SAFETY INVESTIGATION REPORT

Accident to the BOEING 737 - 400 registered **EC-NLS** operated by Swiftair on Saturday 24 September 2022 at Montpellier - Méditerranée

Source: GTA

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SAFETY INVESTIGATIONS

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SPECIAL FOREWORD TO ENGLISH EDITION

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

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GLOSSARY

Abbreviations	English version	French version
AAL	Above Aerodrome (Airport) Level	Au-dessus du niveau de l'aérodrome
AC	Advisory Circular	Circulaire d'information
AESA (EASA)	European Union Aviation Safety Agency	Agence de l'Union européenne pour la sécurité aérienne
AGL	Above Ground Level	Au-dessus du niveau du sol
AIP	Aeronautical Information Publication	Publication d'information aéronautique
AIREP	Air Report	Compte rendu en vol
ALAR	Approach-and-Landing Accident Reduction	Réduction des accidents en approche et à l'atterrissage
ASPOC	Tool for observing and forecasting storm cells	Application de signalisation et prévision des orages pour le contrôle aérien
ATC	Air Traffic Control	Contrôle de la circulation aérienne
ATCO	Air Traffic Control Operator	Agent du contrôle de la circulation aérienne
ATIS	Automatic Terminal Information Service	Service automatique d'information de région terminale
ATPL	Airline Transport Pilot License	Licence de pilote de ligne
ATS	Air Traffic Service	Service du contrôle aérien
Cb	Cumulonimbus	Cumulonimbus
CdB	Captain	Commandant de Bord
CDFA	Continuous Descent Final Approach	Approche finale en descente continue
CODIS	Departmental fire and rescue operational centre	Centre opérationnel départemental d'incendie et de secours
CRM	Crew Resource Management	Gestion des ressources de l'équipage
CVR	Cockpit Voice Recorder	Enregistreur phonique
DGAC	French civil aviation authority	Direction générale de l'Aviation civile
DME	Distance Measuring Equipment	Radio-transpondeur de mesure de distance
EADI	Electronic Attitude Director Indicator	Indicateur électronique directeur d'attitude

Abbreviations	English version	French version
ECCAIRS	European Co-ordination Center for Accident and Incident Reporting Systems	
EFB	Electronic Flight Bag	Système de documentation électronique
EFIS	Electronic Flight Instruments System	Système d'instruments de vol électroniques
EGPWS	Enhanced Ground Proximity Warning System	Avertisseur de proximité du sol amélioré
EHSI	Electronic Horizontal Situation Indicator	Indicateur électronique de situation horizontale
EOFDM	European Operators Flight Data Monitoring	
EU	European Union	
FAA	Federal Aviation Administration	Autorité des Etats-Unis en charge de l'Aviation civile
FAF	Final Approach Fix	Repère d'approche finale
FCOM	Flight Crew Operations Manual	Manuel d'exploitation des équipages
FCTM	Flight Crew Training Manual	Manuel de formation des équipages
FDM	Flight Data Monitoring	
FDR	Flight Data Recorder	Enregistreur de paramètres
FIR	Flight Information Region	Région d'information de vol
FMC	Flight Management Computer	
FSF	Flight Safety Foundation	
ft	Feet	Pieds
GPS	Global Positioning System	Système de positionnement par satellite
GRF	Global Reporting Format	Format de report global
IAF	Initial Approach Fix	Repère d'approche initiale
IATA	International Air Transport Association	Association internationale du transport aérien
ILS	Instrument Landing System	Système d'atterrissage aux instruments
IMC	Instrument Meteorological Conditions	Conditions météorologiques de vol aux instruments
ISA	International Standard Atmosphere	Atmosphère type international
kt	Knots	Noeuds
LDA	Landing Distance Available	Longueur utilisable à l'atterrissage

Abbreviations	English version	French version
LDTA	Landing Distance at Time of Arrival	Distance d'atterrissage au moment de l'arrivée
LOC	LOCalizer	Radiophare d'alignement de piste
LOSA	Line Operations Safety Audit	Audit de sécurité des opérations en ligne
LVO	Low Visibility Operations	Opérations par faible visibilité
MCP	Mode Control Panel	Panneau de contrôle des modes
MEHT	Minimum Eye Height at Threshold	Hauteur minimale de l'œil du pilote au-dessus du seuil
METAR	Aerodrome routine meteorological report	Message d'observation météorologique régulière d'aérodrome
MOC	Management of Change	Gestion des changements
NPA	Non-Precision Approach	Approche de non-précision
NM	Nautical Miles	Milles marins
OACI	International Civil Aviation Organization (ICAO)	Organisation de l'Aviation Civile Internationale
OFP	Operational Flight Plan	Plan de vol exploitation
OM	Operations Manual	Manuel d'exploitation
OPC	Operator Proficiency Check	Contrôle hors ligne
PAPI	Precision Approach Path Indicator	Indicateur de pente d'approche
PF	Pilot Flying	Pilote aux commandes
PM	Pilot Monitoring	
PRM	Pilot Reference Manual	
psi	Pound per Square Inch	Livre par pouce carré
PWS	Predictive Windshear System	Système prédictif de cisaillement de vent
QNH	Altimeter setting required to read altitude	Calage altimétrique requis pour lire une altitude
QRH	Quick Reference Handbook	
RCR	Runway Condition Report	Rapport d'état de piste
RESA	Runway End Safety Area	Aire de sécurité d'extrémité de piste
RFFS	Rescue Fire Fighting Service	
RNAV	aRea NAVigation	Navigation de surface
RNP	Required Navigation Performance	Performance de navigation requise
RWYCC	Runway Condition Code	Code d'état de piste

Abbreviations	English version	French version
SGS	Safety Management System (SMS)	Système de gestion de la sécurité
SIGMET	SIGnificant METeorological Phenomena	Messages de phénomènes météorologiques en route spécifiés
SIGWX	Significant weather chart	
SOP	Standard Operating Procedures	Procédures standard d'exploitation
STAC		Service Technique de l'Aviation Civile
TAF	Terminal Area Forecast	Prévision d'aérodrome
TAWS	Terrain Awareness and Warning System	Système avertisseur de proximité du sol
TDZ	Touch-Down Zone	Zone de toucher des roues
TEM	Threat and Error Management	Gestion des menaces et des erreurs
TMA	Terminal Manoeuvring Area	Région de contrôle terminale
TOGA	Take-Off Go-Around	Décollage / Remise des gaz
TRE	Type Rating Examinator	Examinateur de qualification de type
TRI	Type Rating Instructor	Instructeur de qualification de type
UTC	Universal Time Coordinated	Temps universel coordonné
Vapp	Approach Speed	Vitesse d'approche
VMC	Visual Meteorological Conditions	Conditions météorologiques de vol à vue
VNAV	Vertical Navigation	Mode de guidage vertical
VOR	VHF Omnidirectional Range	Radiophare omnidirectionnel VHF
Vref	Approach Reference Speed	Vitesse d'approche de référence
V/S	Vertical Speed	Vitesse verticale

SYNOPSIS

Aircraft	Boeing 737- 400 registered EC-NLS
Date and time	24 September 2022, at 00:37[1]
Operator	Swiftair
Place	Montpellier - Méditerranée
Type of flight	Mail commercial air transport
Persons on board	Captain (PM), co-pilot (PF), 1 flight crew member
Consequences and damage	Aeroplane substantially damaged

Windshear, long landing, runway overrun on landing

In the night of 23 to 24 September 2022, the crew of the Boeing 737-400 registered EC-NLS, operated by Swiftair, were carrying out a mail commercial air transport flight between Paris - Charles de Gaulle and Montpellier - Méditerranée. The captain, in the left seat, was the Pilot Monitoring (PM), and the co-pilot, in the right seat, was the Pilot Flying (PF). An aircraft maintenance mechanic was also on board this flight, sat in the cargo area.

After having prepared and carried out the briefing for an ILS approach to runway 30R, the crew were informed that the runway in use had been changed. They then prepared a VOR-DME approach to runway 12L. There was no briefing for the new approach.

A storm cell was approaching the airport from the south-west. During the approach, the crew's awareness of the presence of this cell was low despite available information.

On short final, the captain and co-pilot agreed to change roles. The co-pilot, now the PM, did not carry out his monitoring tasks.

When flying over the threshold, the aeroplane encountered windshear characterised by a sudden reduction in the tailwind. The crew did not detect this phenomenon and did not perceive its impact on the flight parameters. In particular, they did not observe that the aeroplane had exceeded the touchdown zone without coming into contact with the ground.

The aeroplane touched down on the runway beyond the touchdown zone, at around 1,500 m from the threshold of runway 12L. It overran the runway and finished its run in Or lake.

[1] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC). Two hours should be added to obtain the legal time applicable in Metropolitan France on the day of the event.

ORGANISATION OF THE INVESTIGATION

On 24 September 2022, at around 01:00, the BEA was informed of the accident by the 24/7 operations service of the French civil aviation authority (DGAC).

In accordance with Annex 13 to the Convention on International Civil Aviation and Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety investigation was opened by the BEA.

In compliance with the provisions of Annex 13, accredited representatives for the State of Registration and the State of Manufacture (Spain, United States) and their advisers (Swiftair, Boeing, Honeywell) were associated with the investigation. The draft final report was submitted to the accredited representatives and their advisers for consultation, in accordance with article 6.3 of Annex 13. It was also sent to the BEA's technical advisers: EASA, the DGAC, Météo-France, the airport operator and Safran Aircraft Engines.

1. FACTUAL INFORMATION

1.1 History of the flight

Note: the following information is principally based on the CVR and FDR, and statements.

The crew were carrying out the first flight of a three-leg rotation out of Paris - Charles de Gaulle, bound for Montpellier - Méditerranée. They took off at 23:33.

At 23:50, in cruise, the co-pilot (PF) carried out the briefing for an ILS approach to runway 30R at Montpellier[2]. The landing was planned with flaps 30 and the autobraking was set to mode 2 (see paragraph 1.6.6.8).

After carrying out the before descent checklist, the crew discussed the radar settings as there were echoes that the co-pilot attributed to adverse weather but that the captain attributed to the terrain. The captain explained the settings to the co-pilot, in order to distinguish between weather echoes and terrain echoes. He recommended that at this point of the flight, the co-pilot set the radar tilt to +1° or 0°.

At 00:02, the PM briefly contacted Montpellier tower to obtain up-to-date meteorological information. The controller gave him the conditions (see paragraph 1.7.2), notably visibility of 2,700 m, wind from 130° of 14 kt, rain, the presence of cumulonimbus (Cb), a runway condition code of 555[3], and informed him that runway 12L was in use. He also informed him that a storm had just passed over the airport and that conditions were changing rapidly.

The crew started to prepare the VOR Z approach[4,5] for runway 12L. In particular, they discussed the vertical mode for the final descent (VNAV or V/S) without making a clear decision.

At 00:14, the crew started the descent. In the minutes which followed, the crew continued discussing the flight path to be followed to join the final approach as the co-pilot had never carried out an approach to Montpellier.

At 00:20, the crew left the en-route control frequency and contacted Montpellier control. The controller informed them that visibility had improved but that it was still raining. He confirmed the runway condition code of 555 but indicated that the crew of a preceding aircraft[6] had reported stagnant water level with the touchdown zone of runway 12L and that the runway

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[2] The crew based their briefing on the Montpellier runway in use information provided by the en-route controller, in accordance with the ATIS in force at Montpellier at this point in the flight.

[3] See paragraph 1.10.5. For simplification purposes, in the same way as in an ATIS message, a three-digit code is used to describe the condition of the runway as a whole, the first digit corresponding to the RWYCC code of the first third of the runway, the second to that of the second third of the runway and the third to that of the last third of the runway in the direction of use of the runway.

[4] They were initially cleared for the RNP procedure for runway 12L but the aeroplane was not equipped for such a procedure.

[5] This approach has a final approach slope of 3.66°.

[6] The information had been provided by a crew which had landed on runway 12L at 19:45, i.e. nearly four hours before the arrival of EC-NLS. They mentioned *"two very large puddles in the middle of the touchdown zone.*"

condition code could be 255. After the exchange with the controller, the PM explained to the PF that puddles had been reported level with the touchdown zone but that the runway condition code remained 555.

At 00:26, at 32 NM from VOR FJR, the controller cleared the crew for a VOR Z approach for runway 12L. The autopilot and autothrottle were active. The VOR/LOC mode was engaged shortly before passing the IAF. A discussion then started as to the choice of vertical mode: the PF thought of using VNAV while the PM thought that he was going to use V/S. The V/S mode was used.

At 00:30, on descending through 5,000 ft[7], at 19 NM from the VOR, the approach checklist was carried out. At this point in the flight, the briefing for the new approach to runway 12L had not been formally carried out.

Two minutes later, when the aeroplane was at the 4,000 ft level-off intermediate approach segment, the crew configured the aeroplane, extending the landing gear and selecting flaps 30, the configuration chosen for the landing. The selected airspeed was 159 kt. The PM suggested to the PF that he choose an approach speed (Vapp) of between 140 and 143 kt (the Vref is 136 kt) taking into account a headwind of 14 kt. The PF selected a speed of 143 kt.

At 11.4 NM from the VOR, i.e. 0.3 NM from the FAF (symbol ✖ on Figure 1 below), when the speed started to decrease, the V/S descent mode was selected and the PF called out a rate of descent of 900 ft/min[8]. The aeroplane encountered a northerly wind of 20 kt at this point in the flight and its ground speed was 183 kt.

[7] Unless otherwise indicated, the altitudes indicated are QNH altitudes.

[8] The vertical speed selected was not recorded on the FDR. Except when the PF called out the selection of the vertical speed and it was picked up by the CVR, it was not possible to determine with certitude, what vertical speed had been selected.

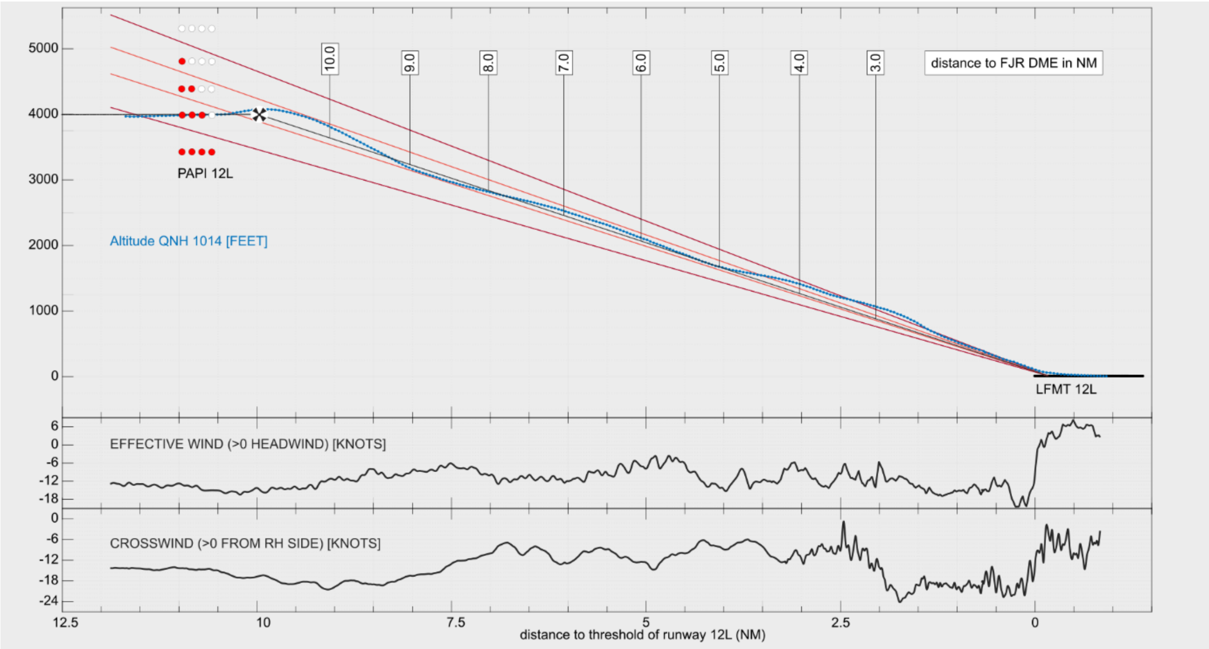

Figure 1: vertical profile of flight path and wind[9],[10] (Source: BEA)
(The labels with numbers correspond to the VOR-DME altitude/distance cross-checks of the procedure)

On approaching the altitude/distance cross-check at 10 NM, the PM informed the PF that the aeroplane was above the approach slope. The PF called out the landing checklist. The aeroplane passed the 10 NM cross-check point 200 ft above the published altitude. While the checklist was being carried out, the rate of descent increased to values of the order of 1,700 ft/min[11].

At 9 NM from the VOR, the aeroplane joined the published approach slope, the airspeed was 146 kt and the ground speed 158 kt. The rate of descent stabilized at around 800 ft/min.

Three separate times, the PM suggested increasing the rate of descent. The PF seemed to hesitate, replying that 1,000 ft/min seemed a lot to him. At 7 NM from the VOR, the aeroplane was nearly 100 ft above the slope, the airspeed was 144 kt and the ground speed 160 kt.

At 00:34, the crew were cleared to land. The wind information provided by the controller was 040° of 8 kt. The crew did not pick up that the surface wind information had changed with respect to the value previously provided by the controller. The aeroplane encountered a northerly wind of 14 kt at this point.

On passing the cross-check at 6 NM from the VOR, the aeroplane was nearly 100 ft above the slope, the airspeed was 146 kt and the ground speed 155 kt. The PM suggested holding the rate of descent at 900 ft/min.

[9] The distance to the threshold was 0.9 NM less than the distance to the VOR which the crew used as the reference for the approach.
[10] The wind values used in this figure are based on a calculation carried out by the BEA using the recorded data (see paragraph 1.11.1).
[11] The vertical speed was not recorded on the FDR. The values used in the report are values calculated using the evolution in the recorded altitude.

Shortly before passing 5 NM from the VOR, at 1,800 ft, the speed decreased to 136 kt. The PM called out "*SPEED*". The rate of descent decreased to around 550 ft/min. The PF mentioned a gust. At the altitude/distance cross-check at 5 NM, the crew checked that the aeroplane was on the approach slope.

At 4 NM from the VOR, the aeroplane was at 1,430 ft, 180 ft above the approach slope. The rate of descent increased to 1,000 ft/min and then decreased to 800 ft/min. The airspeed was 150 kt and decreasing. The ground speed was of the order of 155 to 160 kt. The crew did not carry out an altitude-distance cross-check at this point. They selected the minima on the MCP.

The noise of the windshield wipers can be perceived on the CVR recording from 00:35:31.

At 00:35:35, the PF called out that the runway was in sight. The aeroplane was 3.5 NM from the VOR, at 1,200 ft (i.e. nearly 120 ft above the slope), the airspeed was 145 kt and the ground speed 155 kt. A discussion then started between the PM and the PF regarding the confirmation of the identification of the runway.

After this exchange, the crew observed that they were a little high. It is possible that the crew could make out the PAPI[12]. The altitude/distance cross-check at 3 NM was not formalised.

On passing the stabilization gate at 1,000 ft AAL, the aeroplane was configured for landing, nearly 200 ft above the approach slope. The rate of descent was of the order of 900 ft/min, the N1 rating was stable at around 60%, the airspeed was 148 kt (Vapp+5). The ground speed was 156 kt. The northerly wind was roughly 15 kt. The PM suggested changing to manual mode to join the runway axis. The stabilization check was not called out.

At 00:35:53, the PF disengaged the autopilot and the autothrottle. He simultaneously slightly pulled back the throttle levers. The N1 rating of both engines decreased to 50%. Roll inputs on the wheel were recorded, consistent with actions to search for the runway axis[13]. During this phase, the pitch attitude was reduced by one degree. The airspeed slightly decreased to 142 kt. The rate of descent increased to 1,900 ft/min. The PM called out "*SINK RATE*" five times.

The PF made a nose-up input. The vertical speed decreased to 1,200 ft/min. The aeroplane passed the minima at 670 ft[14]. The "*300 ft above minimums*", "*approaching minimums*" and "*minimums*" callouts were not made. The PM identified and verbalized a RH crosswind component of 21 kt[15]. The airspeed was 145 kt, the ground speed was 159 kt.

At 00:36:08, at 2 NM from the VOR, when the aeroplane was at 568 ft, the captain offered to take the controls. The co-pilot agreed and the captain called out, "*I have controls*." The captain was then PF.

[12] Based on the estimation of the aeroplane's position at this time, if the crew could see the PAPI, it would have indicated four white lights.

[13] Boeing considers that these roll inputs are also an indication of a high workload due to the turbulence.

[14] The published minima for a category C aeroplane such as EC-NLS are 620 ft. The operator requires 50 ft to be added to this value during a non-precision approach with a Continuous Descent Final Approach (CDFA) profile.

[15] In reality, the wind was coming from the LH side.

The aeroplane flew through 430 ft, the throttle levers were pushed forward a few degrees, the N1 rating of both engines increased to 66% and the airspeed increased to 156 kt. The recording showed that the throttle levers were briefly pulled and then returned to their original position. The N1 ratings decreased to 50% before becoming established at 66%, the airspeed decreased to 150 kt. The ground speed remained at 166 kt.

As the aeroplane was descending from 250 ft to 210 ft, the wind slightly turned to 350° and increased in strength to 30 kt. The tailwind component increased from 12 kt to 20 kt. The crosswind component remained at around 17 kt from the LH side.

In nearly four seconds, as the aeroplane was descending from 200 ft to 100 ft, the wind encountered by the aeroplane turned from 350° to 70° and decreased from 30 kt to 8 kt. The aeroplane's airspeed increased up 170 kt. The ground speed slightly increased to 170 kt.

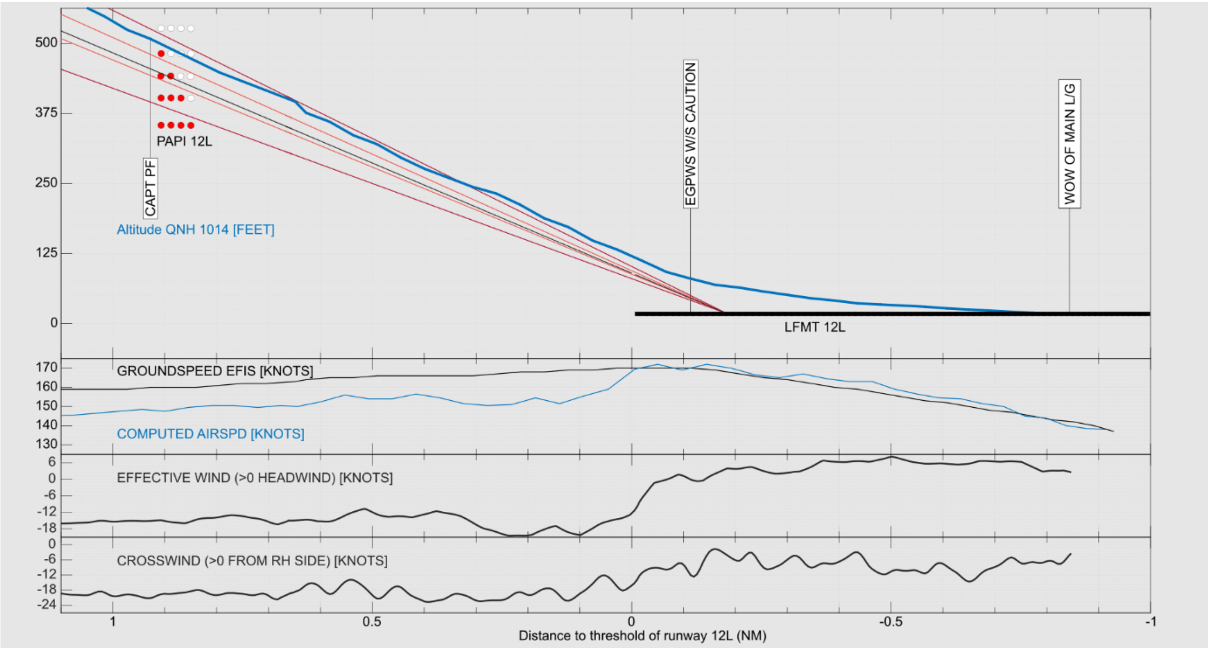

Figure 2: vertical profile of flight path and wind (zoom)

At 00:36:32, the aeroplane crossed the threshold of runway 12L at a height of 100 ft, called out by the synthetic voice. The PF moved the throttle levers back by 10° without setting them to idle[16], the N1 rating of both engines decreased from 66% to 38%. The PF made successive pitch-up and pitch-down inputs, the pitch attitude changed from 0.5° nose down to 2.5° nose up.

At 00:36:35, the synthetic voice called out 50 ft. The PF corrected the roll from a 6° RH roll to a 4° LH roll. The aeroplane's airspeed and ground speed were 170 kt.

At 00:36:37, the synthetic voice called out 40 ft.

At 00:36:39, the synthetic voice called out 30 ft.

[16] The parameter range of the throttle lever position extends from 0° (IDLE) to 45° (TOGA).

At 00:36:41, the synthetic voice called out 20 ft. The aeroplane's airspeed was 159 kt. The PF pulled the throttle levers to idle, the N1 ratings decreased to 32%. A larger nose-up input was recorded.

At 00:36:44, the synthetic voice called out 10 ft.

Six seconds later, at 00:36:50, all the parameters[17] showed that the main landing gear had touched down on the runway. The aeroplane's speed was 144 kt. The aeroplane was at 1,500 m from the threshold of runway 12L. It was at 1,100 m from the end of the runway.

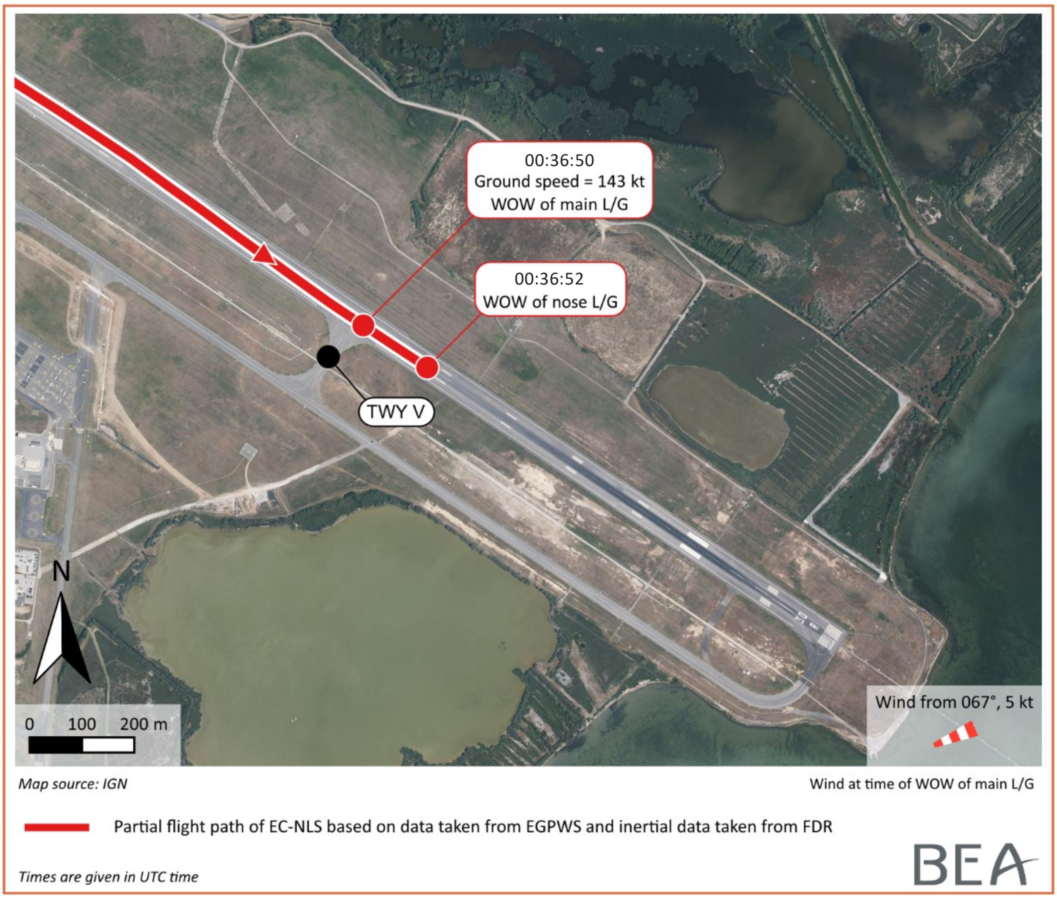

Figure 3: wheel touchdown point

In the following second, the ground spoilers automatically deployed.

At 00:36:53, the thrust reverser controls were set to REV IDLE. The thrust reversers were deployed in the following second. An asymmetric pressure was recorded on the brakes with a pressure of 385 psi on the LH side and 1,485 psi on the RH side, along with a light pressure on the right pedal. The deceleration was around 0.3 g.

[17] The parameters of the landing gear AIR/GROUND sensors changed to GROUND one second later probably because of the residual lift of the aeroplane due to its speed at that time as well as limitations in the available FDR parameter data such as signal delay and low sample rate.

At 00:36:56, the aeroplane's ground speed was 125 kt, the thrust reverser controls were pulled to the FULL REV position. The PM who had made no callouts since handing over the controls to the captain 48 s earlier, called out "*REVERSE*".

The pressure on the brakes increased still in an asymmetric manner.

At 00:37:06, the aeroplane's ground speed was 85 kt, the braking action became symmetric with more than 2,900 psi on each side consistent with maximum manual braking. The N1 ratings reached 80%. The deceleration increased to 0.37 g.

It was estimated that the runway overrun was at 00:37:08, with a ground speed of the order of 70 kt.

The aeroplane finished its run with its nose in the Or lake. The captain asked for the evacuation procedure to be complied with and transmitted a Mayday message on the frequency.

1.2 Injuries to persons

The three persons on board were not harmed.

1.3 Damage to aircraft

The aeroplane sustained extensive damage in the area of the nose gear and power plants. The underside of the aeroplane's nose remained submerged for more than 24 h.

Given this damage, the owners of the aeroplane decided that it was not economically justifiable to repair it. The aeroplane was torn down in the months which followed the accident.

1.4 Other damage and consequences

Three of the threshold lights of runway 30R and an approach light were broken by the aeroplane's wheels passing over them.

Due to the presence of the aeroplane in the runway safety area and on the extended runway axis, the airport was closed for nearly 60 h.

1.5 Personnel information

1.5.1 Flight Crew

1.5.1.1 Captain

1.5.1.1.1 Ratings, experience, training, flight programme

The 48-year-old captain held an ATPL(A) obtained in June 2007. He had logged a total of 14,390 flight hours, including 12,173 hours on the Boeing 737 and 7,890 hours as captain.

He had had the TRI and TRE ratings for the 737 on a licence issued by the Oman aviation authorities. He is believed to have logged 3,500 flight hours as instructor or examiner[18].

He was recruited by Swiftair in September 2021. He had been based at Paris - Charles de Gaulle since June 2022.

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[18] The BEA did not check this information with the Oman authorities.

His last line check had been in November 2021. His general assessment had been ranked as "*high standard*" and his non-technical skills as "*very good*" [19].

His last simulator recurrent training took place in July 2022. His general assessment was ranked as halfway between "*standard*" and "*high standard*". The assessment of the non-technical skills was ranked as good. In the additional comments, the assessor had underlined his good control of the aeroplane, good situational awareness and a good attitude. He had also suggested improving the use of the standard operational callouts as an area for development.

In the week before the accident flight, the captain had not flown. His last flight was on 10 September 2022.

1.5.1.1.2 Statement

The captain explained that they had estimated a landing distance of around 4,500 ft (1,400 m), i.e. almost half the LDA, on the basis of the runway condition of 555 they had received. He was aware that the runway was wet and that it was raining. The strategy chosen for the landing was to select autobrake mode 2 to benefit from the immediate activation of the brakes on touchdown, and then quickly apply manual braking. He explained that they had also planned to use the thrust reversers with full power rather than idle thrust. They were used to using idle thrust on the thrust reversers because of noise constraints in the context of the night flights they carried out.

He recalled that they identified the runway from a considerable distance. He did not remember when they activated the windshield wipers, but did remember that they mentioned rain during the approach. He could not recall any particular echo on the weather radar during the approach. He explained that they were aware that there was bad weather and that it was raining, but they had no echoes on the weather radar on final, nor on the missed approach path.

The vertical speed was around 900 ft/min for the final approach. He indicated that on a 3.66° slope, the rate of descent was very close to the stabilization criterion of 1,000 ft/min.

He explained that he had repeated a SINK RATE callout several times, that they had had a vertical speed of nearly 2,000 ft/min, and that he had felt that the co-pilot was making large pitch inputs in opposite directions. For these reasons, along with the risk of a "black hole" effect on approaching the threshold, he suggested to the co-pilot, that he take the controls.

At this point, he had not initiated a missed approach because they had the runway in sight and visibility was good. Despite his SINK RATE callouts, he felt he could still carry out the landing. He felt that they were stabilized, that the flight parameters were within the windows and that there was no reason to go around when he took the controls.

When he took the controls, he remembered looking at the airspeed but did not remember increasing the power. He thought that his action on the throttle levers was perhaps an "instinctive" action. He then concentrated on the outside for the landing.

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[19] The assessments were based on five levels: for the general assessment, "high standard" was level 4, which corresponded in the key of the assessment document to flight knowledge and technique that improve flight safety. With respect to the non-technical skills, "very good" was the maximum level and corresponded to behaviour which improves safety margins in an optimal manner and which could be an example for other pilots.

He explained that on flaring, he did not perceive the threshold markings or the runway number. He did perceive the amber/red lights[20] when they passed them. He was unable to estimate at what distance they touched down on the runway. He felt that they were fast and that the flare was long.

He said that he felt that the deceleration during the landing run was very slow, despite the use of thrust reversers and maximum braking. He had the impression that the runway was "completely flooded".

He knew that the aeroplane was not equipped with a predictive windshear system, only a reactive system.

Concerning the use of the radar, he indicated that the radar tilt has to be set between 0° and 1° for the final approach.

He explained that while he was PM, during the final approach, he was very focused in order to guide the co-pilot and make sure that the aeroplane stayed on the flight path, and on the parameters in the stabilization windows. This monitoring had taken a lot of his resources. When he took the controls, the aeroplane was being pushed to the RH side of the runway axis and he tried to bring it back onto the axis. He did not remember hearing any deviation callout from the PM. This reinforced his decision to continue.

He said that the co-pilot had to be given some guidance when he was acting as PF, but that his performance was good, given his small amount of experience on the Boeing 737. They duly complied with their tasks and their division. Once they had changed roles, he would have liked more support and cross-checking from the co-pilot as PM.

1.5.1.2 Co-pilot

1.5.1.2.1 Ratings, experience, training, flight programme

The 52-year-old co-pilot held an ATPL(A) obtained in October 2017. He had logged a total of 4,200 flight hours including 186 hours on the Boeing 737 of which 93 hours with an instructor in the scope of his line flying under supervision on this aeroplane type.

He had been working for Swiftair for seven years. He previously flew the ATR and had obtained his Boeing 737 300-900 type rating in March 2022. He had been based at Paris-Charles de Gaulle since June 2022.

The line check on completion of his line flying under supervision period was carried out in July 2022. His general assessment was ranked as standard tending towards high standard and his non-technical skills as good. A few deviations from standard operational callouts had been noted in the comments section of the assessment.

On 14 and 15 September 2022, he had carried out his simulator recurrent training and the OPC. His general assessment had been ranked as standard leaning towards low standard[21] and his non-

[20] It is probable that the captain was referring here to the amber runway edge lights over the last 600 m of the runway.

[21] The "*low standard*" ranking is described as knowledge and flight technique which does not have an impact on safety but which has to be improved.

technical skills as good. In the additional comments, the assessor had underlined good CRM and had suggested revising the standard operational callouts as one of the areas for improvement.

In the week before the accident flight, the co-pilot had not flown. His last flight was on 9 September 2022. In the morning of 24 September, he had taken a positioning flight between Marseille and Paris-Charles de Gaulle with a scheduled take-off at 04:20 and landing at 05:50. For the accident flight which was the first one in the rotation, he was scheduled to report for duty at 22:40

1.5.1.2.2 Statement

The co-pilot explained that he had never flown to Montpellier airport before. It was also the first time he had flown with the captain. He believed that it was also the first time he had flown EC-NLS[22].

He explained that they carried out very few VOR approaches on the Boeing 737 fleet as part of Swiftair's operations. They generally flew ILS or RNP approaches. He explained that he had also carried out very few VOR approaches when on the ATR, before changing to the Boeing 737.

Regarding the preparation of the approach, he explained that being aware of his limited experience on the aeroplane and that he took more time to prepare an approach, he anticipated the preparation. After the runway change, he thought he had given another briefing. He remembered that the captain had calculated the length of runway required for landing and had estimated it at around 4,000 ft. He thought this calculation was made after the runway change.

They had a sufficient fuel endurance on arrival, so this was not a cause for concern.

Regarding the approach, he recalled that they had the windshield wipers on and could see the runway. There were no radar echoes to give him cause for concern: he remembered that the echoes were green. He explained that the radar displayed green, yellow or magenta echoes. He could not remember if there were any yellow echoes, but he was sure there were no magenta echoes. He remembered that the rain became heavier on short final. He did not notice if there was a tailwind during the approach.

Between 2,000 and 1,000 ft, he saw the PAPI. He thought they were well positioned on the approach slope.

When the captain offered to take the controls, he accepted because of his small amount of experience on the aeroplane, because he was not familiar with the airport and because of the weather conditions.

He had no precise recollection of what happened after handing the controls to the captain on final. He thought he kept his eyes on the runway. He was preoccupied with the conditions and did not refocus on monitoring the parameters. He did not see the speed at the time of the flare or touchdown because he was looking outside.
He explained that he felt that the wind was turning at the time of the flare, he felt that it was a crosswind, coming from the LH side. He specified that the environment was very dark and that he had great difficulty perceiving external references.

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[22] The examination of the co-pilot's flight records confirmed this information.

He had the impression that the aeroplane did not brake, that it slid, during the landing run.

He explained that one of the stabilization criteria during the approach was to have a vertical speed of less than 1,000 ft/min. Asked about the case of an approach slope of 3.66° as is the case for the VOR Z 12L approach at Montpellier, he thought that the maximum vertical speed to meet the stabilization criteria remained the same.

He knew that the aeroplane was not equipped with a predictive windshear system, only a reactive system. He knew that the warning was visual, but did not know whether there was also an aural warning. He knew that if there was a warning, the crew had to fly a missed approach and that in the case of a caution, there was no obligation to fly a missed approach. He had never had a windshear warning in operations.

Concerning the use of the radar, he knew that the radar tilt had to be changed from -5° to 1° for the approach. He remembered a simulator training session during which the use of the radar was covered. He explained that the use of the radar was different on the ATR because the latter flew at lower altitudes than the Boeing 737, at altitudes where more storm cells are present.

1.5.2 Flight crew member

A qualified aircraft maintenance mechanic was present. He was sat in the cargo area, in the galley behind the cockpit and separated from the latter by a closed door. His presence did not affect the accident.

1.5.3 Air traffic control services personnel

1.5.3.1 Composition of team

At the time of the accident, two air traffic controllers were on duty. They had come on duty at 19:30.

Only the tower supervisor was in the tower cab. The second controller, who was in the rest room, immediately returned to the tower cab when he heard the activation of the alert by the tower supervisor.

1.5.3.2 Statements

The tower supervisor had begun the shift with a briefing with the team[23]. For this, he had previously analysed the weather information available (weather reports and forecasts, the ASPOC tool for observing and forecasting storm cells, Arome model charts) in order to provide the team with an analysis of the development trend for the night of duty. He had also acquainted himself with an aerodrome warning message issued by Météo-France concerning thunderstorms forecast over the airport between 18:00 and 03:00.

He explained that when the rain started to fall at around 20:00[24], he called the RFFS to ask if they were going to update the Runway Condition Report (RCR). He also told them that, according to his analysis, between midnight and 06:00, there was going to be a heavy thunderstorm and that they would then need precise RCR parameters for the arrival of the Swiftair flight.

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[23] At the time of this briefing, a third controller was present. His duty period ended before the accident.

[24] This telephone call was in fact made at 19:32 (see paragraph 1.10.5.4).

At around 23:30, the controller checked the updated weather information. He was aware of the presence of an active zone to the south of the airport, with a southerly flow.

He remembered checking that the lights had been switched on and set to a brightness level that in his experience, would allow better visual acquisition on final without dazzling the crews.

He observed that the aeroplane was high and fast as it approached the runway. He thought it was going to carry out a missed approach. He had the impression that the aeroplane's touchdown was long. When the aeroplane came to a stop, he could not perceive that it had run off the runway from his position. It was when the crew made a "Mayday" call that he triggered the alert.

When his colleague joined him in the control room after the accident, at 00:38, the former looked at the wind indicator at the control station and mentioned the tailwind. This surprised him because he remembered having cleared the crew to land with a wind which was mainly a crosswind. The second controller also remembered having checked that the lights were on when he returned to the tower cab.

Both controllers expressed difficulties in managing the situation after the runway excursion. This was due to two factors: firstly with no relief controller available, they had to perform their control services for the TMA as well as the coordination required to manage the situation linked to the accident, despite the psychological impact of the accident on them. Secondly, because of their position and their means of communication, they had to manage a certain number of situations linked to the organisation of the rescue on the platform which were not their direct responsibility (for example, the request to bring in the nautical rescue resources, coordination to resolve the problems of access of external resources to the airside zone).

1.6 Aircraft information

1.6.1 Airframe

Manufacturer	Boeing		
Type	737 - 400		
Serial number	25856		
Registration	EC-NLS		
Entry into service	1993		
Certificate of Airworthiness	No 8419	dated 19 October 2020	
Airworthiness review certificate	No ES.CM.047.RA.003	from 08 July 2022	to 3 August 2023
Operation as on 24 September 2022	41,293 cycles, 57,687 flight hours		
Owner	West Atlantic Sweden		
Operator	Swiftair		

The maximum landing weight was 54,884 kg.

1.6.2 Engines

	Engine No 1	Engine No 2
Manufacturer	CFM International	CFM International
Type	CFM56-3C1	CFM56-3C1
Serial number	856740	858825
Date of installation	20 June 2022	11 April 2017

1.6.3 Technical logbook

The aeroplane’s technical logbook did not include any deferred items when the crew carried out the pre-flight check.

1.6.4 Equipment and/or systems

1.6.4.1 Instruments

EC-NLS was equipped with an EFIS, comprising an Electronic Attitude Director Indicator (EADI) and an Electronic Horizontal Situation Indicator (EHSI).

Ground speed information was displayed on the EADI.

The EHSI can display weather radar information when this option is selected, which was the case when EC-NLS landed. It also provides a wind indication, at the bottom left of the screen, consisting of an arrow oriented relative to the aeroplane's heading and numerical information on wind strength and direction.

Wind information is also available on the FMC when the Progress 2 page is selected, in the form of wind direction and speed information, as well as a breakdown into crosswind and headwind or tailwind components.

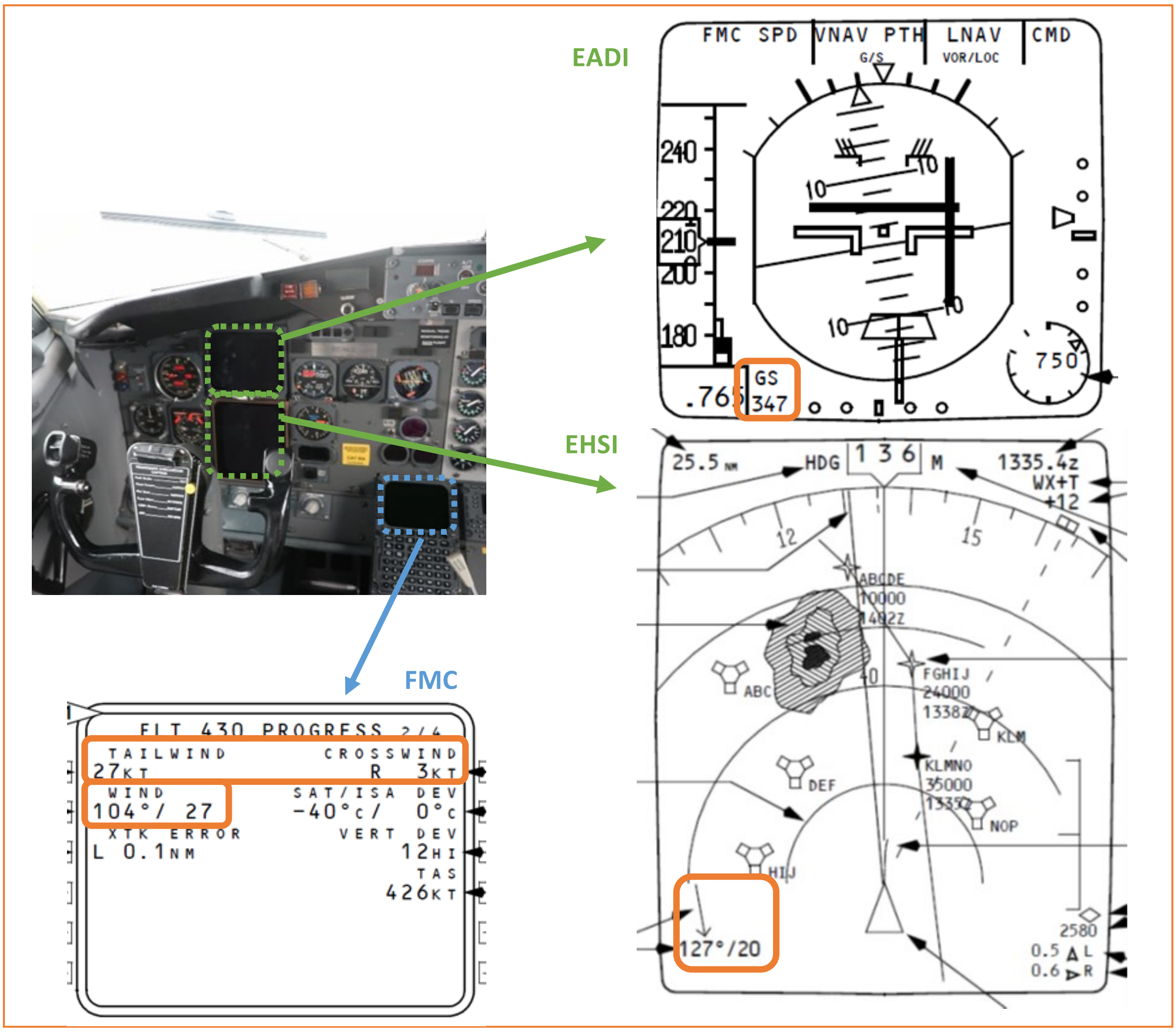

Figure 4: ground speed and wind display (Source: Boeing/BEA)

1.6.4.2 TAWS system/windshear detection function

EC-NLS was equipped with a Honeywell EGPWS Mark V, which incorporates reactive windshear detection in addition to the terrain proximity warning function.

1.6.4.2.1 Description of function

This detection is active at a height of between 10 and 1,500 ft, during the take-off and landing phases. It is based on a comparison between inertial accelerations and air mass accelerations.

On the Boeing 737, windshear warnings are generated when the level of windshear exceeds certain values, either in the horizontal profile or in the vertical profile (see Figure 5, red area of graph). Warnings are generated when the headwind decreases (or the tailwind increases) or when there is a downdraft.

The EGPWS Mark V is capable of detecting and generating cautions when the headwind increases (or the tailwind decreases) or when there is an updraft. The warning functionality generates cautions in the cockpit only if it is certified and configured for the specific aeroplane on which the EGPWS is installed. This function has not been certified by Boeing for the 737.

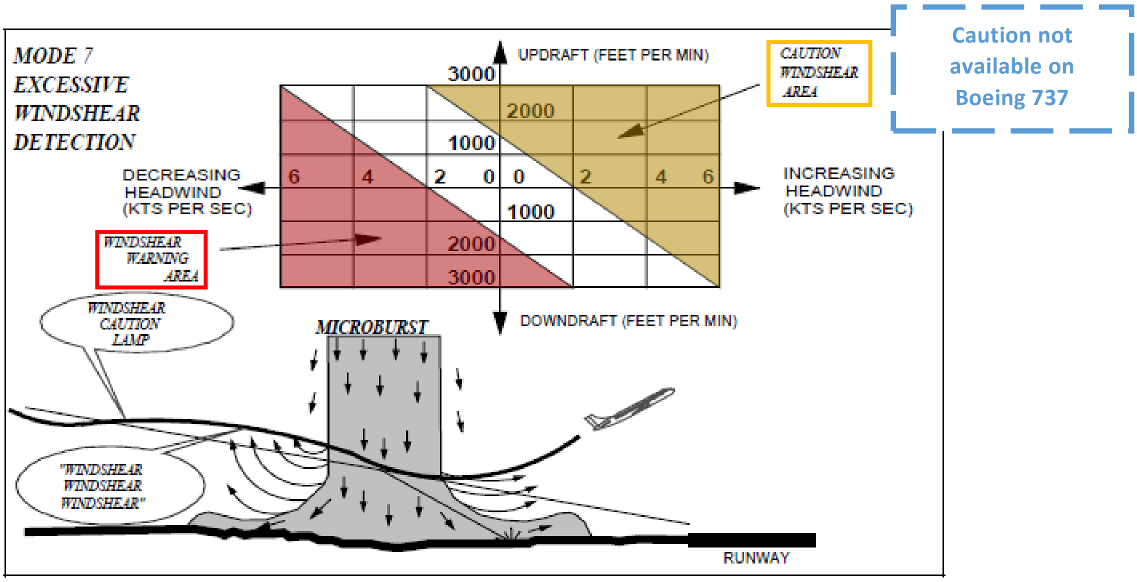

Figure 5: windshear detection modes[25] (Source: Honeywell, annotated by the BEA)

Thus the windshear caution functionality was not available on EC-NLS. For this reason, the crew did not receive a caution when the EGPWS detected the windshear on the sudden reduction in tailwind between 200 and 100 ft (see paragraph 1.11.3).

According to the certification criteria applicable to EC-NLS, this functionality is not mandatory.

Note: the windshear caution functionality had not been certified by Boeing because it had been deemed ineffective during the development and evaluation of the TAWS functionalities for Boeing aircraft.

1.6.4.3 Weather radar

EC-NLS was equipped with a weather radar.

This radar was not equipped with a Predictive Windshear System (PWS).

The radar displays the strength of the precipitation on the navigation screen in contrasting colours against a black background. The areas of heaviest precipitation appear in red, lesser precipitation in yellow and the lowest precipitation in green.

In WX/T mode, the radar also displays precipitation associated with turbulence. When the radar detects a horizontal flow of precipitation with speeds of 5 m/s or more, the target display becomes magenta. This magenta area is associated with severe turbulence.

The IDNT mode activates the ground clutter suppression function: signals that are determined to have a high probability of originating from ground returns are automatically removed from the screen. The purpose of the IDNT mode is to allow pilots to analyse the situation; it is not designed for continuous use, as some parts of the weather targets may have their intensity reduced in this mode, or even suppressed.

[25] The values of the caution activation areas shown in this figure are not exact but are given for illustration purposes.

The EC-NLS radar control panel was not described in the FCOM for the 737-400 used by Swiftair. Other control panels, corresponding to different types of radar, were described. This lack of information was mentioned in Swiftair's 737-CL fleet familiarisation manual, which listed the differences between the aeroplanes in the fleet. The EC-NLS radar control panel was identical to the one on EC-NML, on which the co-pilot had carried out 22 flights.

Figure 6: EC-NLS radar control panel photographed after the accident (Source: BEA)

The examination of the radar control panel after the accident found that:

- the WX/T and IDNT modes were activated;
- the antenna tilt was set to the right at a value greater than 5°.

It was not possible to determine the gain value selected.

Based on this examination, it is not possible to affirm that these were the settings in use during the landing.

1.6.5 Limitations

EC-NLS was not approved for RNP approaches[26].

1.6.6 Operational procedures

The elements in this section are based on a review of the following manuals:

- Swiftair Operations Manual (OM);
- Swiftair Pilot Reference Manual (PRM) applicable to the 737 fleet;
- Boeing Flight Crew Operations Manual (FCOM) applicable to the 737-CL;
- Boeing Flight Crew Training Manual (FCTM) applicable to the 737-CL.

1.6.6.1 Briefing

The standard briefing described by the operator in the OM did not include TEM.

In the case of a non-precision approach, the OM required the crew to determine the approach speed, based on the Vref and wind, the rate of descent and the resulting average engine power, during the briefing. The reasons for the decision to carry out a missed approach also had to be discussed.

A new briefing had to be given if the runway or approach procedure was changed.

[26] Five of Swiftair's fleet of twelve 737-CL were not equipped for RNP approaches. The 737-NG is.

1.6.6.2 Choice of flap configuration for landing

According to the FCTM, the use of flap 30 for landing provided better noise reduction and reduced the loads and wear on the flaps. When the performance criteria in climb in the event of a go-around were met, the FCTM recommended using flaps 40 to minimise speed and landing length.

A note specified that the runway length and conditions had to be taken into account when choosing the flap configuration for landing.

1.6.6.3 Approach speeds

The QRH was used to define the reference speed Vref as a function of the forecast landing weight and the chosen configuration.

WEIGHT (1000 KG)	FLAPS		
	40	30	15
70	155	159	177
65	149	154	171
60	143	147	164
55	137	141	156
50	130	134	149
45	124	127	141
40	116	119	132
35	109	111	123

Figure 7: table to determine Vref (Source: Boeing)

In the conditions of the accident flight, the crew estimated the landing weight as 51.5 t. They chose a Vref value of 136 kt for the flap 30 configuration, in line with the above table.

According to the FCTM, in the case of an approach where it was planned to disconnect the autothrottle before landing, the recommended method for determining the Vapp was to add half the forecast headwind component and the additional gust value, to the Vref, the minimum Vapp value being Vref + 5 kt.

The crew chose a Vapp value of 143 kt, consistent with the Vref value chosen and the indicated wind of 130° for 14 kt.

1.6.6.4 Landing distance

According to the OM, the calculation of the Landing Distance at Time of Arrival (LDTA) had to be carried out in flight, before starting the approach, preferably no more than 30 minutes before the estimated landing time, on the basis of updated meteorological information and the updated RCR. Calculation tables were provided in the QRH, according to the configuration, braking mode, runway condition and braking effectiveness. This LDTA included a safety margin of 15% in relation to the theoretical landing distance.

The captain noted the result of his calculation on the OFP: he estimated an LDTA of 4,580 ft (i.e. 1,396 m) with a flap 30 configuration and a "MAX MANUAL" braking mode. It was not possible to confirm the exact conditions he had taken into account to determine this value.

A similar calculation was carried out by the BEA using the following conditions:

- Forecast landing weight: 51.5 t;
- Flap configuration: 30;
- Braking mode: MAX MANUAL;
- Altitude: 0 ft;
- Wind: 130°/14 kt (comparable to a headwind of 14 kt for the calculation);
- Runway condition and braking effectiveness: wet runway, GOOD (RWYCC 5);
- Slope: 0%;
- Temperature: ISA+3°;
- Approach speed: 143 kt for a $Vref_{30}$ of 136 kt, i.e. $Vref_{30}$ + 7 kt.

The result of this calculation gave a LDTA value of 4,840 ft (i.e. 1,475 m), a value consistent with the calculation carried out by Boeing.

For information, for a flap 40 configuration, the LDTA value obtained in the conditions of the approach preparation was 4,750 ft (i.e. 1,448 m).

Although the OM did not require it, it is good practice to carry out the calculation taking into account a deterioration in conditions, so as to know the distance required in the event of such a deterioration occurring during the approach, and thus facilitate decision-making. This practice is particularly useful when a crew are aware of the existence of changing conditions at the airport, for example in the presence of Cb.

Hypothesis of deterioration in conditions	Corresponding LDTA (flaps 30)
RWYCC 2 – Braking action MEDIUM TO POOR	6,883 ft (2,100 m)
Tailwind of 10 kt	5,800 ft (1,768 m)
Combination of above two cases	8,791 ft (2,680 m)

1.6.6.5 Conducting a Non-Precision Approach (NPA)

For the approach, except in the case of an RNP approach, the PRM suggested that the PF display the Progress 2 page on the FMC, which shows the wind information[27].

The Operations Manual recommended initially selecting a rate of descent that corresponded to the aeroplane's ground speed, based on the rates published on the approach sheet. This recommendation was equivalent to that of the FCTM.

The PRM mentioned, for a NPA flown in V/S mode, that due to a slow autopilot response, 1,000 ft/min had to be initially selected for a 3° slope.

In the case of the accident flight and the VOR Z 12L approach (see paragraph 1.10.2), taking into account the surface wind information (130°/14 kt) provided by the controller when preparing the approach and the Vapp of 143 kt chosen by the crew, the ground speed would have been around 130 kt and the vertical speed to follow the 3.66° approach slope would have been around 840 ft/min[28].

[27] According to the statement made by a Swiftair instructor, this selection was a focus point for instructors during training sessions. The PM was expected to monitor the tailwind component on this page.

[28] For an approach with flaps 40, the Vapp would have been 139 kt, the ground speed 126 kt, and the vertical speed to follow the 3.66° approach slope taking into account the surface wind information 130°/14 kt would have been around 820 ft/min.

When the aeroplane passed the FAF, its airspeed was 156 kt and its ground speed was around 180 kt. Consequently, a vertical speed of 1,166 ft/min had to be selected to follow the 3.66° approach slope according to the inset providing the rate of descent as a function of ground speed available on the published approach chart.

1.6.6.6 Stabilization criteria

The PRM indicated that, "*It should be clearly understood that an unstable approach is more likely to result in a hazardous landing with the resultant high risk of an accident. Most unstable approaches result from a lack of appreciation of the aircraft energy level at an early part of the approach and the resultant failure to slow the aircraft in a controlled manner. The decision to execute a go-around is no indication of poor performance*."

With regard to stabilization on the final approach, the Operations Manual mentioned the following points:

- in the case of a NPA approach, the flight path must be held laterally within 5° of the runway axis;
- the aeroplane must be on the correct approach slope;
- only small corrections in pitch attitude and roll are required;
- the speed is between Vref and Vref + 20 kt[29];
- the rate of descent is less than 1,000 ft/min - in the case of an approach requiring a rate higher than this value, a special briefing must have been carried out[30].

The Operations Manual states that approaches must be stabilized at 1,000 ft AAL in IMC and 500 ft AAL in VMC.

According to the PRM, the PM must call out "1,000 ft" and "500 ft" if there is no automatic callout. The PF must respond to this callout as follows:

1,000 ft AAL	If stabilized: "*stabilized*" If not stabilized in IMC: "*not stabilized, go around*" If not stabilised in VMC: "*not stabilized*"
500 ft AAL	If the approach was stabilized at 1,000 ft: "*checked*" If the approach was not stabilized at 1,000 ft but now is: "*stabilized*" If not stabilized: "*not stabilized, go around*"

According to the Operations Manual, if an approach conducted using the CDFA technique is destabilized below 1,000 ft in IMC or below 500 ft with visual references, a missed approach must be immediately carried out.

During the approach, the PM must call out "*speed*" at -5 kt or +10 kt of the approach speed, "*bank*" if the roll is more than 10° and "*sink rate*" if the rate of descent exceeds 1,000 ft/min.

When crossing the threshold, the speed must be stabilized at Vapp +/- 10 kt and the flight path stable and such that the landing is made in the touchdown zone (the shorter of the two values first 3,000 ft or first third of the runway).[31]

[29] The PRM mentioned a speed between Vref and Vapp + 10 kt.

[30] During the descent and at the time when the briefing could be carried out, with the wind conditions known at the time, the crew could not have anticipated this condition.

[31] For runway 12L, the corresponding value would have been 2,843 ft, i.e. 866 m.

1.6.6.7 Landing

During the landing, the PM must make the following callouts regarding:

- the deployment of the ground spoilers and thrust reversers;
- the deactivation of the autobrake; and
- on passing 80 kt and then 60 kt.

1.6.6.8 Use of thrust reversers and braking

In its chapter on the use of thrust reversers, the OM stresses the importance of checking the limitations imposed by aerodromes (these limitations are designed to limit the additional noise generated by thrust reversers on landing). However, it is stressed that the use of thrust reversers for flight safety reasons is not restricted.

The landing can no longer be rejected once the thrust reversers have been applied.

The PRM recommends the use of autobraking, in mode 1 or 2 for routine operations and in mode 3 when the landing distance available is limited or braking effectiveness is degraded.

In the FCTM, Boeing advises that mode 3 should be used on wet or slippery runways or when the landing distance available is limited. If an adequate landing distance is available, autobraking mode 2 may be appropriate.

1.6.6.9 Rejected or balked landings

In the FCTM, Boeing included techniques for rejected landings (before touchdown) and balked landings (after touchdown). In the event of a rejected landing, it is recommended that the crew comply with the missed approach procedure described in the FCOM or QRH. In the event of a balked landing, the technique described in the FCTM indicates a go-around without changing the configuration and reminds the crew to take into account obstacle clearance, the length of runway available and the transition from a low-energy state.

1.6.6.10 Swapping PF/PM roles

According to the PRM, the swapping of roles between pilots must be carried out in a positive manner using the standard challenge and response method, "*I have control* / *you have control*".

1.6.6.11 Use of radar

The Operations Manuals did not provide detailed procedures or recommended techniques for using the weather radar.

1.6.6.12 Windshear

In the chapter on adverse weather conditions, the OM indicated that, "*a Cb producing precipitation is accompanied by strong downdrafts extending laterally under the base that cause strong gusts and abrupt changes in wind direction in low levels must be taken into account* […]. *This, together with low flight speed and altitude can create a dangerous situation; therefore, precautions shall be taken during approaches, take-offs or landings in these conditions, especially if new storm cells are forming in the proximity of the airport*."

In situations where windshear is likely, the OM indicated that, "*One pilot must always continue to monitor instruments in windshear situations, even on visual.*" […] *Pilots must not hesitate to execute missed approach manoeuvres when windshear occurs below 1000 feet, if the approach path is altered. Missed approaches are much safer than attempting to recover the approach path […] Pilots must be prepared to execute missed approach manoeuvres when storms are in the immediate areas. […] When the wind reported on approach differs from that of the surface, act in anticipation of possible windshear.*"

Likewise in the FCOM, Boeing explained that the crew should look for any signs of windshear along the planned flight path. This may be associated in particular with storm activity. It was emphasised that, for the approach and landing, crew coordination and awareness were very important, particularly at night or in marginal weather conditions. They must closely monitor the vertical flight path instruments, such as the vertical speed indicator and the altimeters. The PM should report any deviation from normal.

In the QRH, it is specified that the following are indications that the aeroplane is in windshear:

- windshear warning;
- unacceptable flight path deviations.

Unacceptable flight path deviations are recognized as uncontrolled changes from normal steady state flight conditions below 1,000 feet AGL, in excess of any of the following:

- 15 knots indicated airspeed;
- 500 ft/min vertical speed;
- 5° pitch attitude;
- 1 dot displacement from the glideslope;
- unusual thrust lever position for a significant period of time.

1.7 Meteorological information

1.7.1 Information received by crew when preparing flight

The weather folder given to the crew for the preparation of the flight contained the 20:00 Montpellier TAF:

> TAF LFMT 232000Z 2321/2421 14010KT 9999 BKN045 BKN055 TEMPO 2321/2323 14015G25KT 3000 TSRA SCT030CB BKN040 BKN050 <u>TEMPO 2323/2402 01015G25KT 3000 TSRA BKN020 SCT030CB BKN040</u> BECMG 2402/2404 36010KT BECMG 2405/2407 28006KT TEMPO 2415/2417 22010KT TEMPO 2417/2420 27015G25KT RA FEW045CB BKN090=

This TAF indicated that for the scheduled landing time at Montpellier, temporarily, visibility reduced to 3 km, thunder showers, a ceiling at 2,000 ft, presence of cumulonimbus (Cb).

The folder also contained the EUROC significant weather (SIGWX) chart valid at 00:00. This chart showed a scalloped zone in the Montpellier area, with isolated and embedded Cb, storms, showers and rain.

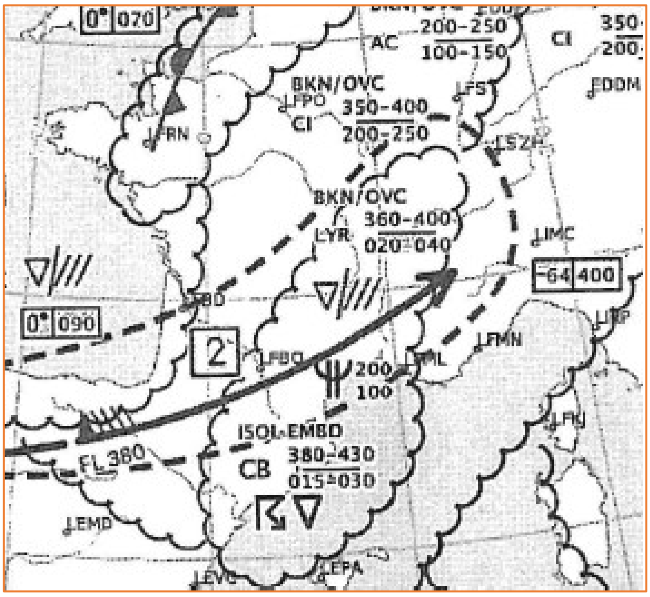

Figure 8: excerpt of EUROC SIGWX chart in weather file

Lastly, the weather file included the following SIGMET for the Marseille FIR, valid at the time of the flight, which indicated storms embedded in the cloud mass, in an area delimited by a series of geographical coordinates.

> LFMM SIGMET 9 VALID 232200/240200 LFPW- LFMM MARSEILLE FIR/UIR EMBD TS OBS WI N4215 E00345 - N4215 E00230 - N4430 E00245 - N4500 E00315 - N4430 E00415 - N4345 E00500 - N4245 E00445 - N4215 E00345 TOP FL380 MOV E 20KT NC=

Montpellier airport was included in the SIGMET zone.

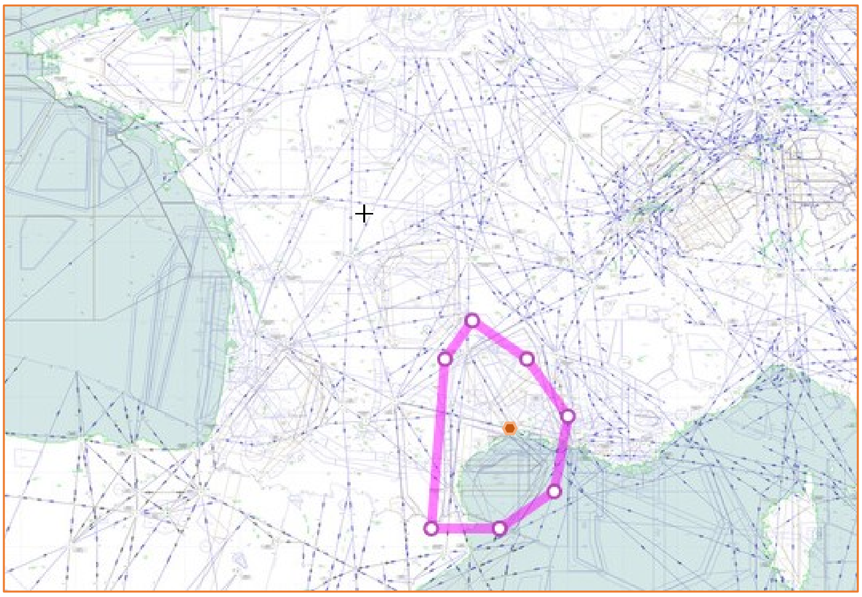

Figure 9: area covered by SIGMET
(red dot corresponds to LFMT)

1.7.2 Weather information received by the crew during the flight

At 00:02, the crew contacted Montpellier control to obtain updated weather information.

The information provided included visibility of 2,700 m, rain, mist, cloud ceiling based at 1,600 ft, presence of Cb, wind from 130° of 14 kt, runway condition code 555.

The crew's handwritten record of this information on the OFP did not mention the Cb information.

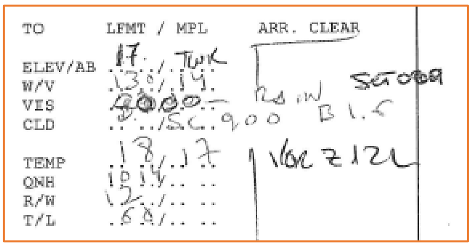

Figure 10: excerpt from OFP, weather notes taken for arrival at LFMT

After this initial information, the controller informed the crew that visibility was improving and gave a value of 3,000 m. He also informed them that a storm had passed over the airport ten minutes earlier, that the situation was now calmer but that the weather conditions were evolving rapidly.

At 00:21, the Montpellier controller informed the crew that visibility had improved to 4,500 ft, that the cloud ceiling was at 1,300 ft, that it was still raining and that there was mist. The runway condition of 555 was confirmed with the information that a preceding aircraft had reported stagnant water level with the touchdown zone of runway 12L and that the runway condition could be 255.

At 00:34, when the controlled cleared the crew to land, he reported wind from 040° of 8 kt[32].

1.7.3 Aerodrome warning message

Météo-France issued an aerodrome warning message on 23 September at 15:00, indicating that storms were forecast for the night, between 18:00 and 03:00.

The personnel of the air traffic control services were aware of this message.

This message was transmitted to certain personnel of the RFFS. Not everyone was aware of it.

1.7.4 Weather situation at time of landing

1.7.4.1 General conditions

The examination of the satellite and radar images found that there was an extended convective system from the Cevennes to the Golfe du Lion. The reflectivity suggested heavy and even intense precipitation locally but, except for the southern edge of the system, south of the Golfe du Lion and over Catalogne, the electrical activity was very sporadic.

[32] The controller must provide the wind information when giving the landing clearance but is not obliged to follow-up this information. The crew can ask for a wind check at any time if they have doubts about the assessment of this value during the approach.

In the Montpellier area, the reflectivity image (see Figure 11) shows an extended area associated with heavy precipitation (in yellow and orange) and a core of more intense precipitation (in red and bistre) at the edge of the airport at 00:35.

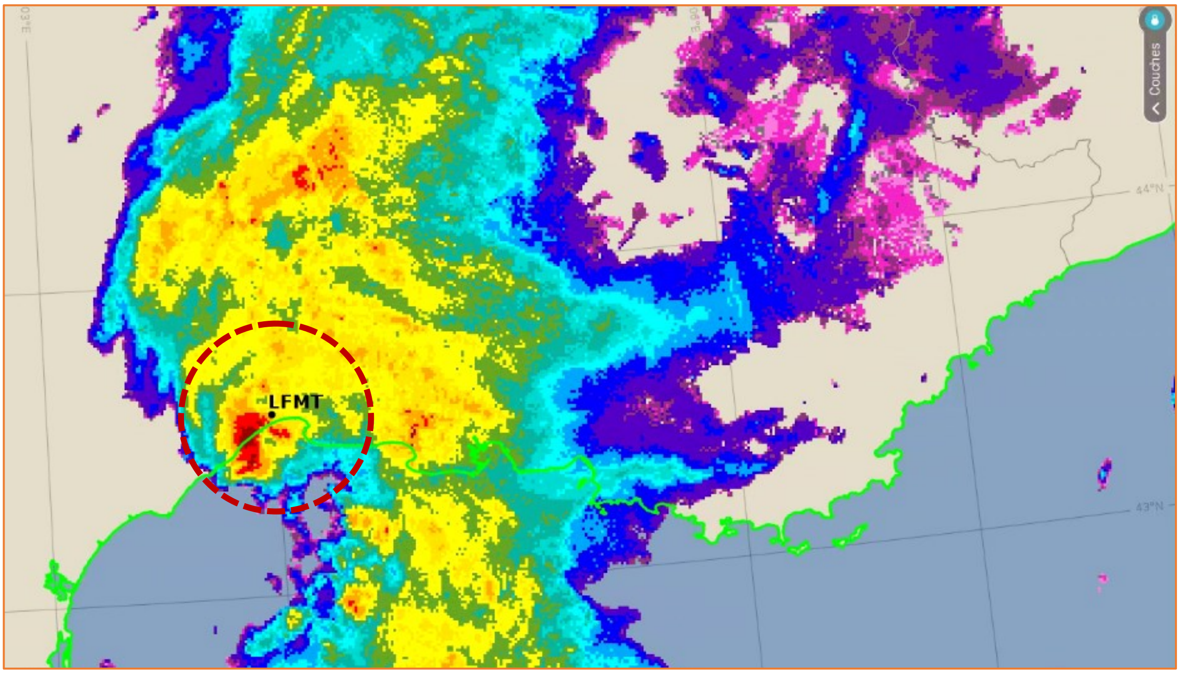

Figure 11: precipitation reflectivity radar image at 00:35
(Source: Météo-France, annotated by the BEA)
(The circle corresponds to a 20 NM radius around the airport)

1.7.4.2 Wind conditions

The wind measurements at the thresholds of runway 12L and 30R were analysed by Météo-France. Three phases were identified between 23:00 and 02:00 (see Figure 12).

According to Météo-France, in the first phase, from 23:00 to 23:55, the conditions were more or less the same at the two runway thresholds, with a south to south-south-easterly wind of between 15 kt and 20 kt.

A second phase, between 23:55 and 00:45, was marked by the wind rotating from the north to the north north east. The change was more abrupt at the threshold of runway 12L than at the threshold of runway 30R, resulting in a horizontal windshear for the majority of the period. At the time of the accident, there was a north-north-easterly wind at the threshold of runway 30R, whereas at the threshold of runway 12L, the wind was swinging sharply between the east and the north-north-west.

Météo-France concluded that it was probable that the aeroplane temporarily encountered LH crosswinds during the landing along with windshear that could not be quantified.

From 00:45, there was a north to north-north-easterly wind at the thresholds of both runway, of around 20 kt for the threshold of runway 30R and between 10 kt and 15 kt for the threshold of runway 12L.

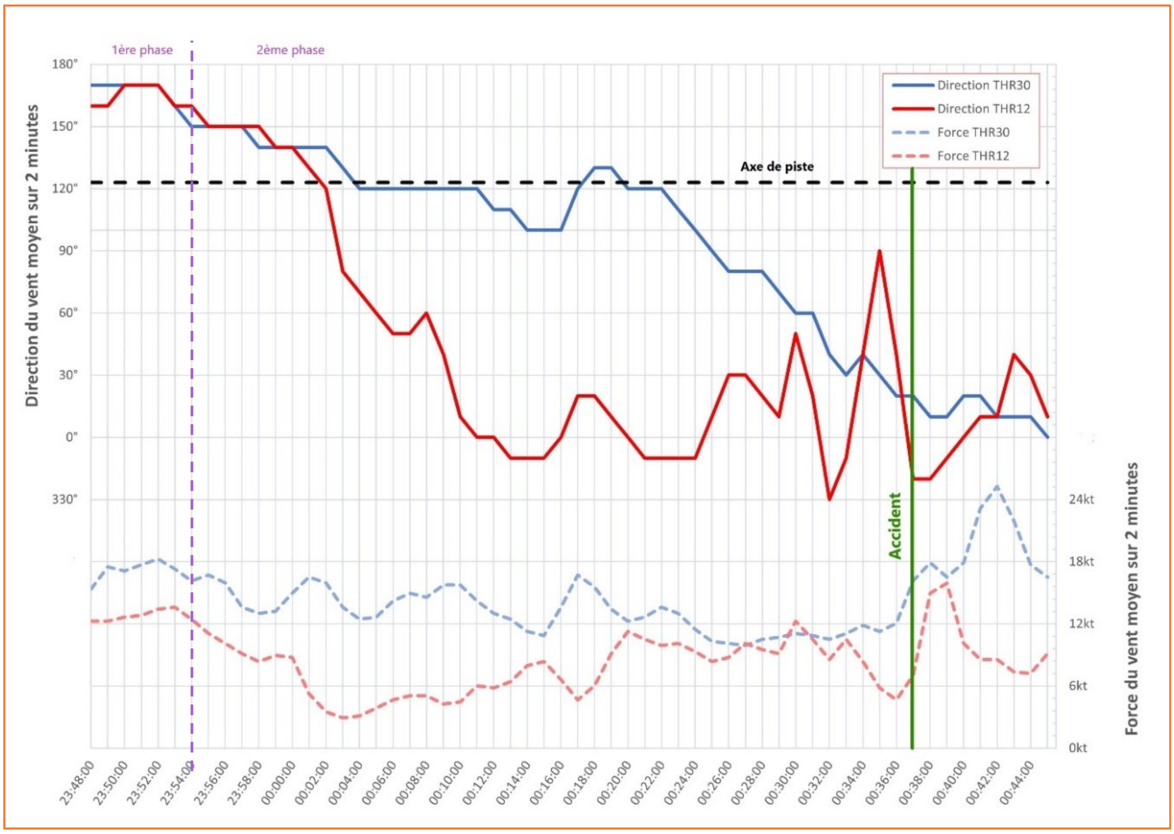

Figure 12: evolution of wind strength and direction every two minutes[33] at the thresholds of runway 12L and 30R (Source: Météo-France/BEA)

The study of the recording of gusts over one minute found that these followed the same phases as the mean wind. Météo-France indicated that the accident coincided with a north-north-westerly gust of 25 kt at the threshold of runway 12L at 00:37 whereas the wind had not exceeded 10 kt at 00:36.

1.7.4.3 Precipitation

Météo-France also provided the rainfall data from the airport weather station.

[33] To avoid discontinuities that would interfere with reading, 360° have been subtracted from directions exceeding 180°.

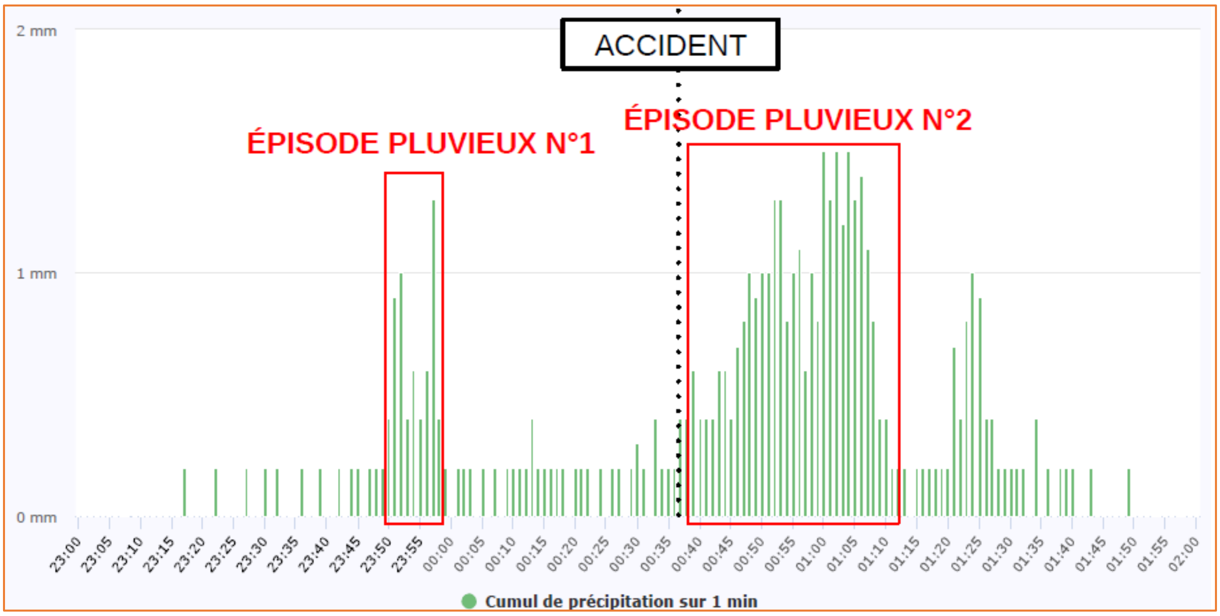

Figure 13: cumulative total precipitation per minute at airport weather station (Source: Météo-France)

Météo-France described the precipitation as being low to moderate between 23:16 and 23:46, giving a cumulative total of 2.6 mm for the period, followed by an episode of heavy rain up to 23:59, resulting in a cumulative total of 6.8 mm. Between 23:59 and 00:32, there was a lull, with moderate rainfall giving a cumulative total of 5.1 mm over the period. At 00:32, a second episode of heavy rain began, comparable in intensity to the first, but lasting much longer.

The landing took place at the start of this episode of heavy rain, confirmed by the security camera images.

Météo-France indicated that the intensity of the rain during the two episodes was high to very high, but was not of an exceptional character. The situation was typical of the Mediterranean rainstorms that hit the Montpellier region several times each autumn.

This data was used to determine the cumulative rainfall over different periods defined in relation to the time of the accident, as shown in the table below:

Cumulative period	Cumulative window	Cumulative total
1 minute	00:36 – 00:37	0.4 mm
5 minutes	00:32 – 00:37	1.4 mm
15 minutes	00:22 – 00:37	2.7 mm

The depth of the water on the runway was estimated using this data (see paragraph 1.16.3).

1.8 Aids to navigation

1.8.1 VHF omnidirectional range

The VOR-DME FJR is the radionavigation means on which the VOR Z 12L approach is based.

The VOR is situated at around 165 m from the extended runway axis and at 1,755 m from the threshold of runway 12L (i.e. around 0.9 NM).

1.9 Communications

During the cruise, while the crew were in contact with the Bordeaux en-route control centre, the PM used the second radio to contact Montpellier tower to obtain up to data weather information. During the descent, the crew were in communication with the Marseille en-route control centre and then Montpellier tower.

1.10 Aerodrome information

1.10.1 General

Montpellier - Méditerranée airport (ICAO code: LFMT, IATA code: MPL) is close to the Montpellier agglomeration, situated below the approach path to runway 12L, and next to Or lake to the south-east.

The altitude of the runway 12L threshold is 17 ft.

Runway 12L-30R at Montpellier - Méditerranée airport is a paved runway measuring 2,600 m long and 45 m wide, oriented on the magnetic heading of 123°[34].

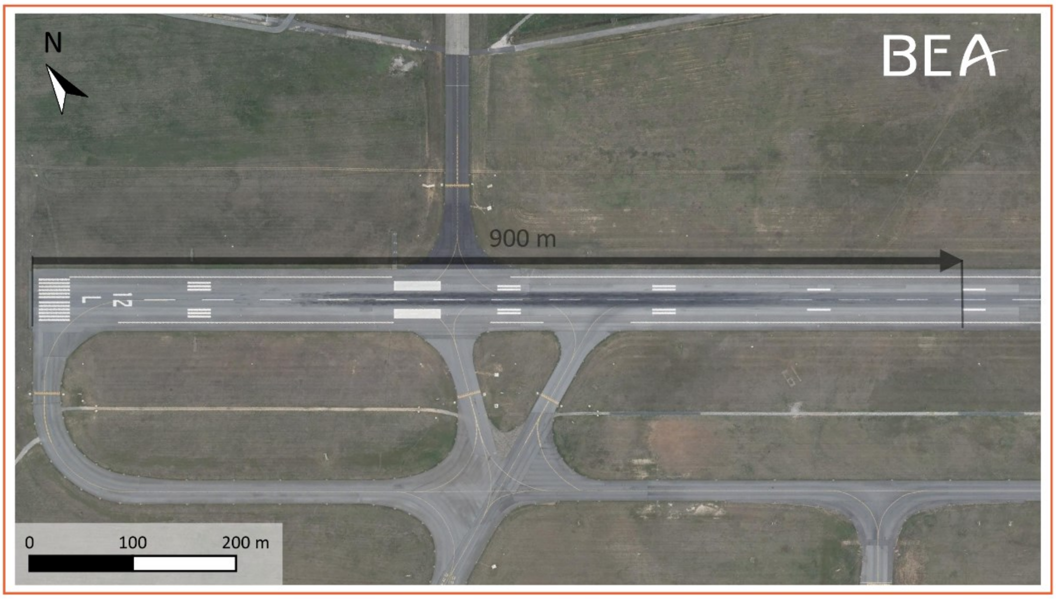

Figure 14: runway 12L, TDZ marking

The airport has a secondary runway 12R-30L measuring 1,000 m long and 30 m wide, solely used for general aviation.

No limitation is imposed at Montpellier with respect to the use of thrust reversers for landing at night.

[34] Published magnetic orientation on the date of the accident.

1.10.2 Approach procedures for runway 12L

The available approach procedures for runway 12L are RNAV or VOR non-precision approach procedures.

The crew carried out the approach from the Initial Approach Fix (IAF), LEKLA.

The final descent for the VOR Z 12L approach, followed by the crew of EC-NLS, was carried out on a descent angle of 3.66°[35] (6.4%) and on a path oriented 120°, offset by 3° to the extended runway axis. This approach complies with the conditions of a CDFA.

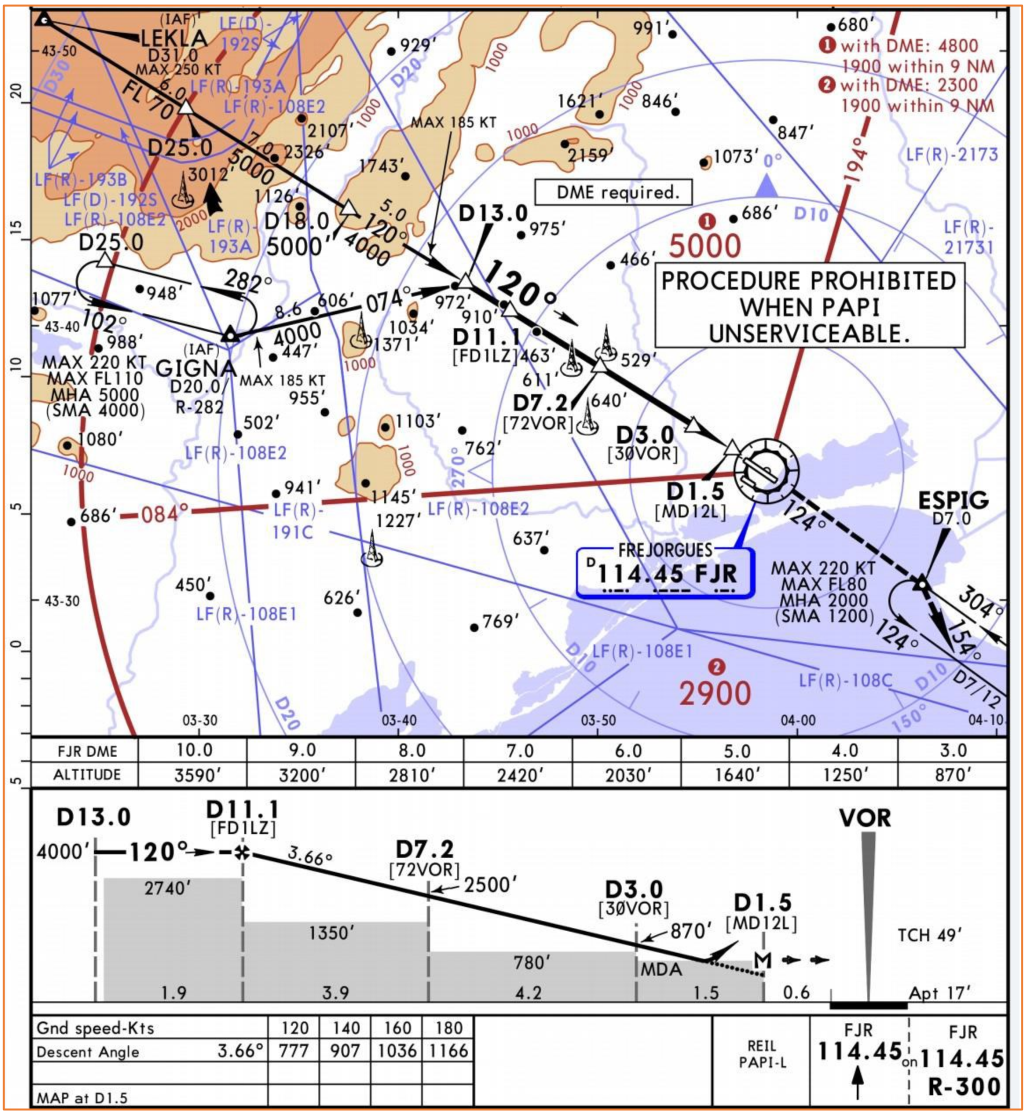

Figure 15: excerpt from VOR Z 12L approach chart used by the crew (Source: Jeppesen)

[35] The descent angle published in the AIP is 3.7° while the value of 3.66° is shown on the Jeppesen chart used by the crew. The value of 3.66° is used in the report.

1.10.3 Lights

The runway 12L lights are composed of a PAPI[36], runway end lights (threshold and end of runway) and runway edge lights. The runway edge lights are white and then yellow over the last 600 m of the runway.

As part of the authority's oversight of the conformity of airport operations, an audit was carried out from 12 to 15 September 2022. A problem with the colourimetry of the yellow runway edge lights was noted: the ageing of the colour filters, which had turned orange, meant that it was not possible to clearly distinguish between the yellow and red lights[37].

The setting angles of the PAPI lights were checked and considered as correct during this audit.

Runway 12L was not equipped with axis lights nor with wheel touchdown lights.

With regard to the touchdown zone lights, the aim of which is to provide pilots with better situational awareness in all visibility conditions and to help them decide whether to initiate a go-around if the aircraft has not landed by a certain point on the runway, certification specifications CS ADR-DSN.M.696 sets out that, *"Except where touchdown zone lights are provided in accordance with CS ADR-DSN.M.695, at a runway where the approach angle is greater than 3.5 degrees and/or the Landing Distance Available combined with other factors increases the risk of an overrun, simple touchdown zone lights should be provided."*

Prior to the accident, when converting French standards to European certification specifications, the local oversight authority's understanding of this certification specification, in particular the "and/or", was such that it had considered that this lighting was not mandatory in the case of runway 12L at Montpellier. A document harmonizing the interpretation of texts relating to aerodrome oversight, published in May 2024 by the competent DGAC services at national level and intended for regional services in charge of this oversight, now establishes, without any possibility of interpretation bias, that this equipment should be installed on runway 12L at Montpellier.

1.10.4 Runway End Safety Area (RESA)

The purpose of a RESA is to minimise the risks to the aircraft and its occupants in the event of a runway excursion. In particular, the properties of a RESA must be such that aircraft can decelerate sufficiently. It must also be strong enough to prevent the nose gear of an aircraft from collapsing during its run through the area.

Runway 12L has a 90 m x 90 m RESA at the end of the runway, corresponding to the minimum standard required. For a runway of the category of runway 12L-30R, the standard recommended a RESA length extended to 240 m wherever possible. In the case of this runway end, the presence of the lake means that it is not possible to have a RESA larger than the minimum standard.

Observations made on site and on the aeroplane led to the conclusion that the nose gear collapsed when the aeroplane exited the RESA and entered the lake. It therefore appeared that

[36] Angle 3.7°, MEHT 69 ft (Minimum Eye Height at Threshold, lowest height at which the pilot will perceive the "on slope" indication on flying over the threshold).

[37] According to the captain's statement (see section 1.5.1.1.2), this colourimetry problem had no influence on the perception of the runway end zone.

the RESA had complied with its strength objective, but that its deceleration objective was insufficiently met given the circumstances of the runway overrun and its limited length.

1.10.5 Runway condition report

1.10.5.1 Definitions

The Runway Condition Report (RCR) is a standardized report on runway surface condition and its effect on aeroplane take-off and landing performance. This runway condition report includes a code for each runway third, which describes the effect of runway surface condition on aeroplane deceleration performance and lateral control.

The runway condition code (RWYCC) is a number corresponding to the condition of a third of a runway. Condition code 6 corresponds to a dry portion of runway, code 5 to a wet portion of runway with a water depth of less than 3 mm (or other cases not described in this report) and good braking effectiveness, code 2 to a wet portion of runway with a water depth of more than 3 mm (or other cases not described in this report) and average to poor braking effectiveness.

1.10.5.2 Procedures

The procedures for publishing the runway condition report were put in place at the airport when the GRF was implemented, in compliance with the established standards. They were the subject of a protocol between the aerodrome operator, who is responsible for drawing up the RCR via the RFFS, and the air traffic services.

The information in the RCR was deemed valid until amended by the operator. The operator was instructed to regularly follow-up the RCR: An RCR shall be written when runway contamination appears or changes or when the RWYCC changes. A significant change in the coverage or depth of the contaminant along with the arrival of new relevant information are also criteria for writing a new RCR. To do this, they must monitor for new AIREPs, analyse the meteorological phenomena reported and/or forecast in order to anticipate potential changes in the contamination, initiate, if necessary, a new inspection or decide on the carrying out of friction measurements in order to monitor the contamination.

If the air traffic services observed a significant modification in the surface condition not taken into account by the operator or a clear error in the RCR transmitted, or generally, an inconsistency between the RCR data and the runway condition, they had to report it to the operator and ask for confirmation of the current RCR or for a new runway inspection. These inspections had to be carried out as quickly as possible and were considered a priority for the safety of landing aircraft.

If the RCR was temporarily unavailable, this situation had to be reported on the frequency or in the ATIS. In the scope of flight information and with a view to providing all useful information to permit flights to be carried out safely and effectively, the ATC can communicate to the crew:

- their own immediate observations when the visibility conditions and configuration of the aerodrome permit it;
- pilot reports;
- any crew reports on braking effectiveness (AIREP);
- the obsolescence of the current RCR.

1.10.5.3 Associated phraseology

The General Air Traffic Phraseology Manual[38] stated, in accordance with ICAO Doc 4444, that the temporary non-availability of the RCR must be communicated on the frequency or in the ATIS messages. It specified in the information in plain language section, the following standard messages:

Standard message in French	Standard message in English
[(lieu)] ÉTAT DE SURFACE PISTE (numéro) NON ACTUALISÉ	[(location)] RUNWAY SURFACE CONDITION RUNWAY (number) NOT CURRENT

And should the information be based on a tower observation or pilot report:

LA TOUR OBSERVE (renseignements météorologiques)	TOWER OBSERVES (weather information)
UN PILOTE SIGNALE (renseignements météorologiques)	PILOT REPORTS (weather information)

1.10.5.4 Transmission of information night of accident

The RFFS agents in charge of runway inspections indicated that when the rain started and they were getting ready to carry out a runway inspection, they received a call from the control tower about the change in runway conditions and the weather conditions forecast for the night. This call was made at 19:32. Due to a misunderstanding, the RFFS agent in charge of the team, cancelled the runway inspection which was about to be carried out, judging that the code had been updated by the ATC agent on the ATIS and that this code was consistent with the current rainy conditions.

Following this telephone conversation, the RWYCC for runway 12L was changed from 666 to 555 by the ATC services in the absence of a runway inspection and included in the Romeo ATIS message recorded at 19:35.

The air traffic controller recorded an AIREP at 20:15 in connection with the information received from the crew of an Airbus A320 which had landed and reported large puddles at the TDZ of runway 12L. At the same time, the controller changed the RWYCC for runway 12L to 255 in the Sierra ATIS message recorded at 20:15.

At 20:22, the Tango ATIS message was recorded with RWYCC 555 and runway 30R in use.

At 23:54, the Uniform ATIS message was recorded with RWYCC 555, runway 12L in use and a heavy rain advisory.

These runway condition codes were modified by the ATC services principally based on the conditions observed from the control tower, no runway assessment having been carried out.

[38] 10th edition dated 15 April 2023, accessible on https://www.ecologie.gouv.fr/sites/default/files/Manuel_Phras%C3%A9ologie.pdf.

The study of the exchanges between the controller and the crew found that, in the absence of updated information based on a runway inspection, the controller tried to inform the crew of the evolving situation in the spirit of the procedures but without using the expressions mentioned in paragraph 03.

Time	Controller's message to crew
00:04	*[…] the weather storm above the field ten minutes ago but now it's quiet quieter so the the weather is quite changing very fast.*
00:21	*For information as well euh runway condition code is five five five but preceding traffic reported some standing water erh around touch down one two left so it's might be something like two five five.*

A runway inspection takes around 15 min. According to the statements made by the RFFS agents at Montpellier - Méditerranée airport who carried out the runway inspections and measured the depth of the water on the runway, the water evacuation properties of the runway mean that five minutes after a heavy storm, the depth of water on the runway is already less than 3 mm, which corresponds to a code 5 (wet runway) for the zone[39].

1.10.6 Rescue and Fire Fighting Service (RFFS)

The specified response level between 22:00 and 05:00 was level 5[40]. This corresponded to a response capability of one vehicle. This response level was compatible with the mail transport operation carried out by Swiftair using a Boeing 737.

As per the rules of the airport operator[41], two people were on duty to ensure the response capability and handle the vehicle.

The airport operator indicated that the RFFS had the following nautical rescue resources:

- 8 platforms for 30 people (6 operational, 2 standby);
- 2 aluminium barges.

Between 22:00 and 05:00, the response level meant that there were no human resources to deploy these nautical rescue resources.

1.10.7 Windshear warning system

Montpellier airport was not equipped with a windshear warning system (see paragraph 1.17.2).

[39] This information was not checked by the BEA, but the BEA is aware of similar observations given in feedback from operational agents involved in the application of GRF procedures on other airports. This is the case, for example, for airports in the Caribbean arc during the passage of squalls, which are frequent in this region at certain times of the year.

[40] Outside of this window, the RFFS level is one level higher.

[41] The regulations define the response capability only in terms of the number of response vehicles and their technical characteristics. The number of firefighters required is not set by the regulation, but is the result of an analysis by the operator.

1.11 Flight recorders

1.11.1 Flight data recorder

EC-NLS was equipped with a Honeywell flight data recorder, model 4700 (part number: 980-4700-003) with a regulatory recording time of at least 25 h.

A total of 53 h 47 min of flight data was recorded. Three hundred and forty five parameters were recorded.

The BEA and Boeing recalculated the wind encountered by the aeroplane based on the recorded data. The wind values used in this report are those obtained from this calculation.

1.11.2 Voice data recorder

EC-NLS was equipped with a L3Harris voice data recorder, model A200S (part number: S200-0012-00) with a regulatory recording time of at least 2 h.

The following tracks were recorded:

- track 1: radio communications and microphone signal of the pilot in the left seat of a duration of 33 min;
- track 2: radio communications and microphone signal of the pilot in the right seat of a duration of 33 min;
- track 3: radio communications and microphone signal of a person sat in the cockpit jump seat of a duration of 33 min;
- track 4: cockpit area microphone of a duration of 33 min;
- track 5: mix of signals from tracks 1 to 3 of a duration of 2 h 6 min and 18 s;
- track 6: cockpit area microphone of a duration of 2 h 6 min and 18 s.

Both recorders contained the information relating to the accident flight.

The CVR-FDR were synchronised using the parameters of the radio-communication activation button and the time stamped data from air traffic control.

1.11.3 Read-out of EGPWS

The EGPWS, located in the avionics hold, was submerged when the nose of the aeroplane was in the lake. In order to extract the content of the internal memory of the EGPWS, the memory component was unsoldered and read by the BEA laboratory. The binary content of the memory was then sent to Honeywell for decoding and analysis.

The EGPWS records the take-off information (flight through 25 ft AGL) and the landing information (flight through 50 ft AGL).

In the case of the landing of the accident flight, flight through 50 ft AGL was recorded at a GNSS position situated nearly 310 m[42] after the threshold of runway 12L.

[42] This position is a GNSS position generated and recorded by the EGPWS for which the uncertainty is recorded and estimated at 8 m.

A windshear caution situation was internally detected by the EGPWS. This situation did not produce a caution in the cockpit because this functionality was not installed on the 737 (see paragraph 1.6.4.2.1). It was recorded by the EGPWS when the aeroplane was at 65 ft AGL[43], shortly before the detection of the landing situation. The aeroplane was nearly 225 m after the threshold of runway 12L. This windshear situation corresponded to the true speed of the aeroplane increasing by 16 kt in three seconds without a corresponding acceleration. This type of caution is typical of the front of a microburst. This detection was consistent with the meteorological information and the evolution of the recorded FDR parameters.

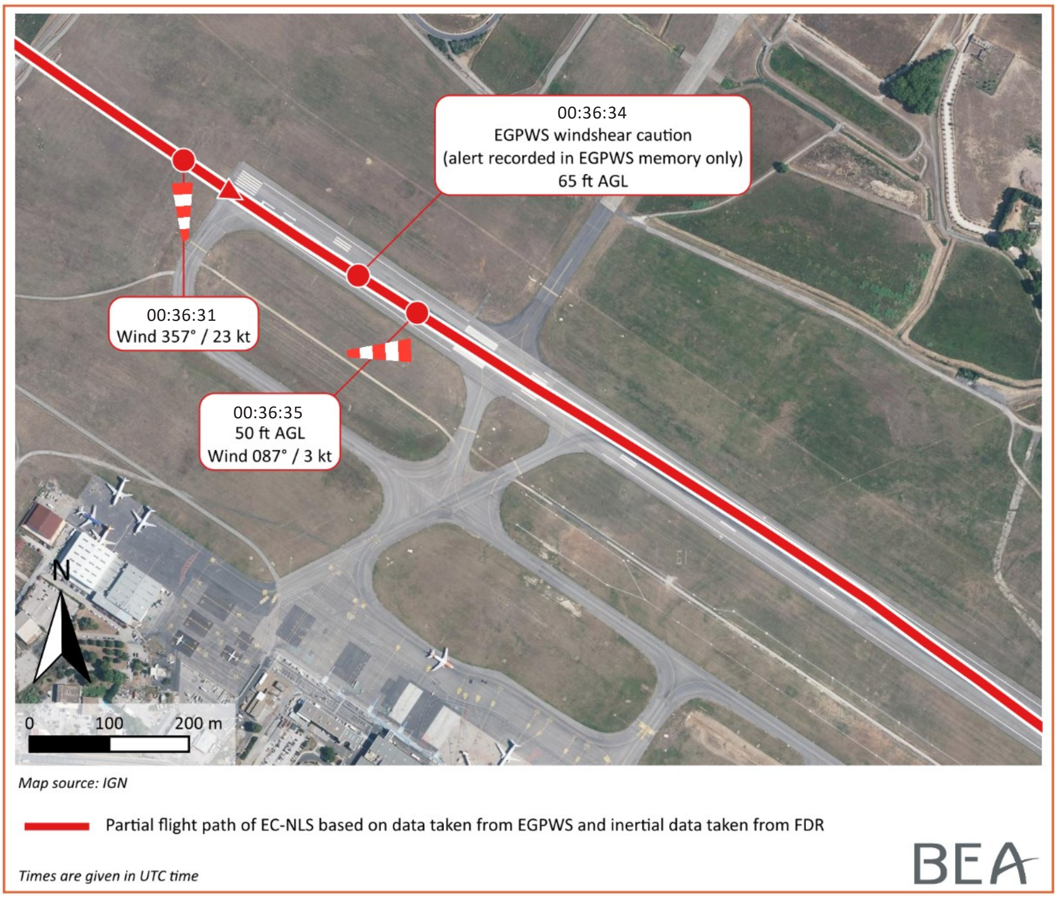

Figure 16: occurrence recorded by the EGPWS

No alert was recorded by the EGPWS memory when the aeroplane encountered an increase in the tailwind component from 12 kt to 20 kt when it descended between 250 and 210 ft.

The data recorded by the EGPWS also made it possible to determine that the display of the weather radar information was active on the co-pilot's EHSI. The examination of the display scales used during the approach, which are recorded in the FDR, found that the scales chosen meant that the area where the storm cell was situated to the south-west of the airport was covered (see paragraph 1.7.4).

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[43] This caution corresponded to the evolution in parameters in the three seconds which preceded it, when the aeroplane was between 200 and 100 ft.

1.12 Wreckage and impact information

The main damage was in the area of the nose landing gear and the engines.

The nose landing gear retracted from the front to the rear and embedded itself in the fuselage structure aft of the landing gear well, level with the avionics bay area. The examination of the marks on the ground made it possible to conclude that this damage occurred when the nose of the aeroplane tipped forward on the slope between the end of the grassy area and the surface of the lake.

There was damage to the external parts of both power plants at the air intakes and lower cowlings. This damage was the result of the engine cowlings rubbing and pressing against the grassy surface of the slope near the lake. Internal damage was also found to the coating on the inside of the fan air intake duct, the fan and the stator. This damage was very probably the result of foreign bodies entering the air intake duct of the RH engine and/or the interaction between the blades and abradable materials following the deformation of the LH engine.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

The airport RFFS were alerted immediately after the accident using a dedicated alert button located at the air traffic controller station. An input on this button triggers a siren on the RFFS premises. The first contact between the controller and the RFFS was made by radio around 2 min after the runway excursion.

The night of the accident, there were two RFFS agents on duty in accordance with the level 5 in force (see paragraph 1.10.5.4). Two other agents were present on the RFFS premises for personal reasons but were not on duty. These two latter agents responded to the activation of the alert and helped their colleagues on duty during the operations by using a second response vehicle.

The RFFS agents indicated that this additional support had facilitated the simultaneous implementation of coordination actions (coordination between RFFS agents on site, activation of external emergency resources, coordination with the tower), along with securing the site by positioning and having on standby, one of the fire-fighting vehicles with its operator, and assisting the crew.

The CODIS was informed at 00:39. External rescue and fire-fighting resources were immediately activated.

The RFFS personnel who intervened after the accident tried to evacuate the crew members through the rear doors and the doors over the wings. They found that these doors were blocked by the cargo on board the aeroplane. The RFFS personnel were not aware of this particularity, which is specific to the operation of aeroplanes transporting freight or mail. The only doors accessible from inside the aeroplane were the two forward doors.

Having succeeded in communicating with the crew and having established that the crew did not require immediate assistance, and in the absence of any apparent danger requiring immediate evacuation, the RFFS personnel decided to wait for the nautical rescue resources to proceed with the evacuation of the crew while keeping watch in case the situation evolved.
The nautical rescue resources were activated at 00:50.

The external resources encountered difficulties in accessing the airside zone of the airport, access to which is regulated and normally only accessible to people with an access badge.

The first nautical rescue resources arrived on site at 01:33.

The crew were evacuated through the aeroplane's forward RH door using one of the boats provided by the RFFS. Due to the relative urgency after the accident, in the absence of any fire, and the limited height of the door sill in relation to the water level, the emergency escape slide was not used.

Figure 17: emergency exit after the accident (Source: BEA)

According to a bathymetric survey of the lake carried out in 2005[44], the average depth of the lake was 1.1 m, with maximum values of around 1.4 m opposite the runway and at a distance from the bank.

When the CODIS agents walked around the nose of the aeroplane to carry out checks, they observed that they sunk into the mud but that the water never exceeded their pelvis.

1.16 Tests and research

1.16.1 Determining aeroplane's flight path

The FMS positions recorded in the FDR were not usable due to a bias in the values recorded at the time of landing.

[44] Source Syndicat Mixte du Bassin de l'Or

The flight paths described in this report were determined based on both the positions recorded by the EGPWS around the caution alert recorded by this system, and either side of the positions recorded by the EGPWS, based on a calculation using the ground speed and heading parameters recorded by the FDR. The portion of the EGPWS data recording was also used to validate the second method.

1.16.2 Measurements of runway friction

Measurements were carried out on the runway after the accident to assess the macrotexture properties of the runway. The macrotexture is the main factor that determines the drainage capacity of the tyre-ground interface at high speeds and therefore the risk of hydroplaning.

These measurements were carried out by an approved company appointed by the airport operator to remove rubber residue from the runway. This operation to remove the rubber residue had been scheduled before the accident and corresponded to regular maintenance, programmed according to the rate of use of the runway.

The measurement report was examined by the STAC (civil aviation technical department) which has expertise in the field at national level, to check the methods and tools used by the company.

The measurements were considered valid by the STAC and showed that the overall runway friction level was correct and of a nature to allow good aircraft braking. The rubber residue on the runway at threshold 30R, the preferred threshold, appeared to be limited in volume and its impact on the macrotexture would not have significantly reduced the runway’s drainage capacity.

1.16.3 Assessment of runway conditions

A study was carried out by the STAC to estimate the depth of water on the runway when the aeroplane landed, based on available rainfall measurements, the geometric characteristics of the runway and several scenarios of profile average depth values, based on texture depth data measured at various points on the runway after the accident. This study concluded that:

- at the start of the second episode of rain, two minutes before landing, the average depth of water on the runway would have been between 0.5 and 1 mm;
- at the time of landing, the depth of water had necessarily increased as a result of the cumulative rainfall during those two minutes, but the models used provided water depth values of less than 1.5 mm up to 4 m from the runway axis and less than 2 mm between 7 and 10 m from the runway axis.

The STAC warned, however, that the models used to carry out these assessments have not been compared, calibrated and/or validated using experimental data and/or data from in-situ tests and that, although the results obtained do not appear to be abnormal, it is difficult to say whether the model is accurate and sufficiently precise (non-quantification of uncertainties).

1.16.4 Hydroplaning

Boeing carried out a study of the braking coefficient on the basis of the data recorded by the FDR. This study was valid only for the portion of the landing run over the last 180 m of the runway, when braking was applied symmetrically. Over this portion, the calculations showed that the aeroplane was able to maintain an average braking coefficient of around 0.4, which corresponds to braking action values equivalent to dry runway conditions.

The pressure of the main gear tyres recorded during the daily check, measured and noted on the check report on the day of the accident, was 200 psi. For this pressure, the theoretical hydroplaning speed is deemed to be between 85 and 128 kt[45]. The aircraft touched down on the runway at a speed of 150 kt and crossed the threshold of runway 30R at a speed of around 70 kt.

The examination of the run marks on the runway found areas whitened by the passage of the EC-NLS main landing gear tyres (a phenomenon known as "vapour cleaning"). These marks may correspond to hydroplaning. However, the examination of the aeroplane's tyres did not reveal any characteristic tread rubber reversion marks that would have confirmed with certainty that the aeroplane had hydroplaned.

Figure 18: marks similar to a case of vapor cleaning (Source: BEA)

1.17 Organisational and management information

1.17.1 Swiftair information

1.17.1.1 General

The operator, Swiftair, carried out international passenger and freight transport operations with ATR42s and 72s, Boeing 737s and 757s and Embraer Emb-120s. Passenger transport operations were carried out exclusively with the ATR72.

Swiftair's Boeing 737 fleet was made up of twelve “classic” 737-CLs (-300 and -400)[46] and five new generation “737-NGs” (-800), all in cargo version.

Cargo transport operations, mainly composed of mail, were mostly carried out at night.

Note: The livery of EC-NLS was that of West Atlantic. In 2020, the aeroplane had been transferred from West Atlantic UK to Swiftair, both companies belonging to the same group. The flight was operated under the West Atlantic Sweden flight number (call sign Air Sweden) as part of a contract between the two operators.

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[45] These values are based on a range of experimental values as indicated in document NLR-TP-2001-242 "Hydroplaning of modern aircraft tires".

[46] Referred to as 737-CL in this report.

1.17.1.2 Crew training

The crew training programmes and the material used were reviewed in the scope of the investigation. Generally speaking, these programmes complied with requirements and addressed the topics highlighted in this investigation:

- CRM;
- GRF, evaluation of landing distances;
- stabilization principles;
- identification, avoidance and recovery from windshear;
- familiarisation with the differences between the aeroplanes in the fleet.

The following points were observed:

- the specific nature of the weather radar installed on EC-NLS was identified, but there was no information on its use;
- crews were reminded of the absence of the predictive detection functionality on Swiftair's 737-CL fleet during annual ground training sessions, particularly in the course on adverse and potentially dangerous weather conditions. The reactive detection functionality was not mentioned during this course;
- the absence of any warning about the possible limitations of the GRF. In particular, the training materials did not include cases of the temporary unavailability of the RCR and made no mention of the associated phraseology.

Swiftair's crew training program includes go-around exercises at various stages of the approach, including "rejected landing between decision altitude and touchdown or after touchdown" exercises[47].

1.17.1.3 Risk management, FDM

Swiftair had set up an operational Safety Management System (SMS). One of the tools implemented as part of this SMS was FDM (Flight Data Monitoring), based on available recorded data.

Swiftair provided the BEA with information regarding the results of the FDM. For the 737 fleet, the data recovery rate was almost 91%[48].

The examination of the statistics over the previous 12 months (September 2021 to August 2022) showed that on average 2.4% of the approaches were not stabilized, for 11,091 flights analysed[49]. No particular trend stood out in relation to operations at Montpellier airport.

The detection of long landings had recently been implemented as part of the FDM, in July 2022, and was in the process of being finalized.

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[47] The BEA did not check how these programmes are carried out in practice nor if balked landing after touchdown exercises were effectively carried out.

[48] Eighty percent is considered a minimum value for FDM to be effective according to the EASA EOFDM forum (https://www.easa.europa.eu/en/downloads/134273/en).

[49] As part of the investigation into the incident to the A318 registered F-GUGM on 12 September 2020 at Paris-Orly, the BEA had obtained information from 42 operators showing that around 4% of the approaches were not stabilized. This percentage is not based on the analysis of the flight data but on LOSA type reports.

Windshear detection was not implemented - this detection can be based on corresponding warning parameters when aircraft are equipped with windshear detection systems, or on the evolution of certain parameters (longitudinal wind component, vertical speed). The number of windshear events reported by the 737 fleet crews was one per year over the last four years.

1.17.2 Provision of weather information

Implementing Regulation (EU) 2017/373[50] defined three requirement levels for aerodrome meteorological offices that relate to windshear phenomena at aerodromes (MET.OR.235). In particular, an aerodrome meteorological office must:

- provide aerodrome warnings concerning the presence of windshear when this presence is known;
- prepare windshear warnings for aerodromes where windshear is considered a factor to be taken into account, in accordance with local arrangements with the appropriate ATS unit and the operators concerned;
- issue, at aerodromes where windshear is detected by automated, ground-based windshear detection or remote sensing equipment, windshear cautions generated by these systems.

The first requirement may be based on information provided by pilots. The next two requirements apply only to aerodromes where windshear is considered a "factor to be taken into account".

Météo-France carried out a study to determine the list of aerodromes that would be concerned by this criterion. In the absence of an objective definition of this criterion in the regulations, Météo-France based its study on:

- events contained in the ECCAIRS database where windshear appeared to be a contributing factor;
- for aerodromes with several wind sensors, a 12-month historical study of cases of non-convective windshear, based on a comparison of the wind vectors on these sensors;
- for aerodromes with a single wind sensor, in addition to the number of occurrences in the ECCAIRS database, feedback from air traffic controllers and local forecasters;
- a complementary study, for convective windshear, based on the statistics of the word Cb appearing in the METARs over two years.

The results were weighted according to passenger traffic in order to formalise a level of risk.

Montpellier - Méditerranée airport did not appear, according to the criteria of this study, as an airport where windshear presents such a risk that additional measures had to be put in place as per requirement MET.OR.235.

Note: Aware of the limitations of the study, Météo-France indicated that it was open to amending the list of airports drawn up at the end of this study. To this end, the results of the study were widely circulated to users and Météo-France indicated that it would study any new proposals to amend the list. Since the initial study, additional studies have been carried out for two aerodromes, and one aerodrome has been added to the initial list of aerodromes affected by the additional requirements.

[50] Commission Implementing Regulation of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight.

1.18 Additional information

1.18.1 Assessment of fatigue

The crew made no mention of fatigue during interviews after the accident.

The positioning, rest and duty times were in compliance with the operator's rules, which were themselves in compliance with the rules laid down by amended Regulation (EU) No 965/2012, known as "AIR OPS"[51].

The approach was carried out in the main hypovigilance circadian trough (02:00 to 06:00 am local time).

Due to the co-pilot's early morning positioning flight in the night preceding the night of the accident, he may have suffered from a sleep debt.

As both crew members had resumed flying after a week without a flight, this could have had an impact on their sleep patterns, in the absence of a re-acclimatization to the nocturnal flight schedules typical of mail transport operations.

Only one yawn was perceived on the CVR, at 00:19, without it being possible to determine whether it was the captain or the co-pilot.

These elements indicate a possible state of slight fatigue on the part of the crew at the time of the approach, in particular the co-pilot, without his being aware of it.

1.19 Useful or effective investigation techniques

Not applicable.

[51] Commission Regulation of 5 October 2012 laying down technical requirements and administrative procedures related to air operations (Version in force the day of the accident).

2. ANALYSIS

2.1 Introduction

In the night of 23 to 24 September 2022, the crew of the Boeing 737-400 registered EC-NLS, operated by Swiftair, was carrying out a mail commercial transport flight between Paris-Charles de Gaulle and Montpellier - Méditerranée. The captain, in the left seat, was the PM, and the co-pilot, in the right seat, was the PF. An aircraft maintenance mechanic was also on board this flight, sat in the cargo area.

After having prepared and carried out the briefing for an approach to runway 30R, the crew were informed that the runway in use had been changed. They prepared the VOR-DME approach for runway 12L but did not carry out a formal briefing for this.

A storm cell was approaching the destination airport from the south. At the time of the approach, the crew's awareness of the presence of this weather hazard was low despite available information.

On short final, the captain and co-pilot agreed to change roles. The co-pilot, now the PM, did not carry out his monitoring tasks.

When flying over the threshold, the aeroplane encountered windshear. The crew did not detect this phenomenon and did not perceive its impact on the flight parameters. In particular, they did not observe that the aeroplane had exceeded the touchdown zone without coming into contact with the ground.

The remaining distance on touchdown was very probably not sufficient for the crew to stop the aeroplane within the runway limits.

The aeroplane overran the runway and finished its run in the lake located at the end of the runway.

The analysis of the occurrence covers the following points:

- situational awareness of the weather;
- insufficient preparation of the new approach and the consequences of this for carrying out the approach;
- taking into account stabilization criteria;
- swapping PM/PF roles on short final;
- no detection of windshear;
- no perception of long landing;
- the condition of the runway at the time of landing and the awareness the various actors of the GRF had of this.

2.2 Situational awareness of the weather

2.2.1 Taking into account weather information

The examination of the meteorological information provided to the crew found that they had at their disposal the elements for them to be aware of the threat posed by the presence of cumulonimbus (Cb) at the time of the approach.

When preparing the flight, the TAF, SIGWX and SIGMET mentioned the presence of Cb.

During the flight, when the crew contacted Montpellier air traffic control to obtain updated information about the airport, the controller informed them of the presence of Cb and that conditions were evolving rapidly.

However, when the PM noted this information as he received it, he did not note the presence of Cb. He did not report the Cb to the PF[52].

At the end of this exchange, the controller also indicated that visibility was improving, that a thunderstorm had passed over the airport ten minutes earlier and that the situation was now calmer. It is possible that the crew unconsciously favoured the information concerning an improvement, which was provided at the end of the message, despite the additional information that conditions were evolving rapidly.

Lastly, after obtaining the information from the controller, the crew's attention seemed to be principally focused on the runway change: the discussions in the cockpit, following the information obtained about the airport, apart from the mention of visibility, focused on the runway change and the reprogramming of the FMS.

These elements tend to show how, despite the information available, the crew seemed to have unconsciously taken insufficient account of this information which could have prepared them for the weather conditions they were going to encounter during the approach. As indicated in the Operations Manual (OM) or Pilot Reference Manual (PRM) (see paragraph 1.6.6.12), situational awareness and threat awareness, combined with the advance identification of a situation conducive to windshear, are of great importance in order for a crew to detect a windshear situation.

2.2.2 Use of radar

Subsequently, it is probable that the radar settings did not allow the crew to detect the presence of the storm cell in the vicinity of the aerodrome at the time of the approach. Unless there was a hypothetical radar malfunction, it should have been possible to detect a storm cell as laden with water as the one approaching the airport, as shown by the precipitation data for the airport and the radar images from Météo-France.

[52] It was not possible to determine whether the PF was listening to the communication with Montpellier at the time this exchange occurred. The exchanges recorded on the CVR showed that he was monitoring the active frequency, with the en route control at Bordeaux, but this does not systematically prevent simultaneous monitoring of the second frequency.

It seems possible to rule out the hypothesis that the radar was malfunctioning based on both the discussion about its settings that took place just before the descent, and on some exchanges during the descent that were heard on the CVR recording.

The hypothesis that the storm cell that was close to the aerodrome was hidden (masking effect) at the time of the landing can also be ruled out. The shadowing effect is when the storm cell is being concealed by another water-laden mass in the foreground. However, in their statements, the crew indicated that they did not perceive any particular echo on the radar image.

The discussion about the radar settings, which took place after completing the before descent checklist, may be an illustration of an insufficient command of the techniques for using and interpreting the tool.

The absence of a description of the radar control unit in the operational documentation that the operator provided to crews may have contributed to an insufficient knowledge of the specificities of the tool's settings.

According to their statements regarding the radar settings, each crew member knew that the radar tilt setting had to be adapted during the approach and that the tilt had to be set at around 1° for the final approach. After the accident, the settings on the radar unit were not consistent with these values.

It was not possible to confirm the radar settings chosen by the crew during the approach: no exchange on this subject could be heard on the CVR recording covering the end of the approach and no parameter relating to these settings was recorded in the FDR. Given the settings found on the unit, it was likely that the crew forgot to set the radar during the approach because of the workload.

It was also likely that the IDNT mode for reducing ground-related information had been activated, either through omission or ignorance of the system. The purpose of the IDNT mode is to activate the reduction in ground information function; this is not designed for continuous use, as some parts of the weather targets may have their intensity reduced in this mode, or even suppressed.

Furthermore, the operational documentation provided little information on the settings to be adopted during the flight.

More generally, the inadequate training in the use of the weather radar has been pointed out by the industry on several occasions. EASA cited this point in its Weather Information to Pilots Strategy Paper. The agency proposed that operators provide formal initial and recurrent training on weather radars and ensure that the aircraft Operations Manual provides a clear description of the recommended techniques for using the weather radar.

The crew's use of the weather radar meant that they were not aware of the presence of a large squall in the immediate vicinity of the airport.

2.3 Preparing the approach

2.3.1 Runway change, specificities of new approach

Preparation for the approach and a relatively complete briefing were initially carried out for the ILS approach to runway 30R. When the crew were informed of the runway change, the PF prepared the new approach with greater time pressure.

Although the PF remembered carrying out the briefing for the new approach, the CVR recording showed that he actually reprogrammed the FMS, calling out the changes aloud and informally checking the new flight path. During this preparation, the crew discussed the choice of descent mode for the final approach, but no clear decision was taken. Similarly, the specificities of the approach were not discussed, whether it be the 3.66° approach slope and the consequences of this slope on the vertical speed during the final approach, the offset final approach path or the lights.

As this was a non-precision approach, mentioning in the new briefing, the rate of descent and the criteria for deciding on a missed approach might have enabled the crew to:

- start the final approach with a relatively precise idea of the vertical speed required to follow the descent slope and to modulate the vertical speed of the aeroplane around this reference vertical speed according to the wind conditions and any deviations detected during the final approach;
- anticipate that the stabilization criterion of 1,000 ft/min needed to be revised, since following the approach slope required a rate of descent close to this criterion.

Thus, during the final descent, when the PM asked the PF to increase the rate of descent to return to the slope, the PF responded by appearing to question the use of a vertical speed of 1,000 ft/min. This could illustrate that part of his cognitive resources during the final approach, a particularly busy flight phase in the case of a non-precision approach with altitude-distance checks, were used to resolve a question that should have been addressed and resolved during the briefing.

These elements tend to show how the absence of a briefing had the effect of increasing the workload on short final.

2.3.2 Threat and Error Management (TEM)

The principle of TEM is built into the CRM course for Swiftair crews, in accordance with the training content required by EASA.

At the time of the accident, Swiftair had not incorporated any specific operational recommendations regarding the application of TEM principles. There is no regulatory obligation to do so.

Through various investigations, the BEA has emphasised that the absence or incomplete implementation of the TEM approach could be a contributing factor in an incident or accident.

In the document *Info Sécurité* No 2020/01[53] published by the DGAC, the aim of which is to promote best practices in the use of the TEM method, the DGAC recommended that aircraft operators:

- determine the conditions for triggering a TEM discussion between crew members, in order to update the identification of threats, errors and associated measures throughout the flight; it must be taken into account at the start of the analysis to set the context during briefings or during specific events;
- structure these TEM discussions, in order to guarantee the identification of relevant measures;
- describe the TEM approach adopted in their Operations Manual;
- include the TEM approach in crew training and instructor standardisation;
- ensure during training and checks that this approach is correctly applied during all flight phases;
- incorporate the principles of TEM into the company's safety communications.

In the case of the accident to EC-NLS, the examination of the facts shows that several threats could have been taken into account by the crew on the basis of the information available to them, in order to develop strategies to manage them:

- presence of Cb in the vicinity of the airport:
    - risk of windshear associated with this presence,
    - threats linked to the landing distance given possible changes in actual conditions at the time of landing;
- specific features of the approach (approach slope of 3.66°, limited lighting on the 12L threshold);
- threats linked to the increased workload due to the type of approach carried out and the methods chosen to conduct this approach;
- threats linked to the fact that the co-pilot had little experience of the aeroplane and this type of approach.

2.4 Carrying out approach

2.4.1 Workload

Carrying out a non-precision approach with monitoring of the approach slope based on altitude-distance checks creates a high workload[54].

This workload may have been increased due to the absence of a formal briefing and the specificities of the approach not being taken into account (see paragraph 2.3). The choice to carry out the final approach with the V/S mode instead of the VNAV mode may have also contributed to an increased workload, especially as the rate of descent adapted to the conditions of the approach had not been determined beforehand.

The weather conditions (wind variations during the final approach) were a factor in increasing the workload as well.

[53] (Document available in French only).
[54] ATSB study *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches*.

The co-pilot's small amount of experience (aeroplane type, aerodrome, type of approach) in the specific conditions of this approach may also have contributed to an increase in the captain's workload, expressed in the latter's statement in which he explained that his flight monitoring function during the approach had used a lot of his resources.

On the final approach, a certain number of standard callouts were omitted:

- the altitude-distance check at 4 NM was not carried out;
- the stabilization callout at 1,000 ft was not made. The stabilization altitude was passed at the same time as the visual transition and discussion of the runway identification, as well as the disconnection of the AP and the change to manual flight. At this moment, the aeroplane was nearly 200 ft above the approach slope and the PAPI was probably showing four white lights (see also paragraph 2.4.2);
- the absence of the callouts "300 ft above minimums", "approaching minimums" and "minimums";
- at 500 ft, the crew did not make a stabilization callout: this altitude was passed at the same time as the crew discussed changing PM/PF roles.

These omissions may be a further illustration of the deterioration in the crew's performance due to the high workload. The absence of these callouts also contributed to a reduction in situational awareness with regard to the stabilization criteria.

2.4.2 Difficulty in assessing stabilization criteria during the approach

The industry[55] has defined stabilization criteria by seeking to determine conditions common to all types of approach, so as to simplify their assimilation and use by crews.

The examination of the stabilization criteria defined by the operator's manuals, which are consistent with those recommended by the industry, found that taking these criteria into account can require substantial resources in a situation where the workload is already high.

In particular, in the case of this accident:

- after the visual transition, the runway axis being different from the final approach axis, the criterion of alignment within 5° of the runway axis could no longer be assessed by examining the VOR deviation;
- in the vertical profile, concerning the criterion linked to the approach slope, there was no numerical criterion linked to the altitude deviation at altitude-distance check points.

There remained, for the final part of the approach, the:

- assessment of the extent of the corrections required in attitude and roll to hold the axis and slope, which can be difficult to perceive;
- taking into account the PAPI.

As the aeroplane approached the runway, the crew's available cognitive resources decreased while some of the criteria to be taken into account to assess stabilization required greater cognitive resources.

[55] For example the work of the Flight Safety Foundation, which IATA, operators and aircraft manufacturers have included in their procedures, techniques and operational recommendations.

2.4.3 Mixed IMC/VMC stabilization criteria

Swiftair used two different stabilization limits depending on whether the conditions were VMC (500 ft) or IMC[56] (1,000 ft). In the Operations Manual, a difference was also made for a NPA approach carried out with the CDFA technique, based on visual references instead of VMC conditions.

In the latest edition of the document[57] edited by the IATA on unstable approaches, proposing risk mitigation policies, procedures and best practices, it is emphasized that the use of variable stabilization altitudes according to the type of approach (precision/non-precision) and/or the meteorological conditions (IMC/VMC) could be a cause for potential confusion.

Thus, the application of a stable approach principle that does not distinguish between VMC and IMC approaches, using the same stabilization altitude, makes it easier to track compliance using FDM, whereas different altitudes require the FDM analyst to know which type of approach was being conducted and in what conditions.

The document indicated that many airlines have implemented a single set of criteria for a stable approach and that pilot feedback has been extremely positive.

2.4.4 Swapping PF/PM roles

After swapping PF/PM roles, the lack of monitoring meant that the unstable flight path on short final was not detected.

As highlighted in the "Practical Guide for Improving Flight Path Monitoring"[58] produced by the Flight Safety Foundation (FSF), effective flight path monitoring is essential for safe operations. Flight crews should use this monitoring to help them identify, prevent and mitigate events that could have an impact on safety margins.

In the case of this accident, the co-pilot's statement showed that after the captain took the controls, he did not carry out the monitoring task that was his responsibility and his eyes remained focused on the external references on which he had been concentrating when he was PF.

This phenomenon has already been identified, as illustrated by this extract from the FAA's AC 120-123 on the subject of flight path management.

"Through analysis of accidents and incidents, situations are identified where both pilots ended up acting as the PF while monitoring was overlooked. This could happen when the PM takes over aircraft control from the PF during a critical moment, including takeoff and landing. Normally, it is easier for the PM to revert to PF than the PF to revert to PM instantly. One reason for this is that the PM may make a decision and take action to be the PF, while the PF may be startled, surprised, lost situation awareness, or trying to figure out why the PM took over, but not thinking about switching roles and being the PM."

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[56] The difference between IMC/VMC is the consequence of a regulatory definition based on visibility and distance from clouds according to the regulatory airspace class.

[57] IATA Unstable Approaches: Risk Mitigation Policies, Procedures & Best Practices, 3rd Edition

[58] A Practical Guide for Improving Flight Path Monitoring

In order to prepare crews to react appropriately to such situations, the FAA recommended that the changing of roles or the transfer of controls is specifically included in pilot training, with different scenario leading to this situation being proposed.

Furthermore, in this AC, the FAA recommended a positive three-step process for exchanging flight controls between pilots:

- “*When one pilot seeks to have the other pilot take control of the aircraft, the first pilot will say, 'You have the flight controls.’*
- *The second pilot acknowledges immediately by saying, 'I have the flight controls.’*
- *The first pilot again says, 'You have the flight controls,’ and visually confirms the exchange.”*

Swiftair's procedure was similar, except that it only used the first two steps.

These methods and the associated callouts, one of the objectives being that there was never any doubt as to who had the controls as indicated in AC 120-123, focused solely on the PF’s role. These callouts did not mention the PM’s role in the transfer of roles.

In view of the importance of the PM’s role, described in numerous studies, it also seems important to ensure that the crew member who hands over the controls then assumes the monitoring role.

An individual, in a situation where he has been strongly concentrating on his role as PF, linked to a situation of a high workload, may need a stimulus which is not limited to telling him that the other crew member is taking the aircraft's controls, but which reminds him in a positive, even active way, that he must now take on a new role, that of PM.

2.4.5 Detection of windshear

The FSF has produced information notes to help prevent accidents on approach and landing (ALAR - Approach-and-Landing Accident Reduction). Among these notes, note 5.4 provides information on the threat posed by windshear.

From the point of view of operating procedures, the FSF stressed, among other things:

- in order to be aware of the threat and to avoid it, the importance of the briefing:
    - assess the approach and landing conditions based on, for example, the most recent weather bulletins and forecasts or visual observations;
    - consider delaying the approach and landing until conditions improve, or consider diverting to a suitable airport;
    - be prepared to react immediately in the event of windshear by complying with the appropriate procedures;
- in order to detect the threat:
    - use of the weather radar to ensure that the flight path is clear of any potential danger;
    - appropriate task distribution with effective monitoring, including careful monitoring of airspeed and ground speed and their trends, and compliance with standard callouts;
    - good energy management during the approach;
    - a stable approach with compliance with stabilization gates.

In the case of the accident to EC-NLS, several of these barriers failed:

- the lack of a formal briefing following the runway change and insufficient situational awareness of the weather situation meant that the crew were not adequately prepared;
- the absence of TEM may have contributed to this partial preparation;
- the breakdown of CRM within the crew after they had swapped roles resulted in a lack of active monitoring by the PM.

2.4.6 No perception of long landing

The landing was carried out in a rain shower, with the windshield wipers in operation, on a dark night.

A study[59] shows that rain affects visibility in various ways, and that this effect is particularly increased at night: the effectiveness of the headlights is reduced and the raindrops scatter the light (backscatter effect due to the reflection of the light from the headlights on the drops, glare effect linked to this backscatter which affects the visibility of contrasts, blocking of some of the light reflected by illuminated objects), and visibility is reduced due to the presence of water on the windshield.

The mirror effect caused by the presence of water on the runway, amplified by the reflection of the headlights, can also reduce the perception of objects. These effects are affected by the strength of the rain, the speed of the aeroplane, the speed of the windshield wipers and their effectiveness.

Furthermore, at night, the perception of depth and distances are affected.

Level with the touchdown zone, the runway had runway edge lights and touchdown zone markings but did not have specific touchdown zone lights. Visually, the main reference for perceiving the long landing was reduced to the perception of the touchdown zone markings.

The aeroplane flew over the touchdown zone markings at a higher altitude than on a nominal flight path. This also had the effect of reducing the perception of these markings.

All these factors point to the difficulty of visually perceiving a long landing. The crew could have been alerted by the unusual rhythm of the callouts (synthetic voice) from the radio altimeter during the flare and by the duration of the flare.

2.5 Landing, runway excursion

The remaining runway distance at the time of touchdown was very probably insufficient to avoid the runway excursion: the aeroplane touched down 1,100 m from the opposite runway threshold, whereas the minimum LDTA could be considered to be of the order of 1,560 m, which corresponds to a theoretical landing run distance of 1,056 m[60].

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[59] Morden J. N., Caraffini F., Kypraios I., Al-Bayatti A. H., Smith R., Driving in the Rain: A Survey toward Visibility Estimation through Windshields, International Journal of Intelligent Systems, 2023, 9939174, 2023. https://doi.org/10.1155/2023/9939174.

[60] This value corresponds to the LDTA value of 1,560 m calculated with the chosen configuration, in crosswind conditions and with a runway condition 555, from which have been subtracted the 15% safety margin and 300 m for the flare to obtain a theoretical landing run distance.

2.5.1 Runway condition

A number of malfunctions were identified during the investigation concerning compliance with the procedures covering the GRF and runway condition information, by the applicable airport actors. In fact, it was the controller, based on his own assessment from the control tower, who modified the RCR on the evening of the accident. This initiative was not part of the specified procedures.

However, it seems that these malfunctions did not directly contribute to the accident: although certain elements, such as the theoretical hydroplaning speed or the "vapour cleaning" marks on the runway, tend to show that the effectiveness of the braking was probably reduced, the theoretical assessment of the depth of water on the runway carried out by the STAC (see paragraph 1.16.3) and the study of the aeroplane's braking coefficient over the last 180 m of runway carried out by Boeing (see paragraph 1.16.4) do not point to a runway contamination that could have had a significant impact on the aeroplane's braking effectiveness compared with the estimated LDTA, based on an RCR code 555.

However, the investigation's findings reflect a discrepancy between the procedures for assessing runway conditions and the reality of the practical conditions of this assessment. The duration of a runway inspection to determine the runway's RCR code, of around 15 minutes, seems ill-adapted when compared with the time required for the water to evacuate, linked to the runway's drainage properties. This may naturally lead to the actual situation on the runway differing from the situation reported in compliance with the procedures.

Similarly, the contribution made to the GRF by crew reports made after landing is limited when there is no landing immediately preceding the landing in question: in the case of the landing of EC-NLS, there was no landing in the half-hour preceding it.

Thus, despite the improvements brought about by the introduction of the GRF, a crew landing during or shortly after a thunderstorm with rain may not have a true runway condition value.

In the document "*Implementation of Global Reporting Format for Runway Surface Conditions (GRF) - Guidance based on management of change (MOC)*", ICAO identifies this threat among the tasks assigned to air navigation services and proposes the following defences:

Tasks	Hazards	Defences
Inform rapid changes in runway condition observed from TWR (unofficial information)	RCR is not issued when there is a rapid change in runway condition	• *Ensure ATCOs are trained to identify a rapid changes (e.g. weather) which could adversely affect RCR and inform airport operator* • *Develop policy and procedures for ATCOs to inform flight crew of tower observations of runway surface conditions (e.g. use of phraseology plain language remarks)* • *Use standard terminology and phraseology*

In practice, these defences are included in the procedures and phraseology (see paragraph 1.10.5).

However, it appeared that the front-line players had not yet fully assimilated and taken into account these dynamic weather situations and their impact on the GRF, and did not yet fully master the procedures associated with these particular situations.

As a reminder, the GRF came into force in August 2021 in the Member States of the European Union. This accident occurred almost a year after its implementation. As planned by ICAO in the above-mentioned document, the deficiencies identified should now be taken into account and remedied as part of the monitoring of the implementation of the GRF and the associated change management.

2.5.2 Operational factors aggravating the runway excursion

Given the remaining runway distance at the time of touchdown, the investigation did not attempt to carry out a precise and exhaustive assessment of the factors that could have affected the landing run distance.

However, the following factors may have reduced the effectiveness of the aeroplane's deceleration and aggravated the consequences of the runway excursion:

- late use of thrust reversers: the thrust reverser control levers were set to REV IDLE nearly four seconds after touchdown and then to REV MAX three seconds later. The captain suggested that this may have been due to the habit of not using the thrust reversers at full power in the scope of night operations because of the associated noise, to explain this time interval;
- as a result of this late activation of the thrust reversers, the N1 of the engines changed from High Idle to Low Idle (internal logic values corresponding respectively to flight idle on approach and ground idle). Once the lever was positioned in the REV MAX detent, the increase in power[61] was extended by about two seconds due to this power demand being initiated from a power level below the flight idle level.

2.5.3 Mitigation means

The observations made at the accident site found that the RESA had partially fulfilled its role. Although the aeroplane was not damaged when it ran through the RESA, it was not sufficiently slowed down by it.

The dimensions of the RESA met the minimum standard and cannot be increased due to its proximity to Or lake.

In view of the potential consequences of a runway overrun at threshold 30R, highlighted by this accident (major damage to the aircraft, leading to its tear down, closure of the airport for a long period, difficulties in deploying nautical rescue resources, possibility of contaminating a protected site[62]), it might be useful to carry out a study to assess the possibilities of improving the compromise between the RESA's slowing down and load-bearing properties, including the installation of an engineered materials arresting system.

[61] There are no certification specifications for the transition times from idle power to REV MAX power. There are certification specifications for the transition from flight idle power to go-around power.
[62] Or lake is a Natura 2000 protected site.

3. CONCLUSIONS

3.1 Findings

- The crew held the necessary licenses and ratings to carry out the flight.
- The co-pilot had a small amount of experience on the Boeing 737.
- The aeroplane had a valid Certificate of Airworthiness; it was equipped and maintained in accordance with the regulations in force and the approved procedures.
- The aeroplane was equipped with an EGPWS featuring the windshear warning function but not the windshear caution function, as this feature is not certified on the 737.
- The aeroplane was not equipped with a predictive windshear system.
- The co-pilot was the PF, the captain was the PM up to around 500 ft during the final approach.
- The crew carried out a briefing for the ILS approach to runway 30R.
- Following the runway in use change, the crew prepared the approach again but did not formally carry out a new briefing for the VOR Z 12L approach; no decision was taken concerning the descent mode, the approach speed and the rate of descent for the final approach.
- The landing performance was compatible with a landing on runway 12L, with the forecast wind conditions and runway condition.
- The meteorological information at the crew's disposal indicated the presence of Cb close to Montpellier airport; the crew did not sufficiently take into account this information and did not formulate a strategy for managing this threat neither in terms of its detection nor the reaction to the associated phenomena.
- The operator's procedures did not specify including the TEM in the briefing.
- A storm cell with heavy precipitation was present in the immediate vicinity of the airport at the time of landing.
- The crew did not detect the presence of this cell with the settings used for the weather radar.
- The description of the radar control panel and its associated functions were not included in the operator's documentation provided to the crew .
- The aircraft Operations Manual did not provide a clear description of the recommended techniques for using the weather radar.
- On flying through 1,000 ft AAL, the aeroplane was 200 ft above the approach slope.
- After acquiring visual references below 1,000 ft AAL, the PF disengaged the autopilot and autothrottle.
- While searching for the runway axis, the rate of descent increased; this destabilization was called out by the PM and corrected by the PF; a missed approach was not carried out.
- When the visual references are acquired during the approach, the Swiftair Operations Manual allowed the crew to continue the approach to 500 ft AAL despite a destabilization below 1,000 ft AAL.
- On short final, at around 500 ft AAL, the crew swapped PM/PF roles.
- After the roles had been swapped, the co-pilot, who had become the PM, remained focused on the external references and did not assume one of the main tasks of the PM, namely to monitor the parameters using the aeroplane's instruments.
- Due to an increase in thrust, the aeroplane's speed increased; this increase was not detected.

- When the aeroplane flew over the runway threshold, it encountered windshear, with a substantial decrease in the tailwind component which created an increase in the aeroplane's performance (airspeed and lift).
- The windshear and the consequences on the flight parameters were not detected by the crew.
- The flare was started at 100 ft at a speed of 34 kt above the Vref; the throttle levers were not set to IDLE at this point.
- Nine seconds later, the throttle levers were set to IDLE when the aeroplane was at a height of 20 ft.
- The wheels touched down at approximately 1,500 m from the threshold of runway 12L, i.e. 1,100 m from the end of the runway with a Vref + 8 kt.
- The landing took place in a dark night with heavy rain.
- Runway 12L was not equipped with lights in the touchdown zone nor on the axis.
- According to the airport certification specifications applicable to runway 12L at Montpellier – Méditerranée which has an approach angle of more than 3.5°, simple touchdown zone lights must be installed in order to provide pilots with better situational awareness in all visibility conditions and to help them decide whether they have to start a go-around if the aircraft had not landed by a certain point on the runway.
- The crew did not detect the long landing and did not carry out a balked landing.
- Boeing described these rejected or balked landing techniques in the FCTM; some of these techniques referred to the missed approach procedure described in the FCOM.
- The length available after the touchdown point was very probably not sufficient for the aeroplane to be stopped safely within the runway limits.
- The GRF procedures were not able to provide real-time values of the runway condition in highly variable meteorological conditions over short time periods.
- The personnel involved in the GRF at Montpellier airport (airport staff, air traffic controllers and pilots) did not appear to be sufficiently prepared for these marginal situations due to variable weather conditions.
- The aeroplane's high speed during the landing run phase may have contributed to hydroplaning.
- The aeroplane crossed the end of runway 12L at a speed of around 70 kt.
- The aeroplane was substantially damaged after exceeding the Runway End Safety Area (RESA), when it tipped forward and came to a stop with its nose section submerged in the lake.
- The RFFS agents were directly informed of the accident and responded with twice the means specified for the immediate response.
- The first nautical rescue resources arrived on the site about an hour after the accident.

3.2 Contributing factors

The runway overrun occurred because of a long landing at high speed, principally due to the windshear encountered by the aeroplane. A balked landing was not carried out because the crew had not detected these two conditions.

The following factors may have contributed to the crew not detecting the long landing:

- lack of monitoring by the PM;
- no lights in the touchdown zone;
- the environmental conditions (dark night, heavy rain);
- failure to consider the threats linked to the presence of a storm close to the airport.

The following factors may have contributed to the crew not detecting the high speed at the time of the flare:

- the PF focusing on holding the aeroplane's path due to the changing wind conditions at the time of the landing phase, in conditions where the external references were marginal (dark night, heavy rain, no axis lights);
- lack of monitoring by the PM.

The following factors may have contributed to the crew not detecting the windshear:

- lack of monitoring by the PM;
- failure to consider the threats linked to the presence of a storm close to the airport.

The absence of monitoring during this flight phase was very probably linked to an unanticipated role change on short final. The co-pilot, switching from PF to PM, did not take his role following the role change and seemed to have kept his attention on the external references he was using when he was PF.

The analysis of the accident found that the crew had had a high workload during the approach due to the insufficient preparation of this approach which was not formally briefed (with certain key points not being mentioned before carrying out the approach), and to the meteorological conditions not being sufficiently taken into account.

The following factors may have contributed to the low awareness of the weather conditions:

- the crew focusing on the runway change which had an immediate impact on the on-going preparation of the approach, to the detriment of an overall situational awareness based on information about wind changes and the presence of Cb close to the airport;
- the situational awareness being biased by the information that conditions were improving rather than taking into account the threat posed by the presence of Cb close to the airport;
- inappropriate use of the on-board radar due to:
  - insufficient knowledge of the radar control unit which was not described in the operator's documentation provided to the crew,
  - no detailed procedures or recommended techniques concerning the use of the radar,
  - a high workload which left the crew with little resources to adapt the radar settings during the approach.

The following factors may have contributed to the crew's weak preparation:

- no new briefing after the runway change;
- no Threat and Error Management (TEM) in the briefing.

3.3 Safety lessons

Importance of briefing

Although the crew were not under particular time pressure, apart from adhering to the itinerary, the change of runway resulted in the execution of a new approach without a formal briefing being carried out.

A briefing is an opportunity to share a plan of action, to discuss the specificities of an approach, to anticipate the threats and to prepare to deal with them. It is also a time for exchanges, which can lead to a discussion and a decision when certain aspects have not been analysed during preparation.

The accident illustrates the necessity of not starting an approach without the crew taking the time to discuss it.

Missed approach

One of the objectives of having a stable approach is to ensure that the crew have available cognitive resources to deal with unforeseen circumstances.

The detailed examination of the history of the flight and the ensuing analysis revealed, a posteriori, a certain number of signals which, taken together, could have prompted the crew to carry out a missed approach: destabilization below 1,000 ft, observed wind conditions different from those reported, heavy rain, the decision to swap PF/PM roles.

In the dynamics of the approach, with a high workload, the crew may not have perceived these signals.

On taking into account the stabilization limit of 500 ft specified by the operator in the event of visual references, the margins in relation to the destabilization criteria were small.

The crew therefore started the short final with an aeroplane with a relatively high energy level, without active monitoring. Passing through the windshear zone was then the factor that made the landing impossible. The crew probably no longer had the cognitive resources to identify this additional threat.

Swapping PF/PM roles

The signals that led the captain to propose swapping roles could probably have led him to reconsider pursuing the approach.

Even though the crew had conferred about swapping roles, it had not been anticipated by the co-pilot, and this may have created a surprise effect that prevented him from marshalling his resources to take on the monitoring task.

The standard callout when swapping PF/PM roles, in line with industry recommendations, focuses solely on the PF role. This accident highlights the fact that it did not provide a sufficient stimulus to bring the PM out of the surprise effect.

In this respect, it might be beneficial to assess whether adding the transfer of the monitoring role to the callout of the transfer of controls (for example "I have controls, you monitor") can, on the basis of a standard callout, bring a crew member surprised by the change of role, back to a sufficient level of awareness for him to assume positively the new role that is now his responsibility (performative effect of the callout).

GRF

The GRF came into force worldwide in 2021, under the impetus of ICAO. Its implementation, as with any change, is the result of a gradual appropriation by the users, through the practical application of the procedures they have been trained in, in circumstances that can sometimes be more complex than the theoretical ones seen in training. It is important to emphasise that the GRF relies on front-line players with different professions and profiles: agents responsible for assessing runway contaminant levels, air traffic controllers and pilots.

ICAO had anticipated certain risks associated with this change, such as the risk associated with meteorological situations in which runway conditions change rapidly. A monitoring phase was also planned, during which new risks would be identified through the safety management systems of stakeholders at all levels (States, operators).

The duration of a runway inspection, of the order of 15 minutes, seems unsuitable given that the water evacuation properties of the runway mean that five minutes after a heavy storm, the depth of water on the runway is already less than 3 mm.

The case of the serious incident involving the Embraer EMB145 registered F-HYOG, operated by Amelia, on 20 October 2022 at Paris - Orly also highlights the fact that the procedures did not allow the runway condition code information to be updated accurately, despite the presence of automatic measurement sensors, due to technical limitations linked to the sensors and the speed and strength of the meteorological phenomenon.

Thus, users still need to perfect their command of the GRF and more particularly its application in marginal situations, and assimilate the inherent limitations of this system in such situations. This event could be used in future training courses, whether initial or refresher, to raise awareness and better prepare GRF users in this respect.

4. SAFETY MEASURES TAKEN SINCE THE OCCURRENCE

4.1 Safety measures taken by Swiftair

In a preliminary internal report issued in November 2022, the operator reiterated the importance of carrying out a missed approach in case of an unstabilized approach.

The operator informed the BEA that it had subsequently taken the following additional measures:

- implementation of wind limitations that are more restrictive than Boeing's, with clarification of these limitations in the operator's various Operations Manuals;
- standardisation of the manuals to clarify that operations are not authorized if the RCR is less than 3;
- addition of a description of the radar control panel and associated functions, in a document to familiarise users with the differences between the Boeing 737s in the fleet, available in the EFB library documentation[63];
- assessment of models for operational application of TEM principles;
- inclusion in the training programme for the semester following the accident, of a simulator training session scenario including aspects identified by the operator in the event, such as a go-around below minima, or even after touchdown, focus on stabilization and the decision to go-around in the event of destabilization, mention of TEM principles in briefings, windshear situation, etc.;
- inclusion of CRM aspects relating to the transfer of control at low altitude into the forthcoming cycle of ground CRM courses.

The crew underwent re-training including theoretical ground courses on topics related to the event (GRF, LDTA assessment, contaminated runways, adverse weather conditions including windshear, conducting non-precision approaches, LVO and performance), as well as line re-training followed by an assessment judged positive.

4.2 Safety measures taken by airport operator

The airport operator informed the BEA that it had taken the following safety measures:

- circulation of a memo to RFFS personnel, supplementing the operational instructions, reminding them of and specifying the conditions for a GRF runway inspection;
- reminding shift supervisors of their role in monitoring the GRF;
- raising awareness among RFFS personnel of the meteorological tools available on the Météo-France portal;
- improving the process for circulating aerodrome warning messages and AIREP messages to RFFS, with the introduction of message reception alerts;
- subscription to Météo-France for a weather alert service when precipitation is greater than 0.4 mm, including a 3-h forecast. This alert is sent to the mobile phone number of the shift supervisor;
- following the DSAC non-conformity notification addressed to the operator concerning the absence of simple touchdown zone lights on runway 12l (see paragraph 1.10.3), the operator informed the BEA that it planned to install these lights the next time the runway surface was reconditioned which should be before 2030.

[63] Another aircraft in Swiftair's fleet is equipped with the same radar control panel as the EC-NLS.

4.3 Safety measures taken by air navigation services

The Montpellier – Méditerranée air navigation services informed the BEA that it had taken the following safety measures:

- a new series of briefings was given to controllers on the GRF in order to remind them of the fundamental principles and practical application procedures;
- at these briefings, a memo summarizing the content was provided;
- the GRF has been integrated into the controller refresher training program;
- the GRF has been added to the initial training program for tower supervisors[64].

The BEA investigations are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.

[64] The tower supervisor, being a controller, had followed the initial GRF training.

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