Serious Incident on Norwegian Flight on August 11, 2024

L2024-01

SYNOPSIS

Pursuant to the second subsection of section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority of Finland (SIAF) decided to investigate a serious incident that occurred on a flight operated by Norwegian on August 11, 2024. The aircraft encountered turbulence, which resulted in injuries to two cabin crew members.

The purpose of a safety investigation is to promote general safety, the prevention of accidents and incidents, and the prevention of losses resulting from accidents. A safety investigation is not conducted in order to allocate legal liability.

Senior safety investigator Juho Posio was appointed as the head of the investigation team. Team members and subject matter experts were Juha-Pekka Keidasto, Antti Rautio and Sanna Winberg. The investigator-in-charge was Chief Air Safety Investigator Janne Kotiranta.

The Swedish Accident Investigation Authority (SHK) and the National Transportation Safety Board (NTSB) of the United States appointed accredited representatives for the investigation, while the European Union Aviation Safety Agency (EASA) appointed a technical advisor.

The safety investigation examines the course of events of the incident, its causes and consequences, and the search and rescue actions as well as any actions taken by the authorities. The investigation specifically examines whether safety had adequately been taken into consideration in the activity leading up to the accident and in the planning, manufacture, construction and use of the equipment and structures that caused the accident or incident or at which the accident or incident was directed. The investigation also examines whether the management, supervision and inspection activity had been appropriately arranged and managed. Where necessary the investigation is also expected to examine possible shortcomings in the provisions and orders regarding safety and the authorities' activities.

The investigation report includes an account of the course of events of the accident, the factors leading to the accident and its consequences, as well as safety recommendations addressed to the appropriate authorities and other instances regarding measures that are necessary in order to promote general safety, the prevention of further accidents and incidents, the prevention of loss and the improvement of the effectiveness of the operations of search and rescue and other authorities.

An opportunity is reserved to those involved in the accident and to the authorities responsible for supervision in the field of the accident to comment on the draft investigation report. These comments have been taken into consideration during the preparation of the final report. A summary of the comments is at the end of the report. Pursuant to the Safety Investigation Act, no comments given by private individuals may be included in the investigation report.

The investigation report was translated into English by TK Translations.

The investigation report, summary and appendix were published on June 13, 2025 on the SIAF´s website at www.sia.fi.

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Cover photo: Norwegian

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1 FACTUAL INFORMATION

1.1 History of Flight

At 02.27 local time[1], Norwegian's flight NSZ2961 departed on a return service from Rhodes, Greece, to Helsinki, Finland. The departure was delayed by 33 min due to air traffic control (ATC) related restrictions. The airplane was a Boeing 737-MAX 8, registered SE-RYC. The copilot was pilot flying (PF)[2].

The crew consisted of two pilots and four cabin crew members (SCCM, CCM2, CCM3 and CCM4)[3]. The SCCM and CCM4 were in the forward galley, and CCM2 and CCM3 in the aft galley. The flight carried 117 passengers, of which 113 were adults and three were children. One lap child was included in the passenger count.

Before departure, the pilots had received updated meteorological information[4], which indicated scattered rain showers and possible thunderstorms over Estonia and the Gulf of Finland, but no turbulence was expected on the intended route.

The initial route would have taken the flight through Swedish airspace. However, before entering Polish airspace, the captain requested a change of route via the airspace of the Baltic countries direct to Helsinki in order to catch up with the schedule, and ATC issued a new clearance as requested.

As the pilots began descent to Helsinki, the captain took the role of PF, and the copilot informed the passengers and the cabin crew about the remaining flight time and Helsinki area weather. While this announcement was in progress, the captain selected the heading mode on the autopilot and altered heading approximately 5° to the right of the heading computed by the flight management system (FMS) with the intention of circumnavigating via east a rain shower or thunderstorm shown on the weather radar to the left of the airplane's track. To avoid the thunderstorm, he altered the heading a further 2° to the right. In accordance with a standard procedure, he flashed the seat belt signs on and off to indicate the cabin crew that time to landing was 20 min, and the SCCM gave the standard descent announcement.

When the airplane reached an altitude of approximately 28,000 ft[5], it encountered turbulence. The first indication was two minor bumps, followed by a significant altitude loss. The autopilot disengaged, and the airplane experienced large variations in vertical speed[6]. Turbulence was classified as severe[7].

As soon as the pilots realized that the airplane had encountered turbulence, they turned on the seat belt signs. The encounter lasted approximately 10 s.

At its onset, the SCCM was engaged in her duties in the forward galley. She immediately took her assigned seat and fastened the harness. CCM4, who was collecting waste at the fourth seat

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1 23.27 UTC (Universal Time Coordinated)

2 The flight crew consists of two pilots. One of them is pilot flying (PF) and the other is pilot monitoring (PM). The roles of PF and PM can be assumed by both the captain and the copilot.

3 Cabin crew members (CCM) are referred to as SCCM (senior cabin crew member, who has overall responsibility for the cabin) and CCM2–4. The number indicates the seating position, assigned cabin section and duties

4 The briefing package that the pilots received included, among other materials, SWC charts for FL230–630 and FL100–450 effective at 00.00 UTC on August 11, 2024, and SWC charts for FL250–630 and FL100–450 effective at 06.00 UTC on August 11, 2024. Also included were Tallinn forecast for 18.00 UTC on August 10 to 18.00 UTC on August 11, and Helsinki forecast for 21.00 UTC on August 10 to 21.00 UTC on August 11. Forecasts for en-route aerodromes were also provided.

5 Foot (ft) (*feet* in plural) is a unit of measurement in aviation. One foot equals 0.3048 m.

6 Vertical speed varied between +200 and -4,500 ft/min. Pitch angle varied between -1.0° and -4.75°. Load factor varied between +1.45 and -0.15 G.

7 Norwegian manuals identify three levels of turbulence: light, moderate and severe.

row, took the nearest available seat and set the brake on the trolley. Because she was holding on to the trolley, she asked the adjacent passenger to fasten her seat belt. After turbulence subsided, CCM4 took the trolley to the forward galley and resumed landing preparations.

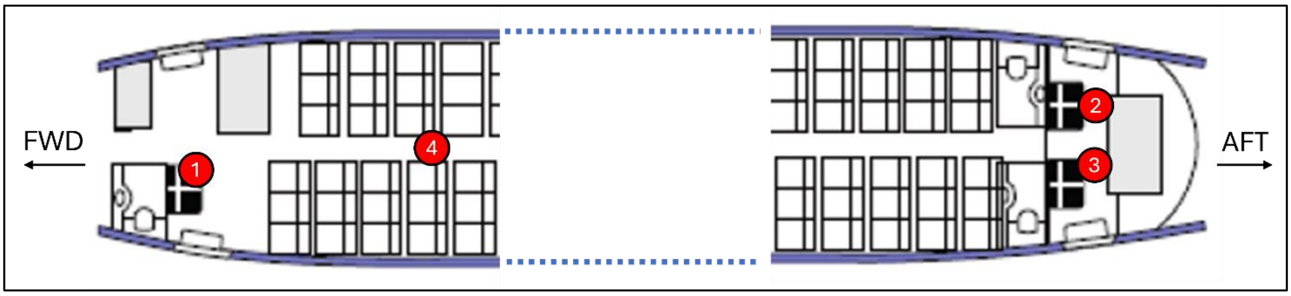

Figure 1. Cabin layout of occurrence airplane. Red circles indicate cabin crew positions at turbulence onset: 1 = SCCM, 2 = CCM2, 3 = CCM3, 4 = CCM4. (Source: Norwegian, annotations: SIAF)

At the onset of the event, CCM2 was in the aft galley switching off payment devices, and CCM3 was about to move into the cabin with a waste trolley. The first indication of the encounter was a series of bumps, which soon increased in intensity. CCM2 and CCM3 elected to stow the trolley, which took longer than anticipated due to airplane motion. They tried to take their seats for self-preservation but were unsuccessful before turbulence intensified.

They repeatedly became weightless. During the first event, the legs of CCM3 were trapped in the airplane structure, while CCM2 impacted the galley ceiling. Then both crew members slammed on the galley floor. Significant vertical motions caused by the unanticipated intensification of turbulence lifted CCM2 and CCM3 up several times until they ended up on the floor and eventually managed to regain their seats and strap in.

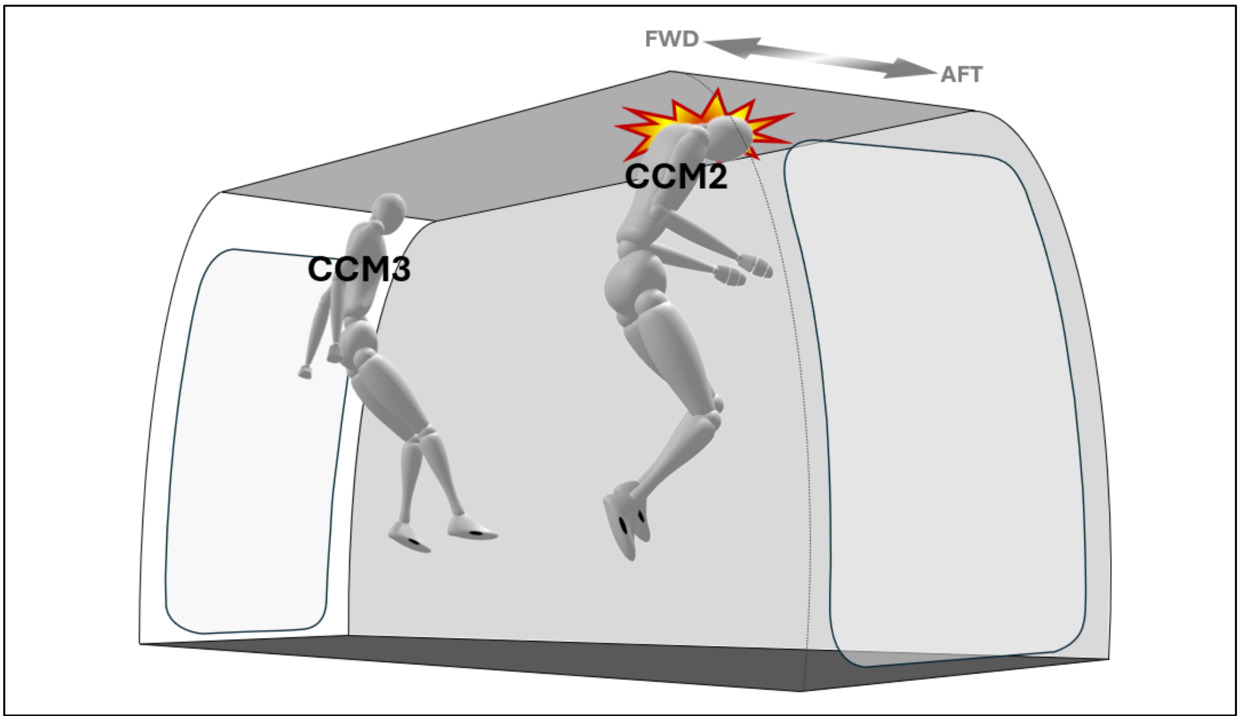

Figure 2. Rendition of aft galley cabin crew members in weightless condition during turbulence encounter. (Figure: SIAF)

Payment devices dropped from the countertop and till paper rolls spread across the floor. After strapping-in, CCM2 and CCM3 managed to recover the devices and place them in the waste trolley.

After turbulence had subsided, CCM3 called the SCCM reporting that she had sprained her neck and CCM2 had sustained head injury. The SCCM came aft to assess the situation. After discussing the event with the injured crew members, she asked them to discontinue landing preparations and remain in their positions for the remainder of the flight. She asked the captain to request an ambulance to meet the airplane upon landing.

The SCCM completed landing preparations in the aft galley and in the cabin on behalf of CCM2 and CCM3. CCM3 called the SCCM after landing and told her that CCM2 appeared pale and disoriented. CCM3 double-checked that an ambulance had been requested.

The pilots continued the approach. They notified the company of injured persons on board but did not provide this information to ATC. The flight landed at 03.09 UTC.

As soon as the airplane was stationary and the seat belt signs were turned off, CCM3 disarmed the emergency escape slides of both rear doors and opened the left-hand door. She closed the curtain that separated the galley from the cabin. A company employer had complied with the pilots' request and alerted an ambulance. The injured crew members were checked and taken to hospital for further examination.

1.2 Alerting and Rescue

The emergency response center (ERC) at Kerava received an emergency call at 06.02 local time and dispatched two rescue units to the scene. These were paramedic unit EKU6232 supported by aerodrome rescue services unit AR101 that provided first response[8]. The units were alerted at 06.05 local time. AR101 reported on scene at 06.13, followed by EKU6232 at 06.17. EKU6232 took the crew members to hospital. AR101 and EKU6232 were called off at 06.41 and 07.14, respectively.

1.3 Consequences

The unanticipated turbulence encounter resulted in injury to two cabin crew members in the aft galley, who were subjected to repeated impacts with airplane structure. CCM2 felt severe pain in his upper body and knees, while CCM3 sustained knee, back and neck injuries.

Both were taken to hospital. CCM3 was released for home recovery, while CCM2 remained in the hospital for further examination. Both were prescribed several weeks of sick leave.

CCM3 subsequently contacted occupational health care services due to protracted neck and back pains and was sent to further examination, which determined that the pains resulted from contacts with cabin structure. After return from the sick leave, CCM3 worked part-time for a one-month period.

Passengers and other crew members were uninjured.

The crew members were offered two occasions for post-incident support. All were given an opportunity for defuzing on the telephone after landing[9]. A discussion with CCM2 took place

8 First response refers to the closest rescue services unit that is capable of providing medical treatment above first aid level in an emergency and is likely to reach the patient before the arrival of the first paramedic unit.

9 Defuzing means "talking the event out" between the persons involved within hours of a mentally stressful occurrence.

on the day of the occurrence, and with CCM3 the next day. A common debriefing session[10] for the entire crew was arranged five days after the occurrence. The injured crew members were also offered an opportunity to receive support from a professional.

[10] Debriefing is a meeting led by a trained specialist after a sudden and shocking event, in which the persons involved participate.

2 BACKGROUND INFORMATION

2.1 Environment, Equipment and Systems

2.1.1 Airplane

The occurrence airplane was a Boeing 737-MAX 8, registered SE-RYC. It had a valid certificate of airworthiness issued by the competent Swedish authority. The airplane had accumulated approximately 5,900 flight hours and 2,450 landings. Its maximum takeoff mass is 82,190 kg, and it is powered by two underwing CFM LEAP-1B turbofan engines. The airplane's maximum speed is approximately 850 km/h. It can accommodate 189 passengers.

Figure 3. Occurrence airplane was Boeing 737-MAX 8, registered SE-RYC. (Photo: Norwegian)

2.1.2 Airborne Weather Radar

The airplane is fitted with a weather radar[11] capable of producing weather picture out to 320 NM[12] (approximately 590 km) range. The main components of the radar system are a transmitter/receiver/antenna, a central processor unit and a control panel that the pilots use to select desired information on the cockpit display.

The radar uses doppler shift to determine distance (time) to reflectors, i.e., precipitation, and the density (intensity) of precipitation. Received returns are shown in a synthetic radar picture together with the airplane's track information. Information can be augmented by using additional multiscan, turbulence and threat track functions.

The radar has three pilot-selectable modes: MAP, AUTO and MAN[13]. With AUTO selected, the radar, among other features, adjusts transmitted power automatically as a function of altitude, eliminates undesirable ground clutter and detects any windshear and turbulence in the vicinity to augment meteorological information. In MAN mode, the pilot can adjust antenna tilt and transmitted power in order to obtain desired meteorological information.

In AUTO and MAN modes, the radar uses temperature correction to adjust transmitted power. As outside air temperature drops, as may happen when the airplane ascends, or for other reasons, the radar's sensitivity to reflected returns increases.

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11 Rockwell Collins WXR-2100, P/N 822-1710-312
12 NM = nautical mile. One nautical mile equals 1,852 m.
13 MAP = ground map, AUTO = automatic, MAN = manual

In MAP mode, the radar shows terrain features and weather, and no turbulence information is displayed. The display uses a standard set of colors, each of which represents a specific level of reflectivity. Generally speaking, black represents dry air mass. Green represents normal, static cloud that does not affect the conduct of the flight. Yellow represents a denser or developing cloud with rain potential, among other meteorological phenomena. A small red area bordered in yellow represents high cloud density. The cloud may contain water droplets in a liquid form or various solid forms. High cloud density is also a common indication of vertical air currents and possible electrical charge, which may appear as lightning. Magenta represents a turbulent area.

At least low reflectivity level will be needed for turbulence detection. The radar cannot detect clear air turbulence (CAT)[14].

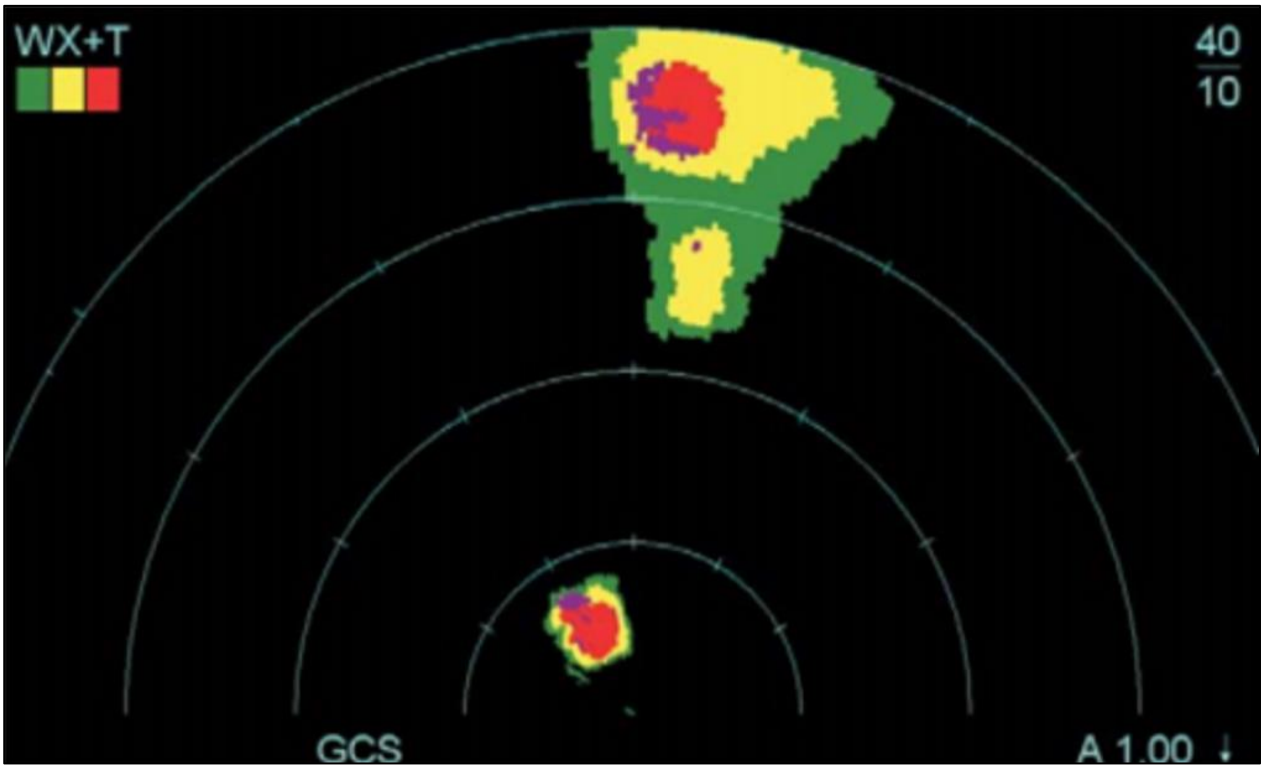

Figure 4. Weather radar display. (Photo: Norwegian)

2.2 Conditions

Meteorological data[15] for the flight indicated that the forecast for the time of the occurrence in the area of the encounter showed isolated rain showers or thunderstorms moving slowly eastward at 28,000 to 36,000 ft (approximately 8.5 to 11 km) among other types of cloud formations, which made their visual detection difficult. No turbulence was forecast for the route.

An analysis provided by Norwegian showed that the occurrence airplane tracked directly above a developing thunderstorm (figure 5). It penetrated the top of the cloud in an area where it was subjected to violent vertical air currents (figure 6).

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14 Clear air turbulence commonly occurs at high altitudes and cannot be detected by radar.
15 SWC charts for FL250–630 and FL100–450 and Tallinn terminal area forecast (TAF).

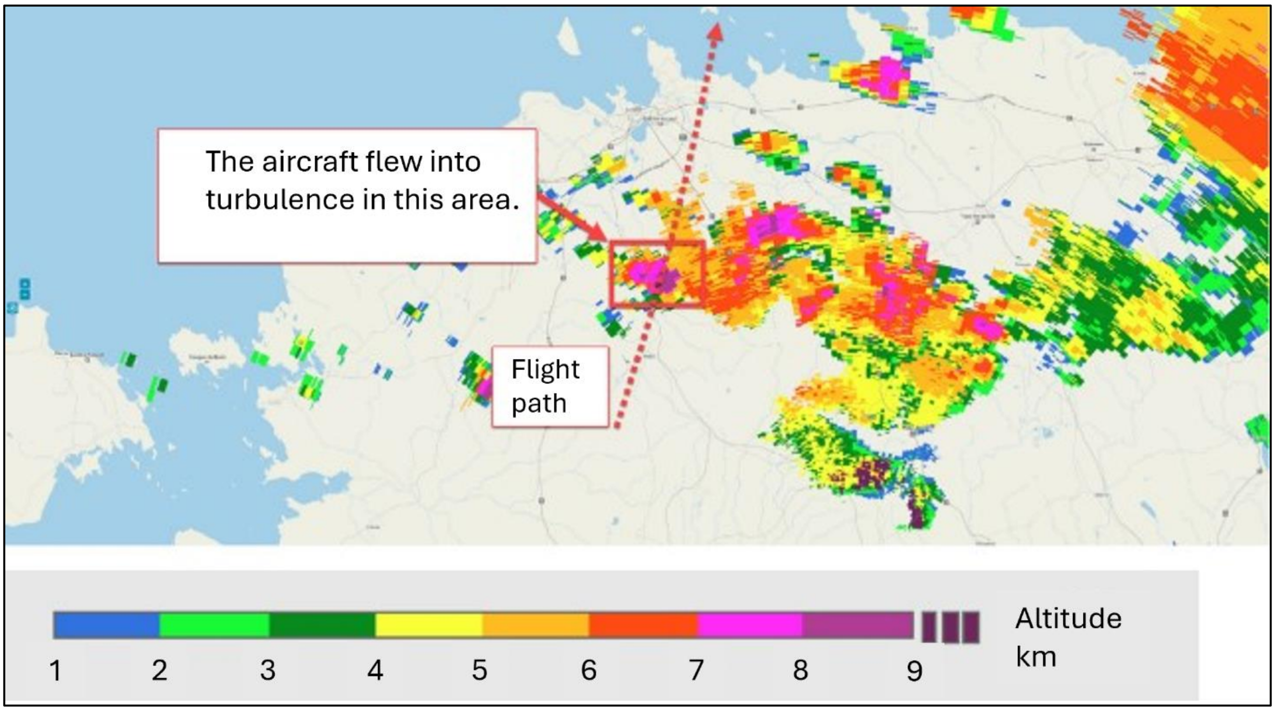

Figure 5. Airplane's route across thunderstorm area. (Figure: Norwegian, annotations SIAF)

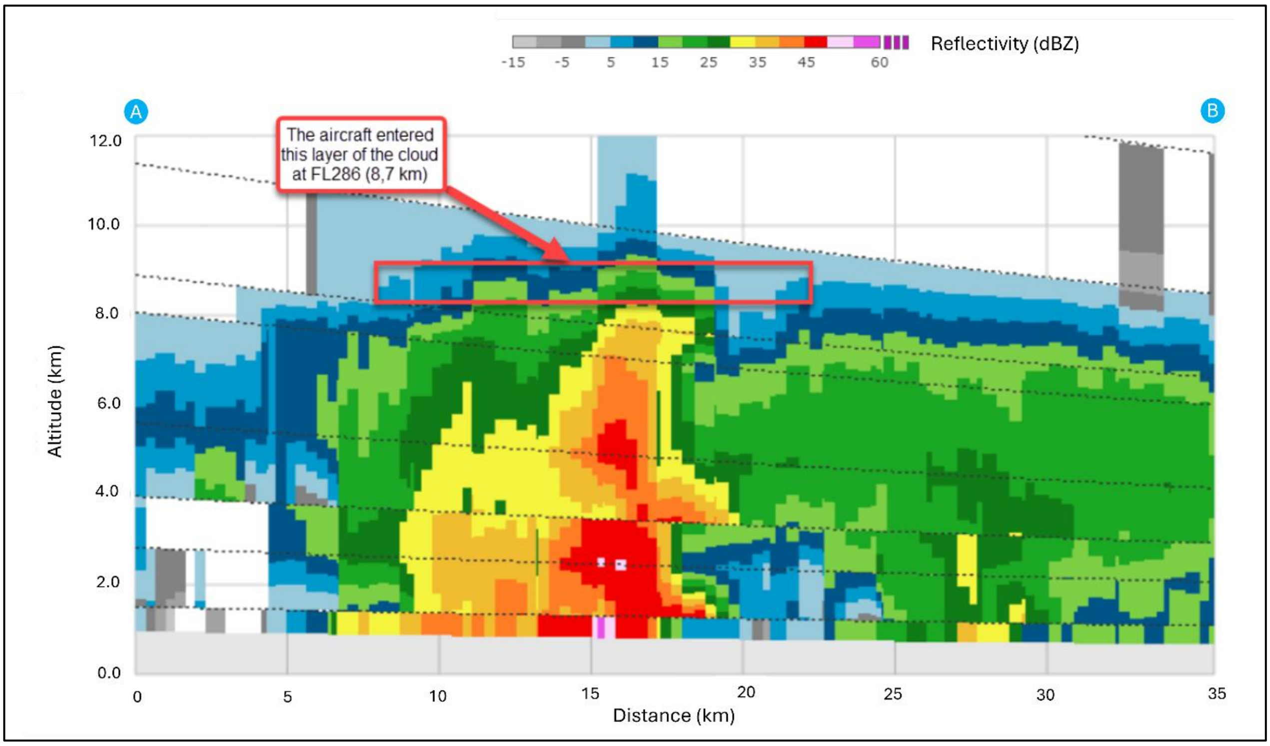

Figure 6. Cross-section of thunderstorm on airplane's estimated track. (Figure: Norwegian, annotations SIAF)

2.2.1 Weather Analysis of Finnish Meteorological Institute

A weather analysis from Finnish Meteorological Institute showed that significant thunderstorm activity existed in Estonian airspace at the time of the occurrence. Based on observations from the ground-based weather radar at Harku, Estonia, a thunderstorm was developing and intensifying along the airplane's track. Its most intense part was very close to the airplane's track between 02.45 and 02.50 h UTC. Lightning was observed within the cloud.

Single thunderstorm cells were moving toward the south-southeast at approximately 24 kt[16] (approximately 12 m/s). Lightning was noted within these clouds. Although it was not particularly heavy, lightning is usually an indication of strong vertical air currents inside the cloud, and these create severe turbulence both within and in the vicinity of the cloud.

At Rhodes, the pilots received a weather forecast for Helsinki airport[17], which showed isolated thunderstorms or rain showers in Helsinki area at the time of the occurrence. The forecast for Tallinn airport[18] showed thunderstorm and strong variable winds the time of the occurrence and noted that thunderstorms and hail would be experienced in the area both before and after the time of the occurrence.

A jet stream with wind speeds of 110 to 240 kt (approximately 56 to 72 m/s) was over southern Estonia and had been forecast to cause moderate or heavy turbulence, but it did not affect weather over northern Estonia.

2.3 Recordings

Voice recorder data was unavailable for the investigation team. The airplane's digital cockpit voice recorder (DCVR) is of continuously overwriting type, and therefore only the last 2 h of audio is accessible at any given time. In this case, the airplane had already departed on the next sector, so recording from the occurrence flight was lost.

On the other hand, the team had access to digital flight data recorder (DFDR) data, which was downloaded for the assessment of the intensity of turbulence and for the evaluation of airplane control -related parameters.

Data from the airplane's communication addressing and reporting system (ACARS)[19] showed that the pilots had downloaded Helsinki airport spot weather observations via ACARS just once, before leaving the cruise altitude. They had not downloaded similar data for Tallinn, which was the alternate aerodrome, or any other airport along the route.

The team extracted from electronic flight preparation and planning documents details of meteorological information that had been available to the pilots. Airplane weight and balance data was also retrieved.

ATC recordings were used to examine pilot-controller communications.

2.4 Personnel, Organizations and Safety Management

2.4.1 Crew

The captain, 41, held the required class and type ratings and valid medical certificates. He had accumulated approximately 6,200 flight hours, 5,900 of which were in the Boeing 737-MAX 8.

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16 Knot (kt) is a unit of speed in aviation and marine navigation. One knot equals 1.852 kilometers per hour.

17 EFHK/HEL HELSINKI/VANTAA
SA 102050 21005KT CAVOK 14/11 Q1001 NOSIG=
FT 102022 1021/1121 25004KT CAVOK TEMPO 1022/1107 SCT030CB TEMPO 1112/1115 4000 TSRA SCT030CB=

18 EETN/TLL TALLINN/LENNART MERI
FT 101730 1018/1118 23014KT 9999 SCT015 SCT025CB TEMPO 1018/1103 VRB25KT 2000 TSRA SCT005 BKN020CB PROB30 TEMPO 1018/1102 TSGR TEMPO 1103/1108 3000 TSRA SCT010 SCT020CBBECMG 1111/1113 29015KT PROB40 TEMPO 1112/1115 TSRA=

19 ACARS is a system for transmission of short text messages between aircraft and ground stations or between aircraft via radio or satellite.

He had flown approximately 2,600 h as pilot-in-command[20], of which approximately 2,000 h were in the type.

The first officer, 43, held the required class and type ratings and valid medical certificates. He had accumulated approximately 4,900 flight hours, 4,750 of which were in the in the Boeing 737-MAX 8.

Table 1. Pilots' Recency.

Pilots' Flying Experience		Last 24 h	Last 30 d	Last 90 d	Total Flying Experience
Captain	On all airplane types	7 h 34 min	81 h	191 h	6,198 h
	On occurrence airplane type	7 h 34 min	81 h	191 h	5,920 h
Copilot	On all airplane types	7 h 34 min	91 h	173 h	4,896 h
	On occurrence airplane type	7 h 34 min	91 h	173 h	4,735 h

The SCCM had 5 years of operating experience with Norwegian, and she had worked in this capacity the entire period. CCM2 had 5 years 11 months of operating experience with Norwegian, including 4 years 5 months as SCCM. CCM3 had 14 years of experience, while CCM4 had been hired by Norwegian 6 months before the occurrence.

All cabin crew members held the required ratings.

2.4.2 Norwegian Group

Norwegian Group consists of the parent company Norwegian Air Shuttle ASA and its subsidiaries in Norway, Sweden, Finland, Ireland, United Kingdom and Singapore. The company is headquartered in Fornebu, Norway. In this report, Norwegian Air Shuttle ASA is referred to as Norwegian for convenience. Norwegian holds two air operator certificates (AOC), one issued in Sweden and the other in Norway.

The financing, leasing and ownership of the company's airplanes are handled by subsidiaries in Dublin, Ireland, under an arrangement with the parent company Arctic Aviation Assets, Ltd.

Norwegian has a fleet of 82 airplanes, of which 62 are Boeing 737-800s and 20 are Boeing 737-MAX 8s.

The company employs approximately 4,700 persons, split between 1,219 pilots and 1,945 cabin crew members. Finland-based aircrew consists of 92 pilots and 129 cabin crew. Aircrew is multinational and uses English as the working language.

[20] The pilot-in-command has ultimate authority on board the aircraft. In a two-pilot flight crew, the role of the pilot-in-command is always vested in the captain, also when the copilot is flying the aircraft.

2.4.3 Safety Management Manual

Norwegian's Safety Management Manual (SMM) describes the company's safety management procedures and safety responsibilities of the personnel. The SMM is based on an EASA[21] regulation on safety management.

The Director Safety has overall responsibility for safety management, the SMM and its revision service. The Director Safety also ensures the initiation and follow-up of internal occurrence and accident investigations.

2.4.4 Safety Management System

In Norwegian's dual-AOC model, a Safety Review Board (SRB) convenes at regular intervals to process air safety reports (ASR) filed under both AOCs. Reports can be grouped into separate files if this is requested by the Swedish or Norwegian authority.

Reports are submitted via a web-based reporting system called SafetyNet. Any company staff may also report direct to the competent civil aviation authority. Reports shall be filed within 72 h of the occurrence. The Safety Department receives the reports and asks the persons involved and other departments to provide further information if necessary. Reports are analyzed and used as a basis of recommendations aimed at promoting flight safety and preventing the recurrence of similar events.

The first step in the processing of a flight safety occurrence is event risk classification (ERC). For this purpose, Norwegian uses a risk classification matrix to determine the safety importance of an occurrence as a numerical value derived from its potential outcome and the effectiveness of remaining barriers. If no barriers are in place and the most credible outcome is catastrophic, this value is 2,500 at maximum. Conversely, the value is 1 for an occurrence that is highly improbable and would have negligible outcome. When interpreting the risk matrix, focus should be on the color of the "box" rather than the numerical value because the colors determine any subsequent actions.

[21] EASA = European Union Aviation Safety Agency

Most Credible Accident Outcome	Effectiveness of Remaining Barriers				Accident Outcome Description	Typical Scenarios
	Effective	Limited	Minimal	Not		
Catastrophic	50	102	502	2500	Loss of aircraft, multiple fatalities	Loss of control, mid-air collisions, uncontrollable fires on board, explosions, structural failures, CFIT
Major	10	21	101	500	1 or 2 fatalities multiple serious injuries, major aircraft damage	High-speed taxiway collision, major turbulence injuries
Minor	2	4	20	100	Minor injuries, minor aircraft damage	Pushback incident, minor weather damage
None	1				No damage or injury was possible	Event that could not escalate into an incident even if it leads to operational consequences (diversions, delays, etc.)

Figure 7. Norwegian's event risk classification matrix. (Figure: Norwegian)

Green boxes represent events that require no immediate risk mitigating actions. However, these events flow into the risk register for statistic-keeping, follow-up or possible re-evaluation.

Yellow boxes represent events that require safety investigation or more refined risk assessment. These events shall be reported immediately to the appointed safety person.

Red boxes represent events that require an immediate investigation and safety actions. "Red events" are automatically considered safety issues and shall be reported immediately to the appointed safety person.

2.4.5 Reports on Investigated Occurrence and Other Turbulence-related Events on Norwegian-operated Flights in 2021–2024

The pilots reported the occurrence. Norwegian's Safety Department processed the report and contacted the flight crew during the morning following the flight. The occurrence was given numerical value of 100 in risk classification.

The investigation team requested from Norwegian reports on other turbulence-related events submitted in 2021–2024 and received nine reports. Five events had been reported during the summer of 2024, including one on the investigated occurrence.

A common denominator was that almost all events had occurred during the approach phase when cabin crew members were preparing the cabin for landing. In most cases, they had been off their seats at the onset of the encounter, moving through the cabin with service carts or waste trolleys.

In approximately half of the cases, the pilots had anticipated possible turbulence and turned on the seat belt signs. However, since they had not notified the cabin crew of turbulence by any other means, cabin crew had assumed that this was part of the normal arrival procedure and had not associated the illuminated signs with a turbulence hazard. For this reason, the encounters had come as a complete surprise.

All reported events had resulted in injuries to one or more cabin crew members. All injured persons had been in the rear of the airplane where turbulence is perceived as worse than in the other sections of the cabin. After one event that had caused serious injury, Norwegian had issued a safety bulletin to all flight crew members. The seat belt signs are normally turned on during descent no later than at 10,000 ft altitude to indicate that the cabin should be prepared for landing. Instructions were augmented in the wake of a serious turbulence-related event. According to the revised procedure, should it be necessary to turn the signs on earlier due to turbulence, cabin crew shall be notified by flashing the signs on and off.

2.5 Preventive Actions of Authorities

The Federal Aviation Administration (FAA) of the United States issued in 2013 Advisory Circular AC 00-24C on hazards of thunderstorms to aviation. The document explains that turbulence may be encountered up to 20 NM from a thunderstorm and advises that pilots should therefore avoid any thunderstorm by at least 20 NM.

Similarly, issue 1/2023 of EASA's *Conversation Aviation* magazine includes an article on turbulence management, in which pilots are instructed to deviate around thunderstorms by 20 NM for turbulence avoidance.

The Intergovernmental Panel on Climate Change (IPCC) of the United Nations published in 2021 a report titled *Climate Change 2021 – The Physical Science Basis*, which looks at the effects of global warming on weather, including extreme weather phenomena.

ICAO's[22] 2022 report *Innovation for a Green Transition* contains, among other information, a chapter titled *Climate Change Adaption & Resilience* that discusses means of analyzing risks resulting from climate change, the effects of climate change on airports and ways of adapting to climate change.

In 2022, EASA set up a working group called Scientific Committee (SciCom), tasked with reviewing and summarizing past and present research on the prevalence and effects of extreme weather phenomena. SciCom provides advise to the EASA Executive Director and advises EASA on processes that may impact aviation safety, environmental protection and aviation health safety.

In 2023, EASA kicked off an initiative called European Network on Impact of Climate Change on Aviation (EN-ICCA). Its participants are subject matter experts from aviation industry, aviation authorities, research organizations and national meteorological institutes. The objective is to equip aviation stakeholders to cope with extreme weather phenomena and thereby improve aviation safety.

2.6 Rescue Services and Their Preparedness

Finavia maintains regulatory aerodrome rescue services at Helsinki airport and provides first response service within the airport area under a contract arrangement.

Central Uusimaa Rescue Department is responsible for rescue services within the municipality of Vantaa. The department operates across eight municipalities, and although administratively governed by Vantaa-Kerava Wellbeing Services County, it also provides services to Central Uusimaa Wellbeing Services County.

[22] ICAO = International Civil Aviation Organization

HUS Group[23] provides paramedic services within Uusimaa region. For Vantaa-Kerava Wellbeing Services County, HUS Group has signed with the rescue department a joint agreement, which stipulates that the department is in charge of category A, B and C[24] tasks and first response services. Non-urgent paramedic care and most patient transfers are outsourced to a private service provider. The municipality of Vantaa and therefore Helsinki airport, and also the municipality of Kerava, belong to the operational area of Peijas hospital, which has eight 24-hour paramedic units and two units in part-time readiness. These are supported at the operational level by an ambulance helicopter and a paramedic field supervisor who cooperates with the ERC to ensure that alerted units are employed in an appropriate manner.

2.7 Regulatory Framework

2.7.1 Regulations and Guidance Issued by Aviation Authorities

ICAO operates under the auspices of the United Nations and sets minimum safety requirements at the international level. Member states shall adhere to standards and recommendations issued by ICAO unless they have notified the organization of national differences. ICAO's mission is to develop guidelines, policies, requirements and recommended practises within international aviation.

EASA regulates and oversees aviation safety at the European level. It issues regulations and acceptable means of compliance that European Union (EU) member states shall comply with. EASA regulations are based on ICAO standards and recommendations and on directives and implementing regulations issued by the EU Commission. EASA also provides guidance and oversees the aviation safety authorities of EU member states.

The 2025 edition of EASA's *European Plan for Aviation Safety* (EPAS)[25] addresses several safety risks. The objective is to look at the ways aviation safety risks have been analyzed, what conclusions have been made, and what risk mitigation actions have been implemented. One of the reviewed risks is extreme weather including turbulence, hail precipitation, lightning and icing. The conclusion is that insufficient risk management may lead to injuries to crew or passengers, or aircraft handling is significantly hampered by adverse weather.

Swedish (Transportstyrelsen) and Norwegian (Luftfartstilsynet) civil aviation authorities issue national regulations and bulletins and ensure that the safety standards and procedures of the respective countries meet ICAO standards and EU requirements.

Regulations for Cockpit Voice Recorder Recording Duration

The recording duration of a typical cockpit voice recorder (CVR) is 2 h. After this period, the earliest stored data is overwritten. The 2-hour capacity is sufficient in situations where the aircraft is damaged and cannot resume flying immediately. However, in many incidents the aircraft is undamaged and soon departs on the next flight, in which case recording is often lost and therefore unavailable for safety investigation.

Commission regulation (EU) 2015/2338 amended regulations concerning CVRs. It states that aircraft registered in 2021 and later, with a maximum certificated takeoff mass of 27,000 kg or more, must be fitted with a CVR with a recording duration of no less than 25 h. However,

[23] HUS Group is the parent organization of the City of Helsinki and the wellbeing service counties of the other municipalities of Uusimaa region in matters of social and health care.

[24] Rescue service is divided into four categories regarding response time. Category A tasks are the most urgent. Category D tasks do not require immediate response and can be executed other operations permitting.

[25] *European Plan for Aviation Safety*, Volume III, Safety Risk Portfolios, 2025 Edition

the regulation does not require new recorders on older aircraft, which means that the requirement for extended recording duration will become effective over time in conjunction of fleet renewals.

In 2016, ICAO adopted the same standard for aircraft manufactured after January 1, 2021, noting that the extended time was needed to cover the longest flights, to include preflight and postflight activities, delays, and the time to secure the recordings.

FAA also plans a 25-hour requirement, but the final decision is still pending.

2.7.2 Norwegian Manuals

Norwegian's Operations Manual (OM) describes the principles of the company's operations with the aim of establishing a unified operational culture across the organization. The OM is divided into four parts.

- Part A (OM A) is general part that governs the company's operating principles. It contains, among other topics, descriptions of company management, duties and responsibilities of nominated personnel, flight time limitations and rest periods, aircraft commander's responsibilities and safety actions.
- Part B (OM B) contains operational procedures for the company's airplane types and describes normal and abnormal procedures for flight crew and cabin crew.
- Part C (OM C) includes detailed route and aerodrome instructions and airplane performance data and other such information.
- Part D (OM D) is a training manual that contains qualification requirements for flight crew, training procedures and training-related instructions. The manual covers course structures and training phases and addresses training methods and student progress. Proficiency checks, initial, recurrent and refresher training and requirements for performance assessment are also covered.

In compliance with regulatory requirements, Norwegian has a safety management system (SMS) that is described in a separate section of the OM and in the SMM. The manuals explain how the company addresses safety risks inherent to its operations. A management system (MS) caters for the company's safety policy and objectives, safety risk management, continuous safety promotion and other such topics. The system describes reporting and follow-up procedures and corrective actions and encourages personnel to adopt an open and non-punitive reporting culture.

2.7.3 Severity of Turbulence

The OM contains instructions for flight crew and cabin crew for turbulence encounter. The manual identifies three levels of turbulence that can be encountered within or in the vicinity of thunderstorms. These levels are light, moderate and severe.

The manual gives examples of the effects of turbulence of various intensity. Light turbulence causes slight changes in the airplane's attitude and altitude, and passengers may feel a light strain against the seat belts. Liquids shake but not splash out of cups. Carts and trolleys can be maneuvered with little difficulty. Service can be continued with limitations if the captain deems safe to do so.

The effects of moderate turbulence are more pronounced. Passengers feel definite strain against the seat belts. Walking or standing in the aisle is difficult without balancing or holding on to something. Liquids splash out of cups, and carts and trolleys are difficult to maneuver. Service must be discontinued. All carts, trolleys and galley equipment shall be properly secured, and coffee or tea pots shall be emptied or, if this is not possible, placed on the floor. Cabin crew members shall take the nearest available seat and fasten the harness or seat belt.

Severe turbulence causes sudden, abrupt and large changes in altitude and attitude and large variations in airspeed. Passengers are forced against the seat belts, and walking is impossible. Items fall over, and unsecured objects are tossed about. Service shall be discontinued immediately. Brakes shall be set on all carts and trolleys, and they should be held on to if possible. Passengers can be asked to assist if necessary. Cabin crew shall take the nearest available seat and fasten the harness or seat belt. They shall remain seated until advised by the pilots or the seat belt signs are turned off.

2.7.4 Flight Crew Turbulence Procedures

Norwegian's manuals instruct pilots to use rough air penetration speed given in the airplane flight manual. If turbulence is expected, the manuals advise to fly at 280 kt during climb and descent. At altitudes below 15,000 ft with airplane gross weight below maximum landing weight speed may be reduced to 250 kt.

If it is impossible to detour or fly on top over a cumulonimbus cloud, altitudes between 14,000 and 20,000 ft should be avoided because they are the roughest, while the area between 5,000 and 6,000 ft does not have the same intensity.

The autopilot can control the airplane during all phases of normal flight using parameters provided by the flight management computer (FMC)[26]. The autopilot and autothrottle may remain engaged for light and moderate turbulence, while in severe turbulence autothrottle must be disengaged and thrust set manually to FMC recommended values. Pilots may use autopilot functions as appropriate for the conduct of the flight.

In expectation of anticipated or known turbulence, the seat belt signs shall be turned on, and announcement of expected turbulence shall be given over the public address (PA) system. Pilots shall tell the cabin crew to ensure that all passengers have fastened the seat belt. The flight deck light should be fully bright to reduce the blinding effect of a lightning strike. ATC must be informed of turbulence of above-average intensity.

2.7.5 Cabin Crew Turbulence Procedures

The SCCM is entitled to discontinue cabin service or other services even though the seat belt signs are off. He or she shall notify the pilots of this and advise them of the level of turbulence experienced in the cabin and of the need for the signs to be turned on.

The primary first response by cabin crew upon turbulence encounter is self-preservation. Cabin crew can compromise their safety and functional capability by attempting to continue service and adhere to routine procedures. Cabin crew members have received instructions for risk mitigation in the event of anticipated or unanticipated turbulence. These measures include the following:

- Keep the galleys clean and stow items immediately after each service.
- Stow and latch carts and trolleys, close and lock cabinet doors.

[26] The FMC provides, among other data, waypoint coordinates, aircraft position, optimum speeds and climb and descent profiles, considering prevailing atmospheric conditions.

- Empty tea and coffee pots immediately after service.
- Ensure that passengers only rest or sleep in a passenger seat; it is not safe for them to use the floor area.
- Toilets are not to be used during turbulence.

When the encounter is over, cabin crew should check the condition of the cabin and status of the passengers and inform the SCCM, who then notifies the pilots.

If any cabin crew member receives injures or becomes incapacitated for any other reason, the SCCM shall notify the pilots and reallocate the remaining crew members' duties. At least one able-bodied crew member shall be assigned to each door pair. He or she must have the knowledge needed to arm the emergency escape slides and open the doors.

2.7.6 Two-way Communication

Effective communication between the cabin crew and pilots is an essential safety enabler and critical in abnormal situations, such as during turbulence encounter. It requires mutually agreed phraseology and procedures both before and during the flight. The use of common terms ensures that the pilots and cabin crew members are equally aware of the intensity of turbulence experienced in the cockpit and cabin. This will allow the cabin crew to carry out the necessary duties safely and effectively during the encounter.

Norwegian's manuals highlight the importance of two-way communication in matters related to the conduct of the flight. The pilots should inform the cabin crew of upcoming expected turbulence before the flight so the SCCM can tailor and reschedule service and other duties during the flight.

In-flight, the pilots shall inform the SCCM of any expected weather changes. The SCCM is required to inform the pilots of any activities taking place in the cabin and of the effects of turbulence on cabin service. The manuals explain that the level of turbulence may be more intense in the aft section of the airplane than upfront.

After the encounter is over, the pilots shall advise the cabin crew that it is safe to get up and resume duties. The SCCM shall inform the pilots of any injuries sustained by passengers and crew members and of any damage to the cabin.

2.7.7 Turbulence Training in Norwegian

Boeing Flight Training Manual (FCTM) advises pilots to avoid severe turbulence to the extent possible. However, if they encounter severe turbulence, they shall follow the instructions given in the Flight Crew Operating Manual (FCOM).

When flying with the autopilot disengaged, pilots shall maintain wings level and use smooth control inputs for attitude control. Even though strong vertical air currents may cause significant attitude changes, abrupt or major control inputs shall be avoided.

Flight below the turbulence penetration airspeed shall be avoided even in cases where airspeed variations and attitude changes are expected during the encounter, because reduction in airspeed may lead to excessive narrowing of the stall margin. If necessary, thrust shall be set for the rough air penetration speed and major thrust changes shall be avoided. The use of hight-lift devices shall also be avoided because it would lower the airplane's limiting load factor.

Sudden changes in angle of attack during turbulence may cause momentary stick shaker activation. Load factor increase caused by turbulence will narrow the stall margin, in particular when airspeed is near the stalling speed.

Altitude or airspeed changes are not necessarily required during moderate turbulence encounter. However, if the engines are operating close to the selected maximum power, descent to a lower altitude may be required.

OM D states that pilots' turbulence training is done using computer based training (CBT). Turbulence is a topic in a module for which 1.5 study hours is allocated. The topic covers wake vortex and wake turbulence, severe weather approach and low-level turbulence during final approach.

Initial training of newly hired pilots includes 7 h of CBT, including weather avoidance procedures. Weather radar operation and employment are covered during refresher training at three-year intervals.

Cabin crew members are trained in turbulence management both during basic training and type rating training. Training is delivered as classroom instruction and includes cabin procedures and cabin crew duties during turbulence encounter.

Emphasis is in contingencies that result in injuries to crew members or pilot incapacitation. The cabin crew training syllabus includes a reference to OM A for situations where a cabin crew member is injured. SCCM training covers abnormal procedures such as crew member incapacitation and resulting need to reallocate cabin crew positions.

2.7.8 Fatigue Level Prediction

Norwegian employs Boeing Alertness Model (BAM) software to predict and monitor fatigue of aircrews. BAM uses pre-set parameters and work schedules to provide an estimation of, for example, an individual pilot's alertness or fatigue level within a specific time frame.

Because an individual's circadian rhythm cannot be determined in advance, actual rest times and other fatigue-related data can be incorporated into the software later. The software then uses collected data to calculate an exact numerical value that represents fatigue level and varies between 0 and 9. The higher this value, the more tired the individual.

The day of the occurrence under investigation was the captain's third and the copilot's fifth successive working day. When their fatigue levels were determined after the flight, the results showed elevated values for both: 6.8 for the captain and 7.6 for the copilot, although they had not felt fatigued during the flight. Elevated fatigue levels contribute to an increase in flight safety risks because fatigue increases reaction time and degrades decision-making capability and cognitive functions.

2.8 Other Investigations

2.8.1 Turbulence Theory

Turbulence is defined as rapid changes in liquid or gas flow. In aviation, turbulence means rapid changes in wind velocity and direction across the different layers of the atmosphere. When the direction or velocity of the air mass around the aircraft changes, aircraft occupants experience turbulence.

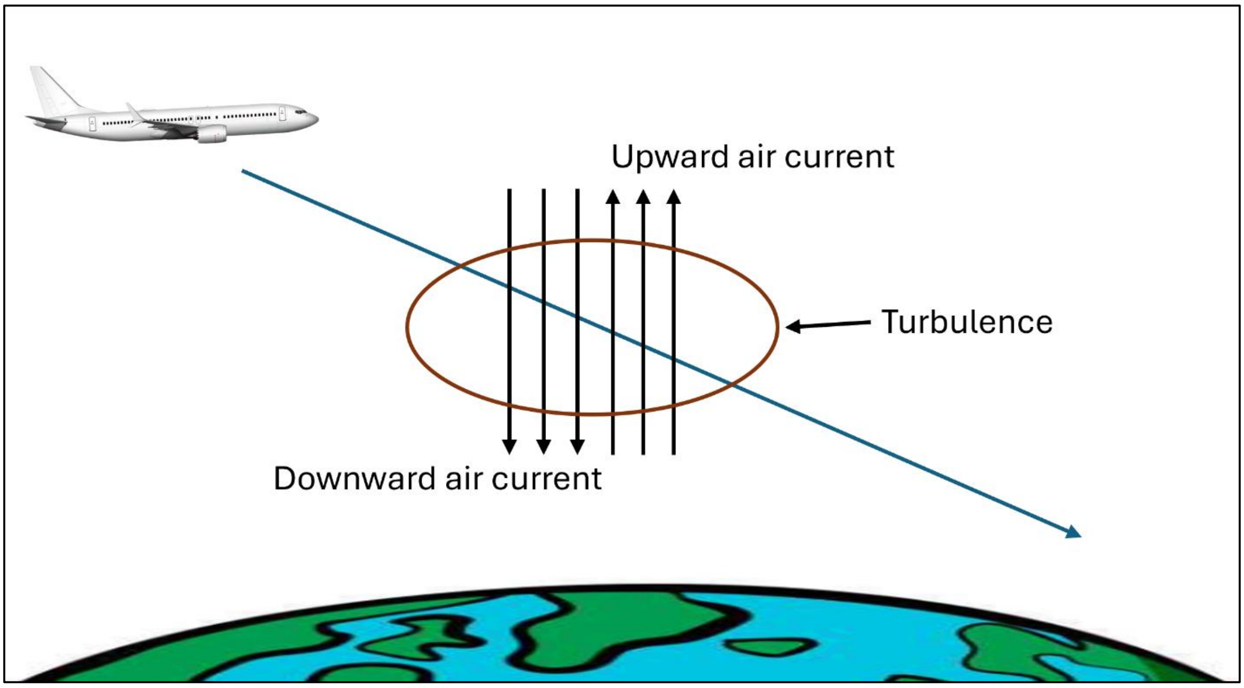

Figure 8. Air flow change between updrafts and downdrafts. (Figure: SIAF)

FAA's Advisory Circular[27] of February 2013 contains information on thunderstorms and associated turbulence. A thunderstorm life cycle progresses through three stages: the cumulus or developing stage, the mature stage and the dissipating stage. Extremely strong air currents may be present within the cloud during all these stages.

The velocity and direction of air flow may change rapidly in a thunderstorm area. When updrafts meet the prevailing wind, turbulence develops around the cloud. Strongest turbulence within the cloud occurs between updrafts and downdrafts.

Within large thunderstorm cells air currents may produce gravity waves that propagate from the cloud both horizontally and vertically, and when they dissipate, turbulent waves are created. Large hailstones may also be present inside the cloud.

Thin, curved cirrostratus clouds that are linked to strong updrafts may appear above the thunderstorm during the developing stage. The velocity of air currents within a developing thunderstorm can vary from 6 to 12 m/s in low-intensity cells to 75 to 80 m/s within extremely high-intensity cells that may develop at nearly an explosive rate. These violent downdrafts are a significant flight safety hazard. It may take 15 min for a low-intensity cell to reach the height of 10 km, while for the most violent thunderstorms this time may be in the 2 to 3 min class.

Weather radars cannot measure the intensity of gravity wave -induced turbulence, but they can be used to determine an approximate figure of the velocity of updrafts within the cloud.

Turbulence may be encountered several thousand feet above and up to 20 NM (approximately 37 km) from the cloud. In addition to thunderstorm-generated turbulence, unexpected CAT encounters may occur.

Figure 9 shows the structure of a typical thunderstorm. Blue and dark gray arrows indicate updrafts and downdrafts that occur within and in the vicinity of the cloud, while light gray

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[27] AC 00-24C

arrows represent turbulent air flow inside and above the cloud. White waves and arrows above the cloud top indicate wavy air currents.

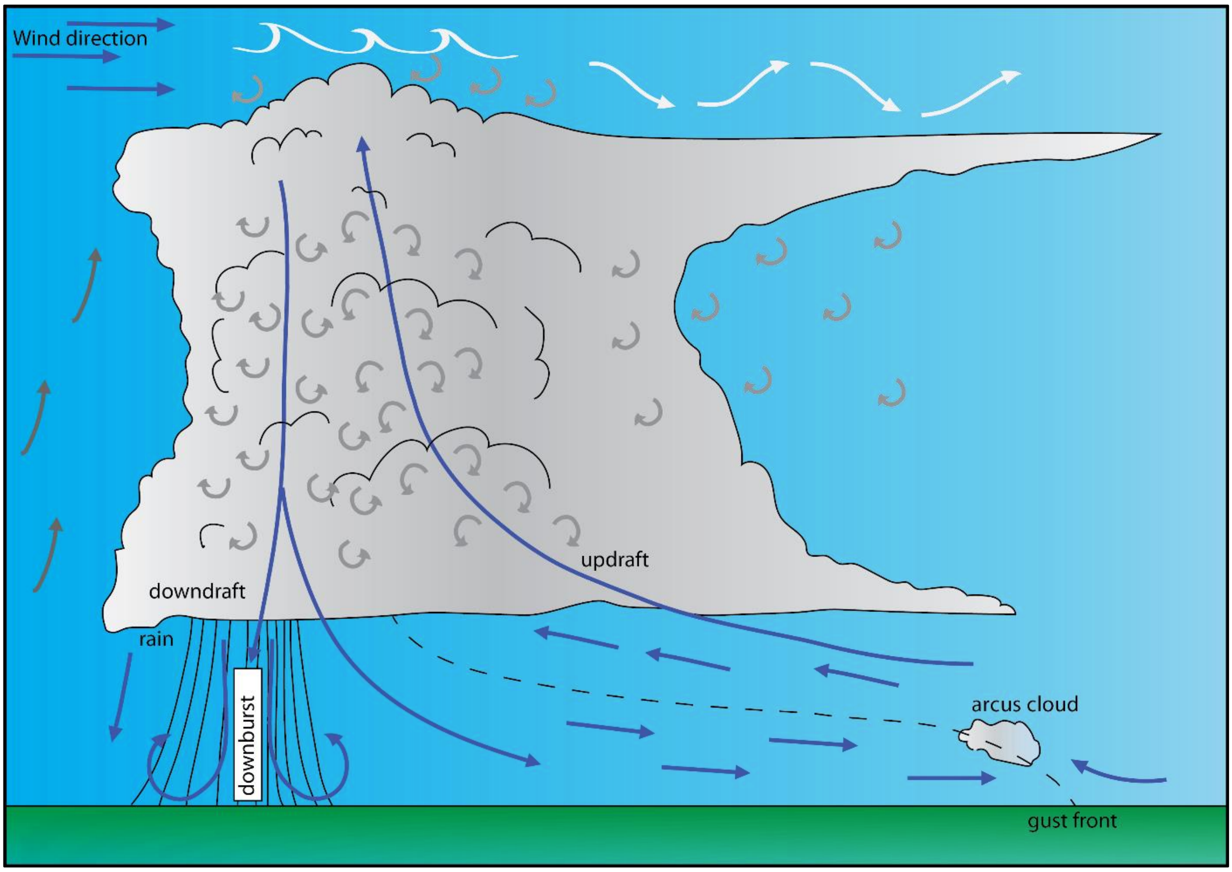

Figure 9. Structure of thunderstorm. (Figure: Finnish Meteorological Institute)

2.8.2 Increased Prevalence of Extreme Weather Phenomena

Climate change is expected to increase the prevalence of turbulence because of changes in jet stream patterns caused by temperature differences. Jet streams are bands of strong winds that occur between 5 and 10 km, which the typical cruising altitude. Since temperature variations affect wind direction and velocity, climate warming is forecast to lead to increased turbulence activity.

The main jet streams are located around middle latitudes in both hemispheres, whereas conditions closer to the equator are conducive to the formation of high towering thunderstorms that generate severe turbulence. Increased turbulence activity may also be more pronounced in specific regions. As an example, scientist predict that turbulent areas may be moving closer to the polar regions and be encountered at higher altitudes.

According to the IPCC report on global climate change issued in 2021, increase in global surface temperature will multiply the effects of extreme weather phenomena, and this will have an impact on flight safety. The report lists several threats, including storms, heavy rain, hail showers and low-level windshear.

A 2023 research letter titled *Evidence for Large Increases in Clear-Air Turbulence Over the Past Four Decades* suggests that turbulence has increased over the past decades. An analysis of turbulence over the North Atlantic in 1979–2020 showed that the total annual duration of light-or-greater turbulence increased by 17 % and severe-or-greater turbulence by 55 %.

According to a study titled *Impacts of Changing Atmospheric Circulation Patterns on Aviation Turbulence Over Europe*, global warming is leading to rising turbulence intensity over the United Kingdom and Northern Europe in particular. The study also showed that CAT encounters are most frequent and intense in winter.

2.8.3 Effects of Turbulence on Airplane

When an airplane penetrates a thunderstorm, it becomes subjected to severe turbulence, which can in the worst scenario affect the airplane's controllability. Hailstones that form within a thunderstorm may, if sufficiently large, cause damage to the windshield and weather radar. They may be ingested by the engines and damage the fan blades, which results in engine damage and even flameout. They may also damage the leading edges of the wings and stabilizers. Turbulence and hail may present a risk within an area that extends to as much as 20 NM (approximately 37 km) from the cloud edge.

The airplane's inherent stability, or a tendency to return to a balanced state after an external disturbance (e.g., wind, gusts, and turbulence) depends on several factors such as the airplane's weight, center of gravity, airspeed and the composition of the surrounding air mass. As a rule, the larger the airplane, the less turbulence perceived in the cabin.

The investigation team analyzed DFDR data, looked at the occurrence airplane's dimensions, mass and other characteristics and examined forces – such as the strength of vertical air currents and their effects on angular rates during disturbances – to which the sections of the airframe were subjected. The results were used to create a composite illustration (figure 10). Absolute flight parameters are insignificant in this case. However, differences shown in the simplified presentation across the forward, center and aft sections describe the situation to a sufficient extent.

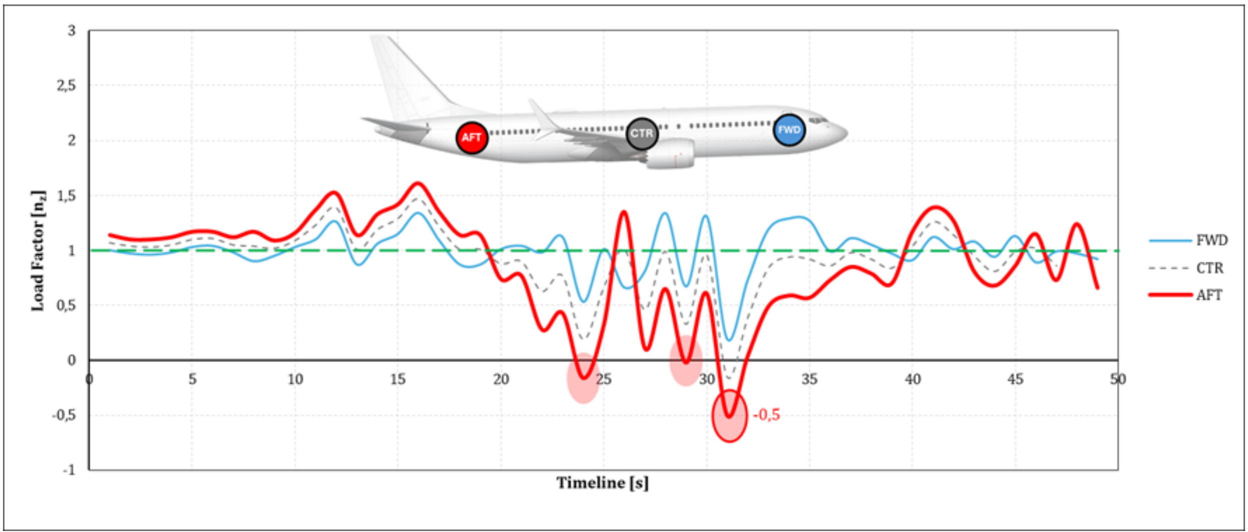

Figure 10. Load factor variations in airplane during turbulence encounter. (Figure: SIAF)

Load factors (G-forces) shown in the figure represent forces to which the crew and passengers were subjected in the three sections of the airplane. The gray dashed line describes load factor around the airplane's center of gravity, while the blue and red lines indicate load factor at the forward and aft galley, respectively. The figure shows that attitude excursions in the aft section exceeded those experienced in the center and forward sections.

Under positive load factor, occupants and unsecured items remain in contact with the floor, seat, tray table, or similar. When load factor is zero (black line), occupants and items are in a weightless state, and under negative load factor they are lifted off toward the ceiling. When load factor alternates repeatedly from negative to positive or vice versa, phase difference becomes a factor. In this context, phase difference is the term used to describe the moment when persons move in the direction opposite to that of the airplane; in other words, a person continues movement in the original direction while the airplane structure is already moving in the opposite direction. Therefore, phase difference can increase impact forces from those that would be encountered in a static situation.

The figure shows three negative peaks in the load factor curve. During the last one of them, CCM2 impacted the ceiling.

A detailed discussion of airplane balance is in Appendix 1.

2.8.4 Turbulence-related Injuries

Most turbulence encounters are unexpected. Turbulence-related injuries typically occur because occupants have insufficient time to prepare for an encounter, for example by fastening the seat belt or taking hold on to something. Even though injuries are often physical, turbulence can also cause psychological stresses and lead to post-traumatic stress disorders, which can in turn develop into a fear of flying and fear of turbulence.[28]

A 2021 report of the National Transportation Safety Board (NTSB) of the United States found that in 2009–2018 turbulence-related accidents accounted for more than one third of all air carrier accidents in the United States. Most of these resulted in one or more serious injuries but no airplane damage. Approximately 80 % of the injuries occurred to cabin crew and 20 % to the passengers. This can be explained by the fact that turbulence-induced forces are greater in the aft section of the airplane, and by the fact that turbulence typically occurs during descent and landing when most passengers are seated and restrained.

The most injured body region was lower extremity, accounting for approximately 60 % of injuries, followed by upper extremity, accounting for 15 % of injuries. Head and neck area injuries were markedly less prevalent and accounted for 5 % of injuries.

The NTSB report suggested that approximately 88 % of cabin crew injuries occurred in the aft section of the airplane, and more specifically, 75 % in the aft galley area. 82 % of passenger injuries occurred in the aft section of the cabin, and more specifically, 40 % in or near a lavatory. Still, these figures do not directly imply that the aft section is a particularly dangerous location. They stem from the fact that occupants typically remain seated and unfasten their seat belts only for lavatory visits, which exposes them to an elevated risk of turbulence-induced injuries. Similarly, the higher number of cabin crew injuries in the aft galley can be explained by the fact that cabin crew carries out a major part of their duties in the aft galley unrestrained.

2.8.5 Other Turbulence-related Reports

The investigation team retrieved data on turbulence-related injuries that have occurred in Europe since the early 2000s from ECCAIRS[29]database. The total number of injuries was 2,700 (figure 11), but only 200 of the reported events had occurred in 2000–2009, when the number remained fairly constant at approximately 20 events per year. The period of 2010–

[28] Vuorio et al., 2025

[29] ECCAIRS (European Co-ordination Centre for Accident and Incident Reporting Systems) is a European-wide database where aviation incidents and accidents are reported. Collected data helps identify, for example, cross-border trends in aviation safety.

2019 showed a clear upward trend, which peaked in 2018 when over 400 events were reported. A total of 2,000 events were reported in 2010–2019. From the early 2020s onward, the data reflects the slump in commercial air traffic due to Covid-19, when the number of events dropped dramatically. However, the annual number of reports is again in a marked increase. The number of reports may also be affected by changes in the reporting culture, because the reporting threshold has lowered, and even minor injuries are reported. Finally, it appears that climate change and resulting increased prevalence of extreme weather may have a bearing on the number of turbulence-related occurrences.

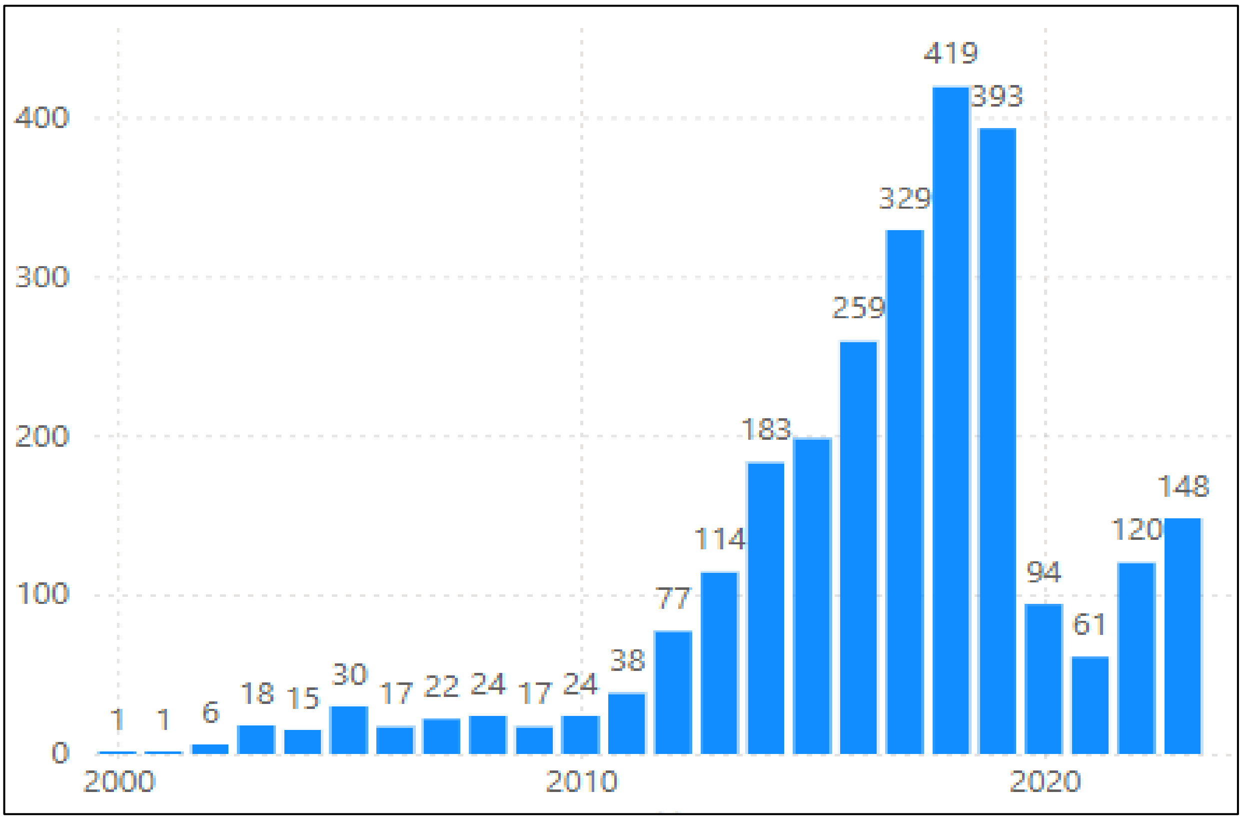

Figure 11. Turbulence-related injuries in Europe in 2000–2023. (Figure: SIAF)

3 ANALYSIS

A SIAF-developed format of the AcciMap approach[30] was used to support the analysis of the occurrence. The following text is arranged in accordance with an AcciMap diagram created during the investigation. The occurrence is depicted as a chain of events along the bottom of the diagram. Contributing factors at various levels can be examined by moving up and down the diagram.

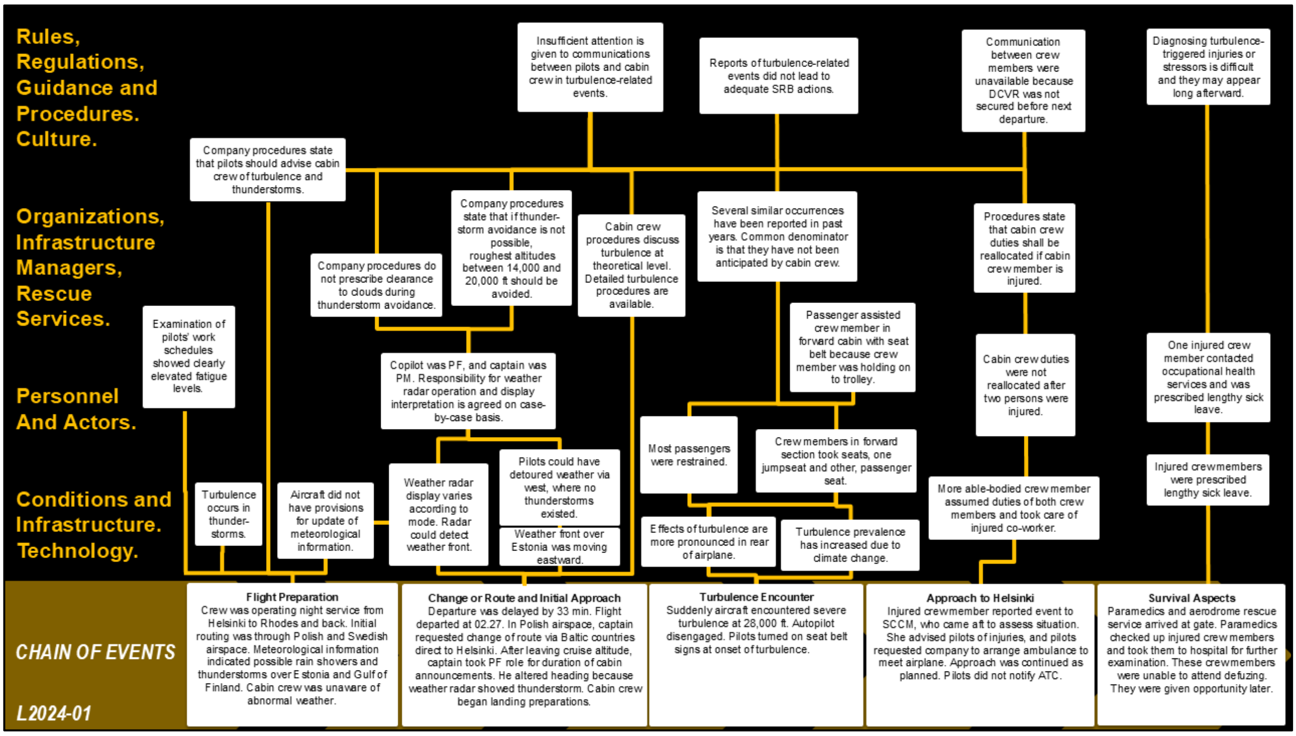

Figure 13. AcciMap diagram, investigation L2024-01. (Figure: SIAF)

3.1 Analysis of Occurrence

Flight Preparation

The crew was operating a night service from Helsinki to Rhodes and back. The initial route for the return flight would have taken the airplane through Polish and Swedish airspace. Before departure from Rhodes, the pilots received updated aeronautical meteorological information, which indicated possible rain showers and thunderstorms over Estonia and the Gulf of Finland, but no turbulence was forecast. The cabin crew remained unaware of abnormal weather en route.

Company procedures state that pilots should inform the cabin crew of forecast abnormal meteorological conditions, such as turbulence, before the flight. During the flight they should keep the cabin crew informed of possible weather changes.

The day of the occurrence was the captain's third and the copilot's fifth successive working day. A BAM analysis showed that the pilots' fatigue levels were significantly elevated. Excessive fatigue leads to increased aviation safety risks because fatigue increases reaction time and degrades decision-making capability and cognitive functions.

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[30] Rasmussen, J. & Svedung, I. (2000) *Proactive Risk Management in a Dynamic Society*. Karlstad, Sweden. Swedish Rescue Services Agency.

Change of Route and Initial Approach

Before entering Polish airspace, the captain requested a change of route via the airspace of the Baltic countries direct to Helsinki in order to compensate for the 33-minute delay on departure. ATC issued a new clearance as requested.

Pilots monitor weather development on the flight route. Procedures for weather radar operation and interpretation of radar information are decided on a case-by-case basis. Because Norwegian's Boeing 737-Max 8 airplanes do not have provisions for updating an en-route weather forecast received at the departure aerodrome, only weather radar picture and meteorological information from ACARS are available to pilots. Weather radar display varies according to the selected mode.

The pilots did not download weather observations for the destination alternate aerodrome or en-route alternate aerodromes via ACARS during the flight, and they downloaded Helsinki airport spot weather data only once, just before leaving the cruise altitude. Therefore, their weather-related situational awareness was degraded because it was based on information received at the departure aerodrome many hours earlier.

Based on observations from the ground-based weather radar at Harku, Estonia, a thunderstorm was developing along the airplane's track. Lightning had been observed within the cloud. The forecast for Tallinn showed thunderstorm and strong variable winds at the time of the occurrence and reported thunderstorms and hail in the area both before and after the time of the occurrence.

The copilot was flying the airplane, and the captain was monitoring. After leaving the cruise altitude, the copilot informed the passengers and cabin crew about the remaining flying time and Helsinki area weather. The captain assumed PF role for the duration of this announcement. After the announcement, the cabin crew began landing preparations.

The weather radar showed a rain shower or thunderstorm over Estonia to the left of the airplane's track moving eastward. The captain altered heading approximately 5° to the right of the heading computed by the FMS. In order to avoid the cloud, he altered the heading a further 2° to the right with the intention of circumnavigating the cloud via east. Suddenly the airplane encountered severe turbulence at 28,000 ft. The autopilot disengaged. The crew had an option to detour the weather front via west, where no thunderstorm activity existed.

Norwegian procedures state that if it is impossible to avoid a thunderstorm, the roughest altitudes between 14,000 and 20,000 ft should be avoided, but do not prescribe clearance to the clouds during thunderstorm avoidance.

Turbulence Encounter

The airplane encountered severe turbulence during the descent. The autopilot disengaged.

As soon as the pilots realized that the airplane had encountered turbulence, they turned on the seat belt signs. The first indication of the encounter was two minor bumps, followed by a significant altitude loss. The encounter was felt as slight shaking in the front of the airplane, followed by a single jolt. The cabin crew members in the aft section explained that the airplane oscillated up and down four times. At the onset of the encounter, the SCCM was preparing the forward galley for landing, and CCM4 was in the aisle with a waste trolley. CCM3 was in the aft galley about to move into the cabin, and CCM2 was storing payment devices.

Because the SCCM had given a descent announcement a moment before the encounter, most passengers had their seat belts fastened. No passenger injuries occurred.

The cabin crew attempted to comply with turbulence procedures by taking a seat for self-preservation and to avoid incapacitation. The crew members in the forward section managed to do this: one regained her jumpseat, while the other took a passenger seat and asked the adjacent passenger to fasten the seat belt because she was holding on to the waste trolley. The crew members in the aft galley did not have time to take their seats and sustained injuries on hitting airplane structure.

Turbulence causes an extremely high risk of injury and may in the worst case be fatal. Unrestrained passengers may be injured, and loose items may cause injuries. The airplane was subjected to three negative load factor spikes. During the most severe of them, CCM2 impacted galley ceiling with a force that equals the dropping of a 10 kg weight from approximately 1.2 m height under static conditions.

In addition to atmospheric conditions, the behavior of an airplane is affected by the airplane type, weight and center of gravity, and by altitude and airspeed. Still, in general terms, the response of an airplane to disturbances in situations comparable to those experienced on board the occurrence airplane is more pronounced in the rear than in the front.

Turbulence prevalence has increased due to climate change. Several occurrences similar to the investigated event have been reported in the past years, and a common denominator between them is that they have not been anticipated by the cabin crew. Sufficient attention is not given to the importance of communication between the pilots and cabin crew during turbulence-related events.

Approach to Helsinki

One of the injured crew members reported the event to the SCCM, who came aft to assess the situation. She advised the pilots of injured persons on board, and the pilots requested the company to arrange an ambulance to meet the airplane upon landing. The approach was continued as planned. Because the pilots did not notify ATC of injuries, controllers could not offer the flight landing priority, which would have shortened the delay in giving medical treatment to the crew members.

While the pilots responded to cabin crew members' incapacitation[31] by requesting an ambulance, cabin crew members' positions and duties were not reallocated. The more able-bodied crew member assumed the duties of both crew members in the aft galley and at the same time took care of her injured co-worker. Company procedures state that remaining cabin crew members' duties shall be reallocated if any cabin crew member receives injuries.

Communication between the crew members was unavailable to the investigation team because the DCVR was not secured before the airplane's departure on the next sector.

Survival Aspects

A paramedic unit and an aerodrome rescue service unit arrived on scene after the airplane had arrived at its assigned gate. After passengers had disembarked, paramedics checked up the injured crew members and took them to hospital for further examination. These crew members were unable to attend a defuzing session immediately after the flight had landed, but they were given an opportunity to talk out the event later. A common debriefing session for the entire crew was arranged a few days after the occurrence.

Both injured crew members were prescribed lengthy sick leave. One of them subsequently contacted occupational health care services, and her sick leave was extended. Diagnosing

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[31] Incapacitation means the total or partial inability of a person to carry out his or her specific tasks or duties.

turbulence-triggered injuries or mental stressors may be difficult in the immediate aftermath of an event, and they may not appear until long afterwards.

4 CONCLUSIONS

Conclusions encompass the causes of an accident or a serious incident. Cause means the different factors leading to an occurrence as well as relevant direct and indirect circumstances.

1. Norwegian's Boeing 737-Max 8 airplanes do not have provisions for updating meteorological information received at the departure aerodrome.

   Conclusion: *Having – to the best extent possible – updated information of expected weather changes increases pilots' situational awareness and ability to forecast the effects of weather along the route of the flight.*

2. The pilots' situational awareness regarding thunderstorms and the weather front was lacking.

   Conclusion: *Emphasizing the timely and continuous use of the weather radar during training will better prepare pilots to respond to changing weather conditions along the route of the flight. Pilots can further improve situational awareness during the flight by utilizing data from other sources, such as ACARS.*

3. Company procedures do not prescribe clearance to the clouds during thunderstorm avoidance.

   Conclusion: *The extent of the effects of turbulence associated with thunderstorms is difficult to determine. Turbulence can be avoided by keeping an adequate distance from a thunderstorm during deviation.*

4. The pilots did not notify air traffic control of injuries.

   Conclusion: *Active communication with air traffic control improves situational picture, ensures landing without delay and expedites the delivery of assistance.*

5. The SCCM did not reallocate cabin crew members' duties after two crew members were injured. The crew members at the rear door positions were significantly incapacitated.

   Conclusion: *Reallocation of duties after cabin crew member incapacitation ensures that an able-bodied crew member is available at each door pair and the flight can be completed in safe manner.*

6. The crew members in the aft galley sustained serious injuries during the turbulence encounter and were were prescribed several weeks of sick leave.

   Conclusion: *Turbulence may trigger physical injuries or mental stressors which may appear long afterwards and lead to a lengthy sick leave.*

7. The airplane departed on the next sector before the investigation team secured cockpit voice recorder data.

   Conclusion: *The company should have clearly defined procedures to ensure that cockpit voice radar data will be secured for investigation purposes also after a serious incident.*

8. The company had experienced similar turbulence-related occurrences during which the pilots did not communicate with the cabin crew. The encounter came as a surprise to the cabin crew.

   Conclusion: *Good interaction and active communication between crew members improves situational awareness and safety.*

5 SAFETY RECOMMENDATIONS

5.1 Two-way Communication

Two-way communication between pilots and cabin crew in matters of weather changes is crucial to the safety of the flight.

The Safety Investigation Authority Finland recommends that

> *Norwegian improves crew training on communication between pilots and cabin crew. [2025-S10]*

Research indicates that climate change is increasing the prevalence of turbulence and other extreme weather conditions, which will highlight the importance of communication in the future.

5.2 Thunderstorm Avoidance

The probability of encounters with thunderstorm-triggered turbulence can be reduced by issuing a specific clearance to a thunderstorm during avoidance.

The Safety Investigation Authority Finland recommends that

> *Norwegian defines minimum clearances and procedures for thunderstorm avoidance. [2025-S11]*

The effects of a thunderstorm may extend to as much as 20 NM from the cloud edge or above the upper limit of the tropopause.

5.3 Use of Weather Radar

Timely use and continuous monitoring of the weather radar gives a more accurate situational picture than automatic mode operation and translates into a better preparedness to respond to changing weather conditions.

The Safety Investigation Authority Finland recommends that

> *Norwegian puts more emphasis on timely and continuous use of the weather radar during pilot training. [2025-S12]*

Proactive pilot approach can help support decision-making during weather-related route selection and reroute.

5.4 Safety Actions

Norwegian conducted an internal investigation. The investigators also looked at other turbulence-related events that had occurred in 2024 and had resulted in injuries. The investigation led to three safety observations, which were implemented.

1. Norwegian subsequently carried out a new risk analysis. As a result, cabin crew procedures were amended to allow the cabin crew to take their seats earlier during descent and departure.
2. The company inserted into OM-B and training scenarios a mention that most injuries occur within thunderstorm clouds. This information was also added to training scenarios.
3. Norwegian has increased training on flight preparation and monitoring in order to provide pilots with information on tools and functions that are available for in-flight meteorological information update.

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Investigation Material

1) Report on Norwegian's internal investigation
2) Norwegian's manuals and instructions
3) Norwegian's training material on turbulence and weather radar operations
4) Norwegian's air safety reports on previous turbulence-related occurrences
5) Minutes of Norwegian's Safety Review Board meetings
6) Weather Analysis of Finnish Meteorological Institute
7) Interviews
8) Crew members' flying experience
9) Crew members' licenses
10) Crew members' rosters
11) Injured crew members' patient records and epicrises
12) Emergency response center authority alert log and incident report
13) Recordings of phone calls to emergency response center
14) Recordings of radio communications
15) Airplane's airworthiness documents
16) ECCAIRS data on turbulence-related accidents in Europe

SUMMARY OF COMMENTS TO DRAFT FINAL REPORT

The draft final report was submitted for comments to the interested parties, the Finnish Transport and Communications Agency Traficom, Norwegian, the National Transportation Safety Board of the United States, the Swedish Accident Investigation Authority and the European Union Aviation Safety Agency. Pursuant to the Safety Investigation Act, no comments given by private individuals are published.

The European Union Aviation Safety Agency (EASA) commented that the draft report did not include a description of the weather-related information in the pilots' briefing package. EASA also suggested minor amendments to the chapters on meteorological information and weather analysis. The proposed amendments were incorporated in the final report, and a footnote explaining meteorological data included in the package was added.

The Finnish Transport and Communications Agency Traficom, **Norwegian**, **the National Transportation Safety Board of the United States** and **the Swedish Accident Investigation Authority** had no comments on the draft report.