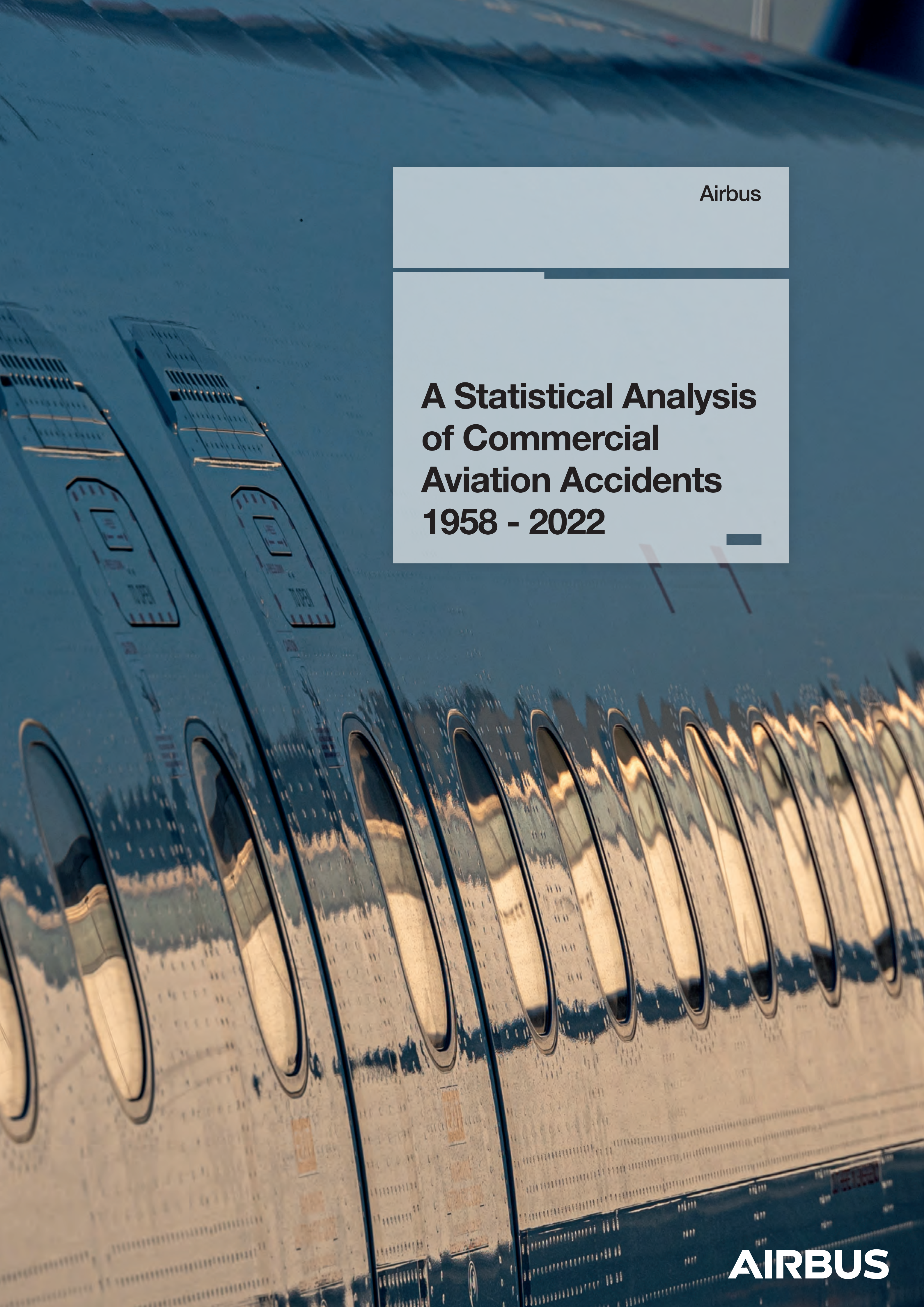

Airbus

A Statistical Analysis of Commercial Aviation Accidents 1958 - 2022

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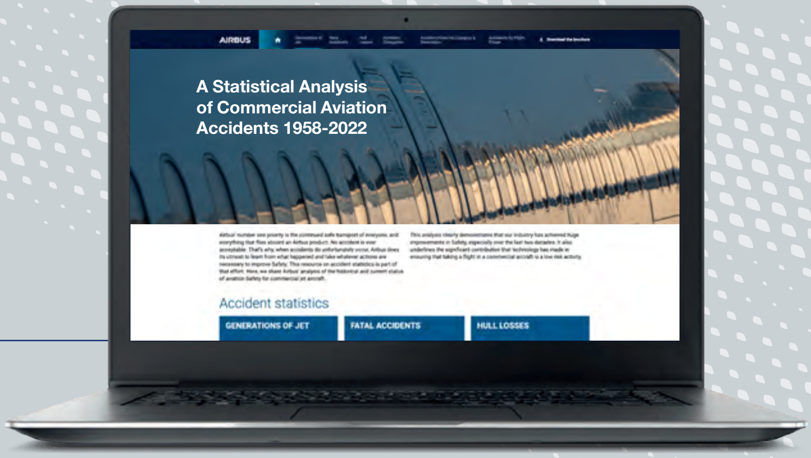

Statistical Analysis of Commercial Aviation Accidents

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AIRBUS

Contents

List of Graphs

Scope & Definitions

This publication provides the Airbus annual analysis of aviation accidents, with commentary on the year 2022, as well as a review of the history of the safety record for commercial aviation.

This analysis clearly demonstrates that the commercial aviation industry has achieved huge improvements in safety over recent decades. It also underlines the significant contribution that technology has made in ensuring that taking a flight in a commercial jet aircraft is a low-risk activity.

The goal of any review of aviation accidents is to help the industry further enhance the level of safety, therefore, an analysis of forecasted aviation macro trends is also provided. This highlights the key factors influencing the industry's consideration of detailed strategies for the further enhancement of aviation safety across the air transport system.

Scope of the Brochure

- **All Western-built commercial air transport jets that carry over 40 passengers (including cargo aircraft):**
  - Airbus: A220, A300, A300-600, A310, A318/319/320/321, A330, A340, A350, A380
  - Boeing: B707, B717, B720, B727, B737, B747, B757, B767, B777, B787
  - Bombardier CRJ series
  - British Aerospace: Avro RJ series, BAe 146
  - British Aircraft Corporation BAC-111
  - Convair 880/990
  - Dassault Mercure 100
  - De Havilland Comet
  - Embraer: E170, E175, E190, E195, ERJ 140, ERJ 145, ERJ 145XR
  - Fokker: F28, F70, F100, VFW 614
  - Hawker Siddeley Trident
  - Lockheed: L-1011
  - McDonnell Douglas: DC-8, DC-9, DC-10, MD-11, MD-80, MD-90
  - Sud-Aviation Caravelle
  - Vickers VC-10
  - Sukhoi Superjet

Note: Non-Western-built jets are excluded* due to lack of information, and business jets are not considered due to their particular operating environment.

- **Since 1958,** the first year with regularly scheduled transatlantic flights using commercial jet aircraft.
- **Revenue flights**
- **Operational accidents**
- **Hull loss** and **fatal** types of accidents

Source of Data

- The accident data was extracted from official accident reports, as well as ICAO, Cirium, and Airbus databases.
- Flight cycle data is revised on an annual basis as further information becomes available from operators.

*except Sukhoi Superjet

Definitions

- **Revenue flight:** A flight involving the transport of passengers, cargo or mail. Non revenue flights such as training, ferry, positioning, demonstration, maintenance, acceptance and test flights are excluded.
- **Operational accident:** An accident taking place between the time any person boards the aircraft with the intention of flight until the time all such persons have disembarked, excluding sabotage, military actions, terrorism, suicide and the like. This does not include any accident that is unclassified or unknown until the official investigation determines otherwise.
- **Fatal accident:** An operational accident in which at least one person is fatally or seriously injured as a result of:
  - being in the aircraft, or
  - direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
  - direct exposure to jet blast.

  This excludes the injuries that are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding on the aircraft outside the areas normally accessible by the passengers and crews.
- **Hull loss:** An event in which an aircraft is destroyed or damaged beyond economic repair. The threshold of economic repair decreases with the residual value of the aircraft. Therefore, as an aircraft ages, an event leading to damage that was economically repairable years before may be considered a hull loss.

Definition of Accident Categories

The accident categories described are based on standard ICAO definitions.
The seven categories listed below are the accident types that are the cause of most accidents.

Runway Excursion (RE)
A lateral veer-off or longitudinal overrun off the runway surface, and not primarily due to SCF or ARC.

Loss of Control in Flight (LOC-I)
Loss of aircraft control while in flight, and not primarily due to SCF.

Controlled Flight Into Terrain (CFIT)
In-flight collision with terrain, water, or obstacle without indication of loss of control.

Abnormal Runway Contact (ARC)
Any takeoff or landing involving abnormal runway contact, not primarily due to SCF, leading to an accident. Hard landings and tail strikes are included in this category.

Undershoot/Overshoot (USOS)
Touchdown off the runway surface in close proximity to the runway. It includes offside touchdowns.

System/Component Failure or Malfunction (SCF)
Failure or malfunction of an aircraft system or component, related to its design, the manufacturing process, or a maintenance issue, and which leads to an accident. SCF includes those related to powerplant (SCF-PP) and those which are not powerplant-related (SCF-NP).

FIRE (F-NI and F-POST)
Fire or smoke inside or outside of the aircraft, in flight or on the ground, and regardless of whether the fire results from an impact (F-POST) or not (F-NI).

2022 & Beyond

01

Traffic and Accidents in 2022

The number of flights on commercial jets in 2022 increased by almost 5 million when compared with 2021, but this is still around 20% below the number of flights recorded prior to the pandemic.

The industry is coming back with a positive traffic trend throughout 2022 but the number of flights was still lower than pre-pandemic levels.

There was a fatal accident in which all passengers and crews lost their lives that is yet to be classified. This is why, at the time of publication of this brochure, that accident is not yet included in the record.

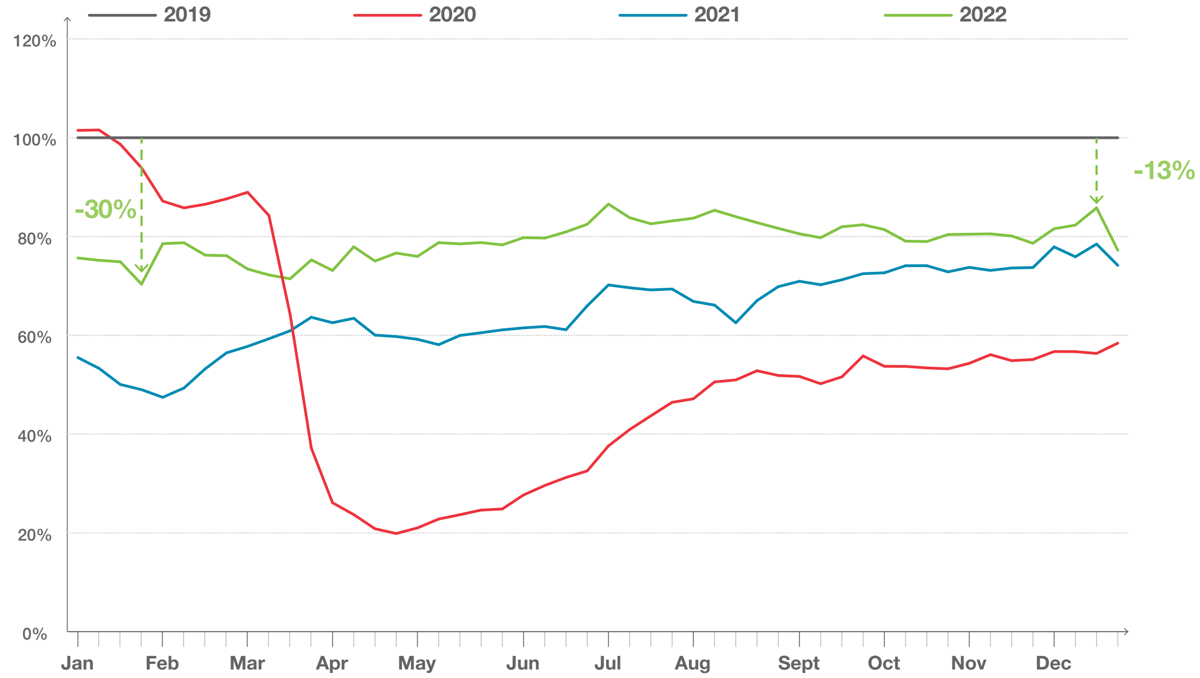
There were 2 fatal accidents recorded involving collisions with ground vehicles entering the runway. One of them was a hull loss and there were 6 additional hull losses.

There were no passenger or crew fatalities in the 2 recorded fatal accidents caused by vehicles entering the runway, however 4 people lost their lives on the ground. These accidents highlight the need to focus on safety across the entire air transport system and to always have a safe aircraft, safely operated, in a safe environment.

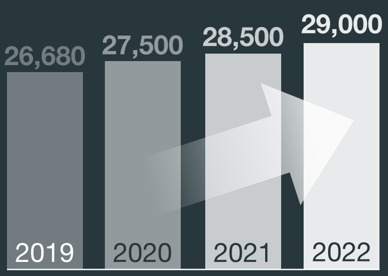
In years with low numbers of fatal accidents, it reinforces the need to continuously learn from accidents that could have been fatal, and make efforts to anticipate risks from reported in-service experience or the analysis of operational data.

It is important to consider that the statistics in one year are not always indicative of the overall safety trends. Analysis of aviation accident statistics over recent decades is more representative for evaluating the effectiveness of the safety initiatives that were implemented to mitigate threats, both before and during the recent Covid-19 crisis.

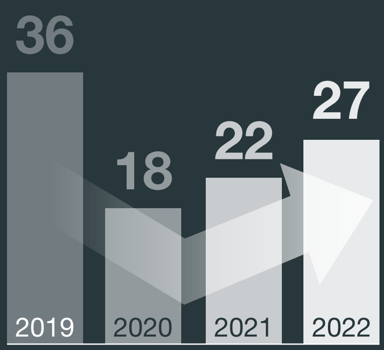
World traffic in flight cycles per week



Fleet & Traffic Evolution

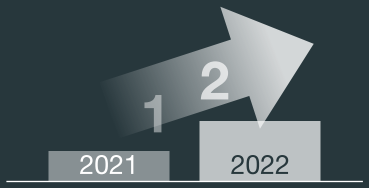


In-Service Fleet Aircraft
(including stored aircraft)



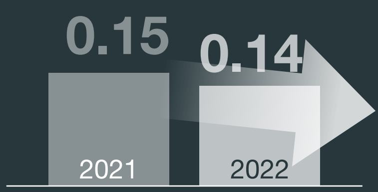
Flight Departures
(in millions)

Fatal Accidents



Fatal Accidents

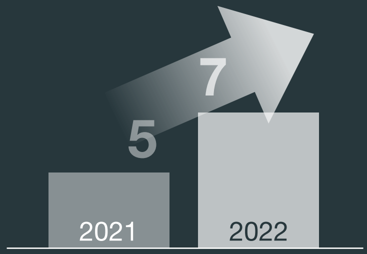
Yearly Fatal Accident Rate
(per million flights)



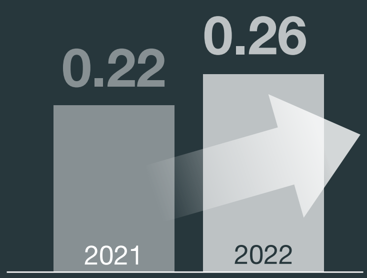
Gen3 Fatal Accident Rate
10yr Moving Average
(per million flights)

Gen4 Fatal Accident Rate
10yr Moving Average
(per million flights)

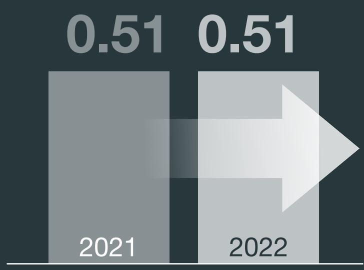
Hull Loss Accidents



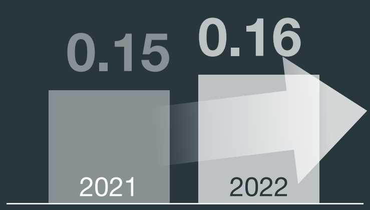
Hull Loss Accidents



Yearly Hull Loss Accident Rate
(per million flights)



Gen3 Hull Loss Accident Rate
10yr Moving Average
(per million flights)



Gen4 Hull Loss Accident Rate
10yr Moving Average
(per million flights)

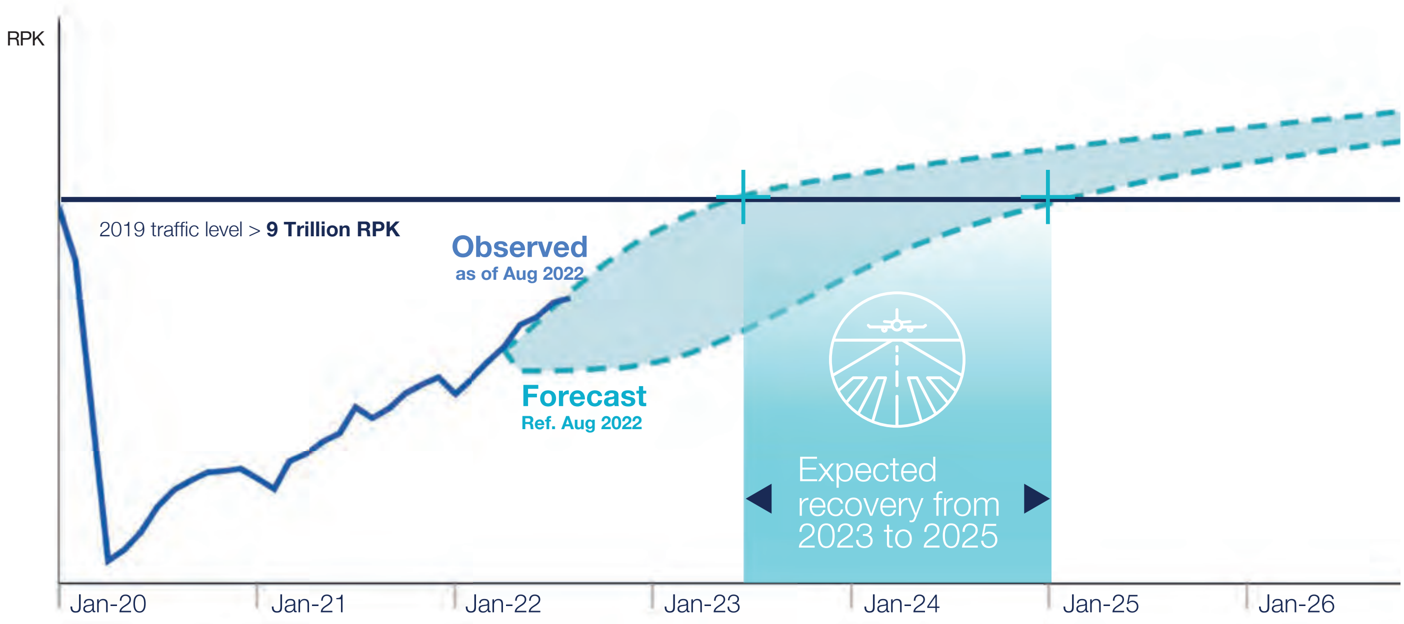
Outlook for 2023 and Beyond

The aviation sector shows a positive trend towards pre-pandemic levels, and this ramp-up also brings the challenge of managing the shortage of aviation professionals. The resilience of the industry relies on the trust of millions of passengers and crew who all expect zero accidents when they fly. This is why safety must always be the priority.

The increase in air travel and cargo demands shows a continuing trend towards a recovery in the number of flights to pre-pandemic levels. This welcome ramp-up also brings with it the challenge of managing a shortage of aviation personnel across the industry. This is a vulnerability that must be recovered in order to have a solid foundation of trained aviation professionals who will ensure safe operations as the industry moves forward in 2023 and beyond.

The resilience of the industry to recover from a crisis is a factor in attracting newcomers and talent to work in a sustainable aviation sector. This recovery relies on the trust of the millions of people who fly on a plane and all expect to reach their destination safely.

Even if the accident rate remains very low across the years affected by the Covid-19 crisis, every effort must be made to avoid the trap of complacency and to always keep safety first. All actors across the air transport system must, therefore, share the same ambition: continuous enhancement of aviation safety in the quest to reach zero accidents.



A need to attract more people to aviation careers.

It is fundamental for the industry to maintain and develop competencies of all aviation professionals, in order to secure safe and efficient operations.

The natural attrition of aviation professionals is further exacerbated by early retirements and career changes that occurred in response to managing the conditions of the recent pandemic.

Attracting new aviation professionals with suitable competencies to ensure safe and efficient flight operations is vital to our industry. Demand has been continuous and increasing, especially during the last 20 years of growth despite the global financial crisis and Covid-19 situation.

In order to manage the recovery to a pre-pandemic level of operations seen in 2019, and to continue a safe ramp-up for further growth in the aviation sector, the graph below shows a projection of the global workforce requirements for the next 20 years with a forecast by region.

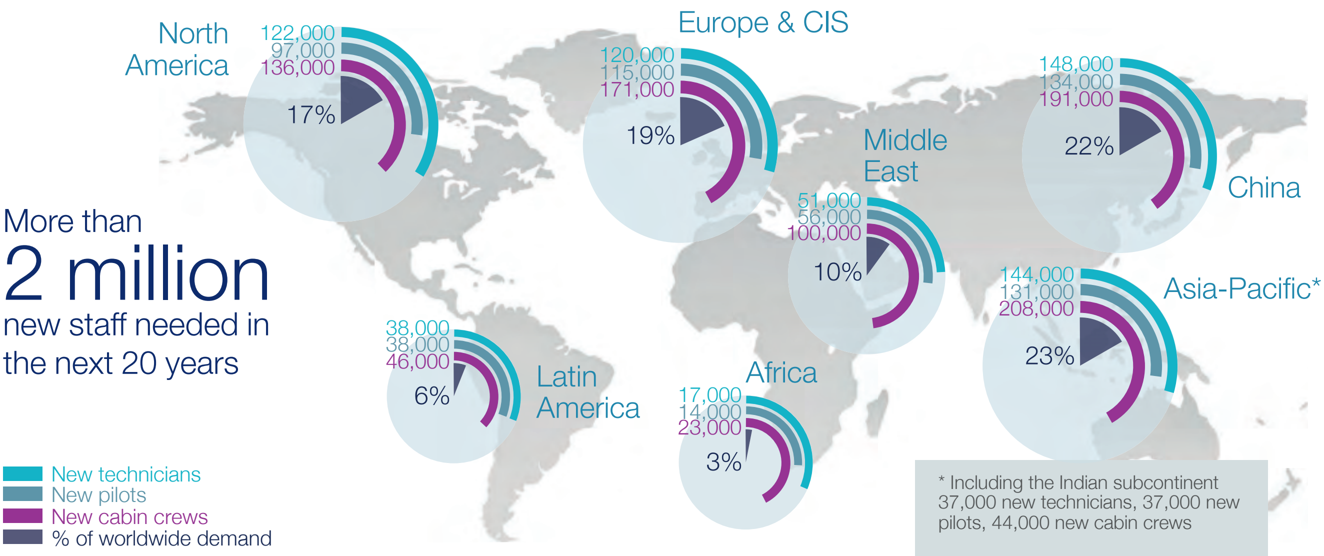
Workforce needed 2022-2041

Technicians needed
640,000
(88 new technicians every day on average)

Pilots needed
585,000
(80 new pilots every day on average)

Cabin crew needed
875,000
(120 new cabin crew every day on average)

More than
2 million
new staff needed in the next 20 years



Passenger aircraft above 100 by seats and freighter with a payload above 10t

Commercial Aviation Accidents 1958-2022

02

Evolution of the Number of Flights and Accidents

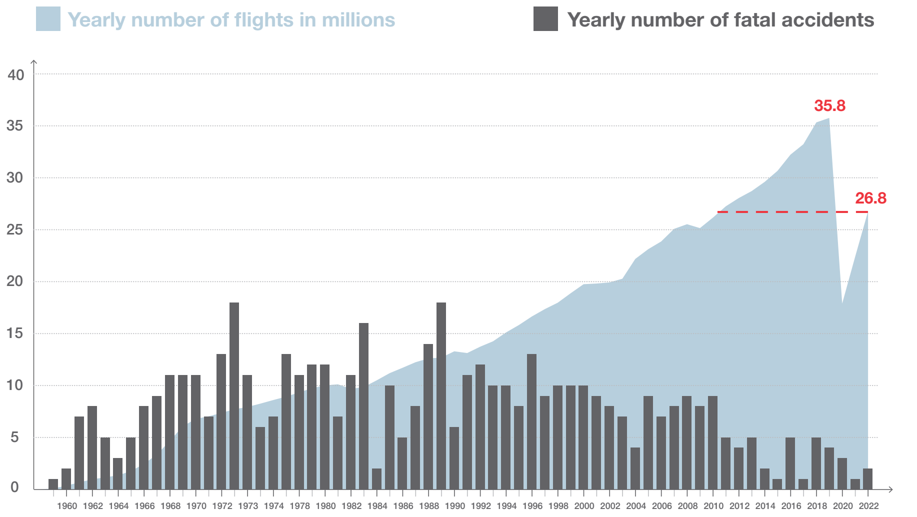
The number of accidents today is significantly lower than a comparable year in the previous decade.

The number of flights on commercial jet aircraft was continuously growing prior to the effects of the pandemic. In spite of this growth, the number of accidents was decreasing each decade.

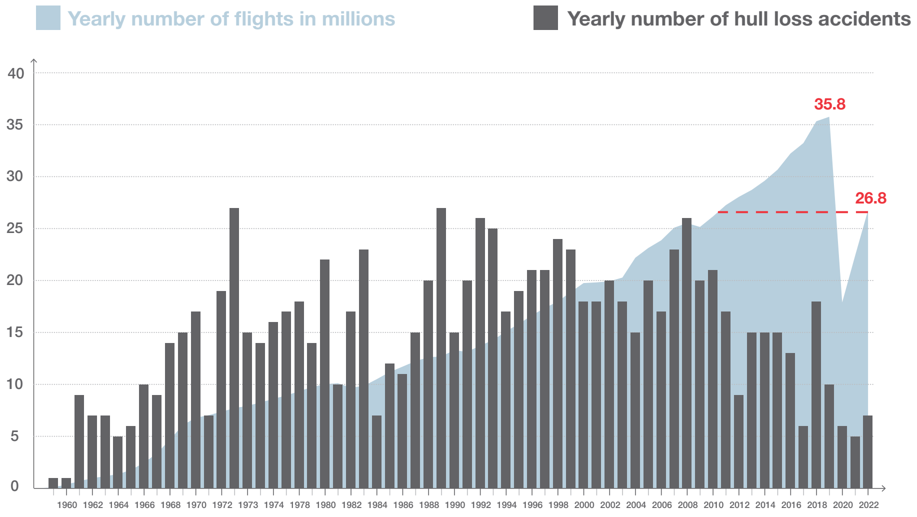
The number of flights in 2022 was still around 20% lower than the flights operated in 2019. In 2022, there were 6 commercial jet hull loss accidents without fatalities recorded and 2 fatal accidents that were due to vehicles entering the runway. There was a fatal accident, where all passengers and crews lost their lives, which is not recorded because it is yet to be classified.

As the number of accidents and flights will vary each year, accident rates are more relevant than reviewing the number of accidents per year when analyzing trends.

Fatal



Hull loss



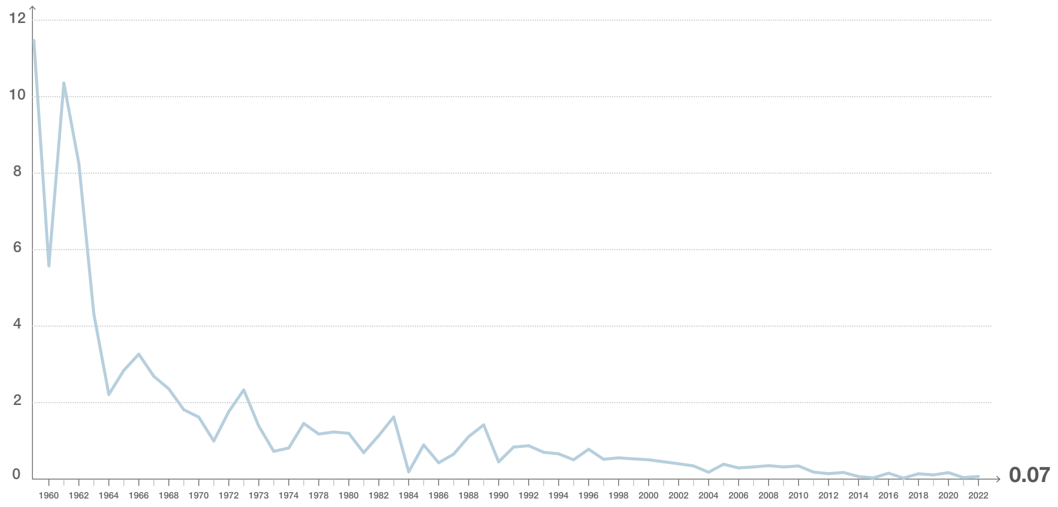
Evolution of the Yearly Accident Rate

The rate of fatal accidents and hull losses is steadily decreasing over time.

There were far fewer flights in the 1960s, but a peak in the accident rates is shown due to the lower number of flights and the higher number of accidents recorded during this period. However, the volume of flights over recent decades is sufficient to show that the accident rate is continually decreasing.

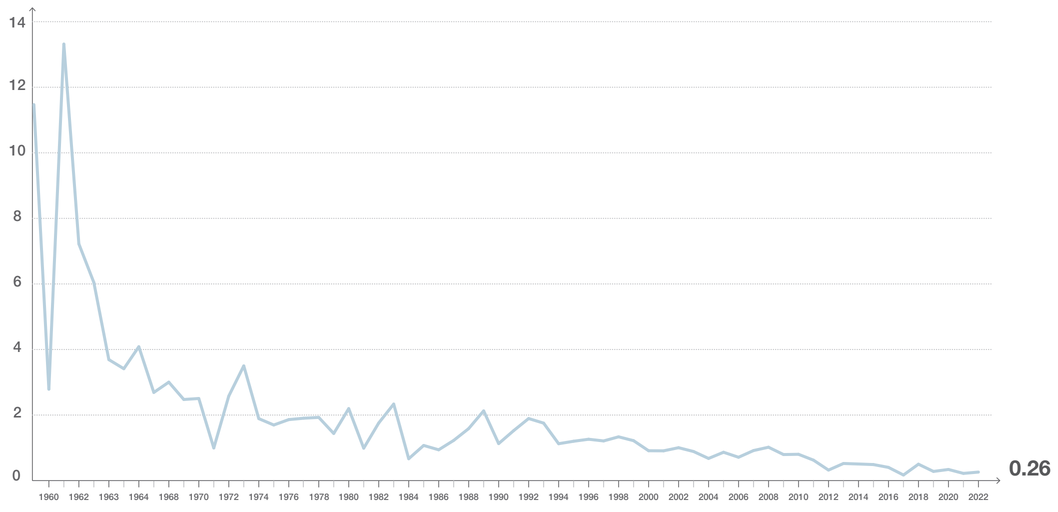
Fatal

Yearly fatal accident rate per million flights



Hull loss

Yearly hull loss accident rate per million flights



Four Generations of Jet

Early Commercial Jets

Generation 1

From 1952

Dials and gauges in cockpit, Early auto-flight systems.
Comet, Caravelle, BAC-111, Trident, VC-10, B707, B720, DC-8, Convair 880/990

Glass Cockpit & FMS

Generation 3

From 1980

Electronic cockpit displays, improved navigation performance and Terrain Avoidance Systems, to reduce CFIT accidents.
A300-600, A310, Avro RJ, F70, F100, B717, B737 Classic & NG/MAX, B757, B767, B747-400/-8, Bombardier CRJ, Embraer ERJ, MD-11, MD-80, MD-90

More Integrated Auto-Flight

Generation 2

From 1964

More elaborate auto-pilot and auto-throttle systems.

Concorde, A300, Mercure, F28, BAe146, VFW 614, B727, B737-100/-200, B747-100/-200/-300/SP, L-1011, DC-9, DC-10

Fly-By-Wire

Generation 4

From 1988

Fly-By-Wire technology enabled flight envelope protection to reduce LOC-I accidents.

A220, A318/A319/A320/A321, A330, A340, A350, A380, B777, B787, Embraer E-Jets, Sukhoi Superjet

Evolution of Commercial Jet Aircraft

Airbus aircraft flew 78% of the flights made by generation 4 commercial jet aircraft in 2022.

There were around 27 million flight departures in 2022, but this remains around 20% lower than the almost 36 million flights in 2019 before the pandemic. 15 million flights were made by generation 4 jets, almost 12 million of which were Airbus aircraft.

The largest percentage of flights in recent years were made using the latest generation 4 commercial jets, which have the lowest accident rate. As the percentage increases over the next decade, this should help to sustain further decreases in the overall accident rate for commercial air transport.

The continual reduction in accident rates shown on the previous pages has been achieved by an ongoing commitment of the commercial aviation industry to enable a safe aircraft to be safely operated in a safe air transport system.

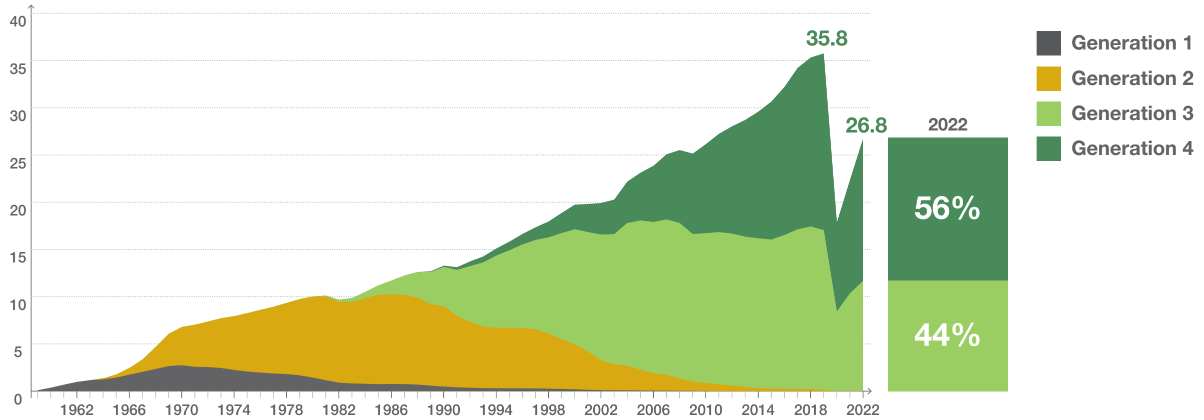
A notable part of this success is due to effective regulation, a strong safety culture, and improvements in training. Technological advances are also a crucial enabler for enhancing the level of safety. In particular, technologies introduced in aircraft systems intentionally evolved with improving safety as their aim.

The first generation of commercial jet aircraft were designed in the 1950s and '60s with system technologies, which were limited in their capabilities by the analogue electronics of that era. A second generation of aircraft quickly appeared with improved autoflight systems.

The third generation of aircraft was introduced in the early 1980s. This generation took advantage of digital technologies to introduce glass cockpits with flight management systems and navigation displays, which significantly improved navigation capabilities and position awareness. Combined with the Terrain Awareness and Warning System (TAWS), these evolutions were key to reducing Controlled Flight Into Terrain (CFIT) accidents.

The fourth and latest generation of commercial jet aircraft first entered into service in 1988 with the Airbus A320. Generation 4 aircraft use fly-by-wire technology with flight envelope protection functions. These functions protect against Loss Of Control In-flight (LOC-I) accidents. Fly-by-wire technology is now the industry standard and it is used on every currently produced Airbus model, Boeing B777 and B787, Embraer E-Jets, and the Sukhoi Superjet.

Yearly number of flights per aircraft generation (in millions)



Evolution of Accident Rates by Aircraft Generation

Advances in technology have helped to reduce accident rates for each generation.

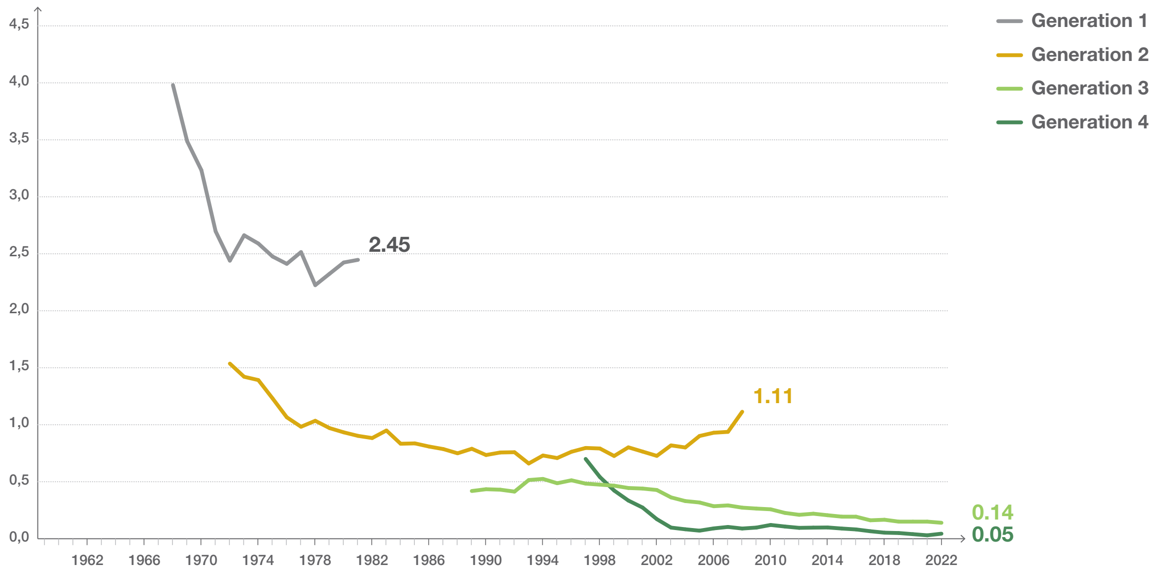
Calculating the 10 year moving average accident rate provides a clearer picture of an overall trend. The data shows when an aircraft generation has recorded more than 1 million flights in a year and begins from the tenth year after the entry into service of each generation.

For example, the 10 year moving average accident rates for generation 4 commercial jet aircraft are shown from 1997, which was the tenth year in service for the A320 aircraft.

The 10 year moving average accident rates for today's generation 4 aircraft are around three times lower than the rates recorded for generation 3 aircraft.

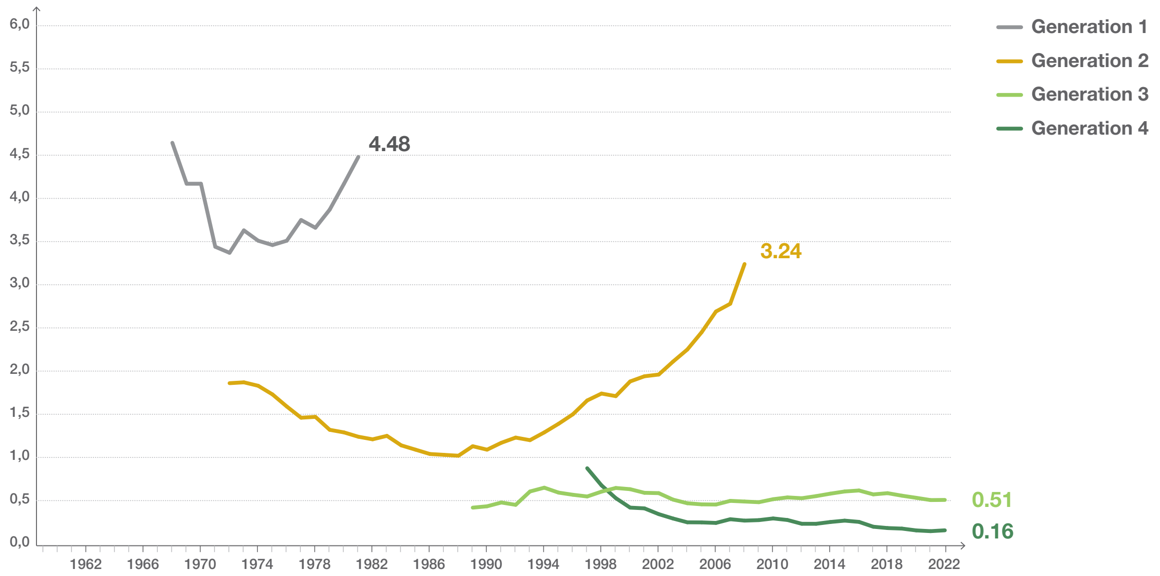
Fatal

10 year moving average fatal accident rate (per million flights) per aircraft generation



Hull loss

10 year moving average hull loss accident rate (per million flights) per aircraft generation



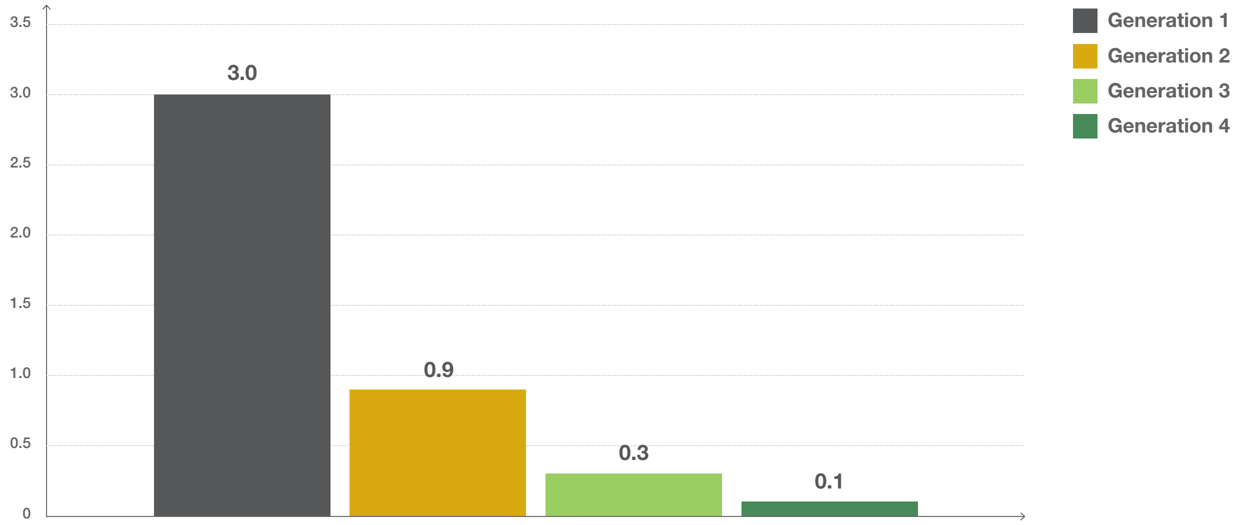
How Technology Helped Reduce Accidents

Statistics over the life of each aircraft generation show a significant improvement in the level of safety, notably since the introduction of generation 3 aircraft, further enhanced by the latest generation 4 aircraft.

Comparison of accident rates by generation of aircraft provides a clear illustration of the value of commercial aviation industry investments in technology to improve safety.

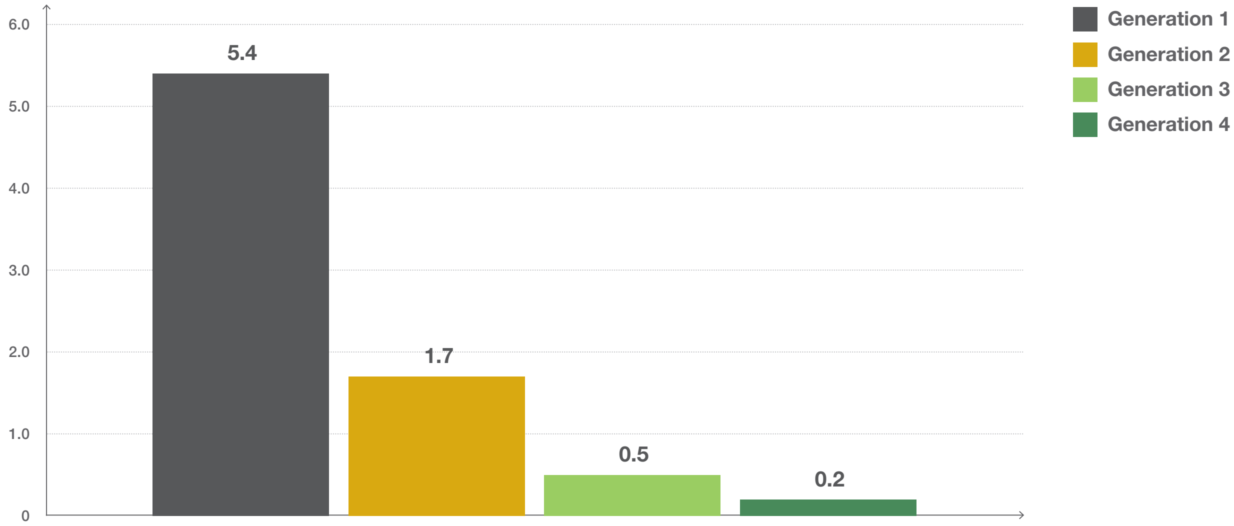
Fatal

Fatal accident rate (per million flights) per aircraft generation 1958-2022



Hull loss

Hull loss accident rate (per million flights) per aircraft generation 1958-2022



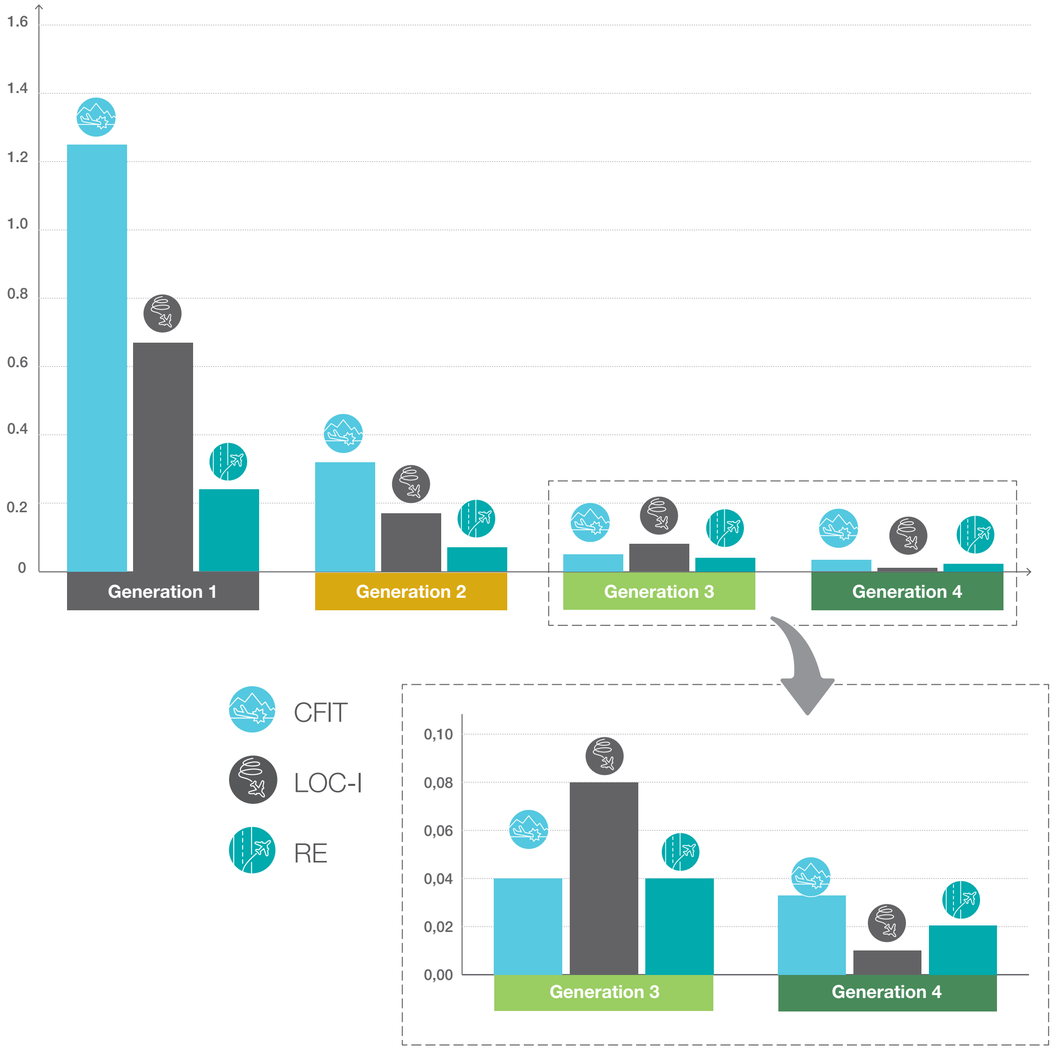
How Technology Addressed the Major Causes of Accidents

Accident rates were further reduced with the introduction of new technologies on each generation of aircraft.

The introduction of Flight Management System (FMS), improved navigation displays, and the Terrain Awareness and Warning System (TAWS) with generation 3 aircraft significantly reduced the number of CFIT fatal accidents when compared to the previous generation 1 and generation 2 aircraft.

The benefits of fly-by-wire technologies and energy management systems, which were first introduced on generation 4 aircraft, show a lower rate of LOC-I and RE accidents when compared with the previous generation 3 aircraft. More detailed analysis about the influence of these technologies on reducing the accident rate is introduced in section 3.

Average fatal accident rate (per million flights) per accident category 1958-2022



-86%

CFIT accident rate
from generation 2
to generation 3

-90%

LOC-I accident rate
from generation 3
to generation 4

Commercial Aviation Accidents Over the Last 20 Years

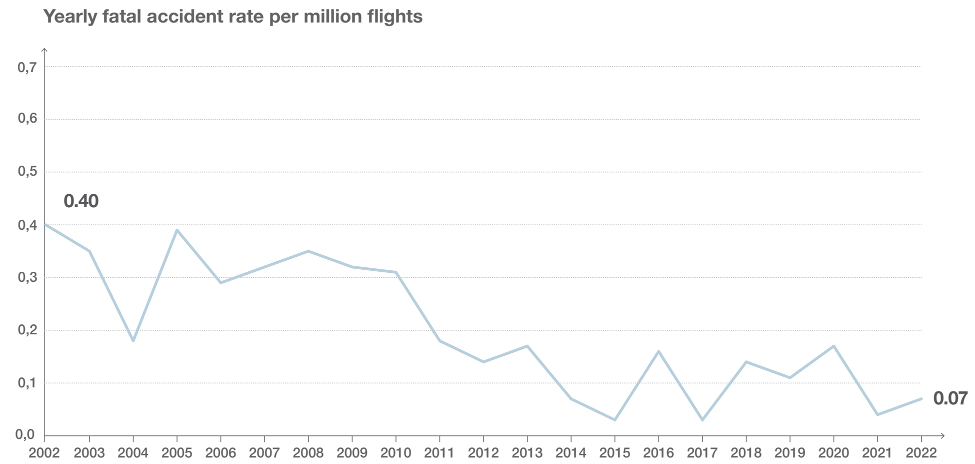
03

Evolution of the Yearly Accident Rate

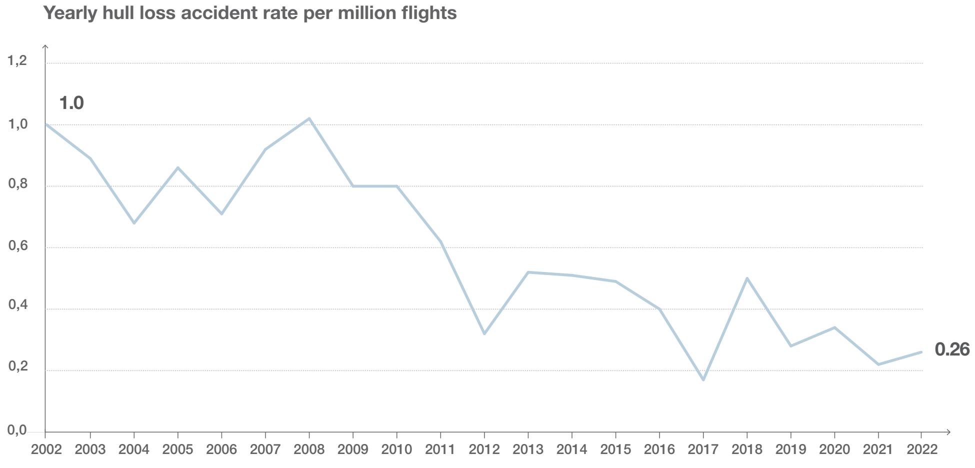
A significant reduction in fatal and hull loss accidents was achieved across the commercial aviation industry since 2002.

Despite the reduction of the yearly accident rate since 2002, rates recorded for the years affected by the pandemic show a varying range. This may be partially attributed to the variability of the number of flights recorded in each year. This also shows that the accident rate for a single year is not indicative of an overall safety trend.

Fatal



Hull loss



Evolution of Accident Rates by Aircraft Generation

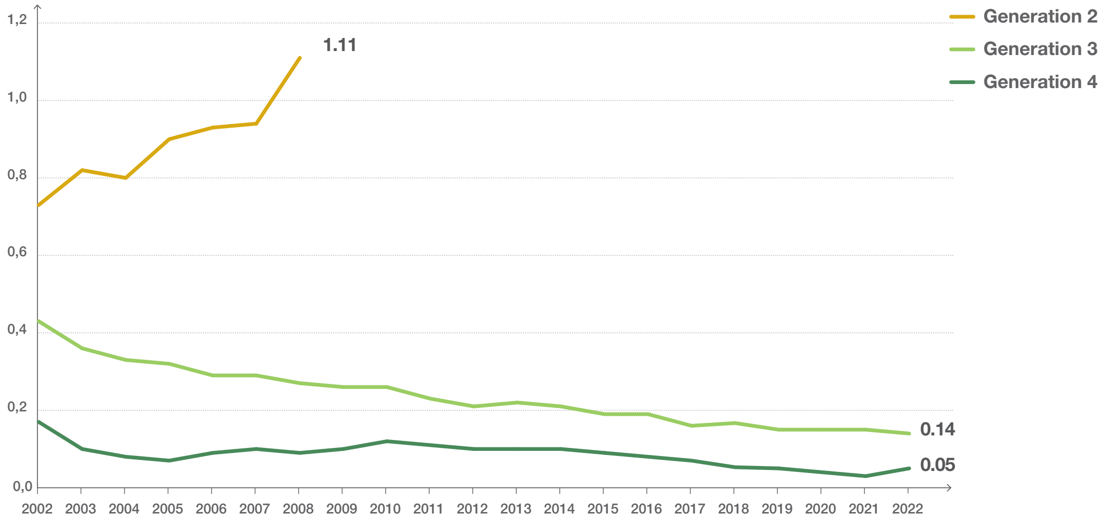
Generation 4 aircraft accident rates are 3 times lower than generation 3 aircraft accident rates.

Generation 3 aircraft technology helped to reduce accident rates by introducing glass cockpits with navigation displays and flight management systems. Generation 4 aircraft technology helped to further reduce accident rates by introducing fly-by-wire technology, which made flight envelope protection possible.

The accident rate for both generation 3 and 4 aircraft remained historically low in 2022. Generation 4 commercial jet aircraft flew 56% of the flights in 2022 and this figure will continue to increase over the next decades. Even if there was an increase in the fatal accident rate due to 2 fatal accidents caused by vehicles entering the runway, these were not aircraft generation related events. The overall accident rate for commercial air transport should continue to decrease due to the noticeably lower rate of generation 4 aircraft.

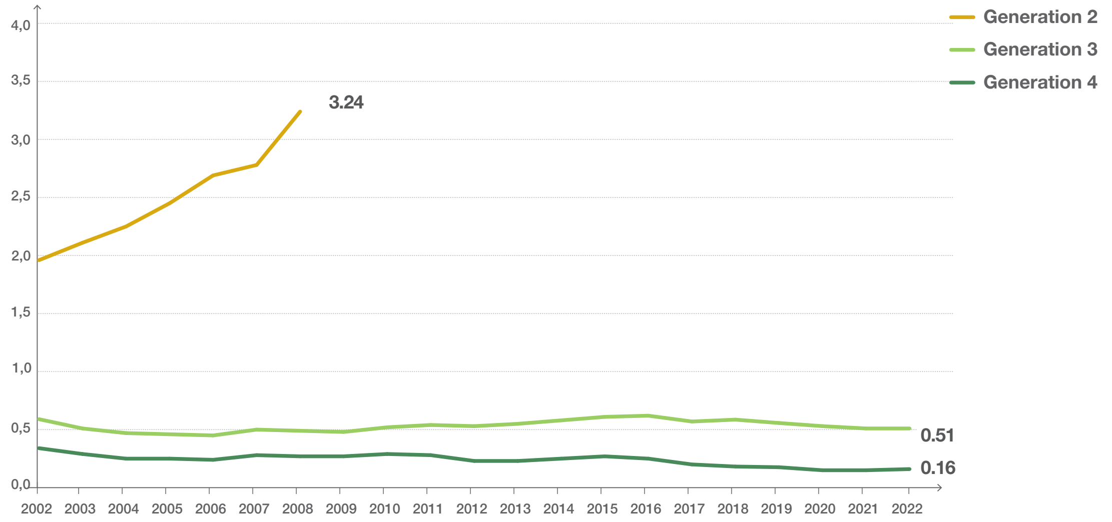
Fatal

10 year moving average fatal accident rate (per million flights) per aircraft generation



Hull loss

10 year moving average hull loss accident rate (per million flights) per aircraft generation



Accidents by Flight Phase

Definitions of Flight Phases

The flight phases described below are based on standard ICAO definitions:

- **Standing:** The phase of flight prior to pushback or taxi, or after arrival, at the gate, ramp, or parking area, while the aircraft is stationary.
- **Taxi:** The aircraft is moving under its own power prior to takeoff or after landing. This phase includes the taxi to runway, the taxi to takeoff position and the taxi from runway until the aircraft stops moving under its own power.
- **Takeoff:** From the application of takeoff power, through rotation and to an altitude of 35 feet above runway elevation or until gear-up selection, whichever comes first. This phase includes rejected takeoff.
- **Initial climb:** From the end of the takeoff phase to the first prescribed power reduction, or until reaching 1000 feet above runway elevation, whichever comes first.
- **Enroute:** From completion of initial climb through cruise altitude and completion of controlled descent to the Initial Approach Fix (IAF).
- **Approach:** From the IAF to the point of transition from nose-low to nose-high attitude immediately prior to the flare above the runway.
- **Landing:** The phase of flight from the point of transition from nose-low to nose-up attitude, immediately before landing (flare), through touchdown and until the aircraft exits the landing runway or when power is applied for takeoff in the case of a touch-and-go landing, whichever occurs first.

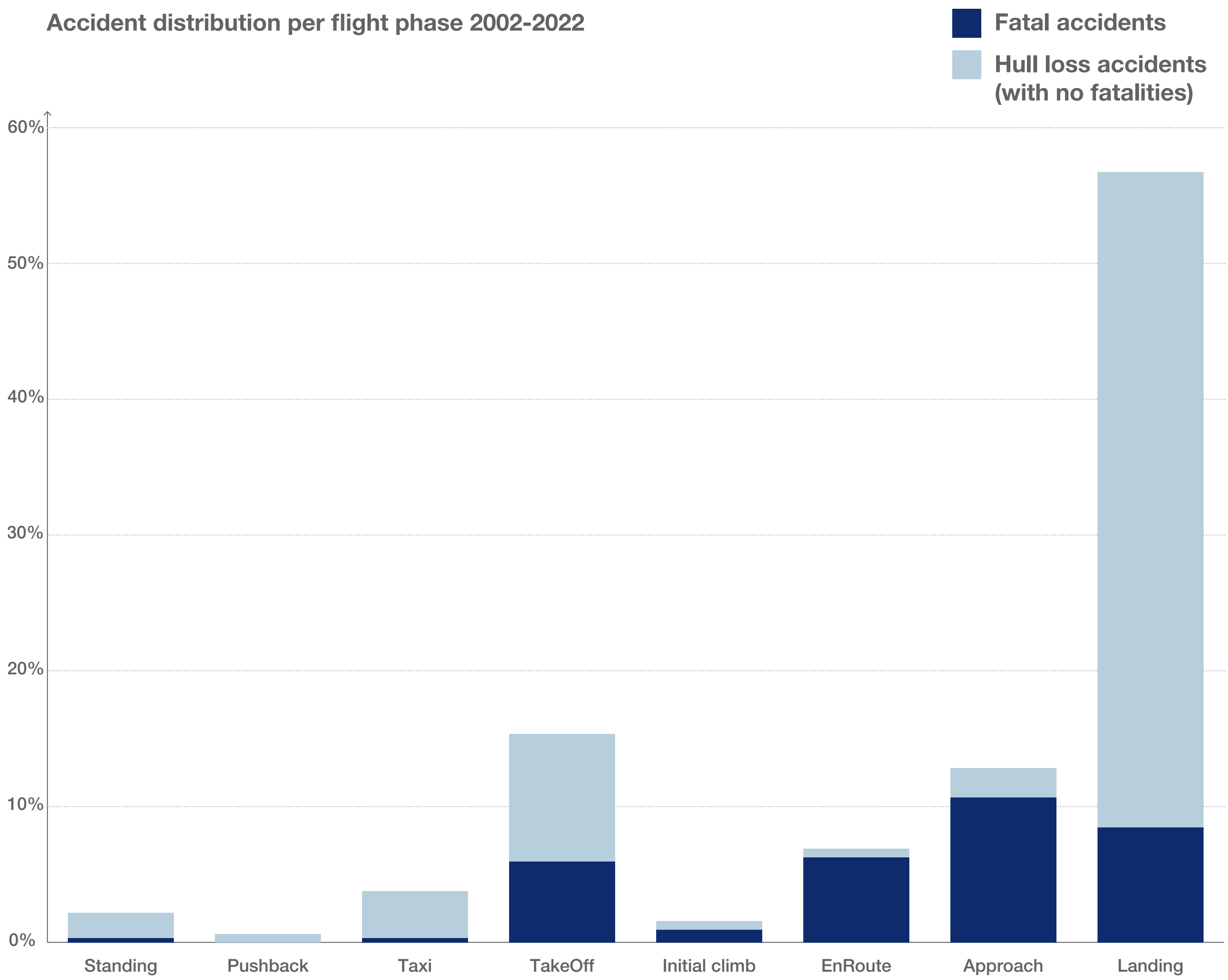
Most of the accidents over the last 20 years occurred during approach and landing phases.

Of the 7 hull loss accidents recorded in 2022, 5 occurred in the landing phase and 2 occurred during the take-off phase.

Approach and landing are highly complex flight phases, which place significant demands on the crew in terms of navigation, aircraft configuration changes, communication with Air Traffic Control, congested airspace, and degraded weather conditions.

This combination of high workload and the increased potential for unanticipated events can create a complex interplay of contributing factors, which may lead to an accident.

Accident distribution per flight phase 2002-2022



Accidents by Accident Category

The leading cause of fatal accidents over the last 20 years was LOC-I.

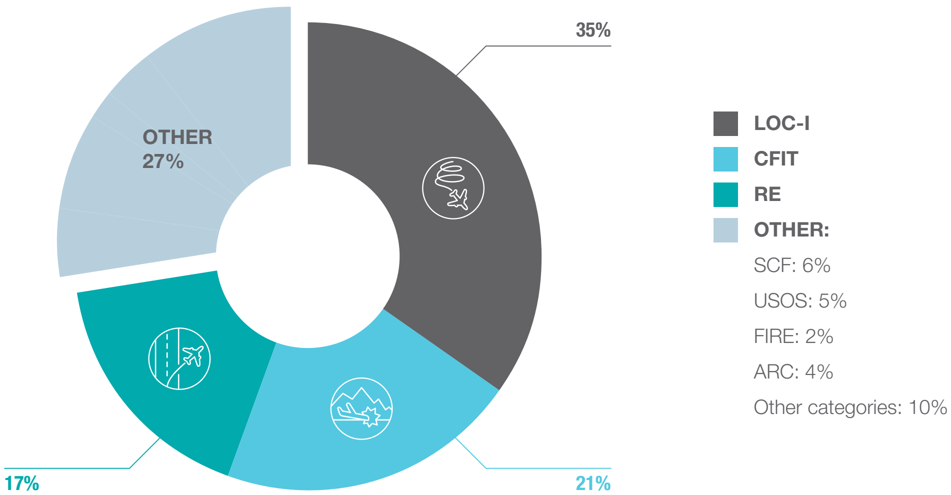
LOC-I accidents have significantly reduced for generation 4 aircraft enabled by fly-by-wire technologies.

CFIT accidents are the second largest category of accidents. The number of these accidents is decreasing with the continued development of navigation and Terrain Awareness and Warning System (TAWS) technologies, which are available on both generation 3 and generation 4 aircraft.

Runway Excursions (RE), including lateral and longitudinal types, are the third major cause of fatal accidents and the primary cause of hull losses. Emerging technologies, both energy-based and performance-based, show promising trends for preventing longitudinal RE accidents.

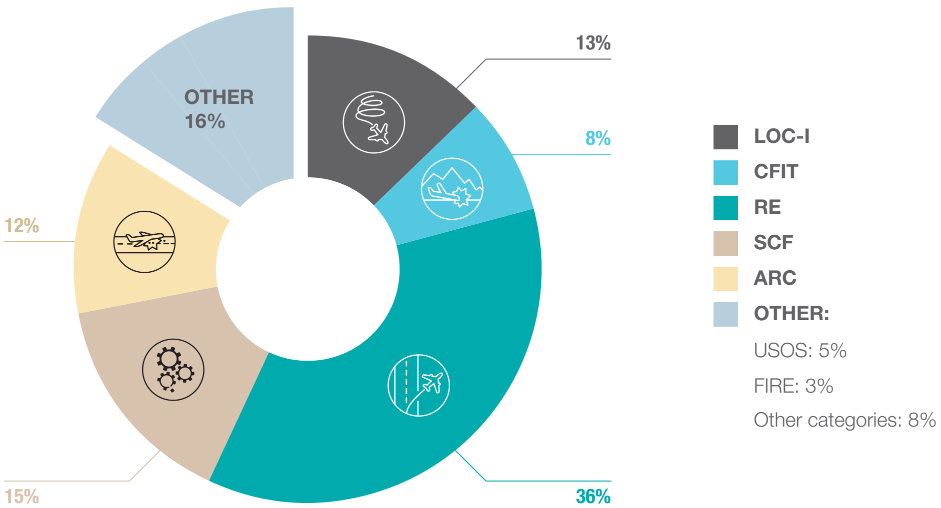
Fatal

Fatal accident distribution per accident category 2002-2022



Hull loss

Hull loss accident distribution per accident category 2002-2022



Evolution of the Main Accident Categories

The fatal accident rate for CFIT accidents reduced by 94%, and the LOC-I fatal accident rate reduced by 65% over the last 20 years.

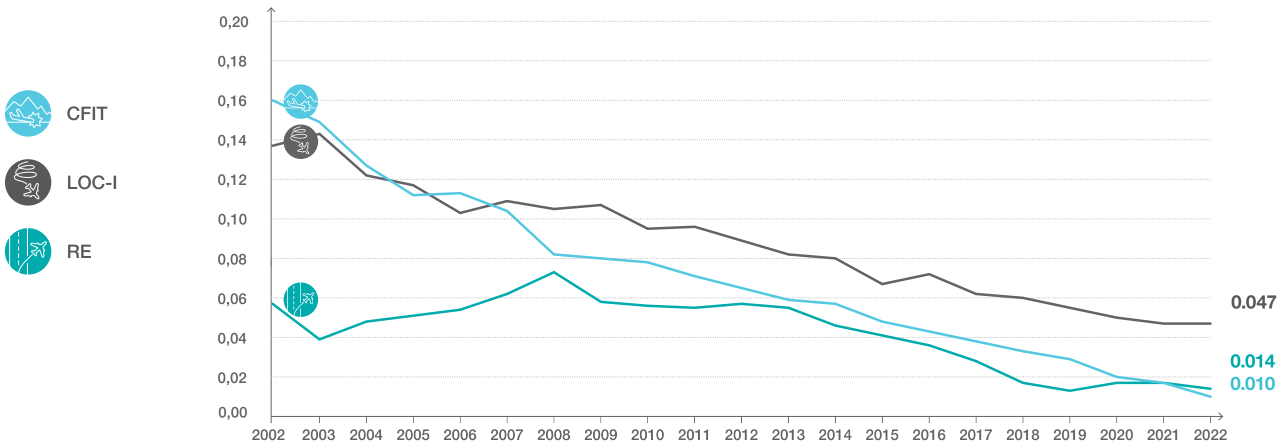
The proportion of flights flown by aircraft equipped with Flight Management System (FMS) and Terrain Awareness and Warning System (TAWS) technologies, which help to prevent CFIT accidents, has grown from 68% to 99% over the last 20 years.

Over half of all flights in 2022 were made using generation 4 commercial jet aircraft equipped with fly-by-wire enabled technologies. The rate of LOC-I accidents is 90% lower for generation 4 aircraft when compared with generation 3 aircraft. As the proportion of flights made using generation 4 aircraft continues to grow, the rate of LOC-I accidents is expected to further decrease.

New technologies to address the causes of RE accidents were first deployed over 10 years ago. The number of aircraft equipped with RE prevention technologies today represents approximately 11% of the in-service fleet. Even if the rate increased in 2022, there is an overall decreasing trend for hull losses due to RE accidents. Aircraft fitted with RE prevention technologies have not recorded any RE related fatal or hull loss accidents over the last decade.

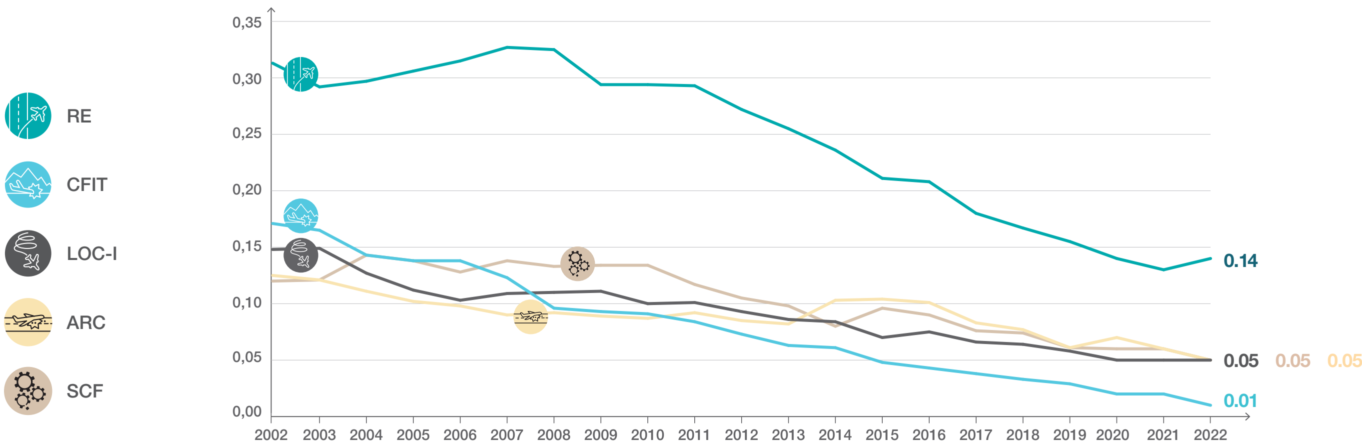
Fatal

10 year moving average fatal accident rate (per million flights) per accident category



Hull loss

10 year moving average hull loss accident rate (per million flights) per accident category



Controlled Flight Into Terrain (CFIT) Accident Rates

The introduction of glass cockpits, FMS, and TAWS has helped to reduce the CFIT fatal accident rate by 86%

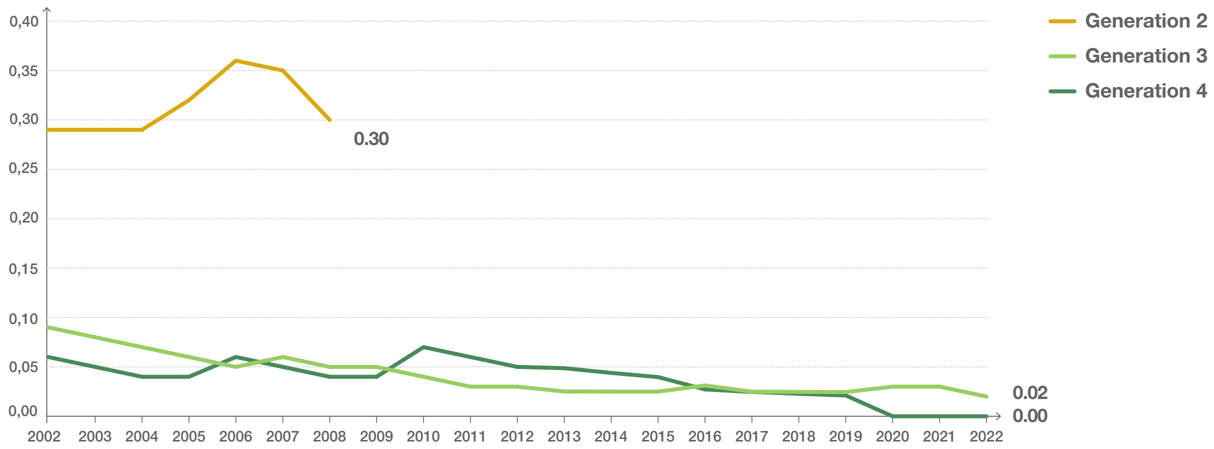
Technologies to reduce CFIT were introduced progressively with Terrain Awareness and Warning System (TAWS).

Glass cockpits installed on generation 3 aircraft improved navigation performance due to the introduction of a Flight Management System (FMS) and navigation displays that helped to further reduce the CFIT accident rates.

There were no fatal or hull loss CFIT accidents recorded for generation 4 aircraft in the last decade. Therefore, the 10-year moving average rate is zero for this generation in 2022.

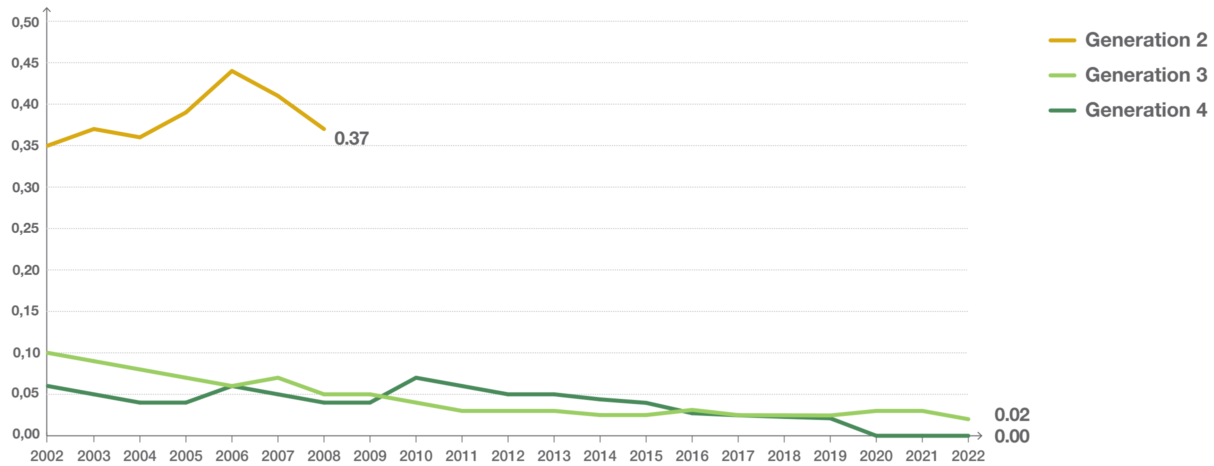
Fatal

10 year moving average CFIT fatal accident rate (per million flights) per aircraft generation



Hull loss

10 year moving average CFIT hull loss accident rate (per million flights) per aircraft generation



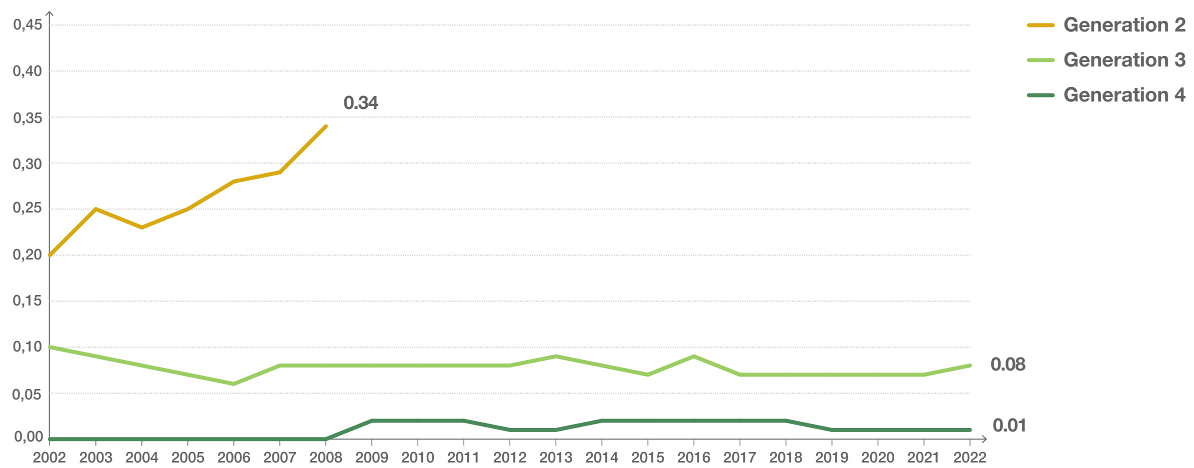
Loss Of Control In-flight (LOC-I) Accident Rates

Flight envelope protection has helped reduce LOC-I fatal accident rates by 90% for generation 4 aircraft.

Generation 4 aircraft have accumulated over 30 years of in-service experience since the A320 aircraft first entered into service in 1988. This represents more than 238 million accumulated flights by the end of 2022, which is a strong statistical basis illustrating the significant safety benefit of fly-by-wire enabled and flight envelope protected aircraft to address LOC-I accidents.

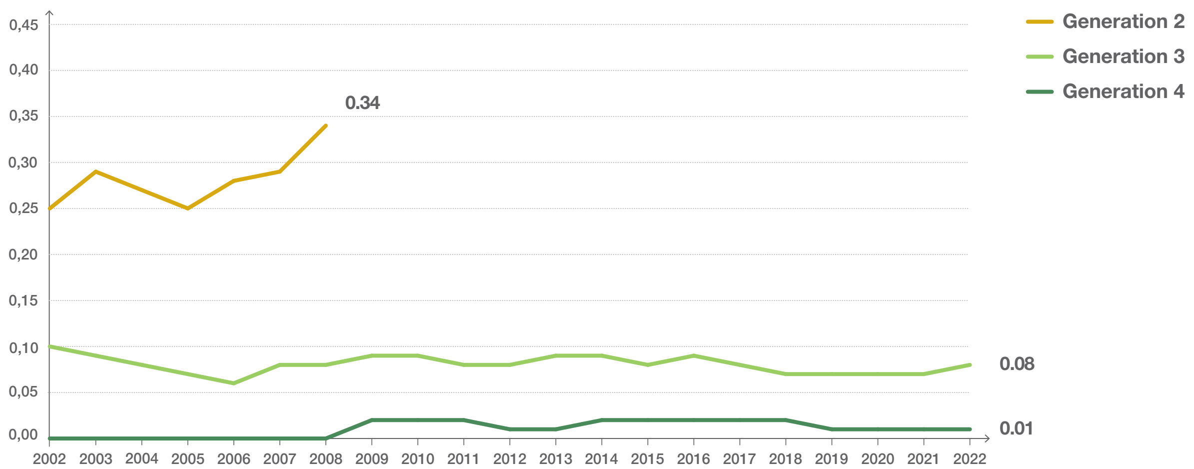
Fatal

10 year moving average LOC-I fatal accident rate (per million flights) per aircraft generation



Hull loss

10 year moving average LOC-I hull loss accident rate (per million flights) per aircraft generation



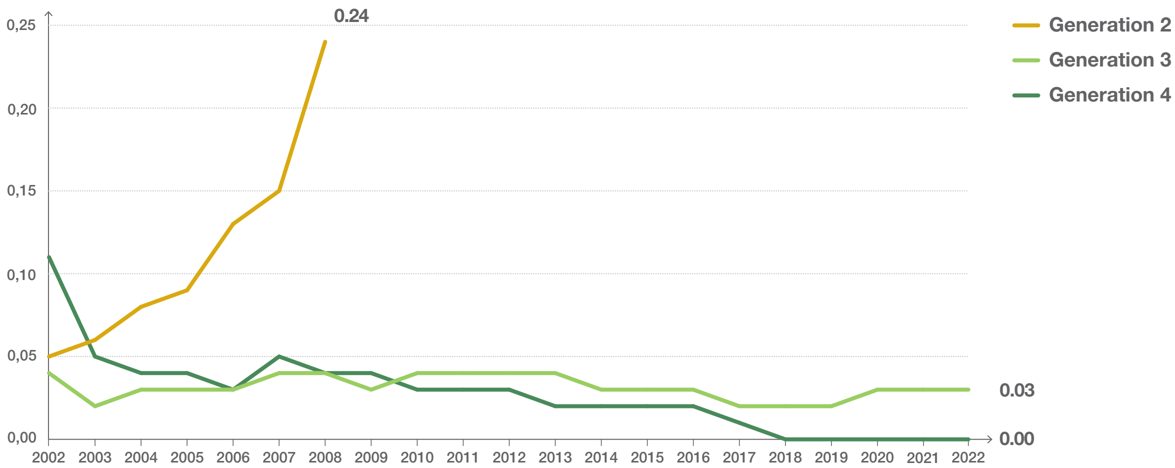
Runway Excursion (RE) Accident Rates

Technologies to reduce RE accidents have been available for over 15 years.

Most longitudinal RE accidents are related to aircraft energy management. An improvement of RE accident rates should be expected with the introduction of real-time energy and landing performance-based warning systems, such as the Runway Overrun Protection System (ROPS) available for Airbus aircraft. In 2022, the number of aircraft equipped with ROPS increased to 11% of the worldwide fleet.

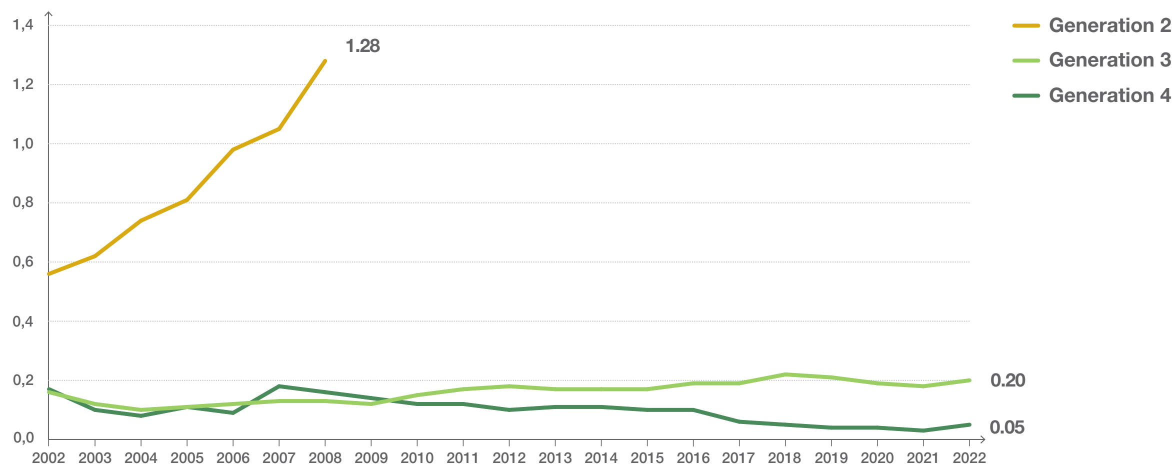
Fatal

10 year moving average RE fatal accident rate (per million flights) per aircraft generation



Hull loss

10 year moving average RE hull loss accident rate (per million flights) per aircraft generation



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