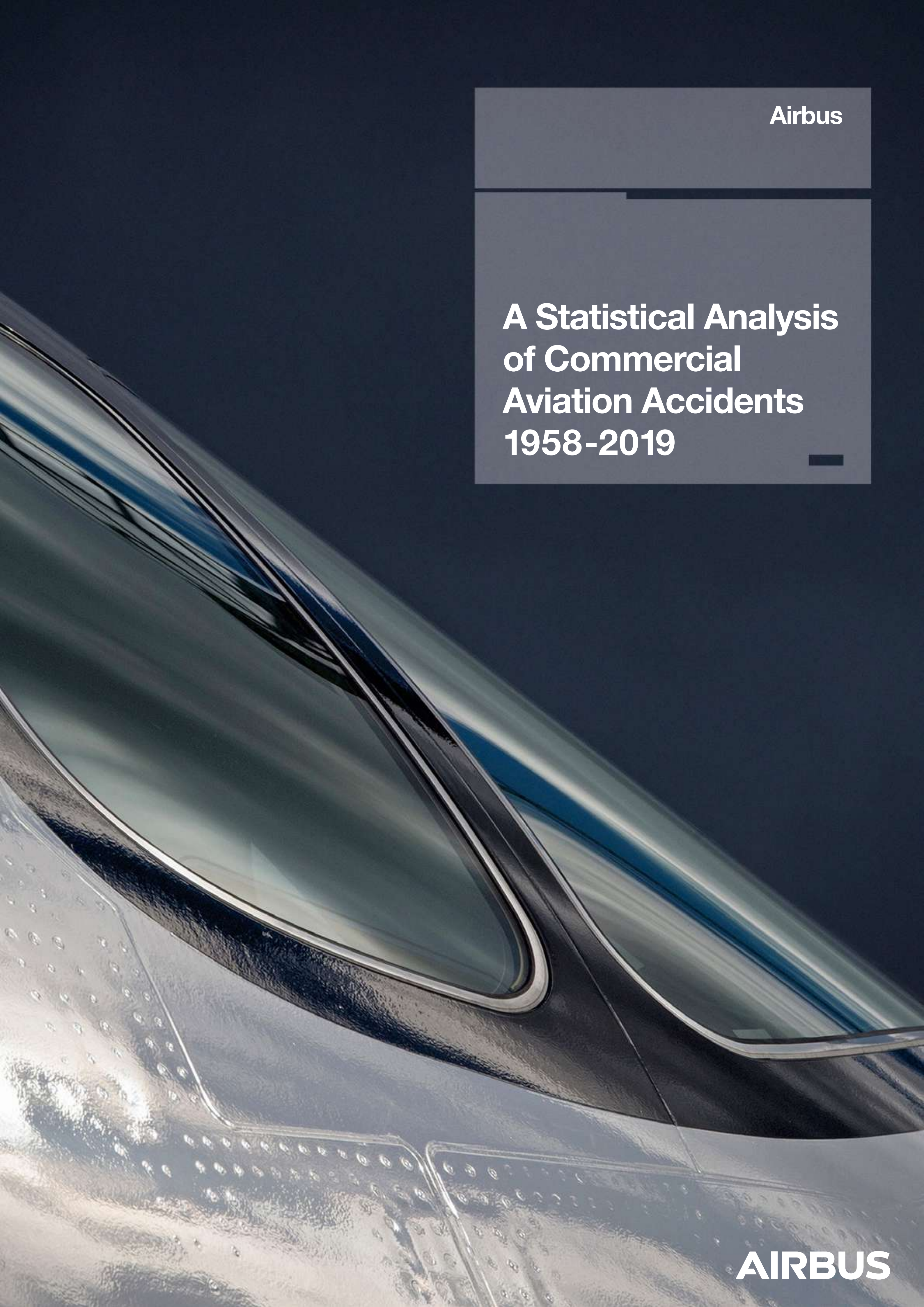
Airbus

A Statistical Analysis of Commercial Aviation Accidents 1958-2019



AIRBUS

Contents

Scope and definitions

This publication provides Airbus' annual analysis of aviation accidents, with commentary on the year 2019, as well as a review of the history of Commercial Aviation's safety record.

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

Since the goal of any review of aviation accidents is to help the industry further enhance safety, an analysis of forecasted aviation macro-trends is also provided. These highlight key factors influencing the industry's consideration of detailed strategies for the further enhancement of Aviation Safety.

Scope of the Brochure

- **All western-built commercial air transport jets above 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 (previously named 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
  McDonnel 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 advent of commercial jets
- **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 data bases.
- Flight cycles data were provided by Cirium for all aircraft. Cirium revises these values on an annual basis as further information becomes available from operators.

Definitions

- **Revenue flight:** flight involving the transport of passengers, cargo or mail. Non revenue flight 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 such time as 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, except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew.
- **Hull loss:** an event in which an aircraft is destroyed or damaged beyond economical repair. The threshold of economical repair is decreasing with the residual value of the aircraft. Therefore, as an aircraft is ageing, an event leading to a damage economically repairable years before may be considered a hull loss.

Definition of accident categories

Aviation organisations define more than 40 different accident categories. However the seven listed below are the individual types which cause the most significant number of accidents.

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

Loss of Control in Flight (LOC-I): Loss of aircraft control while in flight 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): Hard or unusual landing, not primarily due to SCF, leading to an accident.

Undershoot/Overshoot (USOS): An Undershoot/ Overshoot of a runway occurs in close proximity to the runway and includes offside touchdowns and any occurrence where the landing gear touches off the runway surface.

System/Component Failure or Malfunction (SCF): Failure or malfunction of an aircraft system or component, related to either its design, the manufacturing process or a maintenance issue, which leads to an accident. SCF includes the powerplant, software and database systems.

FIRE: A fire which occurs while an aircraft is airborne.

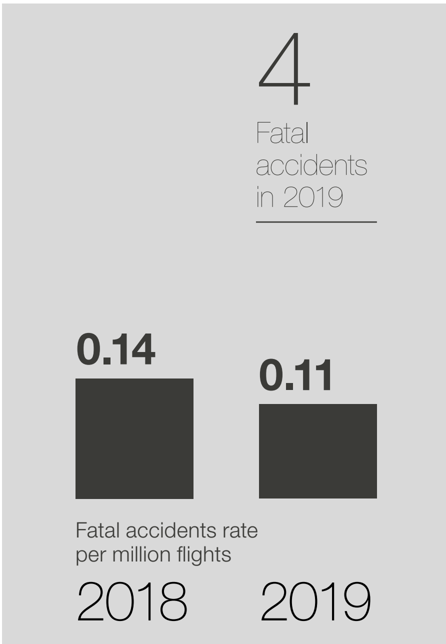
1.0 2020 & beyond

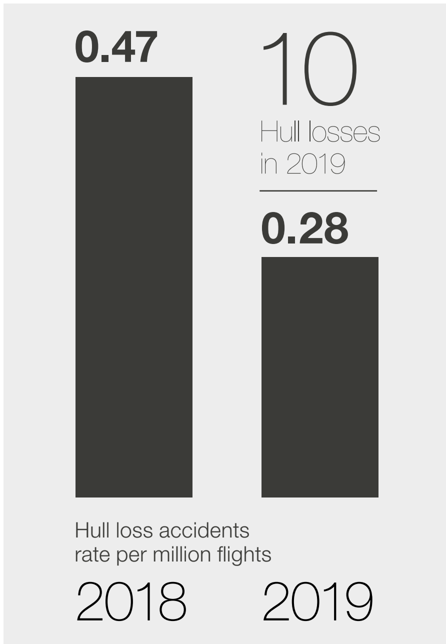
1.1 Accidents in 2019

Following a year when safety in the Air Transport system has been in the spotlight, it may be nevertheless appropriate to review the progress made over the last decade.
2019 was amongst the years with a low number of fatal accidents despite the continually increasing fleet and number of flights. However, a year with 10 hull losses is also a reminder for why 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 industry-wide safety initiatives, and it is why the evolution of accident rates are shown as a 10-year moving average throughout this brochure.

Analysis of the statistics also shows how advances in technology introduced by each generation of aircraft have helped to reduce the fatal accident rate even further than the preceding generation.

The majority of flights over the last 20 years were made by second and third generation aircraft.
Only 34-percent of the flights were flown by the fourth generation aircraft ten years ago and this grew to 52 percent by the end of the decade.
Almost all of the commercial jet flights in 2019 were flown by the latest and safest of aircraft generations.





	2018	2019
Flight departures	**35** MILLION	**36** MILLION
In-service fleet	**25,760** AIRCRAFT	**26,680** AIRCRAFT

1.2

2020 and beyond

Historical data shows air traffic doubles every 15 years

Airbus' Global Market Forecast (GMF) still predict air traffic to double within the next 20 years.

Such a significant growth of industry activity means there is no room for complacency in maintaining safety.

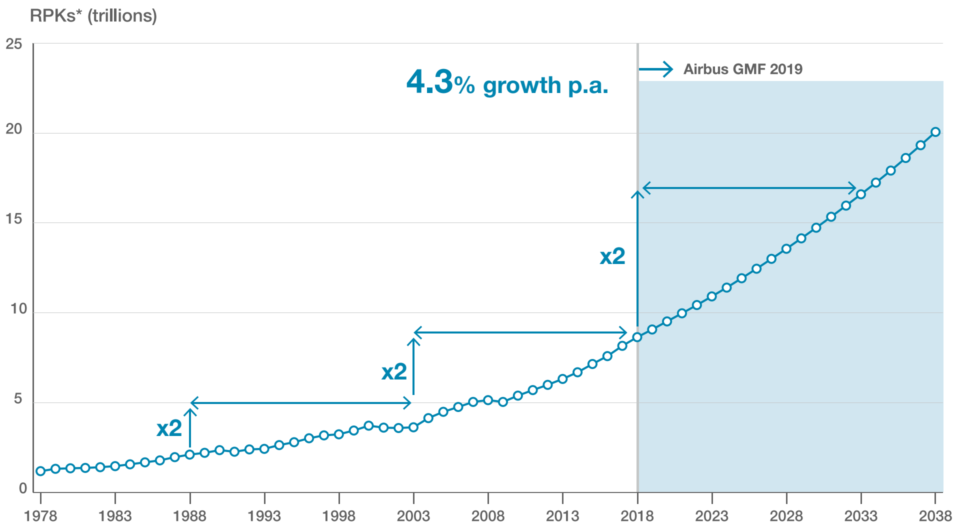
The industry will need to work co-operatively together to increase safety enhancement efforts in order to decrease the accident rate.

The number of people flying will increase and sustain the growth of the industry in the coming decade. This is coupled with a changing operational context, where new routes and services bring an era of ultra-long haul flights together with the opening of many more short haul routes serving new destination airports.

Aircraft delivered today will still be in service beyond the next 20-years. Life extension programs and predictive maintenance can increase the operating lifetime for today's aircraft even further.
Fourth generation aircraft, with Fly-By-Wire and Flight Envelope Protection enabled safety enhancements, are the industry standard today. Over a thousand of these aircraft are delivered each year and they will perform the largest proportion of flights in the next decade. As the fleet is increasing in the number of latest and safest fourth generation aircraft, this will further enable a sustained decrease in the fatal accident rate.

Beyond aircraft safety enhancements and the continuous improvement of training for all aviation professionals, it is also vital to raise the safety culture. There will be more than half-a-million people joining our industry in the next two decades. This next generation must be trained and mentored to foster their deep personal engagement with the safety of flight and understand the role they play to avoid the tragedy of an accident.

World annual traffic forecast



*Revenue Passengers Kilometers

1.3

Forecast increase in number of aircraft 2019-2038

Global increase by 2038

In-service fleet
+38,358

Pilots needs
549,997

Technicians needs
639,996

The in-service worldwide fleet is expected to more than double over the next 20 years.

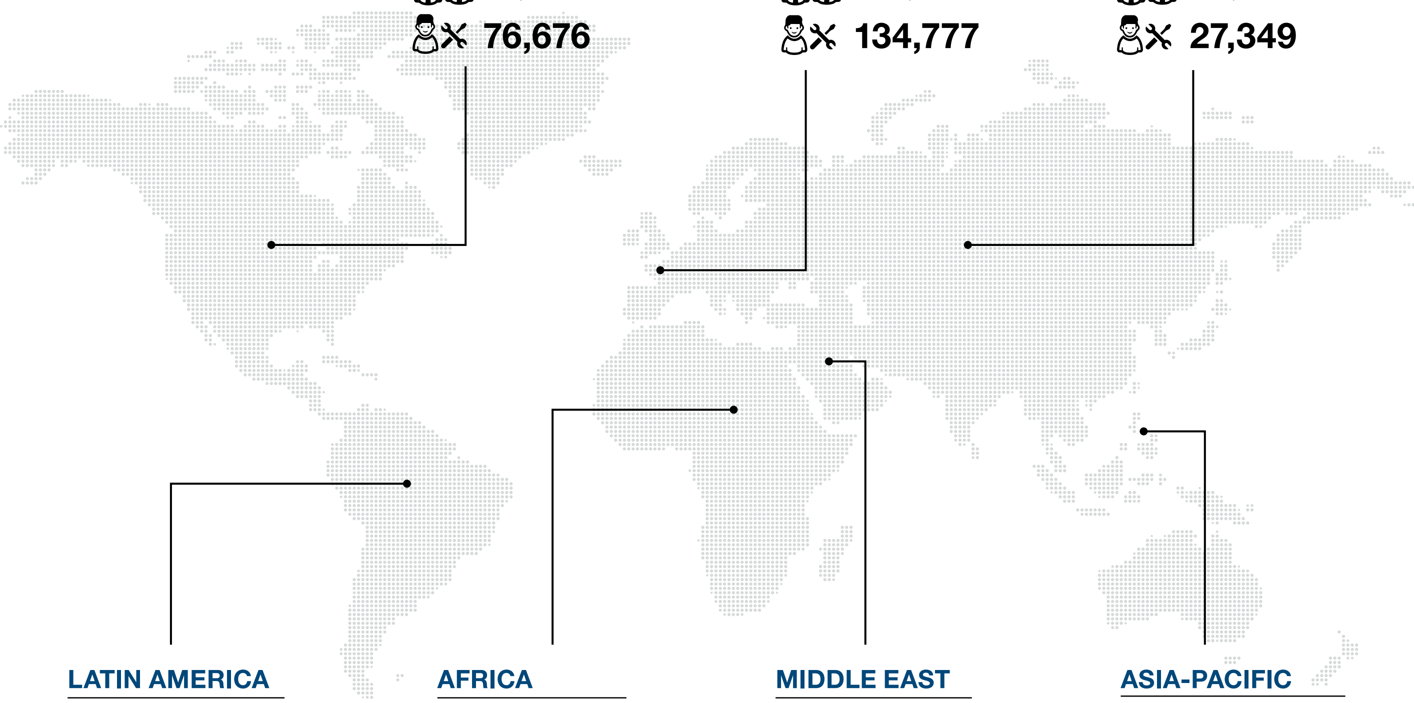
Each delivered aircraft must be supported by a proportional increase in the number of trained pilots, technicians, cabin crew, air traffic controllers, etc.

Ensuring that sufficient numbers of suitably trained personnel will be available is one of the challenges facing our industry.

NORTH AMERICA
+5,969
71,845
76,676

EUROPE
+7,434
114,054
134,777

CIS
+1,498
22,255
27,349



LATIN AMERICA
+2,684
47,552
64,160

AFRICA
+1,249
20,997
25,432

MIDDLE EAST
+3,200
50,080
51,916

ASIA-PACIFIC
+16,324
223,214
259,686

2.0 Commercial aviation accidents since the advent of the jet age


A/C 6023 F-WWBZ
SELCAL DEF.
DR - AE
CHRONO
SIDE STICK PRIORITY
FLASH LIGHT

2.1

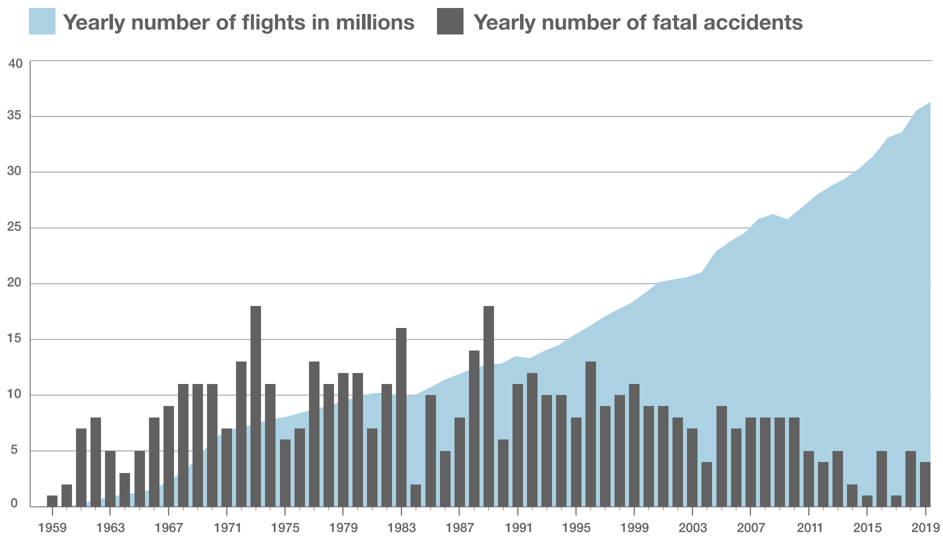
Evolution of the number of flights & accidents

No growth in the number of accidents despite a massive increase in exposure

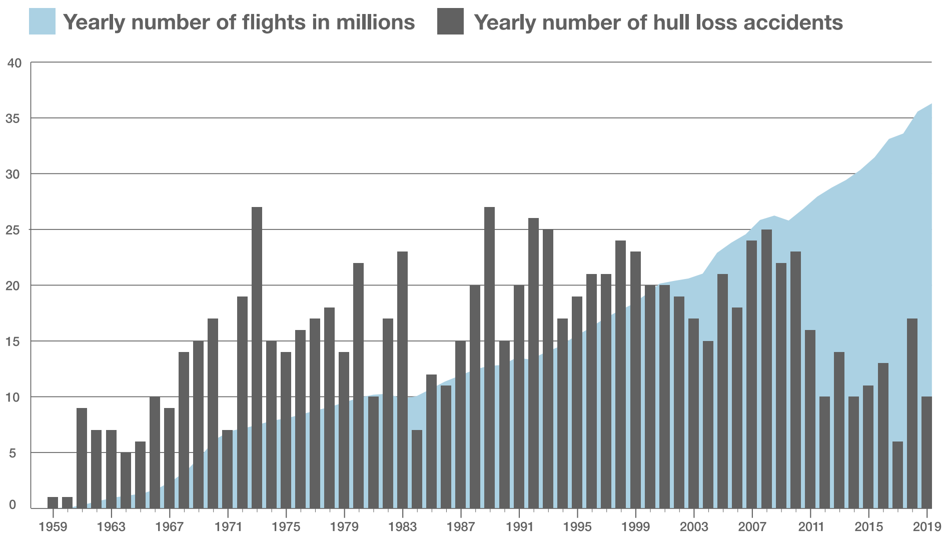
Despite a constant increase of the number of flights, accidents remain rare occurrences. Their number may vary from one year to the next. Therefore, focusing too closely on a single year's figure may be misleading.
In addition, the volume of activity in aviation is constantly increasing and needs to be taken into account.

For these reasons it makes more sense to consider accident rates when making an analysis of trends.

Fatal



Hull loss



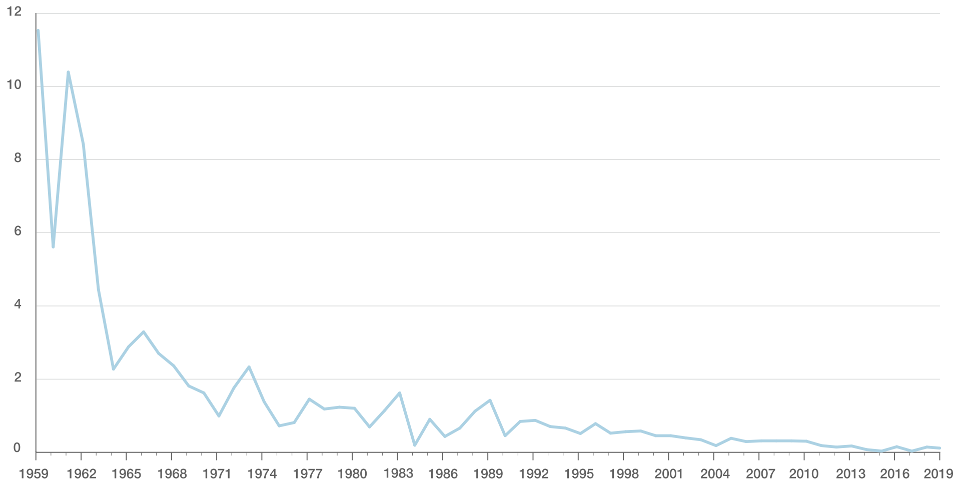
2.2

Evolution of the yearly accident rate

Rates of fatal accidents as well as hull losses are steadily decreasing over time

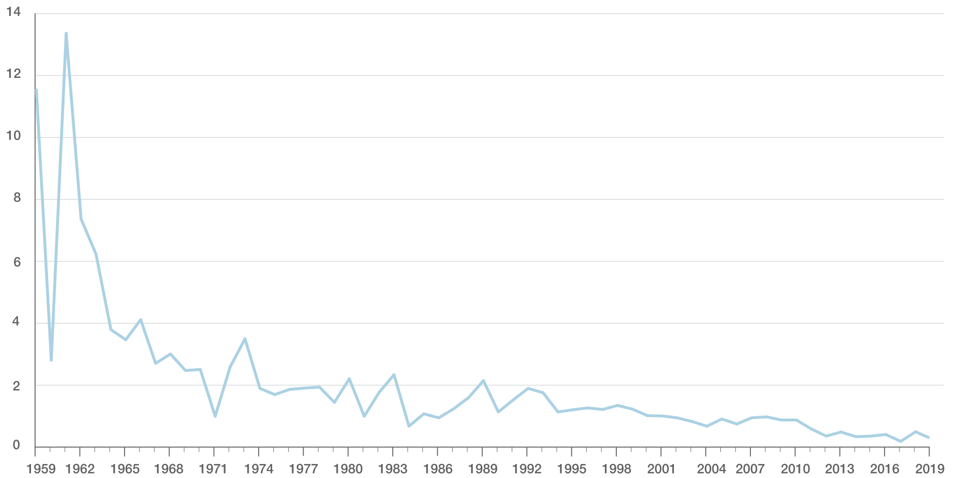
Today, there are around 36 million flights per year. This is in contrast to the 1960's when there was far fewer flights each year but there is a peak in the accident rates shown. It can be difficult to compare accident data from this period with a low volume of industry activity but the volume of flights in the more recent decades are sufficient to show that these rates are continually decreasing.

Yearly fatal accident rate per million flights



Fatal

Yearly hull loss rate per million flights



Hull loss

2.3

Impact of technology on aviation safety

Airbus aircraft flew 79% of the flights made by fourth generation jets in 2019

In 2019, nearly 36 million flight departures were made globally.
Among these, 19 million were made by fourth generation jets, of which Airbus aircraft accounted for 15 million.

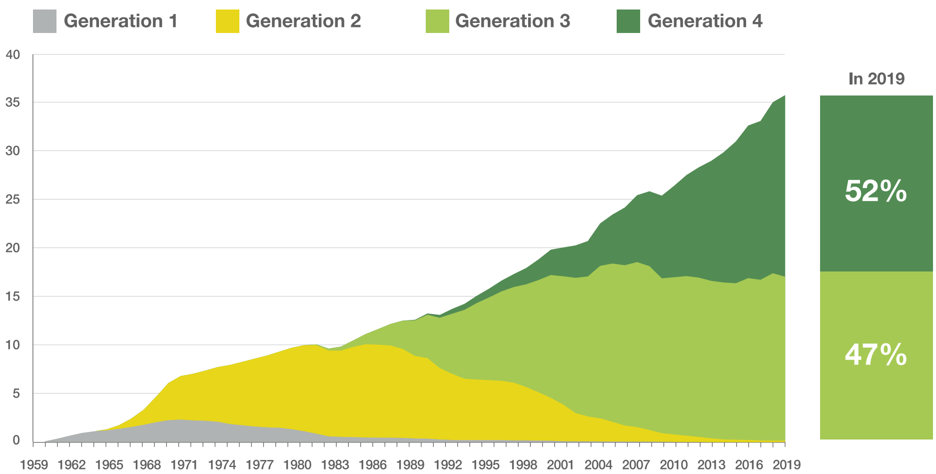
The huge reduction in accident rate evidenced on the previous pages has only been achieved by a long and ongoing commitment by the commercial aviation industry to place safety at the heart of its mission.
Whilst a significant part of this success is due to effective regulation and a strong safety culture and improvements in training, advances in technology have also been a critical element. Aircraft systems technology in particular has conscientiously evolved with safety in mind.

The first generation of jets was designed in the 1950s & '60s with systems technologies which were limited in their capabilities by the analogue electronics of the era.
A second generation of jet aircraft with improved auto-flight systems, quickly appeared.

The third generation of jets was introduced in the early 1980s.
This generation took advantage of digital technologies to introduce 'glass cockpits' with Navigation Displays and Flight Management Systems (FMS). Combined with improved navigation performance capabilities as well as Terrain Awareness and Warning System (TAWS), these capabilities were key to reducing Controlled Flight Into Terrain (CFIT) accidents.

The fourth and latest generation of civil aircraft was introduced in 1988 with the Airbus A320. Fourth generation aircraft use Fly-By-Wire (FBW) technology with Flight Envelope Protection functions. This additional protection helps to protect against Loss Of Control Inflight (LOC-I) accidents. FBW technology is now the industry standard and is used on all currently produced Airbus models, the Boeing B777 & B787, Embraer E-Jets and the Sukhoi Superjet.

Yearly number of flights per aircraft generation (in millions)



Industry status at end 2019	Generation 1	Generation 2	Generation 3	Generation 4
Aircraft in-service	3	200	12,068	14,405
Total accumulated flight cycles (million)	40.6	254.9	410.9	200.6
Flight cycles in 2019 (million)	0.0	0.2	16.9	18.7

FOUR GENERATIONS OF JET

1 Early commercial jets

From 1952

Dials & guages in cockpit. Early auto-flight systems

Comet, Caravelle, BAC-111, Trident, VC-10, B707, B720, DC-8, Convair 880/990

Caravelle

2 More integrated auto-flight

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

A300B2

3 Glass cockpits & FMS

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

A300-600

4 Fly-By-Wire

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

A350 XWB

2.4

Technology has improved aviation safety

Comparison of accident rates by generation of aircraft provides a clear illustration of the value of our industry's investments in technology for Safety.

Statistics over the life of each generation of jet show a significant improvement in the level of safety since the introduction of third generation aircraft and the latest fourth generation. Introducing TAWS technology with the third generation aircraft saw a huge reduction in the number of CFIT fatal accidents when compared to the previous first and second generation. The benefits of Fly-By-Wire technology and energy management systems can also be seen in the lower number of LOC-I and RE accident rates for fourth generation aircraft when compared with its previous third generation. More detailed analyses of the impact of these technologies are introduced in chapter 3.

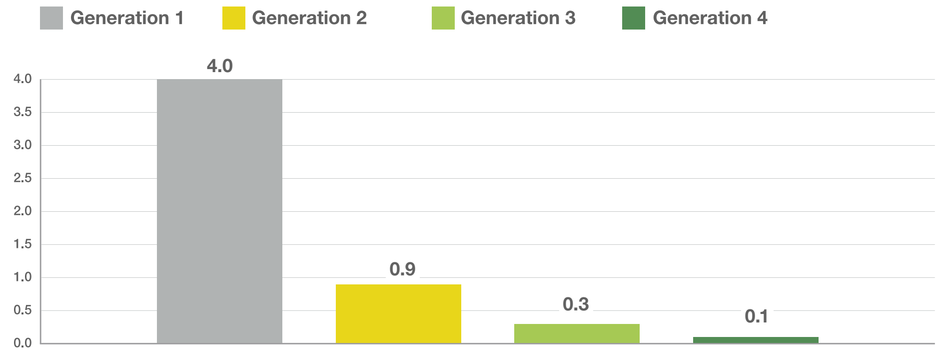
CFIT accidents

-86% from second to third generation

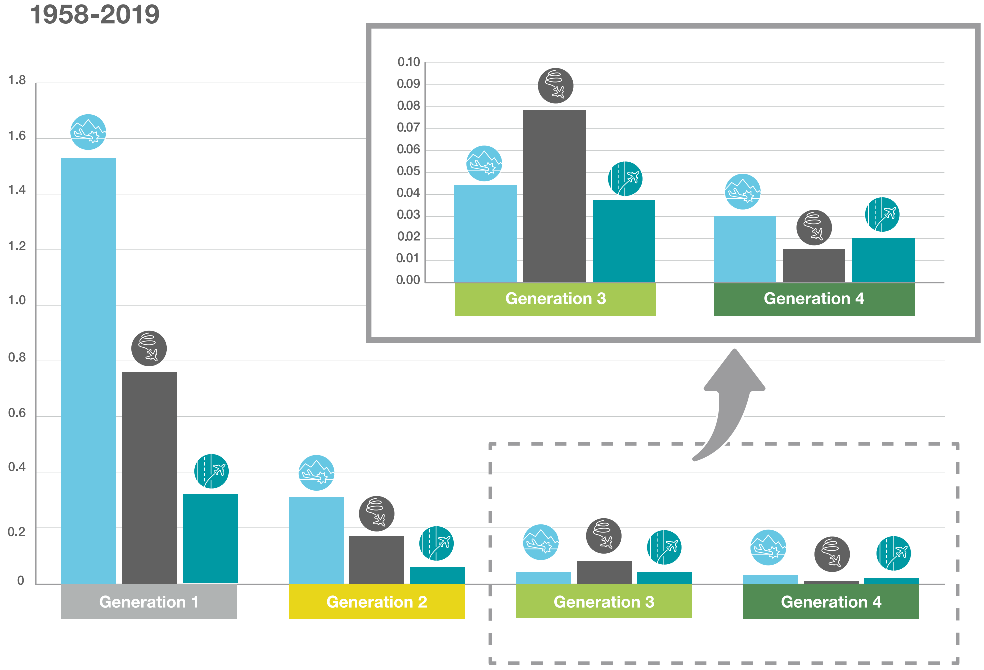
LOC-I accidents

-81% from third to fourth generation

Fatal accident rate (per million flights) per aircraft generation 1958-2019



Average fatal accident rate (per million flights) per accident category 1958-2019



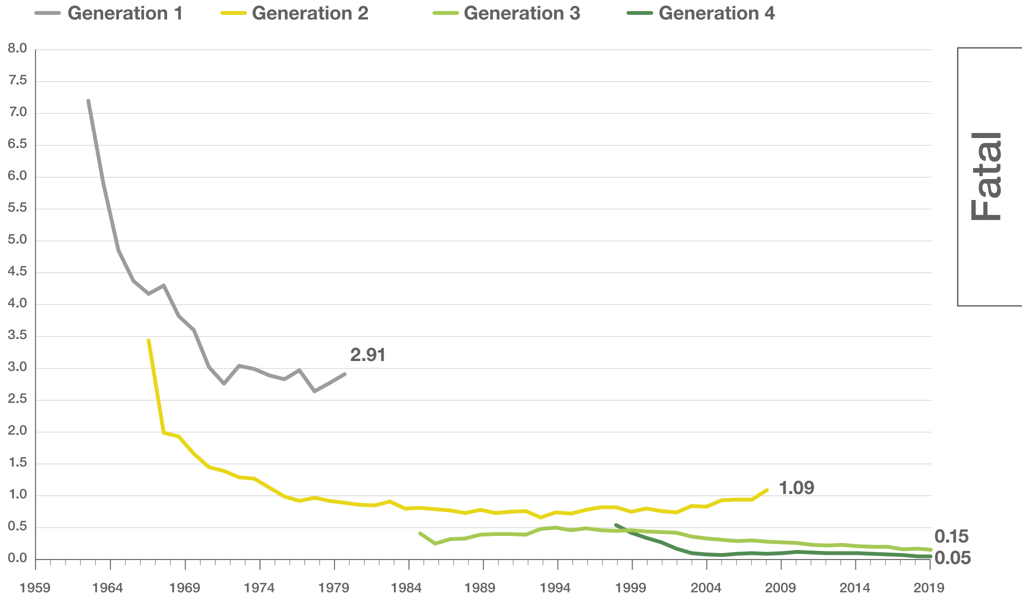
2.5

Evolution of accident rates by aircraft generation

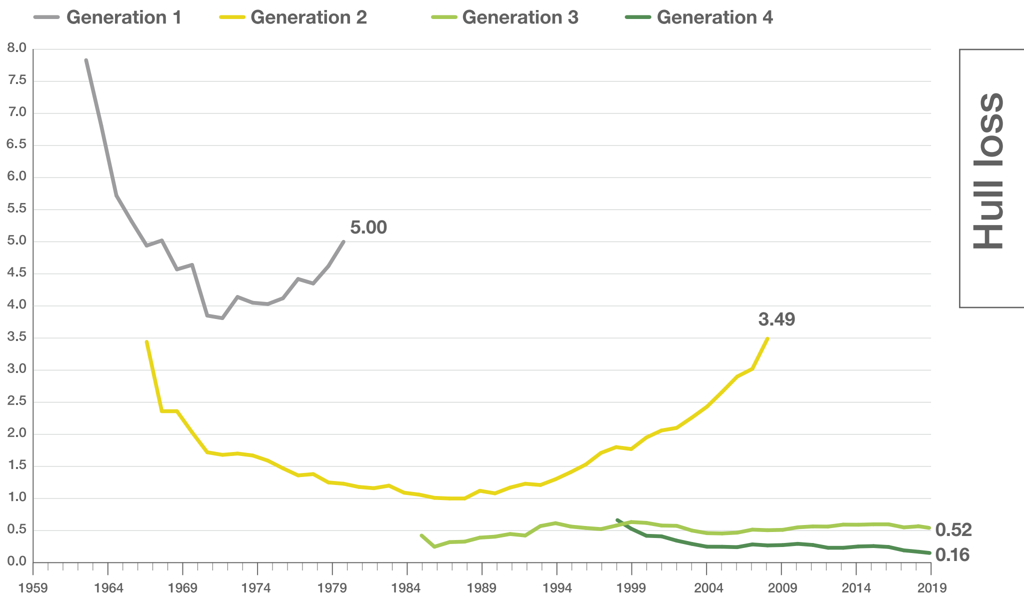
Advances in technology have decreased accident rates for each generation

Calculating 10 year moving average highlights long-term tendencies.
The calculations are only made when an aircraft generation has recorded more than 1 million flights in a year and the data is from 10 years after the entry into service of the first aircraft of that generation.
For example, fourth generation figures commence in 1998, which is 10 years after the entry into service of the A320.

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



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



3.0 Commercial aviation accidents over the last 20 years

A/THR
REV
FULL
A/THR
REV
FULL
ENG
ENG

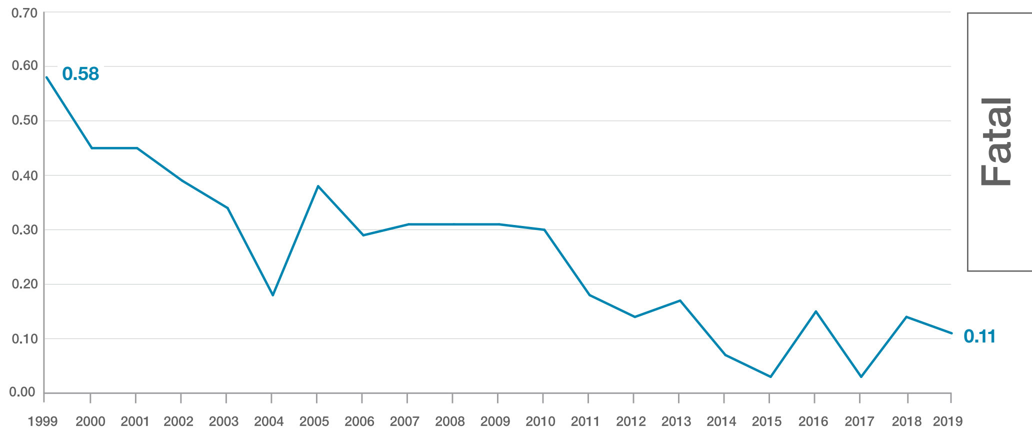
3.1

Evolution of the yearly accident rate

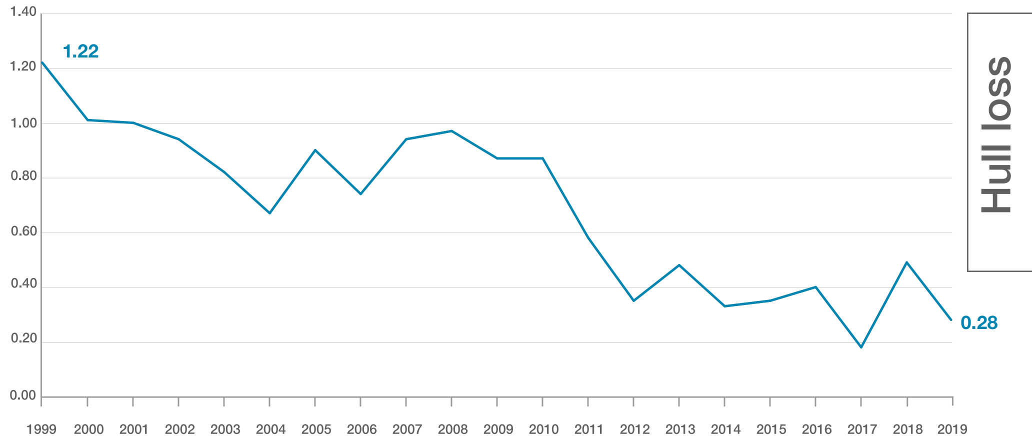
Significant reduction of the fatal accidents and hull losses were achieved across the industry since 1999

A significant proportion of these achievements can be attributed to investment in new technologies which enhance Safety.

Yearly fatal accident rate per million flights



Yearly hull loss accident rate per million flights



3.2

Ten year moving average of accident rate

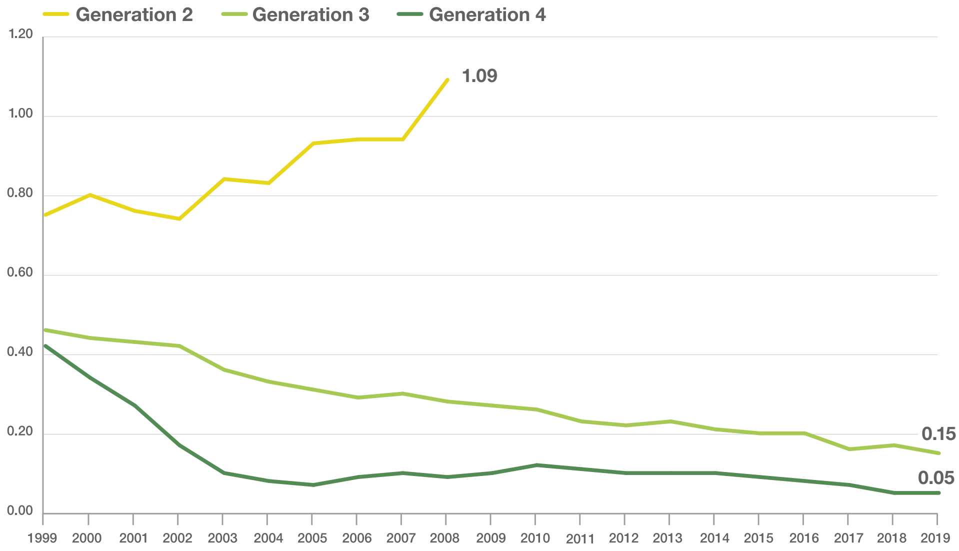
Fourth generation aircraft accident rates are lower than the third generation rates

Third generation aircraft reduced accident rates through 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.

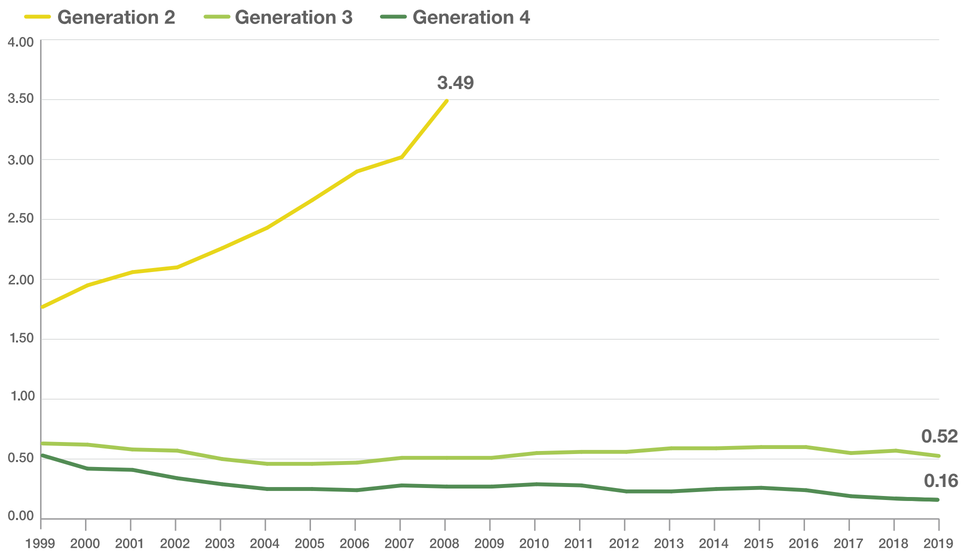
Fatal

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



3.3

Accidents by flight phase

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

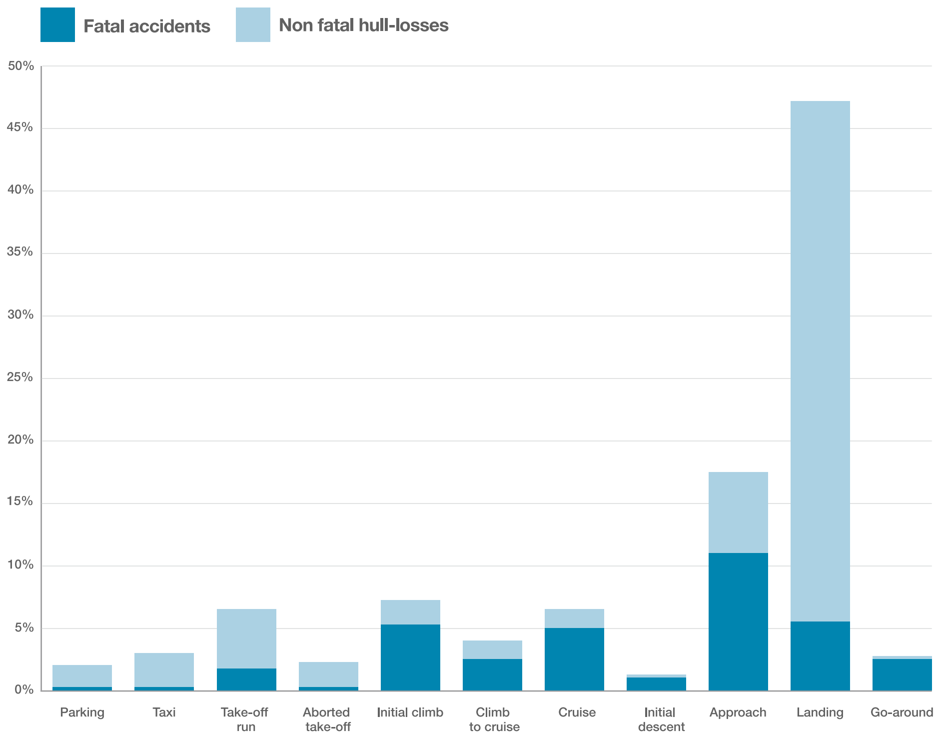
The percentage of accidents occurring in approach and landing highlights that these phases are operationally complex with high crew workload, which can be further aggravated by disadvantageous weather or traffic conditions.

It is not a surprise that the largest number of both fatal accidents and hull losses occur during approach and landing.

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, and frequently in responding to congested airspace or degraded weather conditions.

This confluence of high workload and the increased potential of unanticipated circumstances is exactly the kind of complex interplay of contributing factors that can lead to accidents.

Accidents per flight phase distribution 1999-2019



Definitions of flight phases

- **Parking:** this phase ends and starts when the aircraft respectively begins or stops moving forward under its own power.
- **Taxi:** this phase includes both taxi-out and taxi-in. Taxi-out starts when the aircraft begins moving forward under its own power and ends when it reaches the takeoff position. Taxi-in normally starts after the landing roll-out, when the aircraft taxis to the parking area. It may, in some cases, follow a taxi-out.
- **Takeoff run:** this phase begins when the crew increases thrust for the purpose of lift-off. It ends when an initial climb is established or the crew aborts its takeoff.
- **Aborted takeoff:** this phase starts when the crew reduces thrust during the takeoff run to stop the aircraft. It ends when the aircraft is stopped or when it is taxied off the runway.
- **Initial climb:** this phase begins at 35 feet above the runway elevation. It normally ends with the climb to cruise. It may, in some instances, be followed by an approach.
- **Climb to cruise:** this phase begins when the crew establishes the aircraft at a defined speed and configuration enabling the aircraft to increase altitude for the cruise. It normally ends when the aircraft reaches cruise altitude. It may, in some cases end with the initiation of a descent.
- **Cruise:** this phase begins when the aircraft reaches the initial cruise altitude. It ends when the crew initiates a descent for the purpose of landing.
- **Initial descent:** this phase starts when the crew leaves the cruise altitude in order to land. It normally ends when the crew initiates changes in the aircraft's configuration and/or speed in view of the landing. It may, in some cases end with a cruise or climb to cruise phase.
- **Approach:** this phase starts when the crew initiates changes in the aircraft's configuration and/or speed in view of the landing. It normally ends when the aircraft is in the landing configuration and the crew is dedicated to land on a particular runway. It may, in some cases, end with the initiation of an initial climb or go-around phase.
- **Go-around:** this phase begins when the crew aborts the descent to the planned landing runway during the approach phase. It ends with the initiation of an initial climb or when speed and configuration are established at a defined altitude.
- **Landing:** this phase begins when the aircraft is in the landing configuration and the crew is dedicated to land on a particular runway. It ends when the aircraft's speed is decreased to taxi speed.

3.4

Distribution of accidents by accident category

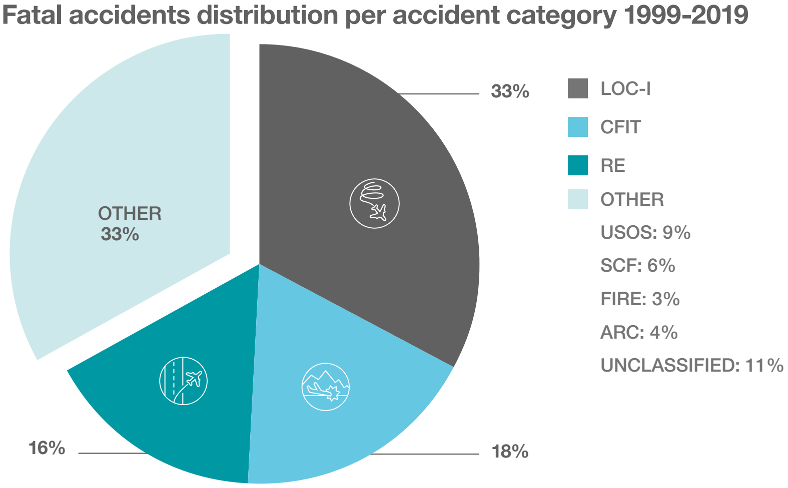
The biggest cause of fatal accidents over the last 20 years was the loss of control in flight (LOC-I)

LOC-I accidents are significantly reduced by technologies already existing on fourth generation aircraft.

CFIT accidents continue to decrease thanks to the availability and continued development of glass cockpit and navigation technologies available on both third and fourth generation aircraft.

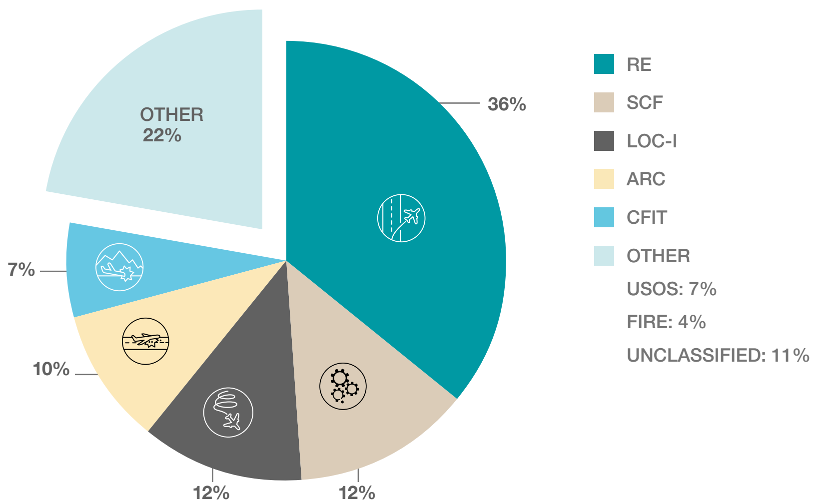
Runway Excursions (RE), including both lateral and longitudinal types, are the third major cause of fatal accidents and the primary cause of hull losses.
Emerging technologies (energy-based and performance-based) are very promising for addressing longitudinal events.

Fatal accidents distribution per accident category 1999-2019



Fatal

Hull losses accidents distribution per accident category 1999-2019



Hull loss

3.5 Evolution of the main accident categories

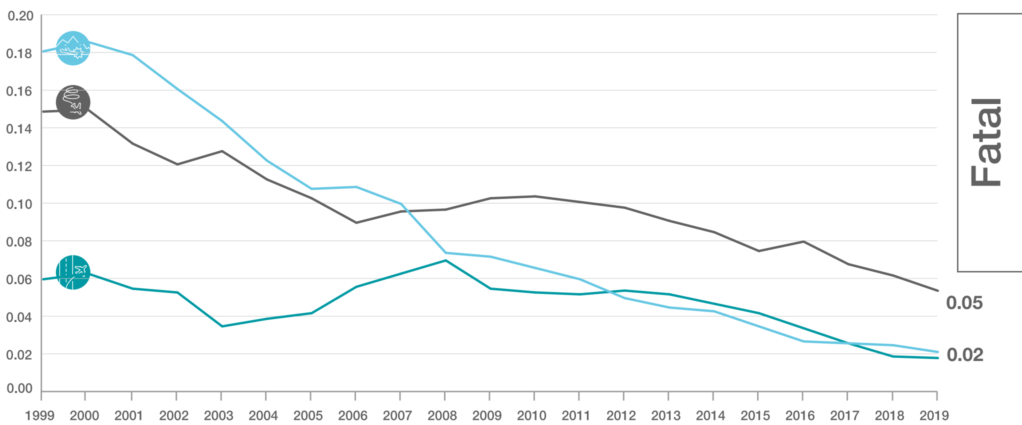
In the last 20 years, the fatal accident rate of CFIT reduced by 89%, LOC-I by 66%

Since 1999, the proportion of the flights flown by aircraft equipped with Terrain Awareness and Warning System (TAWS) technology to prevent CFIT accidents has grown from 68% to 99%. The wide adoption of this technology is a key element in the significant reduction of the CFIT accident rate evidenced on this page.

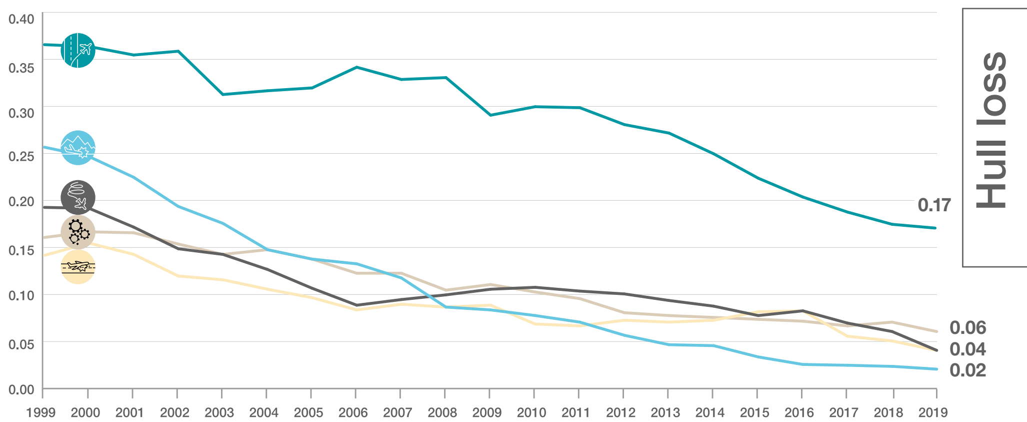
Regarding LOC-I, in 2019 the proportion of flights flown by generation four aircraft equipped with technology to reduce LOC-I accidents was 52%. Since the rate of LOC-I accidents is 76% lower on fourth generation aircraft than on third generation aircraft, we can expect the rate of LOC-I accidents to further decrease as the number of fourth generation aircraft in-service increases.

In terms of RE, the first deployment of technologies to address this cause of accidents was achieved towards the end of the last decade. The number of aircraft equipped with these technologies remains low, at around 8% of the in-service fleet. Therefore, whilst we may observe a decreasing trend in hull losses due to RE, it remains too early to draw conclusions.

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

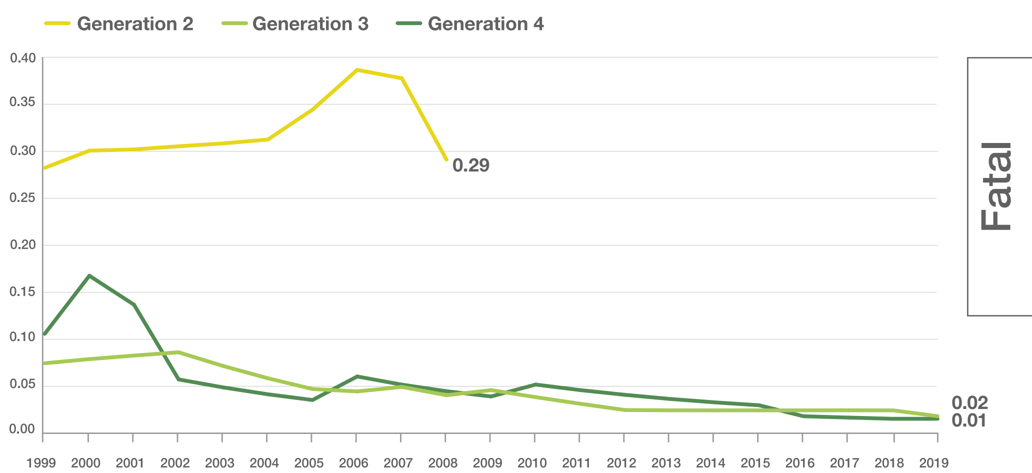
Controlled Flight Into Terrain (CFIT) accident rates

The introduction of Glass Cockpits, FMS & Terrain Awareness and Warning Systems has reduced CFIT accident rates by 89%

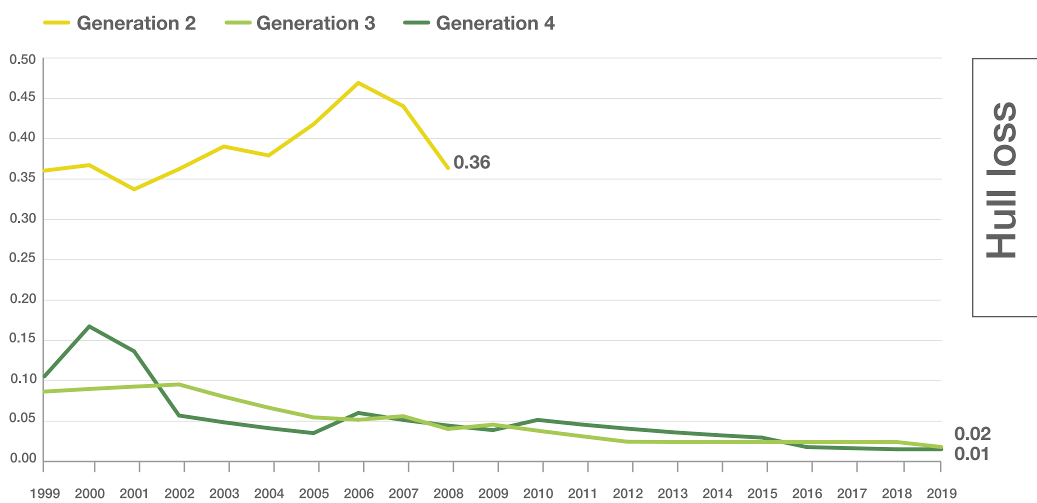
Technologies to reduce CFIT were introduced progressively with Ground Proximity and Warning Systems and then Terrain Awareness & Warning System (TAWS).

Subsequently, Glass Cockpits installed on the third generation of aircraft improved navigation performance and helped to further reduce the CFIT rate.

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



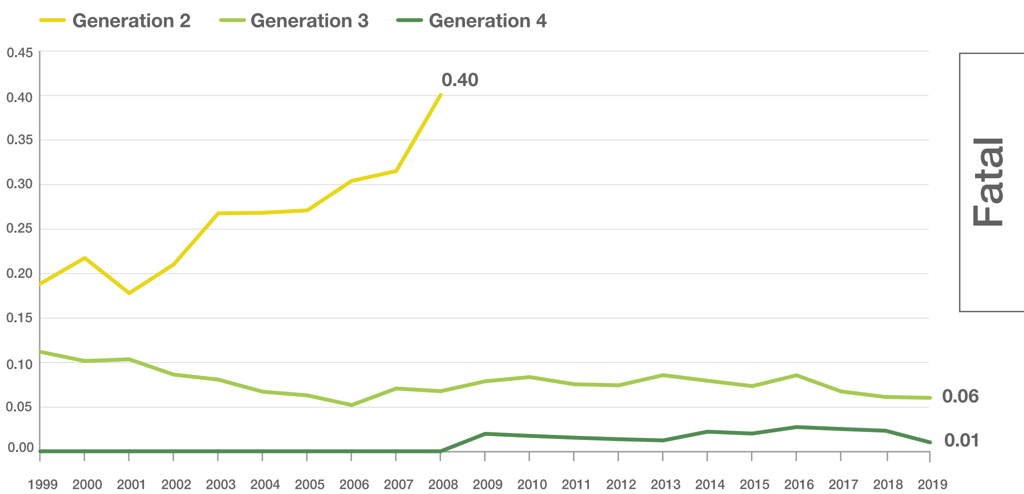
3.7 Loss Of Control In-flight (LOC-I) accident rates

Flight envelope protection has reduced LOC-I accident rates by 76% compared to third generation aircraft

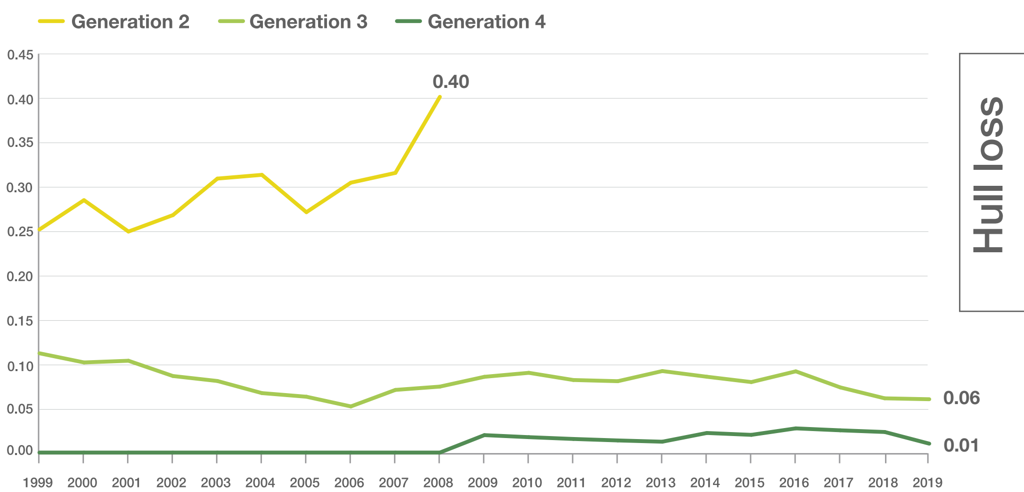
The fourth generation of aircraft has accumulated 30 years of experience since the A320 aircraft entered into service in 1988.

This represents a significant experience with more than 200 million accumulated flights. This strong statistical basis illustrates the significant safety benefit of flight envelope protected aircraft to address LOC-I.

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



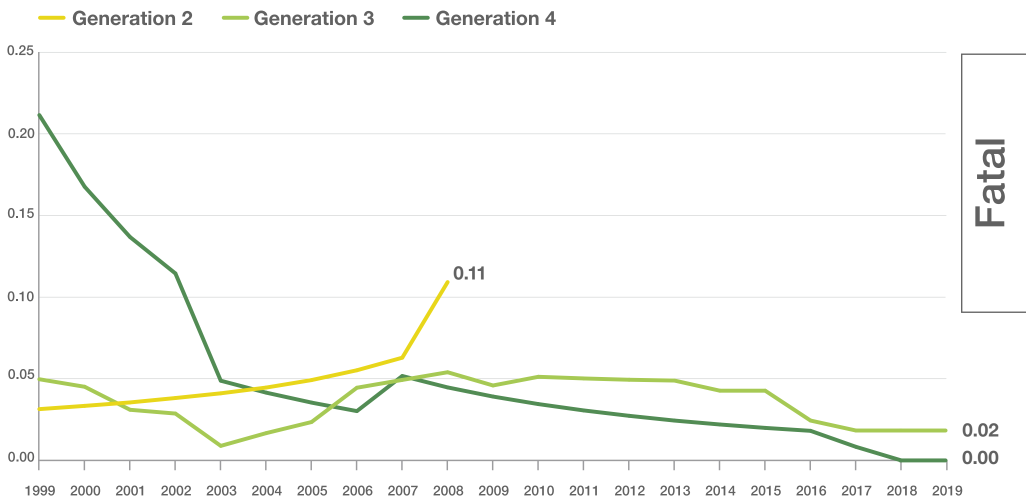
3.8

Runway Excursion (RE) accident rates

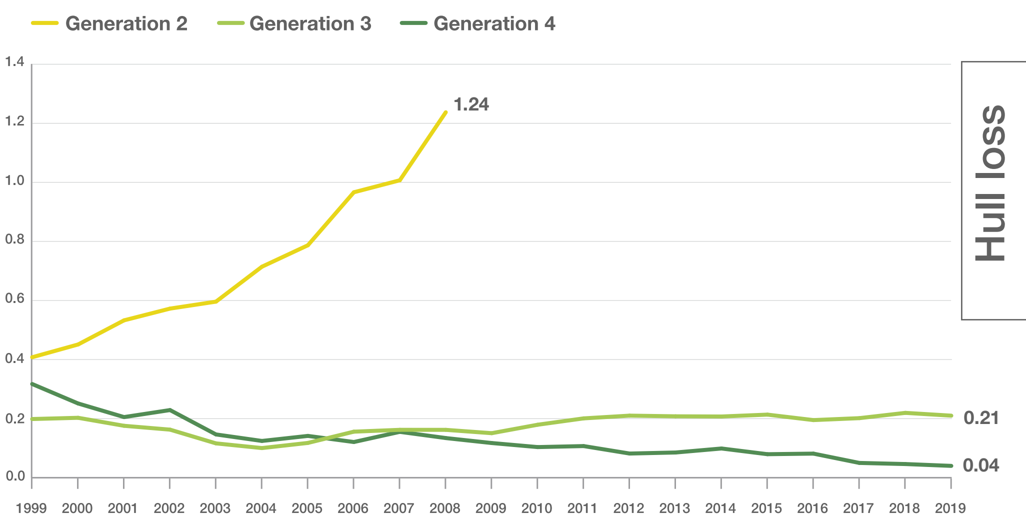
New technologies to reduce RE accidents have recently been introduced

Most longitudinal Runway Excursions are related to aircraft energy management. Significant improvement of RE accident rates can be expected from the introduction of real time energy and landing performance-based warning systems. Today, the proportion of aircraft equipped with such system is too low for the overall gain to be visible but this additional safety net is a promising step change to reduce longitudinal RE occurrences.

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



List of tables and graphs

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