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INVESTIGATION REPORT

Accident to the Embraer EMB-550 Legacy 500 registered RA-02788

on 27 November 2017
at Paris Le Bourget airport (Seine-Saint-Denis)

Time	At 05:55[1]
Operator	LLC L39 Engineering
Type of flight	Cross country
Persons onboard	Captain, first officer, cabin crew
Consequences and damage	Aeroplane substantially damaged

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in June 2020. As accurate as the translation may be, the original text in French is the work of reference.

[1] Except where otherwise indicated, times in this report are UTC. One hour should be added to obtain the local time in France.

Activation of angle-of-attack (AOA) limiter protection during flare, hard landing

1 - HISTORY OF THE FLIGHT

Note: This information is based on the crew's statements, the flight parameters recorded in the FDR and the data recorded in the CVR.

The crew of the Embraer Legacy 500 were carrying out a private flight from Moscow-Domodedovo airport, bound for Paris-Le Bourget airport.

At Moscow, a thin film of ice covered the aeroplane and the crew had it de-iced. As icing conditions were prevailing at Moscow airport, the crew set the selector of the ice protection control panel to ALL before starting up the engines. During their start-up, the A-I WINGSTAB FAIL message[2] appeared on the EICAS[3]. The crew tried to reinitialize the system by pressing the WINGSTAB pushbutton and then using the ICE PROT MODE selector (see Figure 2 hereafter). The failure message continued to be displayed[4].

Around five minutes after take-off, the STALL PROT ANTICIPATE warning message[5] appeared on the EICAS and remained on the screen until the end of the flight.

[2] This message indicates a failure of the anti-icing system of the wing and horizontal stabilizer leading edges. (see section 2.3).

[3] Engine Indication and Crew Alerting System.

[4] According to the flight parameters recorded in the FDR, the A-I WINGSTAB FAIL message was displayed on the EICAS for all of the flight.

[5] This message indicates the reduction in the angle of attack values used to activate the AOA limiter protection. (see section 2.3).

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[6] Pilot Flying.

[7] Pilot Monitoring.

The captain was PF[6] and the first-officer PM[7] for the arrival at Le Bourget airport. The METARs did not indicate icing conditions. The crew performed the ILS 27 approach at a speed of between 120 and 130 kt.

At an altitude of 2,200 ft, while the aeroplane was on the ILS glide path, the AOA limiter protection activated itself and the autopilot (AP) automatically disengaged. The aeroplane passed under the glide slope and a glide slope warning sounded. The captain then increased thrust and levelled off in order to return to the approach path. The AOA limiter protection deactivated itself and the crew re-engaged the AP.

At around 1,000 ft QNH, the AOA limiter protection activated itself again and the AP disengaged. The first officer told the captain to keep the speed above the red tape corresponding to the minimum speed authorized by the protection. This protection limits the angle of attack and did not allow the captain to sufficiently increase the aeroplane's pitch attitude in order to flare, despite making a full nose-up deflection on the sidestick.

The aeroplane touched down with a rate of descent of around 1,350 ft/min and a load factor of 4 g. The right main landing gear ruptured and the upper rear hinge made a hole in the upper surface of the wing.

2 - ADDITIONAL INFORMATION

2.1 Captain information

The captain, aged 44 years, is a former instructor on the L-39 Albatros. He obtained his type rating on 24 October 2016 and carried out a simulator training flight session on 17 March 2017.

At the time of the occurrence, he had logged more than 1,507 flight hours of which 151 on type. He had flown 3 h 30 min on type in the previous 24 hours and 15 flights hours in the previous seven days. In the previous 90 days, he had flown 67 flight hours of which 53 on type.

2.2 First officer information

The first officer, aged 42 years, was a former airline pilot. He obtained his type rating on 28 August 2017. At the time of the occurrence, he had logged 5,000 flight hours of which 26 on type, all flown in the previous three months. He had flown 3 h 30 min on type in the previous 24 hours. The first officer was employed by LLC L39 Engineering.

2.3 Aircraft information

The Legacy 500 is a twin-engine business jet built by the Brazilian aircraft manufacturer, Embraer. It is equipped with fly-by-wire controls.

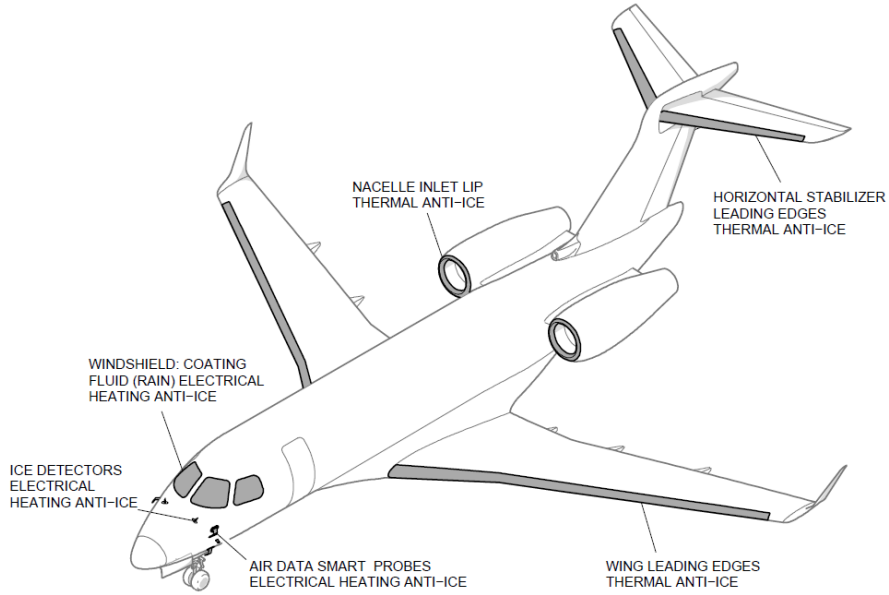
The RA-02788 was purchased new in March 2017 by LLC L39 Engineering. It had flown 93 hours and 50 cycles at the time of the accident.

2.3.1 Ice protection system

2.3.1.1 General description

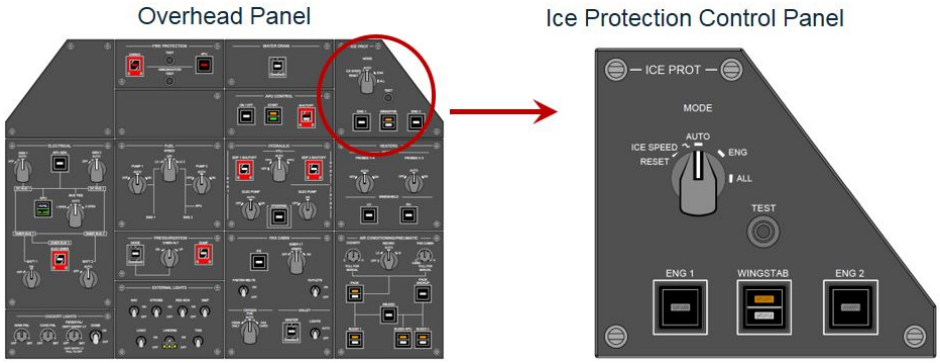
The aeroplane is equipped with an ice protection system. The wing and horizontal stabilizer leading edges along with the nacelle inlet lips are heated with air bled from the engines whereas the air data probes (smart probes and TAT probes) are heated electrically.

The system can function automatically using the signal sent by an ice detector positioned on the nose of the fuselage or manually via the control panel on the cockpit overhead panel.



Source: Embraer flight manual

Figure 1: diagram of ice protection system



Source: Embraer flight manual

Figure 2: view of overhead control panel

The selector on the ice protection control panel can be set to one of the following three positions:

- AUTO: the system automatically activates the heating of the wing and horizontal stabilizer leading edges along with the nacelle inlet lips on receiving the signal sent by the ice detector.
- ENG: forces the heating of the nacelle inlet lips on the ground and in flight, without taking into account the ice detector.
- ALL: forces the heating of the wing and horizontal stabilizer leading edges along with the nacelle inlet lips, without taking into account the ice detector.

The ICE SPEED RESET position reinitializes the speeds associated with the AOA limiter protection in icing conditions with the values calculated in non-icing conditions. This action is carried out when the aeroplane has left icing conditions and the crew have checked that there is no ice accretion on the plane. It only functions if the ice protection system is operational.

2.3.1.2 Internal monitoring of system

The correct operation of the ice protection system is automatically checked by means of BITE[(8)] tests. The different components of the system are continuously checked as soon as the engines are started up in order to detect any possible failures of the PSC (Pneumatic System Controller), pressure or temperature sensors or pneumatic system shut-off valves.

[(8)] Built-In Tests Equipment.

As soon as a failure is detected by one of the BITE tests, a message is displayed for the crew on the EICAS.

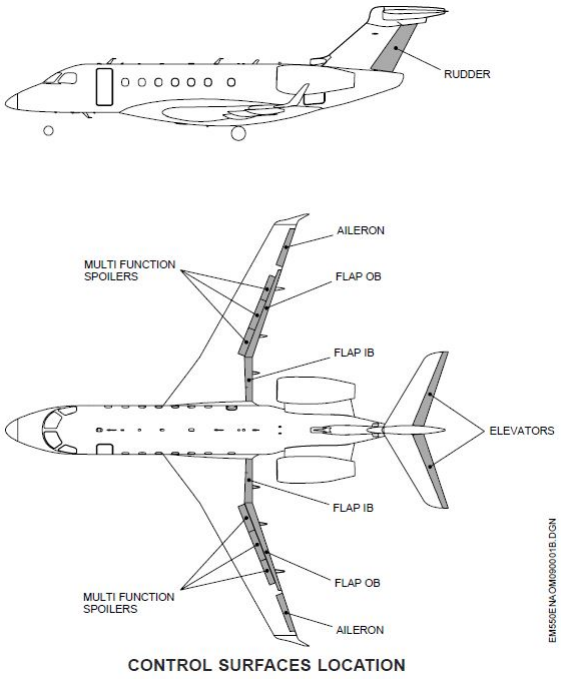
An amber A-I WINGSTAB FAIL caution type message is displayed on detection of a failure of the anti-icing system of the wing and horizontal stabilizer leading edges.

This message also appears when the ICE PROT MODE selector is set to ALL before engine start-up as the leading edge pneumatic heating system cannot be supplied in this situation. This is why the Internal Safety Inspection procedure, to be carried out before engine start-up, requires the ICE PROT MODE selector to be set to AUTO.

2.3.2 Flight control system

2.3.2.1 General description

The Embraer Legacy 500 is equipped with a fly-by-wire control system which controls and monitors the primary control surfaces (ailerons, elevators and rudder) and the secondary control surfaces (trimmable horizontal stabilizer, flaps and spoilers when used as speed brakes or ground spoilers).



Source: Embraer flight manual

Figure 3: diagram of control surfaces

Two operating modes are available:

- Normal Mode (NM);
- Direct Mode (DM).

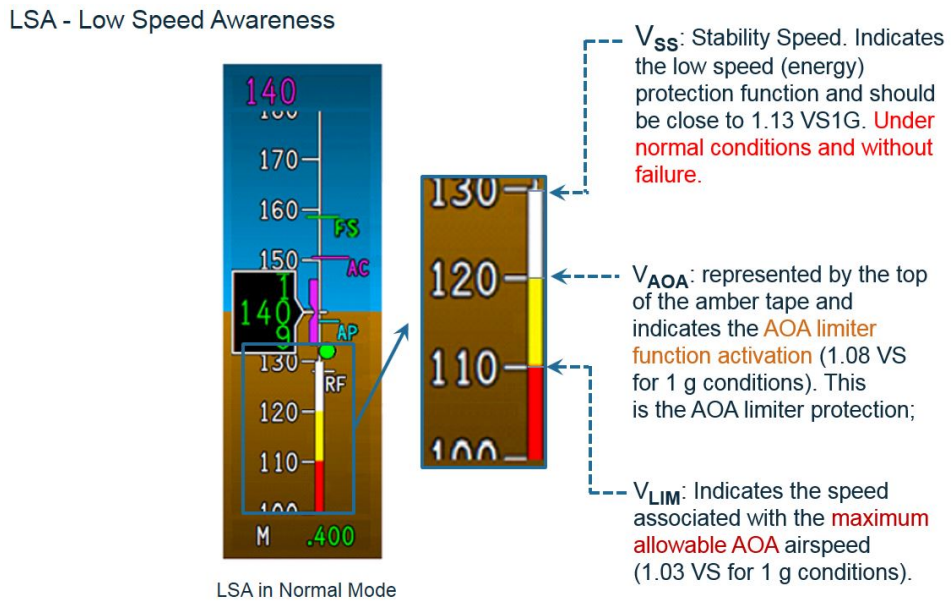
In NM, crew actions on their sidestick and on the rudder pedals are sent to the two Flight Control Computers (FCC). The FCCs then calculate the position of the control surfaces based on flight controls laws, taking as inputs, the sidestick position along with other data such as the air and inertial data or flap position.

In DM, the position of the flight control surfaces is directly linked to the crew's actions on their sidestick and rudder pedals. In this operating mode, the aeroplane behaves like a conventional plane.

2.3.2.2 Flight envelope protection – AOA limiter protection

The flight control laws implemented by the flight control system in NM provide functions designed to prevent the aeroplane from leaving its flight envelope.

One of these functions, the AOA limiter protection, protects the aeroplane, in particular, from a low speed stall by limiting the maximum angle of attack of the plane. This protection is activated when the angle of attack exceeds a certain threshold or when the indicated airspeed passes below the Vaoa speed symbolized by the top of the amber tape represented on the speed tape (see diagram below).



Source: Embraer

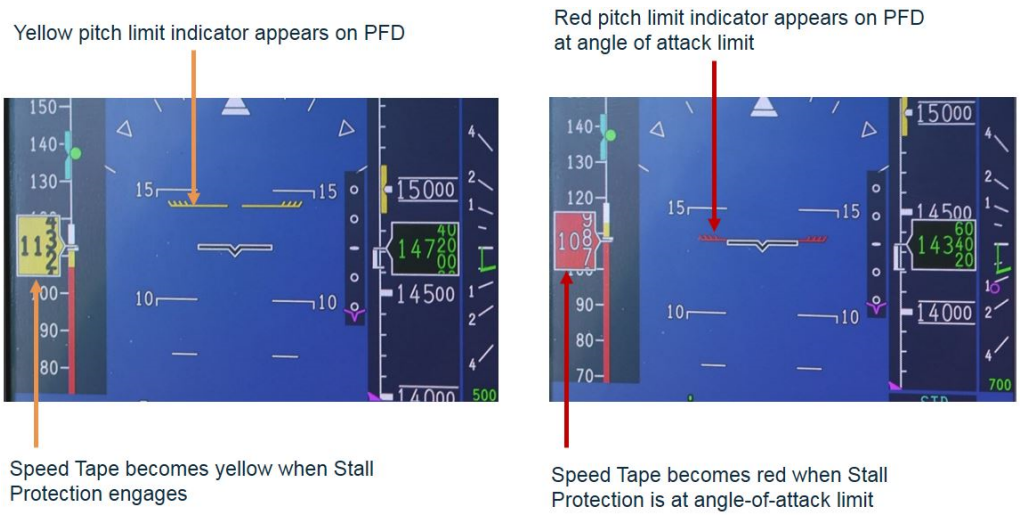
Figure 4: speed tape

When the indicated airspeed is in the amber tape area, the AP is automatically disengaged. The nose-up inputs on the sidestick will then control an angle of attack instead of a load factor and the control law will calculate the position of the control surfaces in order to reach the corresponding angle of attack. If the pilot makes a full backstick input with constant engine thrust, the angle of attack increases and the indicated airspeed decreases to the minimum value Vlim corresponding to the maximum angle of attack authorized to keep a sufficient margin against stalling. The control law prevents the maximum angle of attack from being exceeded, irrespective of the sidestick position. If the pilot returns his sidestick to neutral, then the control law positions the control surfaces so that the indicated airspeed increases to Vaoa.

The activation of the AOA limiter protection is both represented on the PFD[(9)] speed scale and symbolized on the PFD horizon by means of the PLI[(10)]. The PLI is displayed on the attitude scale and shows the margin with respect to Vaoa and Vlim. When the margin is sufficiently large, the PLI is not displayed. When there is a reduced margin, the PLI is displayed in either yellow or red: if the speed decreases to below Vaoa, then the PLI is displayed in yellow, if the speed reaches Vlim, the PLI is displayed in red.

[(9)] Primary Flight Display.

[(10)] Pitch Limit Indicator.



Source: Embraer

Figure 5: view of PFD when AOA limiter protection is active

The calculation of the Vaoa and Vlim speeds is carried out by the FCCs and depends on numerous parameters. The presence of icing conditions and the correct operation of the ice protection system are taken into account to calculate these speeds.

When a failure of the ice protection system is detected and the aeroplane encounters icing conditions during the flight (determined from the system's view point by the activation of the ice detector or by the manual setting of the control panel selector to ENG or ALL), the angle of attack values to activate the protection and the maximum angle of attack values are significantly reduced. The Vaoa and Vlim speed values are increased. In this situation, in addition to the message associated with the failure encountered[(11)], the STALL PROT ANTICIPATE information message is displayed on EICAS to inform the crew that the Vaoa and Vlim thresholds have been increased. These conditions remain up to the end of the flight whatever the meteorological conditions and the position of the ICE PROT MODE selector.

[(11)] In the scope of the occurrence, the A-I WINGSTAB FAIL message was displayed.

2.4 Meteorological information

2.4.1 Moscow-Domodedovo departure airport

The METAR for Moscow-Domodedovo airport available at the time of departure of flight RA-02788 indicated visibility of 5,000 m, haze, an overcast ceiling at 600 ft and icing conditions at the take-off time. The temperature was - 5° and the dew point - 6°.

2.4.2 Paris-Le Bourget destination airport

On landing, the meteorological situation was anti-cyclonic without any specific phenomenon reported. The Le Bourget airport METAR indicated a westerly wind from 220 at 7 kt, visibility above 10 km, few clouds at 2,800 ft, a broken ceiling at 4,200 ft, a temperature of 7°C and a dew point of 4°C.

2.5 Witness statements

2.5.1 Captain's statement

The captain said that there had been light freezing drizzle during the night. A thin film of ice covered the RA-02788. Before start-up, the aeroplane had been de-iced using a lorry. The captain started up with the first officer.

During the start-up, they positioned the selector on the ice protection control panel to ALL. A failure warning was then triggered. They changed the position of the selector to AUTO which made the message disappear[(12)].

[(12)] FDR data shows that in reality the A-I WINGSTAB FAIL message was still present.

According to him, the message had appeared because the aeroplane had remained at a standstill and they had not started taxiing.

The take-off proceeded normally. No warning was triggered.

During the climb, the message indicating that the anti-icing system was inoperative appeared again. The rest of the flight proceeded normally.

During the approach to Le Bourget airport, he specified that the aeroplane was not in icing conditions. At 3,000 ft the autopilot automatically disengaged.

The captain reduced the speed to 125/120 kt which was the approach speed in the conditions of the day. He said that a warning then sounded and the aeroplane flew under the glide slope. He then increased thrust and levelled off for a very short time in order to return to the glide slope. Initially, the captain was not aware that this was the glide slope warning.

At around 80 ft, observing that the pitch attitude was too low, the pilot wanted to raise the aeroplane's nose but without success.

While the aeroplane was approaching the ground, the captain continued to try and flare but the aeroplane did not react. He made a full backstick input. He said that the first officer asked him to raise the aeroplane's nose.

The aeroplane then made a hard touchdown, the nose landing gear touching down first. Upon touchdown, a landing gear warning was triggered. The captain felt slight vibrations making him think that there was a flat tire. He specified that the aeroplane made a normal run.

They informed the air traffic controller of this once the runway was vacated, and then stopped the aeroplane on the taxiway before going to check for damage.

He specified that he had not understood why he had not been able to flare.

2.5.2 First officer's statement

The first officer said that he arrived before the captain in order to prepare the flight and the aeroplane. After de-icing the aeroplane, at 02:12, he started the aeroplane start-up procedure with the captain. He said that during the start-up, the A-I WINGSTAB FAIL message appeared on the EICAS. The captain told him that he associated the appearance of this message with the fact that the aeroplane had not moved for a while and that everything would be fine in a short time. The taxiing time was short. The air traffic controller cleared them to take off at 02:24.

The first officer indicated that when they reached the en route altitude, the message was still displayed. Although he could not see any ice on the aeroplane, the first officer considered at this point that the message was still being displayed because of the presence of icing conditions. Another message was briefly displayed but the pilot said that he could not remember what.

As the rest of the equipment was operating normally, the crew finally thought that it was a system error. The flight continued without incident.

On approaching Le Bourget airport, the meteorological conditions were favourable. The captain and first officer planned to land with a normal landing speed of around 120 kt on runway 27.

On arriving at 5,000 ft, they were cleared for the approach and continued the descent. The captain decided to directly descend to 3,000 ft and to intercept the ILS. The autopilot had captured the localizer and then the ILS glide slope. The speed was in the yellow arc towards the lower limit. A glide slope warning suddenly sounded, the aeroplane having passed under the glide slope.

The first officer recommended that the captain interrupt the descent and maintain a slightly higher speed of around 125 kt. The latter applied a little more thrust and kept the speed in the yellow arc.

During this first level off, the autopilot disengaged, the crew tried to re-engage it but without success. The first officer then checked the speed which was still in the yellow arc, at around 120 kt.

According to him, this approach speed was correct for landing, notably to reduce the run distance on runway 27 which was shorter than the other runways at Le Bourget airport. In short final, he asked the captain to raise the aeroplane's nose. He also pulled on the stick but the aeroplane did not react and made a hard touchdown on the runway. After vacating the runway, the crew stopped the aeroplane. They carried out a post-flight inspection on the taxiway in order to assess the damage.

2.6 Additional information

2.6.1 Examination of aeroplane

The examinations found that the upper rear attachment fitting of the right landing gear had sheared following the application of substantial loads caused by a landing with a high vertical speed. The aeroplane was slightly inclined to the right.

Figure 6: view of right main landing gear broken at top

2.6.2 Flight data

2.6.2.1 Flight recorders

The aeroplane was equipped with two FA 5000 type L3Com recorders:

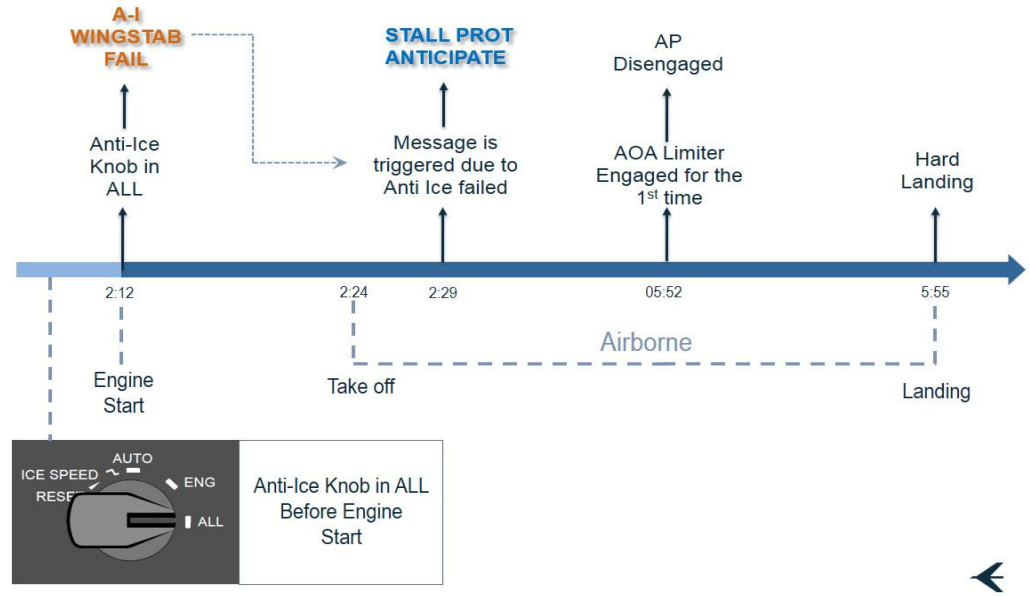
- ❒ a flight data recorder (FDR);
- ❒ a cockpit voice recorder (CVR).

The data related to the event was present in the two recorders and was read out.

2.6.2.2 Onboard Maintenance System (OMS)

The aeroplane is equipped with a centralized maintenance aid system designed to collect information concerning failures, threshold exceedances, trends and configurations encountered during a flight in order to facilitate and speed up ground maintenance operations.

The analysis of this data made it possible to validate and date the appearance of the STALL PROT ANTICIPATE message which was not recorded in the FDR.



Source: Embraer

Figure 7: synthesis of FDR and OMS data of the flight, times in UTC

2.6.3 Normal and abnormal procedures

OPERATION IN ICING CONDITIONS
The OPERATION IN ICING CONDITIONS normal procedure is described in the flight manual. It indicates, in particular, that the ICE PROT MODE selector must be set to ALL after engine start-up if the outside air temperature is below 5 °C and there is a possibility of climbing through clouds in the climb out up to a height of 1,700 ft.

OPERATION IN ICING CONDITIONS

AFTER START

ICE PROTECTION SYSTEM SETTING

– ICE PROT MODE Knob must be set to ENG when OAT is between 5°C and 10°C and:

- If there is any possibility of encountering visible moisture up to 1700 ft AGL, or
- When operating on ramps, taxiways, or runways where surface snow, ice, standing water, or slush may be ingested by the engines, or freeze on engines, nacelles, or engine sensor probes.

– ICE PROT MODE Knob must be set to ALL when OAT is below 5°C and:

- If there is any possibility of encountering visible moisture up to 1700 ft AGL, or
- When operating on ramps, taxiways, or runways where surface snow, ice, standing water, or slush may be ingested by the engines, or freeze on engines, nacelles, or engine sensor probes.

Source: Embraer flight manual

Figure 8: OPERATION IN ICING CONDITIONS procedure

The analysis of the FDR data found that the crew had set the ICE PROT MODE selector to ALL before starting up the engines.

Setting the selector to this position before start-up generated the display of the A-I WINGSTAB FAIL message.

BEFORE TAKEOFF

The flight manual instructs pilots to check the EICAS messages before take-off.

BEFORE TAKEOFF

The before takeoff checklist may be performed during taxi out and completed down to the line. Below the line items should be performed when cleared to line up on the runway. Use all available information such as heading and FMS course indication (PFD), lateral profile (CTR DU) and departure runway on route page (LWR DU) to ensure the airplane is at the assigned runway for takeoff. The last minutes change should be also briefed.

FUEL XFEED Knob.....OFF
IFE Button.....PUSH OUT
OUTLETS Switch.....OFF
EICAS.....CHECK

Check that no CAS message is displayed and engine parameters are within limits.

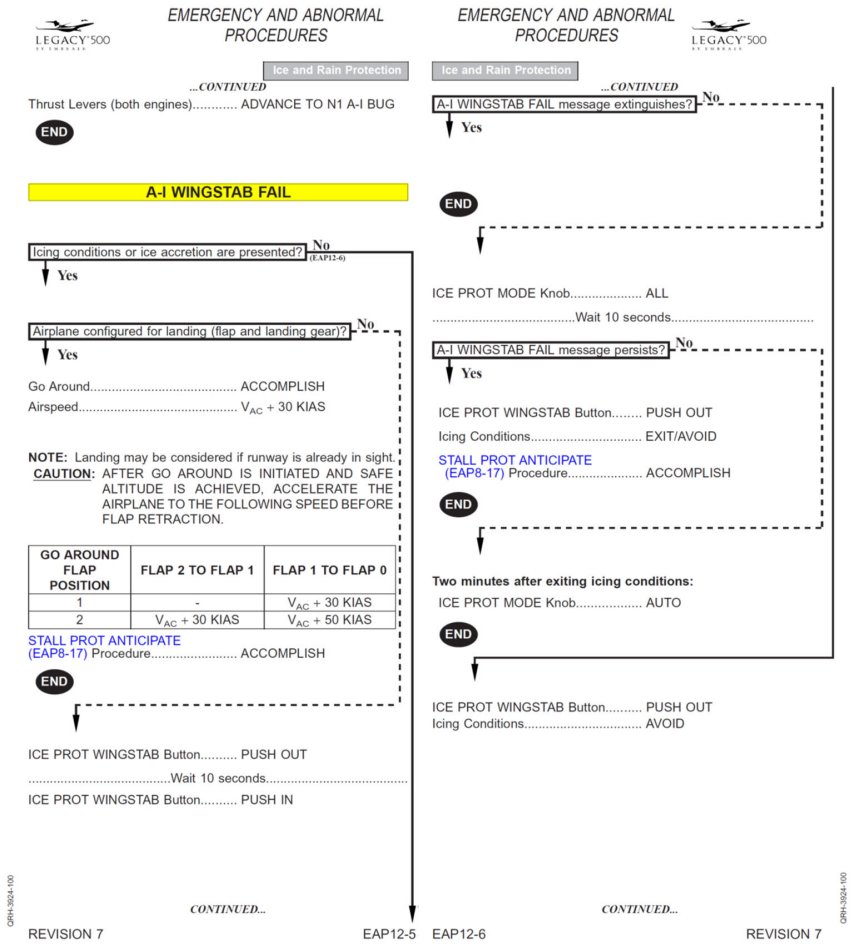
Source: Embraer flight manual

Figure 9: BEFORE TAKEOFF procedure

A-I WINGSTAB FAIL:

The A-I WINGSTAB FAIL abnormal procedure is described in the flight manual. It assumes that the ICE PROT MODE selector is set to AUTO.

This procedure does not enable the crew to reinitialize the ice protection system in the specific case where the warning appears during engine start-up with the selector set to ALL, and the A-I WINGSTAB FAIL message stays on the EICAS. In this case, the ICE PROT MODE selector must be set to AUTO and the system must be reinitialized by pushing to OFF and then ON the WINGSTAB button on the ice protection control panel.



Source: Embraer flight manual

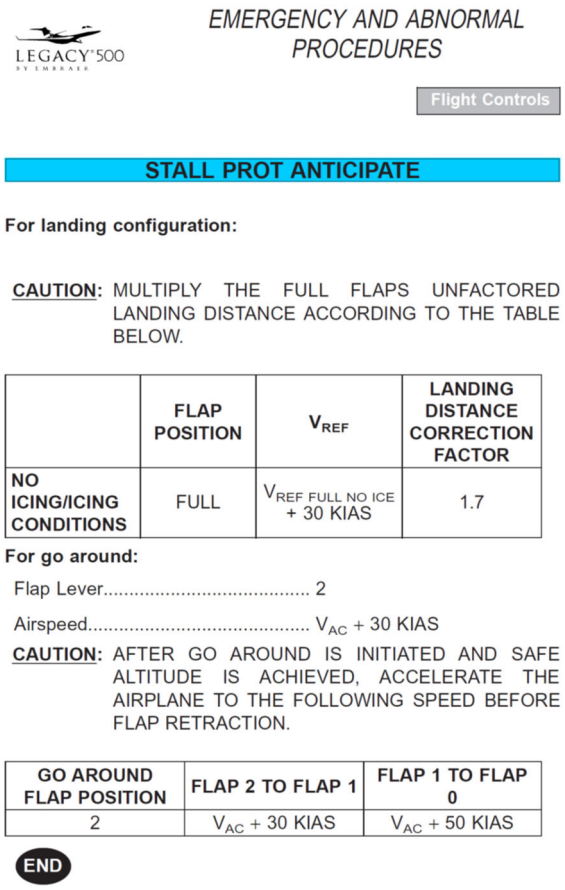
Figure 10: A-I WINGSTAB FAIL procedure

The analysis of the flight parameters found that, on the ground at Moscow, the crew had unsuccessfully tried to reinitialize the ice protection system with the ICE PROT MODE selector set to ALL and not to AUTO.

According to this procedure, when the A-I WINGSTAB FAIL message persists in icing conditions, the STALL PROT ANTICIPATE procedure must be complied with.

STALL PROT ANTICIPATE

The STALL PROT ANTICIPATE abnormal procedure says to add 30 kt to the reference speed with full flaps and to apply a factor of 1.7 to the landing distance.



LEGACY 500

EMERGENCY AND ABNORMAL PROCEDURES

Flight Controls

STALL PROT ANTICIPATE

For landing configuration:

CAUTION: MULTIPLY THE FULL FLAPS UNFACTORED LANDING DISTANCE ACCORDING TO THE TABLE BELOW.

	FLAP POSITION	V_{REF}	LANDING DISTANCE CORRECTION FACTOR
NO ICING/ICING CONDITIONS	FULL	$V_{REF\ FULL\ NO\ ICE}$ + 30 KIAS	1.7

For go around:

Flap Lever..... 2

Airspeed..... V_{AC} + 30 KIAS

CAUTION: AFTER GO AROUND IS INITIATED AND SAFE ALTITUDE IS ACHIEVED, ACCELERATE THE AIRPLANE TO THE FOLLOWING SPEED BEFORE FLAP RETRACTION.

GO AROUND FLAP POSITION	FLAP 2 TO FLAP 1	FLAP 1 TO FLAP 0
2	V_{AC} + 30 KIAS	V_{AC} + 50 KIAS

END

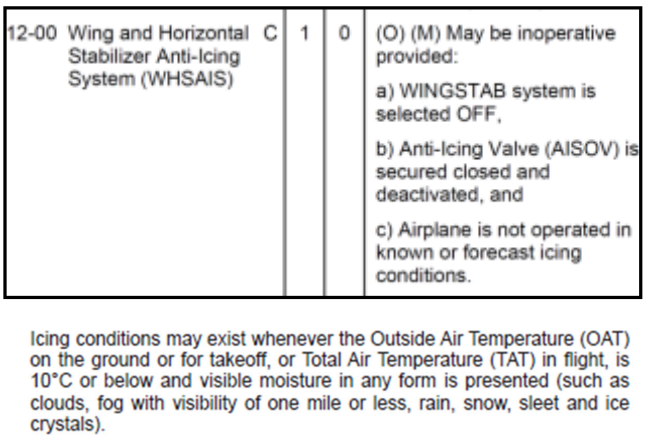
Source: Embraer flight manual

Figure 11: STALL PROT ANTICIPATE procedure

During the approach to Le Bourget airport, the aeroplane speed was between 120 and 130 kt. The application of the STALL PROT ANTICIPATE procedure requires that an approach speed of 144 kt be adopted for a landing distance of 1,219 m.

2.6.4 Master Minimum Equipment List (MMEL)

According to MMEL 30-12-00, it is possible to dispatch the aircraft with an A-I WINGSTAB FAIL message when taking into consideration the following remarks:



12-00	Wing and Horizontal Stabilizer Anti-Icing System (WHSAIS)	C	1	0	(O) (M) May be inoperative provided: a) WINGSTAB system is selected OFF, b) Anti-Icing Valve (AISOV) is secured closed and deactivated, and c) Airplane is not operated in known or forecast icing conditions.

Icing conditions may exist whenever the Outside Air Temperature (OAT) on the ground or for takeoff, or Total Air Temperature (TAT) in flight, is 10°C or below and visible moisture in any form is presented (such as clouds, fog with visibility of one mile or less, rain, snow, sleet and ice crystals).

Source: Embraer flight manual

Figure 12: excerpt from MMEL

However, before referring to the MMEL, the Fault Isolation Manual (FIM) should be used by maintenance to try to troubleshoot the failure. If a system is declared inoperative, the MMEL should be referred to in order to establish the dispatchability status of the aircraft.

2.6.5 Type rating training

The captain and first officer had followed the type rating course in the same training centre. The training programme provided by the centre specifies that the various warnings and procedures encountered during this occurrence were taught.

3 - LESSONS LEARNED AND CONCLUSION

3.1 A-I WINGSTAB FAIL procedure

At Moscow, the crew had the aeroplane de-iced as it was covered in a film of ice. There were icing conditions. The crew probably decided to activate the ice protection system for the take-off and climb out but set the ICE PROT MODE selector to ALL before starting the engines, whereas the flight manual states that this action to be carried out once the engines have been started up. This resulted in the A-I WINGSTAB FAIL message indicating that the anti-icing system of the wing and horizontal stabilizer leading edges was no longer in working order.

The crew then partially carried out the A-I WINGSTAB FAIL procedure by pushing to OFF and then ON the WINGSTAB button to reinitialize the system. However, this action is only effective if the ICE PROT MODE selector has been previously set to AUTO which is not specified in the A-I WINGSTAB FAIL procedure. They did not thereafter finish the procedure which specified carrying out the STALL PROT ANTICIPATE procedure.

3.2 Crew's decision to take off

The A-I WINGSTAB FAIL was not understood by the crew. They saw it as an untimely failure and initially attributed it to the fact that they were on the ground, at a standstill or at low speed. This interpretation led them to take-off with this failure message displayed on the EICAS whereas the BEFORE TAKEOFF procedure includes a check for the absence of EICAS messages by the crew.

In addition, even if the MMEL had been complied with, the latter only authorizes flight with an anti-icing system failure if there are no reported or forecast icing conditions. This was not the case at take-off at Moscow and this should have led the crew to postpone the flight.

Subsequently, during the flight, as the failure message was still displayed, the crew attributed it to a malfunction of the ice protection system.

3.3 AOA limiter protection when ice protection system is inoperative

Five minutes after take-off, the STALL PROT ANTICIPATE information message was displayed on the EICAS screen due to the presence of the A-I WINGSTAB FAIL message.

This message indicates the reduction in the angle of attack values used to activate the AOA limiter protection and thus an increase in the corresponding speeds. The associated procedure requires that the full flap reference speed is increased by 30 kt for landing and that the landing distance is increased by 70 %. However, this message, although identified by the crew at the beginning of the flight, did not lead them to adopt an increased approach speed or to check that the landing distance available was compatible with this increase.

It is not possible to clear the STALL PROT ANTICIPATE message in flight when the anti-icing system of the wing and horizontal stabilizer leading edges is no longer operative, indicated by A-I WINGSTAB FAIL message, even if there is a change in the meteorological conditions. Thus, on arriving at Le Bourget airport, this message was still displayed on the EICAS despite the absence of icing conditions.

Consequently, the AOA limiter protection thresholds were still reduced on arriving but the crew did not realise this. They carried out an ILS 27 approach at a speed between 120 and 130 kt whereas they should have been at 144 kt given the STALL PROT ANTICIPATE message. This led to the AP disengaging and to the activation of the AOA limiter protection during the final approach. The crew did not identify the activation of this protection despite the visual warnings shown on the PFD (speed in yellow tape and chevrons of the PLI). This protection limited the angle of attack and did not allow the captain to sufficiently increase the aeroplane's pitch attitude in order to flare, despite making a full aft deflection on the sidestick (nose-up).

3.4 Conclusion

The crew undertook the flight to Le Bourget airport despite the presence of the A-I WINGSTAB FAIL message and icing conditions at departure from Moscow. The occurrence of the failure is linked to the activation of the ice protection system in the ALL position before engine start-up. The procedure associated with this failure, as written at the time of the accident, did not enable the crew to reinitialize the ice protection system. The BEFORE TAKEOFF procedure and then the consultation of the MEL should have resulted in the crew postponing the flight.

During the climb, the appearance of the STALL PROT ANTICIPATE message on the EICAS informed the crew of the increase in AOA limiter protection activation speeds. The associated procedure should have led the crew to increase the reference speed by 30 kt during the approach.

The approach speed selected by the crew was less than the AOA limiter protection activation speed, this protection prevented the captain from carrying out the flare.

The following factors may have contributed to the accident:

- Crew's insufficient knowledge of how the systems function, in particular the AOA limiter protection system.
- Incorrect application of the normal and abnormal procedures, in particular the engine start-up normal procedure and the A-I WINGSTAB FAIL and STALL PROT ANTICIPATE abnormal procedures.
- Incomplete description of the A-I WINGSTAB FAIL procedure, in particular the requirement to set the ICE PROT MODE button to AUTO before reinitializing the system.

3.5 Actions taken by Embraer following the accident

The current procedure associated with the A-I WINGSTAB FAIL message supposes that the ICE PROT MODE is initially in the AUTO position and therefore does not ask for this action to be carried out. However, in the case of this occurrence, the ICE PROT MODE selector was set to ALL when the crew tried to reinitialize the ice protection system which meant that it was not possible to return the system to working order and clear the A-I WINGSTAB FAIL message.

Following this accident, Embraer will update the flight manual[(14)] to specify that the ICE PROT MODE selector must be set to AUTO in the A-I WINGSTAB FAIL procedure. This update concerns the flight manuals for the Embraer Legacy 450 and 500 aeroplanes.

The manufacturer also reviewed the flight manuals of all the aeroplanes in order to detect any possible similar omissions which could to give for a lack of understanding of the procedures.

(14) Planned for 2Q/2020.