and European laws and regulations. The aim of the training is to equip the pilot with the necessary knowledge and skills to safely control the aeroplane in normal,

25 FDM is a legally prescribed part of an airline's safety management system.

abnormal and emergency situations. The initial training on the aeroplane type comprises instruction on the flight simulator, aeroplane training[26] and line training.[27] The simulator and line training conclude with formal exams.

The airline's Training Manager stated that during the simulator training eight to ten automatic landings are practised. These approaches and landings are flown with one or two engines working and moreover various system malfunctions are presented to the candidates.

During line training two automatic landings are practised in the aeroplane with both engines working; this is the autoland categories I and IIIA. System malfunctions are not introduced intentionally during line training. The candidates are expected to perform the correct actions if unexpected system malfunctions do occur.

The airline is authorised to provide recurrent training for its pilots in accordance with the Alternative Training and Qualification Programme (ATQP).[28] This allows the airlines to set up recurrent training in such a way that topics that require special attention based on measurements during their own operations are covered. The sources of these measurements are, for example, results of previous recurrent trainings, ASRs, FDM results and incident and accident investigations. The airline's recurrent training in the twelve months prior to the occurrence did not include any automatic landings. As they had only recently converted to the Embraer 190, the crew of PH-EZV had not received any recurrent training.

In addition to recurrent training, pilots undergo proficiency checks once a year. There is a statutory obligation for a pilot to perform an automatic landing once a year during the licence revalidation proficiency check. There is no requirement to perform a minimum number of automatic landings during actual flight operations. It is therefore feasible, in principle, that a pilot will not perform any automatic landings in the twelve months between successive licence revalidation proficiency checks.

The airline's Training Manager stated that it is the responsibility of the individual pilots to maintain their own proficiency in all aspects of flying (so including automatic landing).

1.10 Similar occurrences

A similar occurrence involving the same type of aircraft from the same airline took place on 15 December 2009. During the approach towards runway 23 at Hamburg airport an ILS CAT I automatic landing was performed by the First Officer. Because the BARO/RA setting knob was not set to RA at the start of the approach the autopilot did not engage the autoland mode. The crew did not notice this and it resulted in a hard landing.

26 Aeroplane training is a training flight without passengers where the candidate flies circuits in the aeroplane under the supervision of an instructor.
27 Line training consists of 20 to 36 scheduled flights with passengers where the candidate, under the supervision of an instructor, learns to apply the procedures and techniques learned in the simulator training in practice. As part of the line training another two return sessions are flown in the simulator.
28 Commission Regulation (EU) No. 965/2012 Part ORO.FC.A.245.

The aeroplane was not damaged and none of the passengers were injured. The airline did not further investigate this occurrence at the time.

A second similar occurrence involving the same type of aircraft from the same airline took place on 4 October 2015. Prior to commencing the approach to Schiphol Airport an ILS CAT III approach was briefed, including discussion of changing this to an ILS CAT I approach followed by a manual landing if visibility improved. Based on the latest weather report it was decided to fly an ILS CAT I approach followed by a manual landing. At an altitude of approximately 1,000 feet the air traffic controller reported the cloud ceiling and the pilots realised that they might have insufficient visibility at the decision altitude. The crew decided to fly the approach to the CAT II minima and at 800 feet they engaged the autopilot and the autothrottle, upon which an amber APPR2 indication appeared on the FMA. The crew then selected a decision height of 100 feet and the colour of the APPR2 changed to green, the indication for a manual landing. From that moment the pilot flying was under the impression that the automatic approach would be followed by an automatic landing while the pilot monitoring expected a manual landing. The result was that the aeroplane made a hard landing.

The Brazilian investigating authority and aircraft manufacturer Embraer stated that they had no knowledge of similar occurrences.

1.11 Additional information

In the operations manual the airline has stipulated the type of occurrences that should be reported and how they should be reported to ensure that this information is received by the relevant departments and that correct follow-up actions are set out. In the event of a (serious) incident[29] or accident the Captain is obliged to:

1. Inform Operations Control.[30] They evaluate the occurrence and decide based on guidelines what follow-up actions are required. It is customary for the airline to ground the pilots involved if an investigation is started. This prevents recollections of the occurrence fading because of experiences during more recent flights. A hard landing is not explicitly named as an occurrence that must be notified to Operations Control.

2. Submit an Air Safety Report (ASR) as soon as possible after the occurrence. The airline specifically stipulates that an ASR must be submitted after a hard landing.

3. Write a damage report and make a note in the Aircraft Maintenance Log (AML) in the event of damage to the aircraft. A hard landing is also explicitly named as a reason for writing a damage report. This obligation does not apply to damage sustained at

29 An incident is defined as an occurrence - not being an accident - where the safety of the aircraft operation is or could be comprised. A serious incident is defined as an occurrence where the circumstances indicate that a accident nearly took place.
30 Operations Control is the airline's department that handles the daily control of aircraft operations.

Schiphol Airport when Operations Control has been notified because this department ensures that a damage report is drawn up.

The airline's procedures further stipulate that the data from the flight recorders must be retained in the event of a (serious) incident or accident.

The company employs a so-called just culture policy that encourages employees to report incidents and unsafe situations and which should ensure that this does not, in principle, have any negative consequences for those involved. This policy is communicated to the employees in various ways.

2 ANALYSIS

This chapter attempts to answer four investigation questions.

- What were the causes of the hard landing?
- While the approach was being made, why was the fact that the aeroplane was configured for an ILS CAT I approach that should have been followed by a manual landing not detected?
- What evidence is there that the aircraft was prepared for an ILS Category I approach with manual landing in all respects prior to the final approach?
- To what degree did not starting an investigation immediately after the occurrence influence how the investigation was conducted?

2.1 Causes of the hard landing

What were the causes of the hard landing?

The autothrottle and the autopilot are two independent systems. The reason for the autothrottle to close the throttles is the value registered by the radio altimeter. Whether the autopilot is active or how it has been programmed has no effect on the functioning of the autothrottle.

In a Category I autoland, the landing is initiated at 50 feet above the runway by the autopilot activating the landing flare. This manoeuvre increases the aircraft's nose position, which reduces the rate of descent. The autothrottle then closes the throttles at 30 feet above the runway. This further reduces the rate of descent until the main landing gear contacts the runway. In a Category I approach without autoland, the automatic landing flare is not performed; however, the throttles may nevertheless close, depending on the selected settings. The QAR record shows that during the occurrence the throttles were closed between 48 and 34 feet above the runway threshold.

At roughly 50 feet above the runway threshold, the captain realised that the aircraft was not going to perform the intended landing flare. Due to the selected configuration, the autopilot had kept the control column and the elevator in practically the same position. As a result, the aircraft's nose position also remained more or less constant at 1.6 degrees above the horizon.

The automatic pilot switches off if a large amount of force is applied to the control column in a short period of time in a direction that is contrary to the control signals from the automatic pilot. The QAR record shows that the automatic pilot disengaged below a height of 9 feet, but before the wheels touched the ground. The captain's statement that

he pulled back on the control column in an attempt to reduce the rate of descent is thus confirmed by the QAR record.

The tractive force on the control column appeared to increase to twice the value for a normal landing. Immediately after the automatic pilot automatically disengaged, the position of the control column and the elevator changed and the aircraft's nose position increased. This could not prevent the aircraft from making a hard landing with a force 2.78 times gravitational acceleration.[31]

As a result of the valid yet unintended configuration, the system gave no warning that warranted earlier intervention by the crew. There was thus no reason for the crew to have initiated a go-around, for instance, during the final approach.

The QAR data shows that the aeroplane's pitch increased to 8.6 degrees above the horizon after the landing, after which the Captain landed the nose wheel. The Captain stated that the aeroplane could be steered properly during the roll-out on the runway and when taxiing to the aircraft stand.

Finding 1
In accordance with the selected configuration, the aircraft did not perform a landing flare and flew at a constant rate of descent in the direction of the runway. The crew were incorrectly under the impression that they had configured the aircraft for an automatic landing.

At roughly 50 feet above the runway, the captain became aware that the aircraft was not going to perform the intended automatic landing. He then tried to reduce the rate of descent by pulling back on the control column in an attempt to prevent a hard landing.

2.2 Execution of the approach and landing

While the approach was being made, why was the fact that the aeroplane was configured for an ILS CAT I approach that should have been followed by a manual landing not detected?

The crew used the aircraft's autopilot and autothrottle to execute the approach and the intended automatic landing. The system settings were displayed as status indications on the *Flight Mode Annunciator* (FMA). The FMA indications corresponding to an ILS

31 According to information from the airline, this value of 2.78 is significantly greater than was observed in the two similar incidents mentioned earlier. The Dutch Safety Board did not investigate whether, and to what extent, the fact that the pilot raised the aircraft's nose position shortly before hitting the runway increased the severity of the impact.

Category I approach followed by a manual landing and an ILS Category I approach followed by an automatic landing are shown in Appendix C.

BARO/RA setting knob

The QAR record shows that while flying the final approach course an FMA indication was displayed for an ILS Category I approach, followed by a manual landing. This FMA indication is displayed during this flight phase after the BARO/RA decision height knob is set to BARO and implies that the automatic pilot will not be performing an automatic landing. In other words, a system setting was indicated that did not correspond with what the pilots had in mind.

The (intended) *autoland* mode (AUTOLAND1) is only activated on the Embraer 190 if the BARO/RA setting knob is set to RA and the flaps are set to position 5. When the aircraft is configured correctly, this mode is activated on the glide slope between 1,500 and 800 feet above the runway threshold. In an ILS Category I automatic landing, the BARO/RA setting knob must be set to BARO and the decision height must be set after activating AUTOLAND1. The pilots involved were fully certified to fly the Embraer 190 and familiar with this procedure. Incidentally, having to make manual settings during this flight phase differs from the procedures in aircraft types previously flown by the crew (Fokker 70/100 and Boeing 777), where an ILS approach is always followed by an automatic landing unless this function is manually disengaged. The BARO/RA setting knob and the position of the flaps do not play a role in activating the autoland mode of the automatic pilot on these types of aircraft.

Aircraft configuration

According to the QAR record, the APPR1 mode was activated after passing 1,500 feet above the runway threshold. The QAR record shows that the flaps were set to the FULL position at 1400 feet. As a result of this the automatic landing would not have been activated even with the correct setting on the BARO/RA selection knob. According to the QAR record the FMA indications had still not changed when passing 150 feet above the runway threshold and corresponded to an ILS Category I manual landing.

Both pilots have stated that the majority of the ILS Category I approaches they had previously made were followed by a manual landing. As such, the FMA indications that they saw during the approach were what they were used to seeing. The aeroplane was in a valid configuration, which meant no error messages were generated. As a result, both pilots had no reason to think that the aeroplane was not flying in the correct mode for an ILS Category I approach followed by an automatic landing.

Finding 2
Because the FMA indications the crew members saw during the approach were the same as what they were used to seeing, the indications from the automatic pilot did not cause them to notice that the aircraft was configured for an ILS Category I approach followed by a manual landing. Moreover, the aircraft was in a valid configuration, which meant no error messages were generated. As a result, both pilots had no reason to think that the aircraft was not flying in the correct mode for an ILS Category I approach followed by an automatic landing.

The system is not designed to draw the pilots' attention to the fact that they have to switch off the automatic pilot at low altitude above the runway, in accordance with the procedure for a manual landing. Combined with the fact that the actions necessary for configuring the system for an automatic landing differ from those in other aircraft types, this raises the question of whether safety benefits can be achieved by modifying these components of the man-machine interaction in the Embraer 190. After all, the way in which the interface between an automated system and its human user is designed can affect whether or not unintended system settings are noticed. Mistakes can be prevented by optimally modifying the interface to the performance of tasks by humans. Given the severity and frequency of occurrence of the investigated type of occurrence, however, the Dutch Safety Board finds that a further analysis of the man-machine interface falls outside the scope of this investigation.

2.3 Considerations for selecting a CAT I automatic landing

What evidence is there that the aircraft was prepared for an ILS Category I approach with manual landing in all respects prior to the final approach?

The pilots' decision to take an ILS Category I approach followed by an automatic landing was based on the weather report from ATIS message India. This report indicated a flight visibility of 1,400 metres and no cloud base (only a 1/8 coverage of clouds at 1,300 feet). Accordingly, there would be sufficient visual reference[32] when reaching the Category I decision height of 230 feet to continue the approach and make a safe landing.

The pilots have stated that updates indicated an improvement in the weather during the approach to Schiphol Airport. The actual runway visibility (see Table 2) during the approach was sufficient for an ILS Category I approach. The captain has stated that the improvement of the weather did not serve as a reason for him to change the plan for an ILS Category I automatic landing, as this might have caused confusion among the crew. Moreover, visibility could still decrease at sunrise.

32 An ILS Category I approach can be continued upon reaching the decision height if the crew can visually observe all or part of the approach lighting, the runway threshold and associated lighting, visual glide slope indicators, runway aiming point markings and/or lighting or the runway edge lighting.

Approach preparation

The Cockpit Voice Recorder data have not been retained. As a result, the crew's statements are an important source of information on the preparations for the approach and landing at Schiphol Airport. The Captain stated that the preparations were completed prior to the top of descent. Both pilots stated that considerable attention was paid to the set-up of the ILS CAT I automatic landing and the procedure to be followed was clear and that this gave no cause to consult the manuals. However, the QAR records show that the aeroplane was not correctly configured for an ILS CAT I autoland prior to the approach.

The airline's operations manual prescribes that it is recommended to have prepared the approach 50 nautical miles (93 km) before the top of descent. The preparations comprise going through the relevant information, setting up the onboard equipment and briefing the other pilot. The briefing must cover the following topics; approaches to the home base of the airline, Schiphol Airport are excepted for this:

1. *Weather and NOTAMs for the destination and alternate aerodromes.*
   The ATIS information was used for the current weather and runway use at Schiphol Airport. Due to the change of take-off and landing peaks at Schiphol Airport it is possible that the crew based the preparations for the approach on main runway 18C (Zwanenburg runway). No NOTAM had been published for this runway. Air traffic control (Amsterdam Radar) only assigned runway 36R during the descent. This could explain why the higher decision altitude of 230 feet in accordance with the NOTAM for this runway was only set when passing FL255 during the descent.

2. *Arrival route, holding areas and approach procedure for the intended runway.*
   German air traffic control had given permission to fly a straight line to point ARTIP near Lelystad. Radar vectors towards the final approach path could be expected from ARTIP. The final approach would be commenced from 2,000 feet above mean sea level.

3. *The use of the autopilot during the approach and the corresponding indications on the Flight Mode Annunciator (FMA).*
   The autopilot can only perform an automatic landing if both BARO/RA selection knobs (see Figure 1) are set to RA before the final approach is commenced.

   Configuring the ILS CAT I autoland requires additional actions in relation to the ILS CAT III approach. This differs from the procedure in aircraft types previously flown by the crew (Fokker 70/100 and Boeing 777) where the BARO/RA selection knob does not have a function in activating the autopilot's autoland mode.

   The QAR record shows that the decision altitude was set to BARO 190 feet at FL290 and was changed to BARO 230 feet at FL255. This change was probably made as a result of the assignment of runway 36R by Amsterdam Radar and the corresponding NOTAM for that runway. The airline's procedures stipulate that the highest value for the decision altitude and the increased obstacle clearance altitude must be observed.

No further changes to the decision altitude were recorded. As a result of setting the decision altitude/height to BARO 230 instead of RA (with an arbitrary value for the DH) the autopilot was not set to perform an automatic landing.

Finding 3
The crew set the BARO/RA selection knob to BARO instead of RA before commencing the final approach. As a result the autopilot was set to perform an ILS CAT I appraoch followed by a manual landing.

4. *Required flap position and braking actions during the landing.*
The aircraft manual stipulates that automatic landings must be flown with flaps at position 5. Moreover, the speed during approach has to be increased in comparison to a manual landing. The crew have to determine the speeds for the approach and the landing based on Table 4. With a planned landing weight of 39 tonnes the last column in Table 4 shows the reference speed for an automatic landing should be 134 knots. With the prevailing wind the approach speed should be 139 knots. The QAR record shows that at FL160 the crew entered a reference speed of 119 knots into the Flight Management System. According to the fifth column of Table 4, with a landing weight of 39 tonnes, this value matches the reference speed for a landing with flaps in the FULL position.

WT (t)	V_{FS}	V_{REF} FL5 V_{AC} FL3 NO ICE ACCR	V_{REF} FL5 V_{AC} FL3 + ICE ACCR	V_{REF} FULL V_{AC} FL4	CAT II/ AUTOLAND V_{REF} FL5 V_{AC} FL3
28	156	104	110	104	114
30	161	107	114	104	118
32	167	111	118	107	122
34	172	114	121	111	126
36	177	118	125	114	129
38	182	121	128	117	133
40	187	124	132	120	136
42	191	127	135	123	140

Table 4: Airspeeds (in knots) in relation to aeroplane weight, flap positions and type of landing.

The automatic pilot will not perform an automatic landing on an approach with the flaps in the FULL position. Both pilots stated that they were convinced that they had selected position 5 for the flaps during the approach. The QAR record has thus shown that the flaps had been set to the FULL position.

Finding 4
The crew programmed the approach speeds for an approach with flaps in the FULL position and put the flaps actually in this position. An automatic landing is not possible with flaps in the FULL position.

5. *Intended taxiway for leaving the runway and the taxi route to the aircraft stand.*
   This topic in the manual was not examined further during the investigation.

2.4 Start of the investigation

To what degree did not starting an investigation immediately after the occurrence influence how the investigation was conducted?

The airline should report a serious incident or an accident to the Dutch Safety Board by telephone as soon as possible. For proper analysis of the occurrence it is essential to be able to collect as much factual information as possible about the circumstances surrounding the occurrence. The time aspect plays an important role in this.

In this case the procedures for reporting an occurrence were interpreted in such a way that the Operations Control department was not informed immediately after the event. As a result, the airline did not start the safety investigation immediately. It was not possible to determine whether or not the existence of the just culture policy had an effect on the actions of those involved after the occurrence.

A damage report was not compiled immediately after the occurrence, the flight recorders (CVR and FDR) were not secured and the flight crew were not grounded for a safety investigation. As a result, an important information source for the investigation, the CVR, was lost and the memories of the flight crew have faded.[33] Not having the CVR available had consequences for reconstructing the events and gain insight into the crew's considerations prior to the hard landing.

Following routine analysis of the ASR, the reports by the engineering department and the information from the Flight Data Monitoring (FDM) system, it was only two weeks after the occurrence that the flight safety department that investigates occurrences within the airline established that this hard landing required further investigation. Subsequently, three weeks after the occurrence, the airline formally decided to institute an investigation. The pilots could not be scheduled-in for an interview with investigators from the airline's flight safety department any earlier than 4 November 2014.

33 The QAR was available for the investigation; the QAR information is comparable with the FDR information.

The airline notified the Dutch Safety Board of the occurrence on 20 October 2014. The Dutch Safety Board commenced its own investigation in parallel with the airline's investigation. The manuals, audio recordings of interviews with the crew and the QAR information supplied by the airline were used in this investigation.

Finding 5
The procedures for reporting occurrences, as described in the operations manual of the airline, allow room for interpretation which occurrences should be reported and what follow-up actions are required. As a result of this, important sources of information for the investigation of occurrences are lost.

Not having the Cockpit Voirce Recorder available had adverse effects on the reconstruction of events and gaining insight into the crew's considerations prior to the hard landing. The crew's recollections of the occurrence had faded and/or may have been influenced by more recent flight experiences.

2.5 Further findings

A number of potential risk factors have been excluded as having had an effect on the hard landing:

- Prior to and during the flight there were no problems with the onboard equipment for receiving ILS signals, the autopilot or the autothrottle.
- During approach and landing there were no malfunctions in the ILS on runway 36R (Aalsmeerbaan).
- There were no other air traffic or vehicles in the ILS protection area.
- The Captain and First Officer met the legal requirements for conducting the flight.
- According to the airline the employment of the crew met both the legal requirements and standards for work and rest times and the (more stringent) agreements set out in the Collective Labour Agreement.

2.6 Fatigue

Fatigue can lead to a reduced ability to make judgements and to safety risks. The Captain has stated that he could not rule out the possibility that fatigue played a role in the occurrence of the incident. However, no concrete evidence for this has been found. The crew has stated that they began the working day fully rested, despite the early reporting time on the day of the incident and the two preceding days. After the hard landing, the crew still decided to conduct a subsequent flight, which suggests that the crew felt sufficiently fit.

2.7 Training

During the initial training on the Embraer 190 the necessary knowledge and skills to fly the aeroplane safely during normal, abnormal and emergency situations must be conveyed to the pilot. According to the syllabus various automatic landings are practised during the training sessions, but only a small number of these are ILS CAT I automatic landings. It is therefore possible that training in this subject was inadequate and that the crew relied too much on their experience with other types of aircraft. The Dutch Safety Board has found no concrete indications that point to the occurrence having arisen as a result of (flawed) training.

2.8 Measures taken by the airline

Parallel to the investigation of the Dutch Safety Board, the airline carried out a safety investigation that found, among other things, that the user interface between the aircraft's automation and the pilots makes it possible for such an incident to occur. The airline has shared its full investigation report with the Dutch Safety Board.

Within the airline lessons have been learned from the incident and a measure has been put in place to prevent similar incidents in future. The occurrence is discussed during refresher training given to all of the airline's Embraer 190 pilots. In addition, the airline is going to examine how the procedures relating to reporting incidents and follow-up actions can be improved.

2.9 Recommendations

The Dutch Safety Board has not formulated recommendations.

3 CONCLUSIONS

The crew were incorrectly under the impression that they had configured the aircraft for an automatic landing. The indications of the automatic pilot did not lead the pilots to suspect that the aircraft was actually configured for a manual landing. The FMA indications that they saw during the approach were what they were used to seeing. Moreover, the aircraft was in a valid configuration, which meant no error messages were generated. As a result, both pilots had no reason to think that the aircraft was not flying in the correct mode for an ILS Category I approach followed by an automatic landing. The aircraft did not perform a landing flare and made a hard landing.

The fact that the Cockpit Voice Recorder was no longer available has had adverse effects on reconstructing events and gaining insight into the crew's considerations prior to the hard landing. The crew's recollections of the incident have faded and/or may have been influenced by more recent flight experiences. The procedures for reporting incidents described in the airline's operations manual leave room for interpretation regarding which incidents should be reported and what follow-up actions are required. This results in the loss of important sources of information for the investigation of incidents.

APPENDIX A

DRAFT VERSION REPORT

A draft version of this report has been presented to the parties involved in accordance with the Dutch Safety Board Act. These parties have been requested to check the report for any factual inaccuracies. The report has been presented to the following persons and organisations:

- Airline;
- Captain;
- First Officer;
- CENIPA - Aeronautical Accidents Investigation and Prevention Center, Brazil;
- Embraer S.A.

The Dutch Safety Board received a response from all these parties.

The Board has incorporated corrections of factual inaccuracies, additional details as well as editorial comments, where relevant. The relevant passages were amended accordingly in the final report.

The Board replied to the responses that were not included in the report and included them in the table below (both the original responses and the Board's replies). The page numbers listed in the table refer to the numbering of the draft report and no longer necessarily correspond to the numbering in the final report.

	Party	Page number	Text report	Response party	Board's reply
1	Airline	1	Title of report	Furthermore, the format of the title is not in line with international standard as defined in ICAO Annex 13 (Appendix: Format of the final report).	Annex 13 specifies a recommended format for the final report. Annex 13 indicates that the format may be modified depending on the circumstances of an accident or incident. The Dutch Safety Board employs its own format for the title page of the report.
2	Airline	4	Classi-fication: accident	From footnote 30 on page 16, it is clear that the Dutch Safety Board uses the same definitions of 'incident, serious incident and accident' that the ICAO uses. This means that the examined occurrence should be classified as an 'accident' because of the damage to the aircraft. In order to warrant classification as an 'accident', there must be a causal link between the occurrence and the observed damage to the aircraft. After the occurrence in question, the aircraft underwent an inspection. During the inspection, damage to the aircraft was found as described on page 4 of the report. However, the sequence of occurrence and inspection in no way demonstrates that the damage was caused by the occurrence. The investigation does not rule out that the damage to the aircraft may already have been present before the occurrence under investigation. Thus, the classification of this occurrence and the obligation to investigate this occurrence is debatable.	The airline reported the hard landing to the Dutch Safety Board at the time because damage to the aircraft was found during an inspection after the hard landing that took place after the automatic approach. When classifying the occurrence, the Dutch Safety Board assumed that the damage was caused by the hard landing. The Dutch Safety Board is free to investigate any occurrence, regardless of how it is classified.

APPENDIX B

ILS SYSTEM

An ILS system comprises various components:

- The localizer transmitter, for transmitting a horizontal guidance signal to the runway. The antenna from the transmitter associated with runway 36R is located 259 metres past the end of the runway.
- The glide slope transmitter, for transmitting a vertical guidance signal to the runway. The antenna for the transmitter associated with runway 36R is located 120 metres west of the centreline of the runway at 299 metres from the runway threshold.
- Distance markings for checking the vertical guidance signal. This is achieved for runway 36R by Distance Measuring Equipment (DME) transmitting signals for determining the distance in relation to the runway threshold.

The quality of the ILS ground system is expressed in the ICAO ILS classification system. Here the performance category (CAT I, II and III), the accuracy and range of the ILS signal and the integrity of the signal are combined into a code of numbers and letters. The ILS on runway 36R, according to the Dutch Aeronautical Information Publication (AIP)[34], is classified in the highest classification (CAT III/E/4).

Because the localizer antenna is at the end of the runway, the signal could possibly be disrupted by aircraft or vehicles moving in the immediate vicinity of the runway. This is prevented by keeping the protection area free of aircraft during low visibility operations. This area comprises a sensitive area[35] and critical areas[36] around the localizer and glide slope antennas.

34 www.ais-netherlands.nl.

35 The sensitive area is the area within which aircraft and vehicles can disrupt the ILS signal. The dimensions of the area depend on the type of approach; 75 metres from the centreline of the runway for ILS CAT I approaches and 150 metres from the centreline of the runway for ILS CAT II/III approaches.

36 The critical area is the area within which the presence of aircraft or vehicles results in an unacceptable disruption of the ILS signal. This area has fixed dimensions and must remain clear at all times.

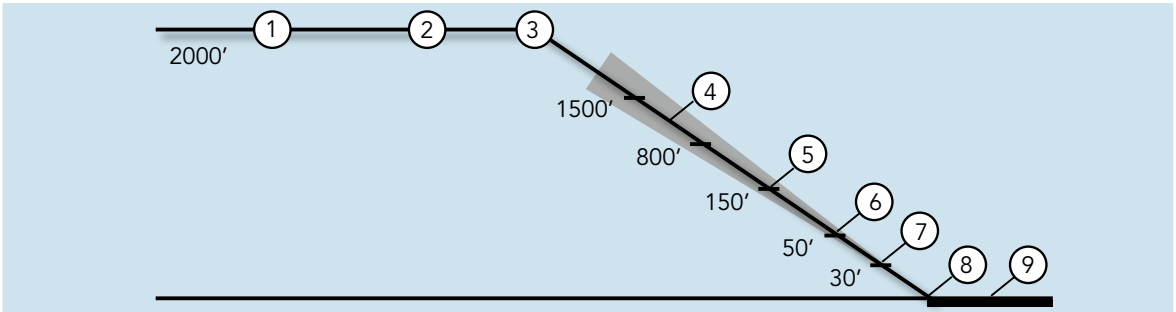
FMA INDICATIONS

Location 1: Route towards final approach path
When flying towards the final approach path, the approach (APP) mode of the autopilot must be set to be able to follow the signals from the localizer antenna and the glide slope antenna. As a result of this, LOC and GS will be displayed in white on the FMA. The white colour indicates that this mode is ready (armed) for activation.

Setting the BARO/RA knob to BARO will activate the ILS CAT I approach. This is shown on the FMA by the indication APPR1 (see the left-hand column of Figure 3). The QAR record shows that during the flight the white APPR1 indication was displayed on the FMA.

When the BARO/RA setting knob is set to RA an ILS CAT I autoland is armed. This is shown on the FMA by the white AUTOLAND1 indication (see the right-hand column of Figure 3). In this case, the corresponding minima can be set to zero, to prevent the EGPWS announcing minima at an incorrect height.

Location 2: Interception of the final approach path
On intercepting the final approach path the FMA indicates that the heading to the final approach (HDG) is no longer being followed but that the signal from the localizer antenna (LOC) will be followed. Activation of the LOC mode is first displayed on the FMA against a green background, after which the FMA field turns black and LOC appears in green letters.



Nr	Description	FMA indications	
		ILS CAT I manual landing	ILS CAT I autoland
1	Route towards final appoach path	APPR1 SPD$_T$ AP HDG ALT AT LOC GS	AUTOLAND1 SPD$_T$ AP HDG ALT AT LOC GS
2	ILS localizer capture	APPR1 SPD$_T$ AP LOC ALT AT GS	AUTOLAND1 SPD$_T$ AP LOC ALT AT GS
3	ILG glide slope capture	APPR1 SPD$_T$ AP LOC GS AT	AUTOLAND1 SPD$_T$ AP LOC GS AT
4	On ILS glide slope below 1,500 ft	APPR1 SPD$_T$ AP LOC GS AT	If flaps set to position 5 AUTOLAND1 SPD$_T$ AP LOC GS AT ALIGN FLARE Thereafter, BARO/RA selector must be manually set to BARO and set CAT I minima
5	On ILS glide slope at 150 ft	APPR1 SPD$_T$ AP LOC GS RETD AT	AUTOLAND1 SPD$_T$ AP ALIGN GS RETD AT RLOUT FLARE
6	Switching of automatic pilot/ start of flare at 50 ft	APPR1 SPD$_T$ AP LOC GS RETD AT	AUTOLAND1 SPD$_T$ AP ALIGN FLARE RETD AT RLOUT D-ROT
7	Retard of throttles at 30 ft	APPR1 RETD LOC GS AT	AUTOLAND1 RETD AP ALIGN FLARE AT RLOUT D-ROT
8	Landing	APPR1 LOC GS AT	AUTOLAND1 AP RLOUT D-ROT AT
9	Roll-out on runway	APPR1 LOC GS AT	AUTOLAND1 AP RLOUT D-ROT

Figure 3: FMA indications for an ILS CAT I approach with manual landing (left-hand column) and for an ILS CAT I approach with automatic landing (autoland, right-hand column)

Location 3: Glide slope interception
On intercepting the glide slope the FMA indication ALT is replaced by the FMA indication that the glide slope (GS) will be followed.

Location 4: On ILS glide slope below 1,500 feet
On passing 1,500 feet above the runway threshold the APPR1 mode is activated in most cases in an ILS CAT I approach. This is shown on the FMA by the word APPR1 moving to the right and turning green. This FMA indication remains unchanged until the moment that the autopilot is disengaged. According to the QAR record APPR1 mode was indeed activated at 1,500 feet.

The autoland mode is activated instead of the APPR1 mode if the BARO/RA setting knob is set to RA in this flight phase and flaps are set to position 5. When the aeroplane is correctly configured the autoland mode is activated between 1,500 and 800 feet. This can be seen on the FMA because AUTOLAND1 moves to the right and turns green.

In addition the autopilot arms the ALIGN and FLARE modes. The ALIGN mode allows the autopilot to align the longitudinal axis of the aeroplane with the centreline of the runway. The FLARE mode reduces the aeroplane's rate of descent on landing. If these FMA indications are not displayed at 800 feet the aeroplane will not perform an automatic landing.

Once the autoland mode has been activated, the autopilot will trim the aeroplane to a higher pitch at 800 feet to prepare for the landing or initiate a missed approach if necessary. As a result of this the control column moves slightly forward to continue following the glide slope.

For an ILS CAT I autoland the corresponding minima must be set and the BARO/RA selection knob must be turned to BARO after AUTOLAND1 has been activated. This will cause the EGPWS to announce the correct minima.

Location 5: On ILS glide slope at 150 feet
In an ILS CAT I autoland the autopilot will align the longitudinal axis of the aeroplane with the centreline of the runway at 150 feet above the runway threshold. This is shown on the FMA as the activation of the ALIGN mode that had been armed earlier, between 1,500 and 800 feet. Moreover, the roll-out (RLOUT) and retard (RETD) modes are armed (displayed in white). The roll-out mode allows the autopilot to have the aeroplane follow the localizer signal after landing on the runway. The retard mode prepares the autothrottle to close the throttles during landing.

Location 6: Switching off automatic pilot/initiating the flare at 50 feet
In an ILS CAT I autoland the aeroplane inititates the landing at 50 feet above the runway through activation of the flare by the autopilot. The aeroplane's pitch will be increased, reducing the rate of descent. This can be seen on the FMA by the activation of the FLARE mode (turns green) and the arming of the de-rotate (D-ROT) mode. This is the mode in which the aeroplane's pitch will be lowered once the main landing gear has landed on the runway.

When the intention is to make a manual landing, the automatic piot must be switched off at no lower than a radio altitude of 50 feet.

Location 7: Closing the throttles at 30 feet
In the automatic landing the throttles are closed automatically at 30 feet above the runway. This is shown on the FMA by the activation of the RETD mode. The autopilot flies the aeroplane to the runway.

Location 8: Landing
In an automatic landing the autopilot keeps reducing the rate of descent until the main landing gear touches down on the runway. Once this happens the RLOUT mode is activated. This allows the aeroplane to be kept in the middle of the runway. Moreover, the D-ROT mode is activated to allow the nose wheel to land and the autothrottle is switched off. The latter is shown by an AT indication against a green background.

Location 9: Rolling-out on the runway
In an automatic landing the autopilot disengages five seconds after the main landing gear has touched down on the runway. This can be seen on the FMA from a flashing AP indication on a red background. After a few seconds all FMA indications disappear.

Note: The use of the autothrottle system is not linked to the type of approach. The autothrottle can be switched on or off for either an automatic or manual landing. This means that the SPDt and AT indications can be present or absent on both FMAs. This depends on the choice of the *pilot flying*.

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