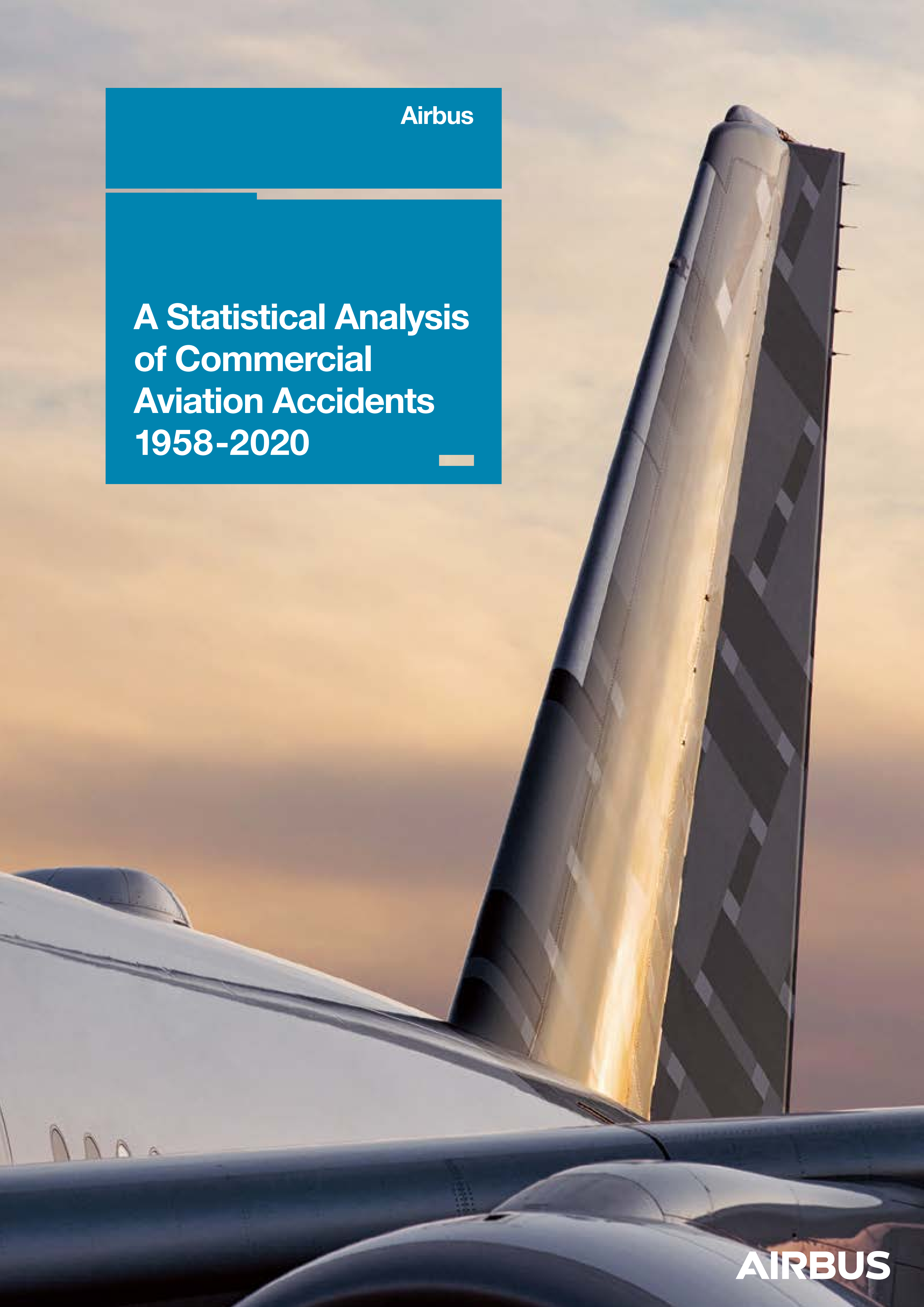
Airbus

A Statistical Analysis of Commercial Aviation Accidents 1958-2020



AIRBUS

Contents

	List of Graphs	**03**
	Scope & Definitions	**04**
1	**2020 & Beyond**	**07**
	Traffic and Accidents in 2020	08
	Outlook for 2021 and Beyond	11
2	**Commercial Aviation Accidents 1958-2020**	**13**
	Evolution of the Number of Flights and Accidents	14
	Evolution of the Yearly Accident Rate	15
	Evolution of Commercial Jet Aircraft	18
	Evolution of Accident Rates by Aircraft Generation	19
	How Technology Helped Reduce Accidents	20
	How Technology Addressed the Major Causes of Accidents	21
3	**Commercial Aviation Accidents Over the Last 20 Years**	**23**
	Evolution of the Yearly Accident Rate	24
	Evolution of Accident Rates by Aircraft Generation	25
	Accidents by Flight Phase	26
	Accidents by Accident Category	28
	Evolution of the Main Accident Categories	29
	Controlled Flight Into Terrain (CFIT) Accident Rates	30
	Loss Of Control In-flight (LOC-I) Accident Rates	31
	Runway Excursion (RE) Accident Rates	32

List of Graphs

1 **2020 & Beyond** 07

World traffic in flight cycles per week 08

2 **Commercial Aviation Accidents 1958-2020** 13

Yearly number of fatal accidents 1959-2020 14
Yearly number of hull losses 1959-2020 14
Yearly fatal accident rate per million flights 15
Yearly hull loss rate per million flights 15
Yearly number of flights per aircraft generation (in millions) 18
10 year moving average fatal accident rate (per million flights) per aircraft generation 19
10 year moving average hull loss rate (per million flights) per aircraft generation 19
Fatal accident rate (per million flights) per aircraft generation 1958-2020 20
Hull loss accident rate (per million flights) per aircraft generation 1958-2020 20
Average fatal accident rate (per million flights) per accident category 1958-2020 21

3 **Commercial Aviation Accidents Over the Last 20 Years** 23

Yearly fatal accident rate per million flights 24
Yearly hull loss accident rate per million flights 24
10 year moving average fatal accident rate (per million flights) per aircraft generation 25
10 year moving average hull loss accident rate (per million flights) per aircraft generation 25
Accident distribution per flight phase 2001-2020 27
Fatal accident distribution per accident category 2001-2020 28
Hull loss accident distribution per accident category 2001-2020 28
10 year moving average fatal accident rate (per million flights) per accident category 29
10 year moving average hull loss rate (per million flights) per accident category 29
10 year moving average CFIT fatal accident rate (per million flights) per aircraft generation 30
10 year moving average CFIT hull loss rate (per million flights) per aircraft generation 30
10 year moving average LOC-I fatal accident rate (per million flights) per aircraft generation 31
10 year moving average LOC-I hull loss accident rate (per million flights) per aircraft generation 31
10 year moving average RE fatal accident rate (per million flights) per aircraft generation 32
10 year moving average RE hull loss accident rate (per million flights) per aircraft generation 32

Scope & Definitions

This publication provides the Airbus annual analysis of aviation accidents, with commentary on the year 2020, 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/A319/A320/A321, 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.

  *except Sukhoi Superjet

- **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 was provided by Cirium for all aircraft. Cirium revises these values on an annual basis as further information becomes available from operators.

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.
- **Fatal accident:** An event 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 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, and 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).

1

2020 & BEYOND

1.1	TRAFFIC AND ACCIDENTS IN 2020	08
1.2	OUTLOOK FOR 2021 AND BEYOND	11

1.1

Traffic and Accidents in 2020

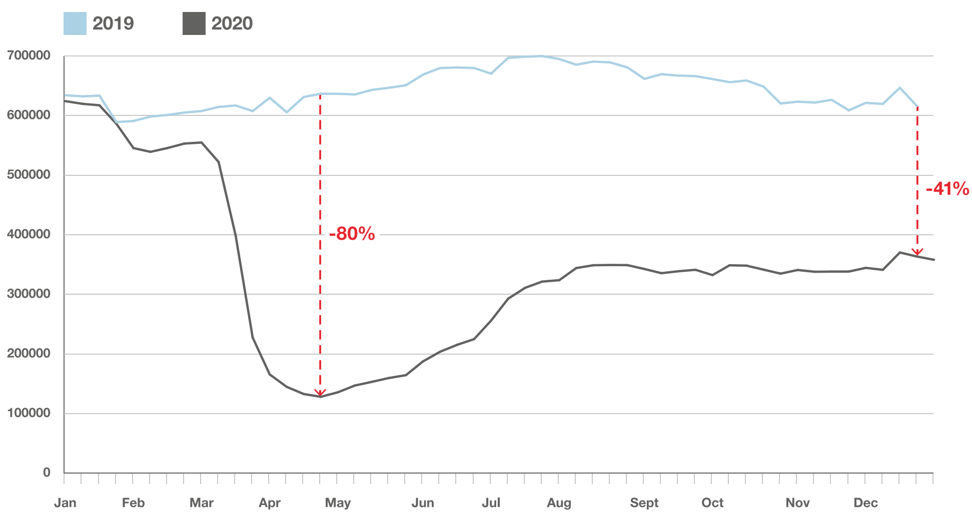
2020 was a year when the number of operating aircraft and flights recorded was at its lowest level for over 20 years

The impact of the Covid-19 pandemic took a noticeable effect from March in 2020 when the number of flights operated globally dropped significantly.

Over the entire year, there were just under 18 million flights recorded for commercial jet aircraft. This is approximately half the number of flights that were operated in 2019. Industry estimates show that up to 60 percent of the global fleet was grounded last year due to the effects of the pandemic on air transport.

2020 was a year when the number of operating aircraft and flights recorded was at its lowest level for over 20 years. It is comparable to the year 1998 in terms of capacity. However, there were 3 fatal accidents and 6 hull losses in 2020, compared with the 10 fatal accidents and 24 hull losses in 1998. Even if the number of accidents recorded in a single year is not indicative of the overall level of safety in the commercial aviation industry, this contrast highlights the continual reduction of the accident rate achieved over the last 20 years.

World traffic in flight cycles per week



	2019	2020	
In-Service Fleet (including stored aircraft)	**26,680** AIRCRAFT	**27,500** AIRCRAFT	↑
Flight Departures (in millions)	**36M** FLIGHTS	**18M** FLIGHTS	↓
Fatal Accidents	**4**	**3**	↓
Hull Loss Accidents	**10**	**6**	↓
Yearly Fatal Accident Rate (per million flights)	**0.11**	**0.17**	↑
Yearly Hull Loss Accident Rate (per million flights)	**0.28**	**0.34**	↑
Gen3 Fatal Accident Rate 10yr Moving Average (per million flights)	**0.15**	**0.15**	→
Gen4 Fatal Accident Rate 10yr Moving Average (per million flights)	**0.05**	**0.04**	↓
Gen3 Hull Loss Accident Rate 10yr Moving Average (per million flights)	**0.56**	**0.53**	↓
Gen4 Hull Loss Accident Rate 10yr Moving Average (per million flights)	**0.18**	**0.15**	↓

1.2 Outlook for 2021 and Beyond

Recovery relies on management of the health risks combined with the mindset of travellers and overcoming the economic impacts of the pandemic

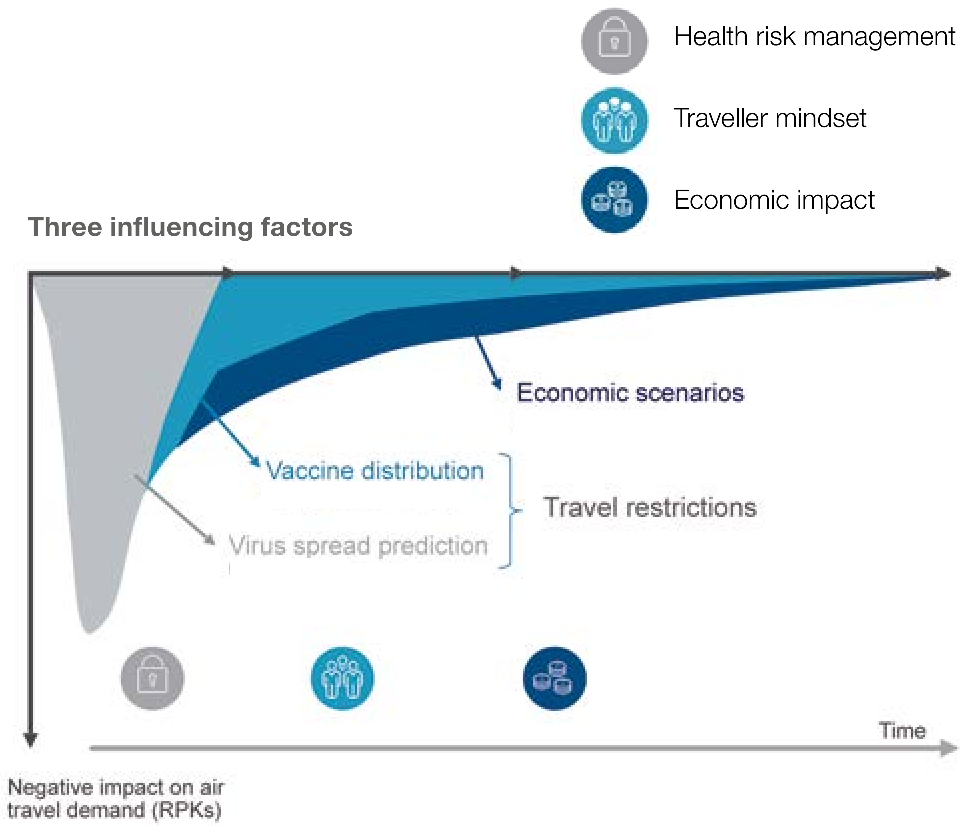
Commercial air transport traffic was at its peak in 2019, and was doubling every 15 years. However, the Covid-19 pandemic caused the commercial air transport system in particular to face an unprecedented crisis in 2020. The outlook for 2021 and beyond remains uncertain with the travel restrictions still in place. The trend of commercial air traffic doubling every 15 years will be challenged until the industry recovers to levels seen prior to the pandemic.

Recovery from this crisis relies on management of the health risks combined with the mindset of travellers and overcoming the economic impacts of the pandemic.

As soon as travel restrictions are lifted, operators expect to rapidly return their aircraft to service, many of which were grounded and parked at the height of the pandemic.

From a safety perspective, this scenario requires all actors to be focused on the right priorities, which is to ensure safety as aircraft, crews, and passengers return to the skies.

The entire air transport system must adopt a holistic and cooperative approach to continuously enhance the level of safety across the industry in order to protect the future of commercial air travel.



2

COMMERCIAL AVIATION ACCIDENTS 1958-2020

2.1	EVOLUTION OF THE NUMBER OF FLIGHTS AND ACCIDENTS	14
2.2	EVOLUTION OF THE YEARLY ACCIDENT RATE	15
2.3	EVOLUTION OF COMMERCIAL JET AIRCRAFT	18
2.4	EVOLUTION OF ACCIDENT RATES BY AIRCRAFT GENERATION	19
2.5	HOW TECHNOLOGY HELPED REDUCE ACCIDENTS	20
2.6	HOW TECHNOLOGY ADDRESSED THE MAJOR CAUSES OF ACCIDENTS	21

2.1

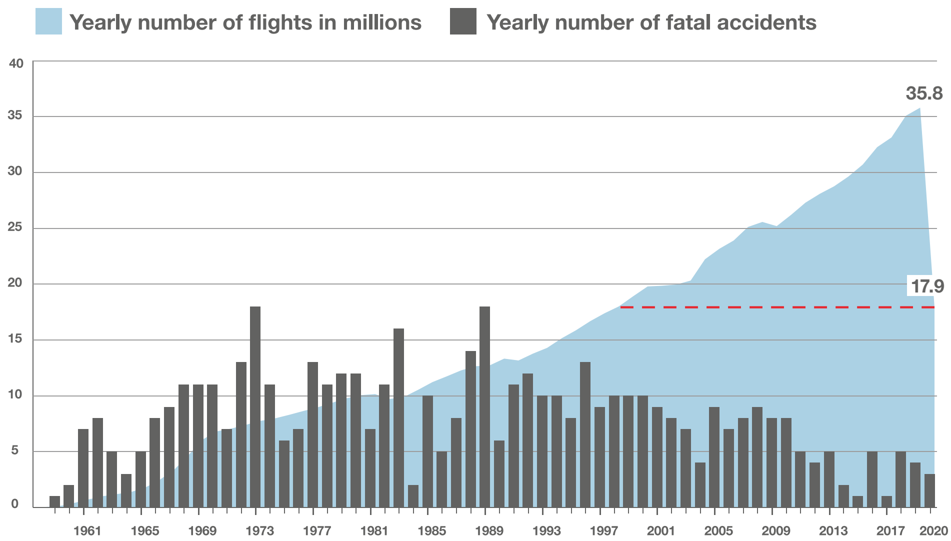
Evolution of the Number of Flights and Accidents

The number of accidents today is significantly lower than a comparable year more than 20 years ago

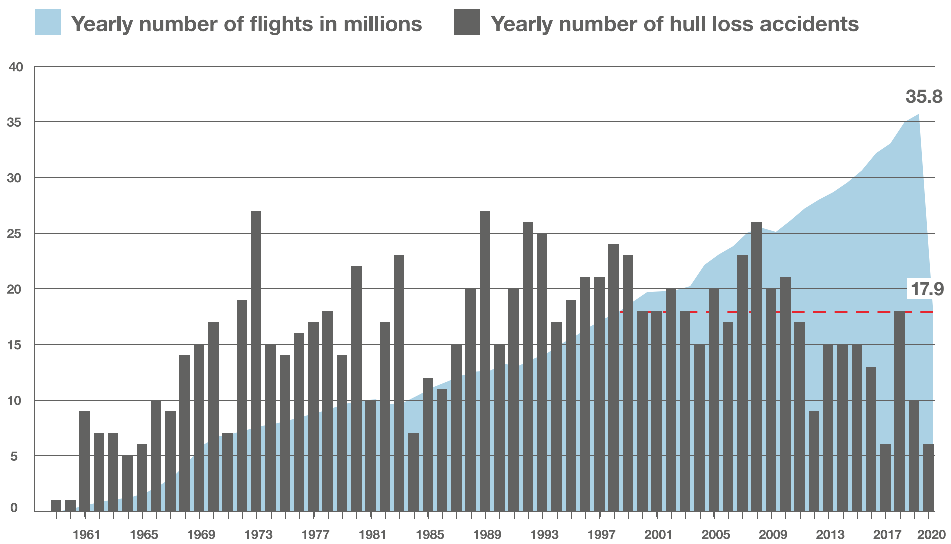
The number of flights on commercial jet aircraft was continuously growing prior to the effects of the pandemic. In spite of this growth, the number of accidents was decreasing each decade.

The number of flights in 2020 was less than half of the flights operated in 2019, and there were 3 fatal accidents and 6 hull losses recorded. When compared to a period with an equivalent number of flights, it is in contrast to the 10 fatal accidents and 24 hull losses recorded in 1998.

These figures illustrate the continuous enhancement of safety within the commercial aviation industry over recent decades. However, the number of accidents and flights will vary each year and it is the reason why accident rates are more relevant than reviewing the number of accidents per year when analyzing trends.



Fatal



Hull loss

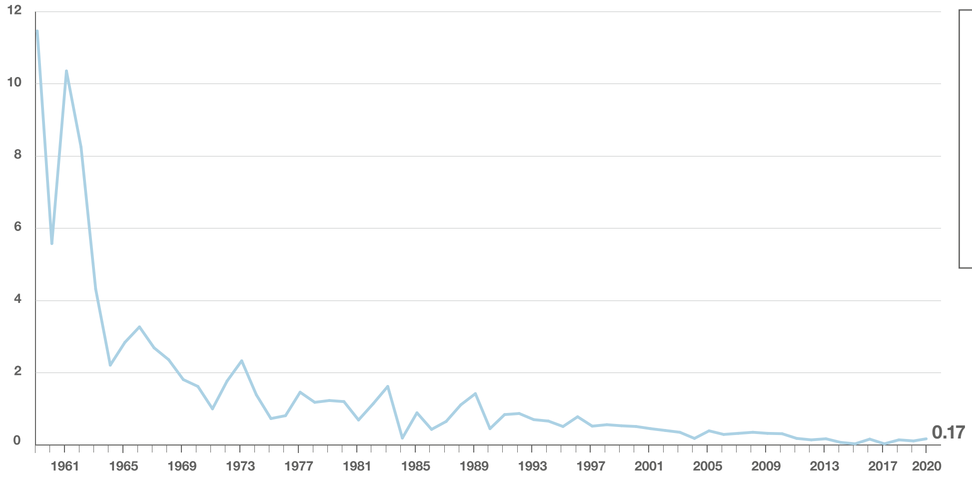
2.2

Evolution of the Yearly Accident Rate

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

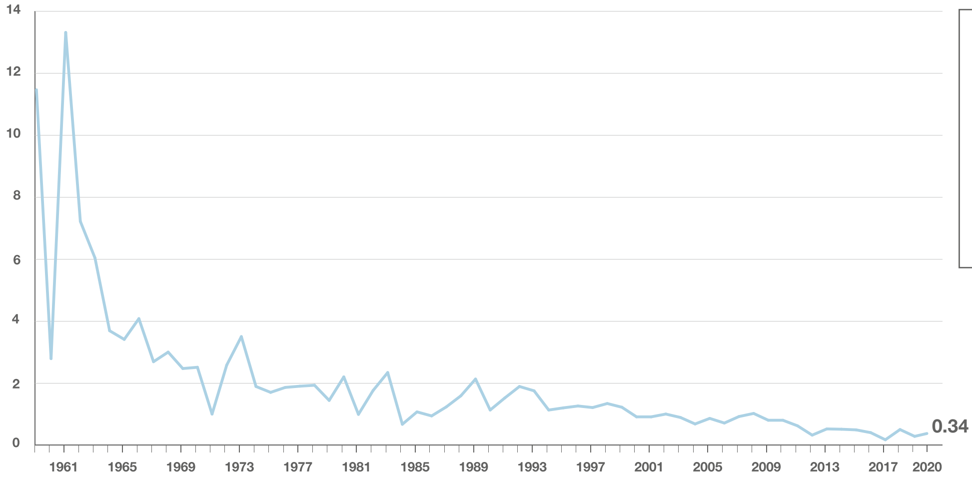
There were far fewer flights in the 1960s, but a peak in the accident rates is shown due to the lower number of flights and the higher number of accidents recorded during this period. It can be difficult to compare accident data from this period with such a low volume of activity in the commercial aviation industry. However, the volume of flights over recent decades is sufficient to show that the accident rate is continually decreasing.

Yearly fatal accident rate per million flights



Fatal

Yearly hull loss rate per million flights



Hull loss

Four generations of commercial

Early commercial jets

1st Generation

From 1952

Dials and gauges in cockpit, early autoflight systems
Comet, Caravelle, BAC-111, Trident, VC-10, B707, B720, DC-8, Convair 880/990

Glass Cockpit, FMS & TAWS

3rd Generation

From 1980

Electronic displays, Flight Management System (FMS), and Terrain Awareness and Warning System (TAWS) reduced CFIT accidents
A300-600, A310, Avro RJ, F70, F100, B717, B737 Classic, B737 NG, B737 MAX, B757, B767, B747-400/-8, Bombardier CRJ, Embraer ERJ, MD-11, MD-80, MD-90

jet aircraft

More integrated autoflight

2nd Generation

From 1964

More elaborate autopilot and autothrottle 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

4th Generation

From 1988

Flight envelope protection enabled by fly-by-wire technology reduced LOC-I accidents
A220, A318/A319/A320/A321, A330, A340, A350, A380, B777, B787, Embraer E-Jets, Sukhoi Superjet

2.3 Evolution of Commercial Jet Aircraft

Airbus aircraft flew 76% of the flights made by fourth-generation commercial jet aircraft in 2020

There were less than 18 million flight departures in 2020, due to the effects of the global pandemic, compared with almost 36 million flights the year before. 9 million flights were made by fourth-generation jets, 7 million of which were Airbus aircraft.

The largest percentage of flights in recent years were made using the latest fourth-generation commercial jets, which have the lowest accident rate. As the percentage increases over the next decade, this should sustain further decrease 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.

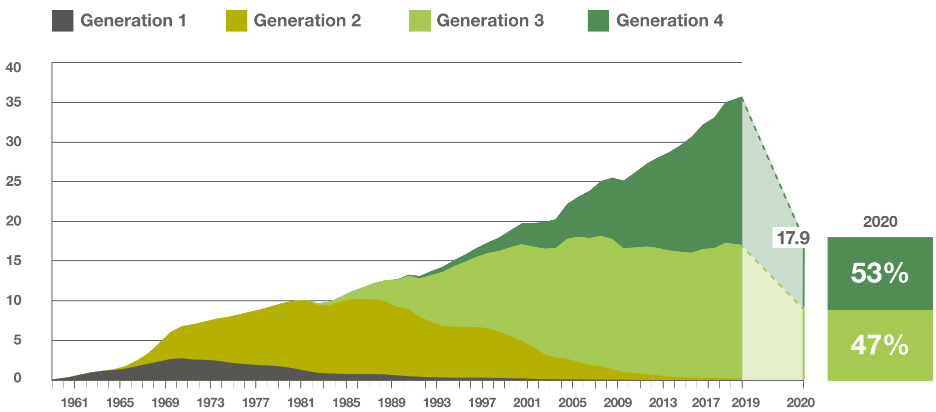
A notable part of this success is due to effective regulation, a strong safety culture, and improvements in training. Technological advances are also a crucial enabler for enhancing the level of safety. In particular, technologies introduced in aircraft systems intentionally evolved with improving safety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



2.4 Evolution of Accident Rates by Aircraft Generation

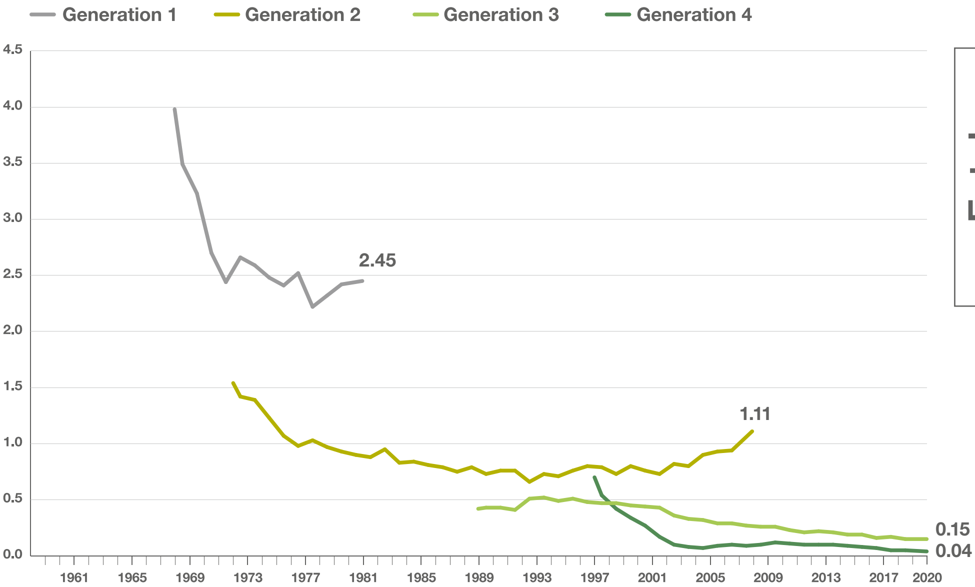
Advances in technology have helped to reduce accident rates for each generation

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 the fourth-generation commercial jet aircraft are shown from 1997, which was the tenth year in service for the A320 aircraft.

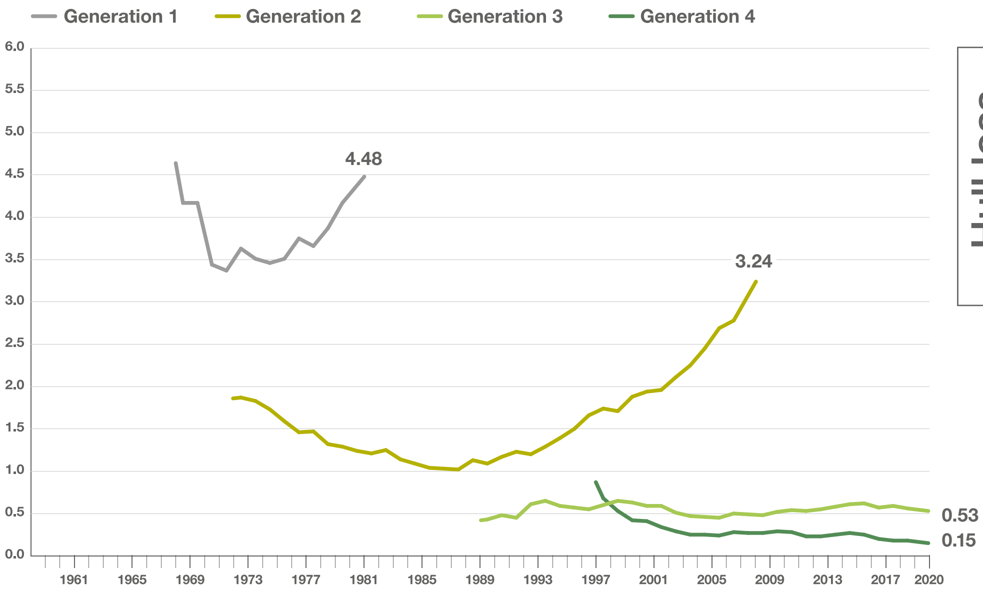
The 10 year moving average accident rates for fourth-generation aircraft are around three times lower than the rates recorded for the previous third-generation aircraft.

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



Fatal

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



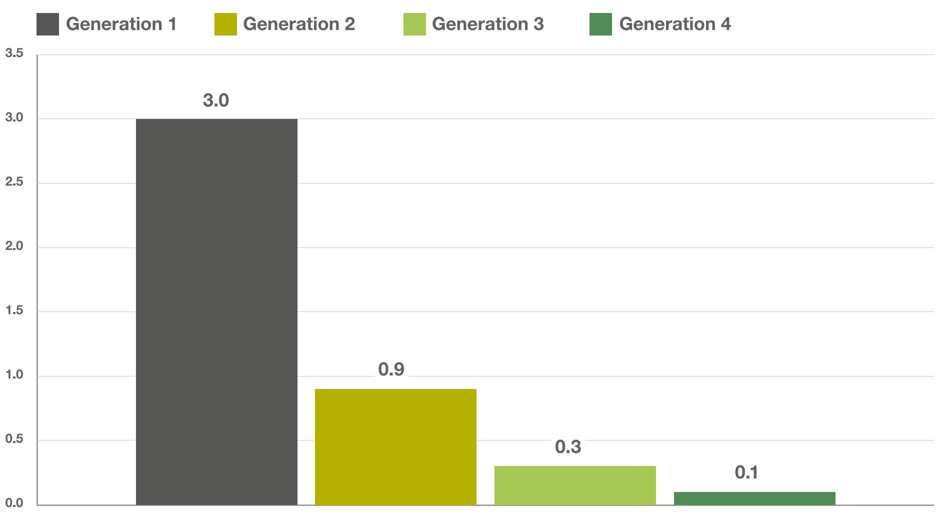
Hull loss

2.5

How Technology Helped Reduce Accidents

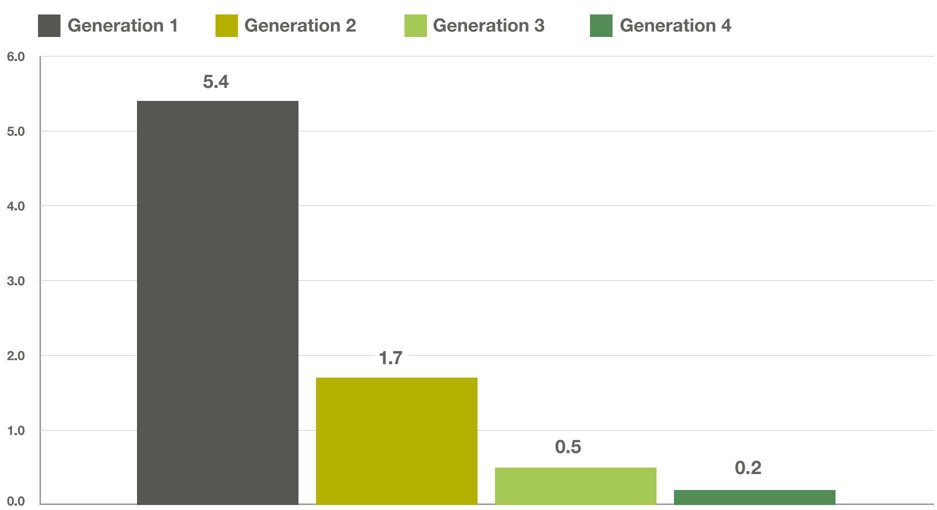
Statistics over the life of each aircraft generation show a significant improvement in the level of safety, especially since the introduction of third-generation and the latest fourth-generation aircraft

Fatal accident rate (per million flights) per aircraft generation 1958-2020



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.

Hull Loss accident rate (per million flights) per aircraft generation 1958-2020



2.6

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 the Flight Management System (FMS), improved navigation displays, and the Terrain Awareness and Warning System (TAWS) with the third-generation aircraft significantly reduced the number of CFIT fatal accidents when compared to the previous first and second-generation aircraft.

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

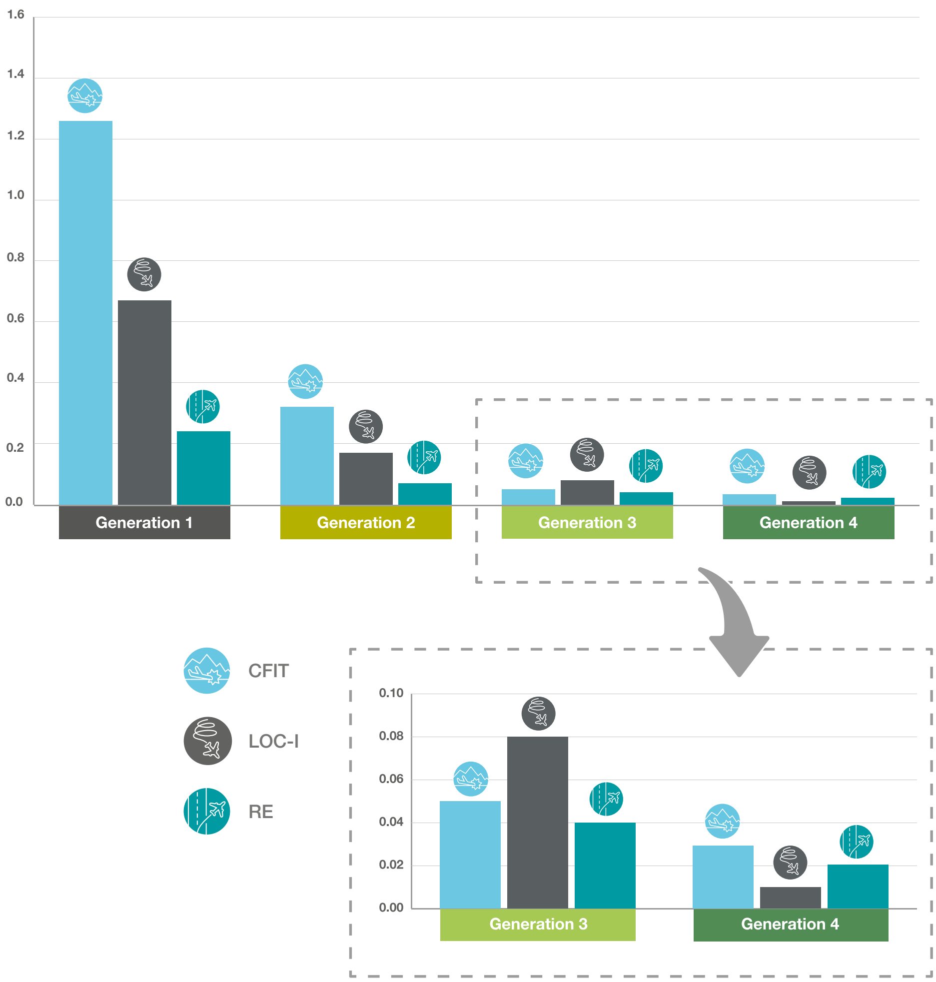
CFIT accident rate

-86% from second to third generation

LOC-I accident rate

-89% from third to fourth generation

Average fatal accident rate (per million flights) per accident category 1958-2020



3

COMMERCIAL AVIATION ACCIDENTS OVER THE LAST 20 YEARS

3.1	EVOLUTION OF THE YEARLY ACCIDENT RATE	24
3.2	EVOLUTION OF ACCIDENT RATES BY AIRCRAFT GENERATION	25
3.3	ACCIDENTS BY FLIGHT PHASE	26
3.4	ACCIDENTS BY ACCIDENT CATEGORY	28
3.5	EVOLUTION OF THE MAIN ACCIDENT CATEGORIES	29
3.6	CONTROLLED FLIGHT INTO TERRAIN (CFIT) ACCIDENT RATES	30
3.7	LOSS OF CONTROL IN-FLIGHT (LOC-I) ACCIDENT RATES	31
3.8	RUNWAY EXCURSION (RE) ACCIDENT RATES	32

3.1

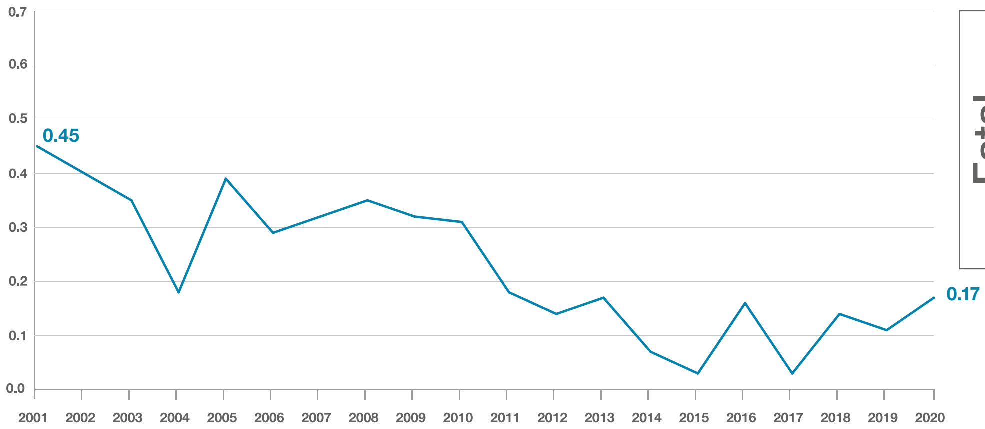
Evolution of the Yearly Accident Rate

A significant reduction in fatal and hull loss accidents was achieved across the commercial aviation industry since 2001

Even with a lower number of accidents compared with 2019, the yearly accident rate in 2020 slightly increased. This is due to a significantly lower number of flights caused by the pandemic, which affects the calculated rate. It shows that the accident rate for a single year is not indicative of the overall safety trend.

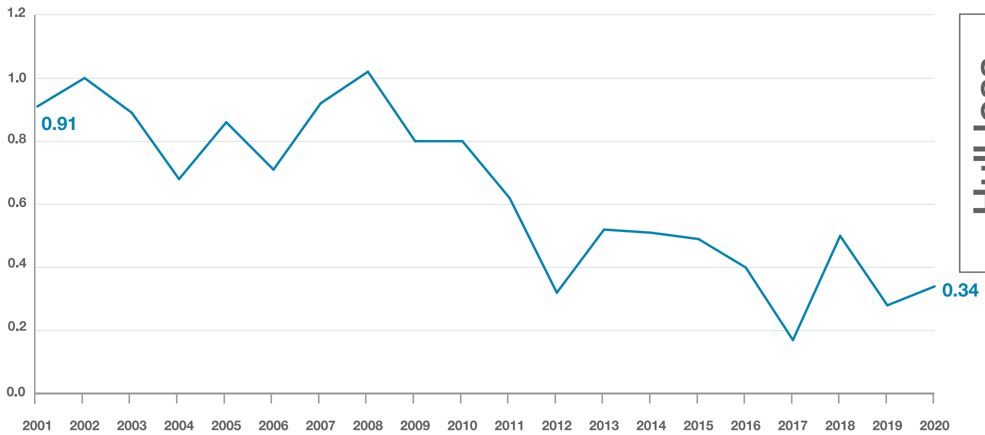
Despite the reduction of the yearly accident rate since 2001, the yearly rates of recent years have remained above the lowest figures recorded in 2017.
It is a call to action for all actors in the commercial air transport system to be safety vigilant and avoid this becoming an adverse trend.

Yearly fatal accident rate per million flights



Fatal

Yearly hull loss accident rate per million flights



Hull loss

3.2 Evolution of Accident Rates by Aircraft Generation

Fourth-generation aircraft accident rates are lower than the third-generation rates

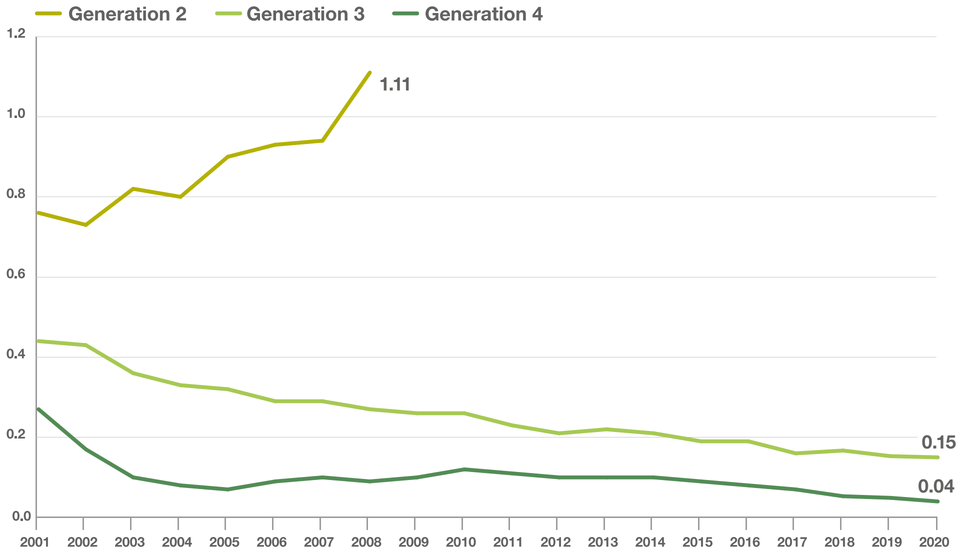
Third-generation aircraft reduced accident rates by introducing glass cockpits with navigation displays and flight management systems.

Fourth-generation aircraft further reduced accident rates by introducing fly-by-wire technology, which made flight envelope protection possible.

The accident rate for the third and fourth generation continued to decrease in 2020. This is indicative of the overall safety trend observed over recent decades.

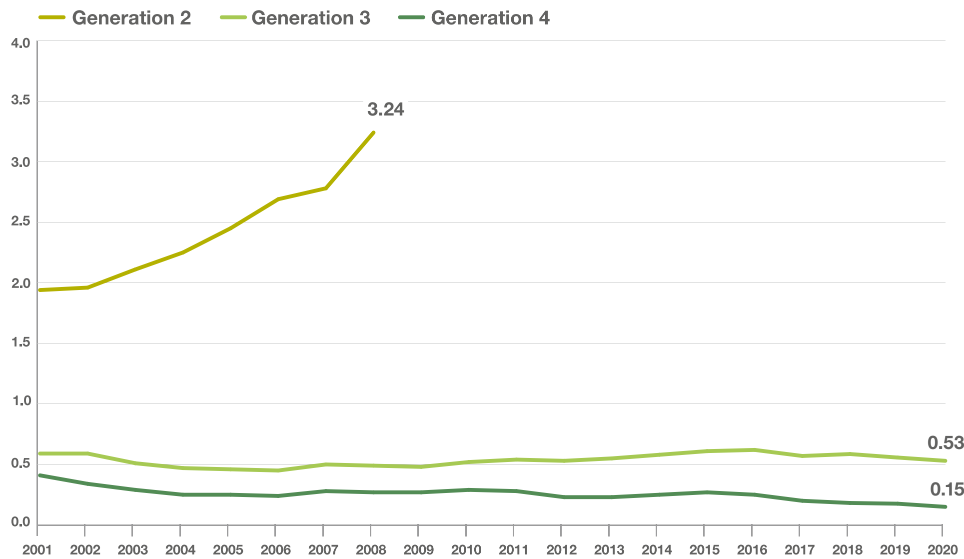
Fourth-generation commercial jet aircraft flew 53% of flights in 2020. As this percentage increases over the next decade, the overall accident rate for commercial air transport should further decrease due to the noticeably lower rate of this generation when compared with the previous third-generation aircraft.

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



Fatal

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



Hull loss

3.3

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.

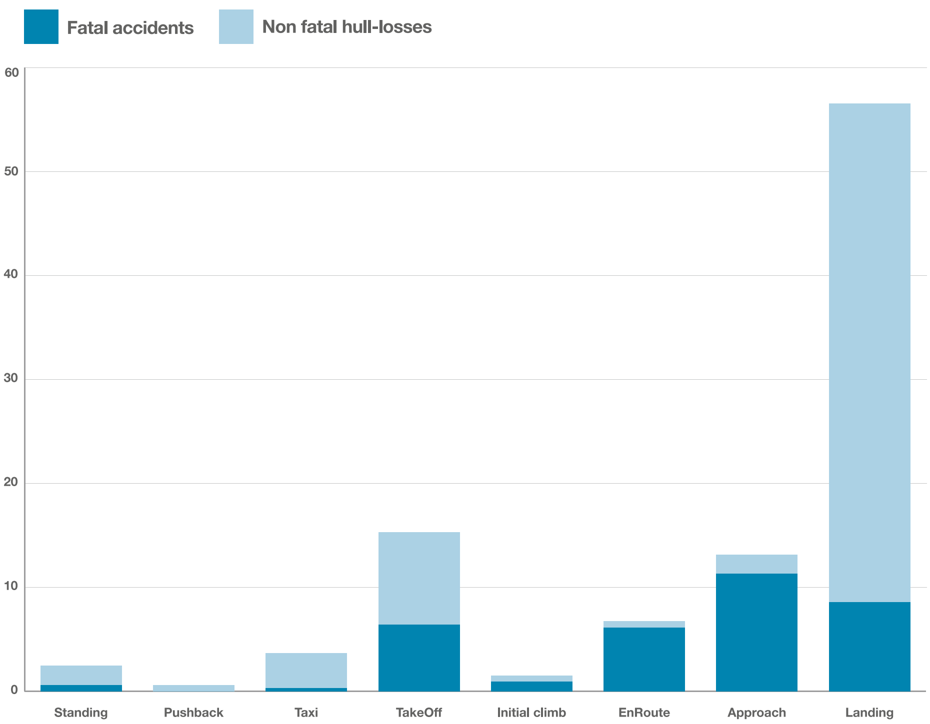
Most of the accidents over the last 20 years occurred during approach and landing phases

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.

All 3 fatal accidents recorded in 2020 occurred in the approach and landing phases.

Accidents distribution per flight phase 2001-2020



3.4

Accidents by Accident Category

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

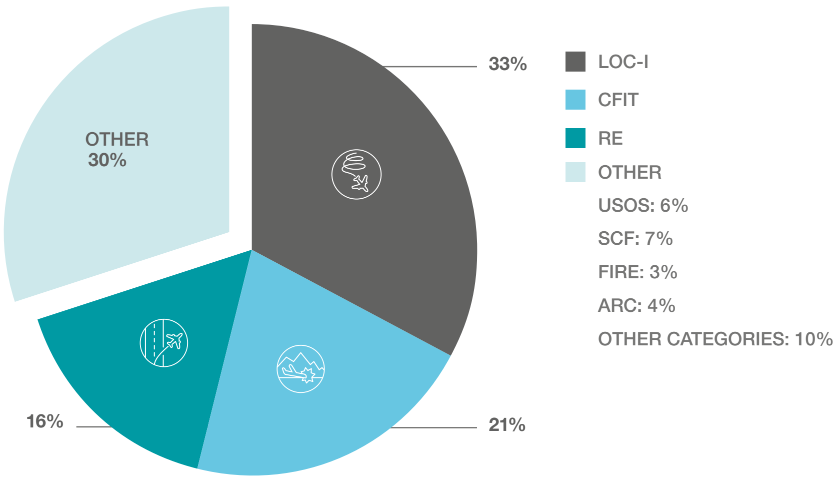
LOC-I accidents have significantly reduced for fourth-generation aircraft enabled by fly-by-wire technologies.

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 third and fourth-generation 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.

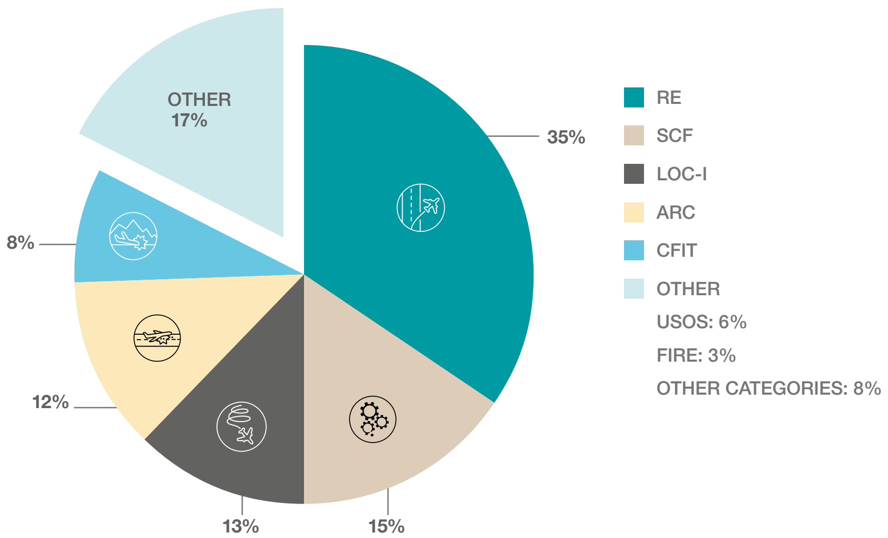
Fatal

Fatal accidents distribution per accident category 2001-2020



Hull loss

Hull losses accidents distribution per accident category 2001-2020



3.5

Evolution of the Main Accident Categories

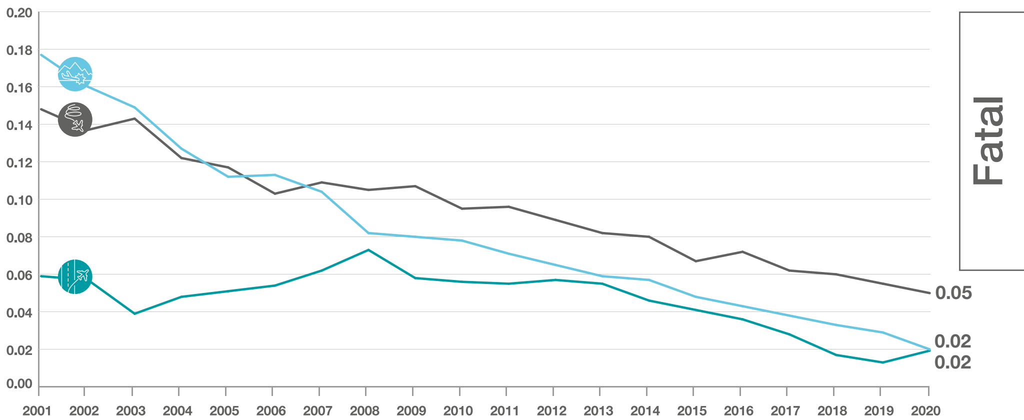
Over the last 20 years, the fatal accident rate for CFIT accidents reduced by 89%, and LOC-I by 66%

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.

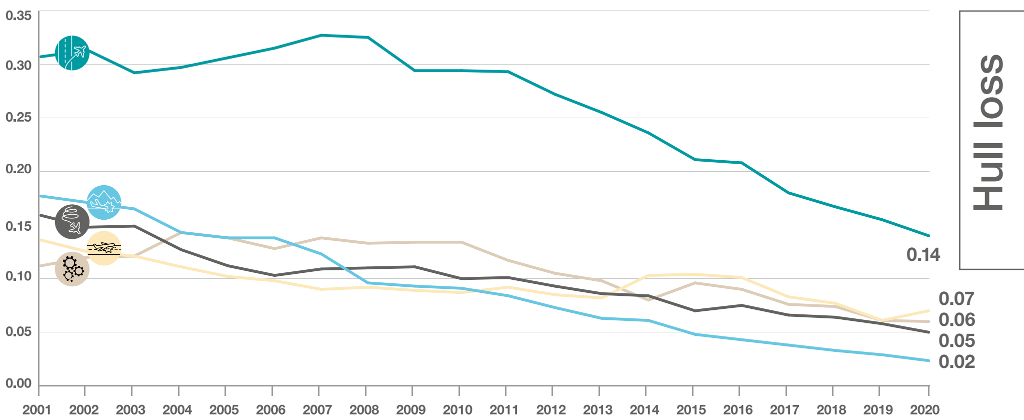
Over half of all flights in 2020 were made using fourth-generation commercial jet aircraft equipped with fly-by-wire enabled technologies. The rate of LOC-I accidents is 89% lower for fourth-generation aircraft when compared with third-generation aircraft. As the proportion of flights made using fourth-generation aircraft continues to grow, the rate of LOC-I accidents is expected to decrease further.

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 8% of the in-service fleet. 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.

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



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



3.6 Controlled Flight Into Terrain (CFIT) Accident Rates

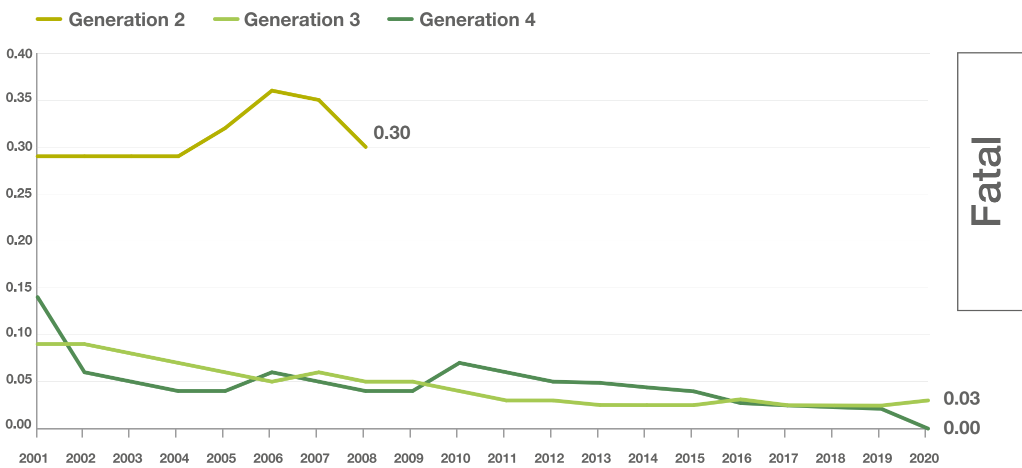
The introduction of glass cockpits, FMS & TAWS has helped to reduce the CFIT fatal accident rate by 86%

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

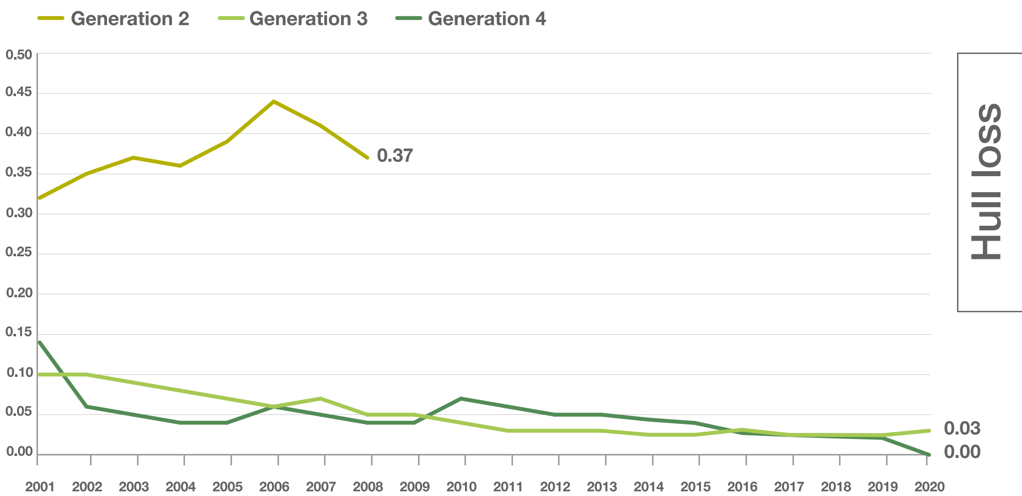
Glass cockpits installed on the third generation of aircraft improved navigation performance due to the introduction of a Flight Management System (FMS) and navigation displays that helped to further reduce the CFIT accident rates.

There were no fatal or hull loss CFIT accidents recorded for fourth-generation aircraft in the last decade. Therefore, the 10 year moving average rate is zero for this generation in 2020.

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



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



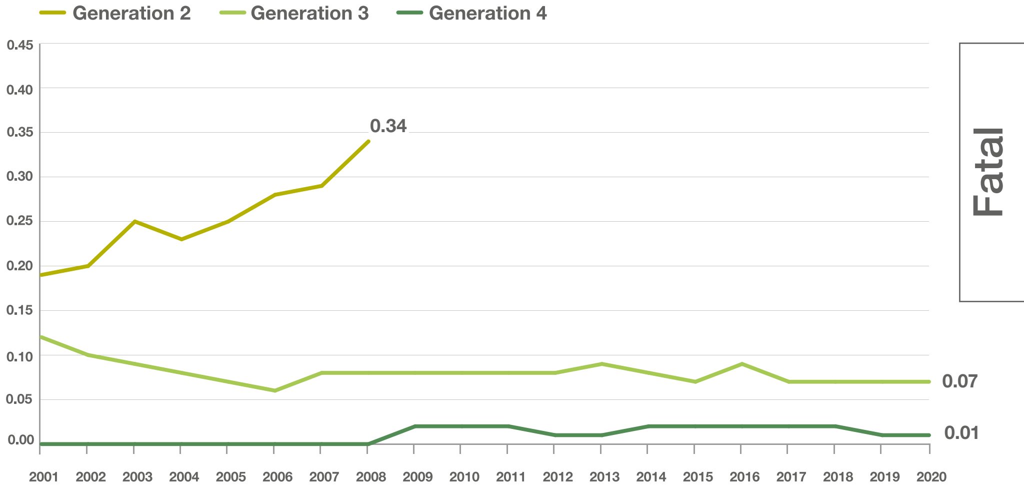
3.7

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

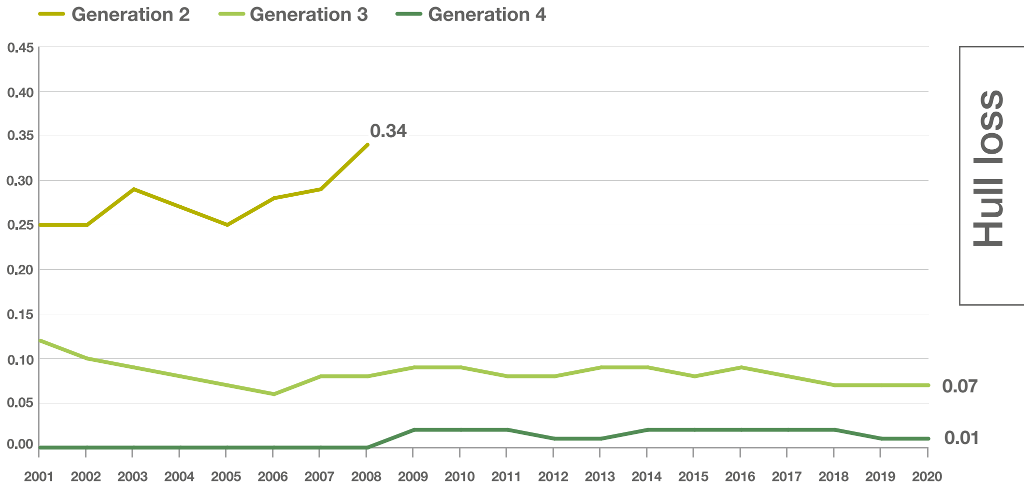
Flight envelope protection has helped reduce LOC-I fatal accident rates by 89%

The fourth-generation aircraft have accumulated over 30 years of in-service experience since the A320 first entered into service in 1988.
This represents more than 210 million accumulated flights by the end of 2020, 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.

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



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



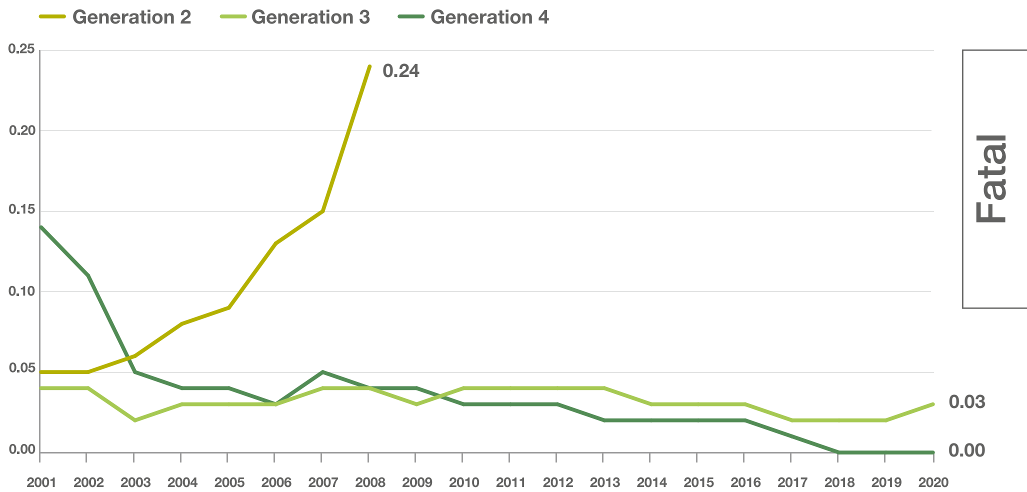
3.8

Runway Excursion (RE) Accident Rates

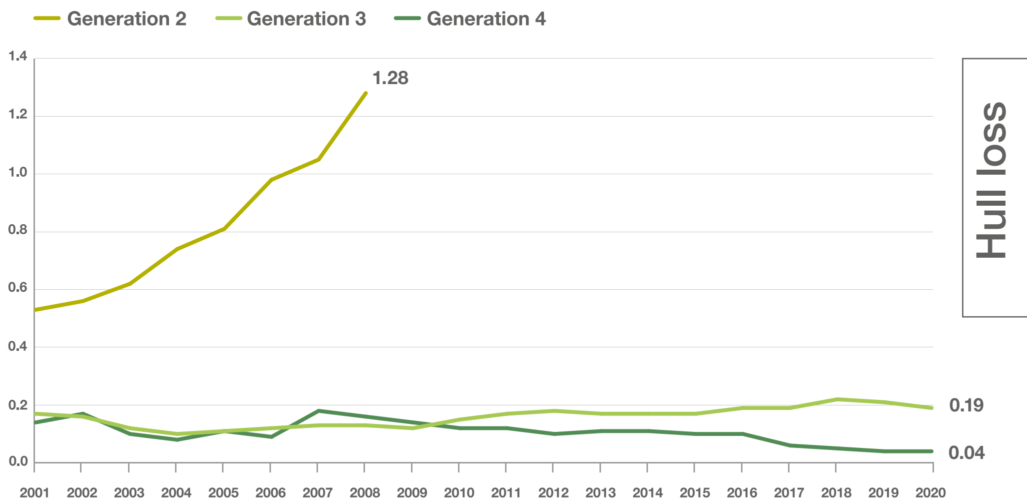
Technologies to reduce RE accidents have been available for over 10 years

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 2020, the number of aircraft equipped with ROPS has increased to 8% of the worldwide fleet.

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



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



AIRBUS

AIRBUS S.A.S. 31707 Blagnac Cedex, France

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The printing inks use organic pigments or minerals. There is no use of basic dyes or dangerous metals from the cadmium, lead, mercury or hexavalent chromium group.

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