Airbus

A Statistical Analysis of Commercial Aviation Accidents 1958-2018

AIRBUS

Contents

Scope and definitions

This publication provides Airbus' annual analysis of aviation accidents, with commentary on the year 2018, 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.**
  The following aircraft are included in the statistics: 328 JET, A220, A300, A300-600, A310, A318/319/320/321, A330, A340, A350, A380, Avro RJ series, B707, B717, B720, B727, B737, B747, B757, B767, B777, B787, BAC -111, BAE 146, Caravelle, Comet, Concorde, Convair 880/990, DC-8,DC-9, DC-10, Embraer E series, Embraer ERJ series, F-28, F-70, F-100, L-1011, MD-11, MD-80/90, Mercure, Trident, VC-10, VFW 614.
  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 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 five 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.

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.

1.0 2018 & beyond


NO STEP
DANGER
HEATED PROBE
NO STEP
DANGER
HEATED PROBE
NO STEP
DANGER
HEATED PROBE
NO STEP
DANGER
HEATED PROBE

1.1 Accidents in 2018

In the accident analysis of 2017 we wrote that, “Now more than ever, we must avoid complacency and remember to keep our eyes clearly focused on emerging threats.” Unfortunately, in 2018 our industry has witnessed not only five fatal accidents of revenue flights, but also seventeen hull losses.

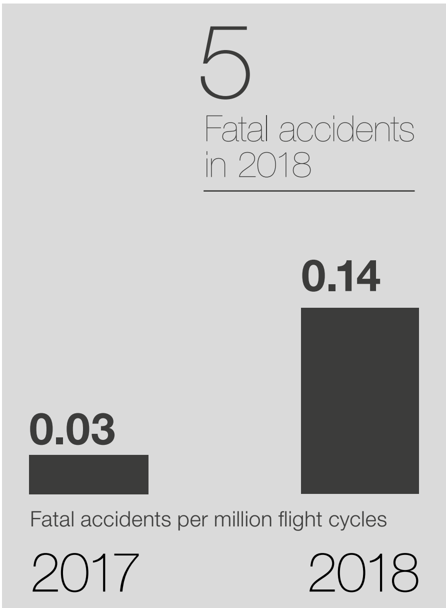
This disparity in the past two-years underscores the message that we must not allow a year with few accidents to make us complacent, and we cannot afford to take the level of safety achieved in our industry as a given.

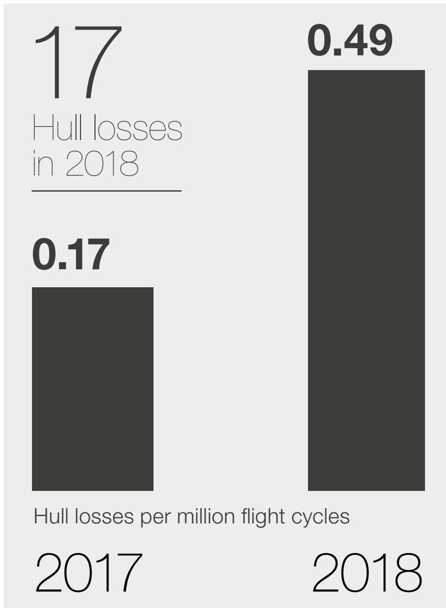
The crews operating the growing fleet of aircraft, and the flying public, expect zero accidents. An aviation accident is first and foremost a human tragedy – one that touches everyone.

Technology introduced in successive generations of aircraft has continuously reduced the rate of CFIT and LOC-I fatal accidents in 3rd and 4th generation aircraft respectively. Recently introduced energy and performance based technologies are showing a positive trend in reducing the rate of longitudinal Runway Excursions (RE) accidents.

However, even as this ongoing investment delivers greater reliability and resilience, it must be continuously supported by robust safety governance, pragmatic regulation and a shared vision of safety for the entire aviation industry – and all those who rely upon it.

To avoid the complacency risk, it is essential that all actors across our industry continue working together, to share information about how to address the systemic, operational and emerging threats – so that safe aircraft, are safely operated, in a safe air transport system.





	2017	2018
Flight departures	**33** MILLION	**35** MILLION
In-service fleet	**24,550** AIRCRAFT	**25,970** AIRCRAFT

1.2 Beyond 2018

Historical data shows air traffic doubles every 15 years

Airbus' Global Market Forecast (GMF) predicts the same doubling of global air traffic over the next next 15 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.

KEEPING AN EYE ON EMERGING THREATS

In the last 20 years, the industry-wide accident rate has been divided by around 8 for fatal accidents, and by around 3 for hull losses considering all generations of aircraft. Over the same period, traffic increased by around 150%. This shows that investments in safety bear fruit, safety is enhanced, and accidents are largely prevented from happening.

However, when we observe the increasing levels of congestion in our airports and skies, the relative stability of the industry in current times could be considered as somewhat stressed.

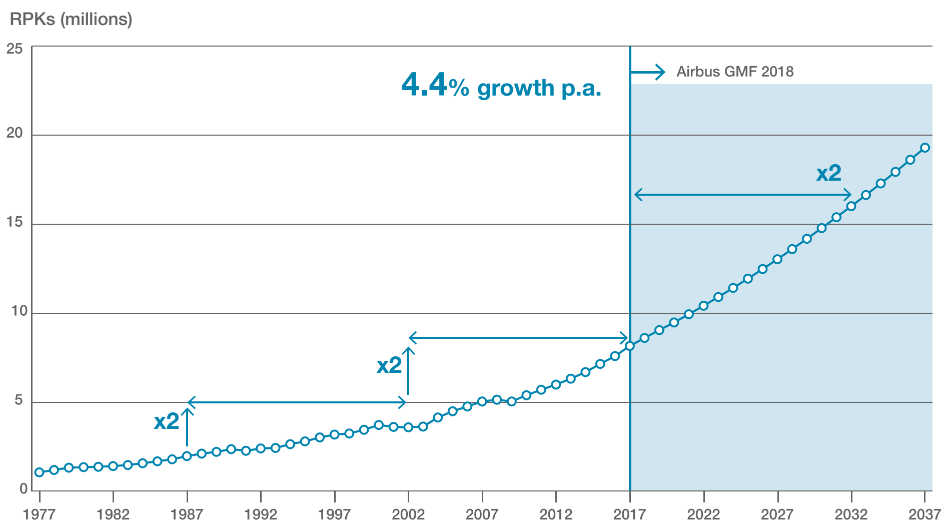
Additionally, the fleet's growth rate is tremendous, with traffic doubling every 15 years and the industry delivering around 2000 new aircraft per year. This growth must be supported by a proportional increase in the number of trained personnel including pilots, technicians, cabin crew, and air traffic controllers and beyond.

Considering these trends, we might conclude that if the accident rate stays the same, the industry's increased exposure to accidents in numerical terms is in direct proportion to this increase in activity. To put it simply, more flights will mean more accidents unless we work to decrease the accident rate.

That is why we at Airbus believe there is no room for complacency. We believe we must be ambitious, inject even more vigour into our industry's long tradition of improvement, and challenge ourselves to drive accident rates lower than ever before,

To achieve this, we will need to work co-operatively together, and increase our safety enhancement efforts by identifying the most promising opportunities we have for responding to the new hazards and threats which are arising.

World annual traffic forecast



1.3 Forecast increase in number of aircraft 2018-2037

Global increase by 2037

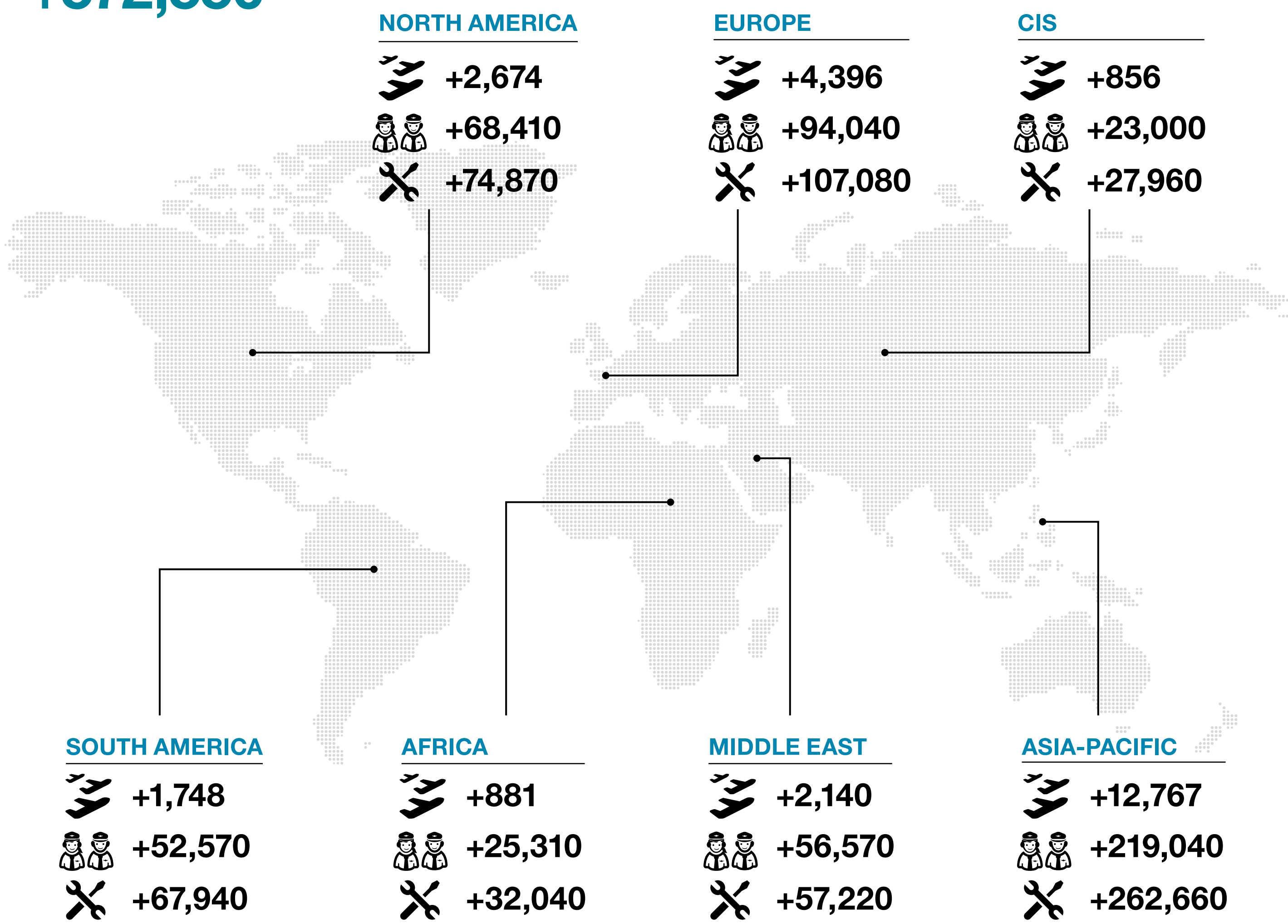
In-service fleet
+25,462

New pilots
+484,370

New technicians
+572,550

Each aircraft delivered 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.



2.0 Commercial aviation accidents since the advent of the jet age


FLASH LIGHT

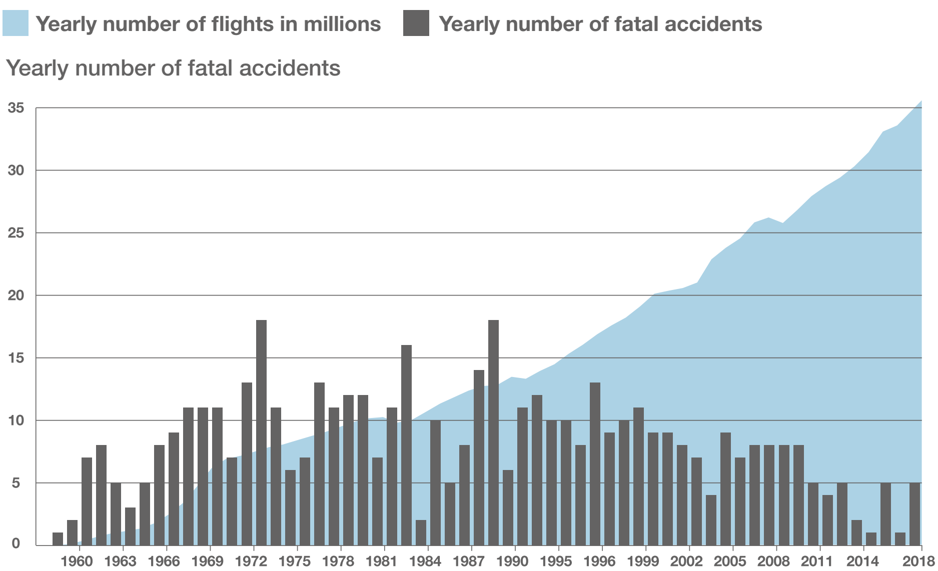
2.1 Evolution of the number of flights & accidents

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

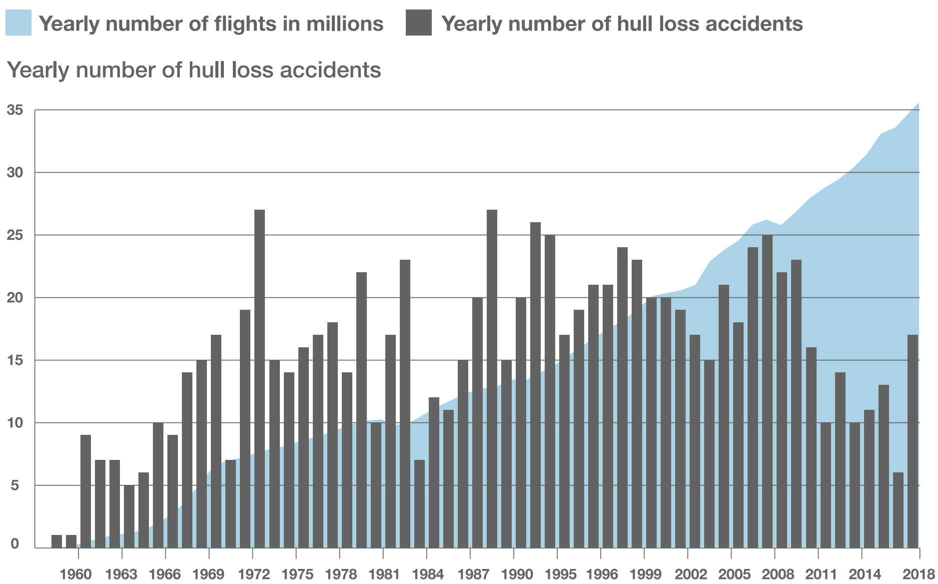
Accidents are rare occurrences, consequently their number may vary considerably from one year to the next. Therefore, focusing too closely on a single year's figure may be misleading.

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

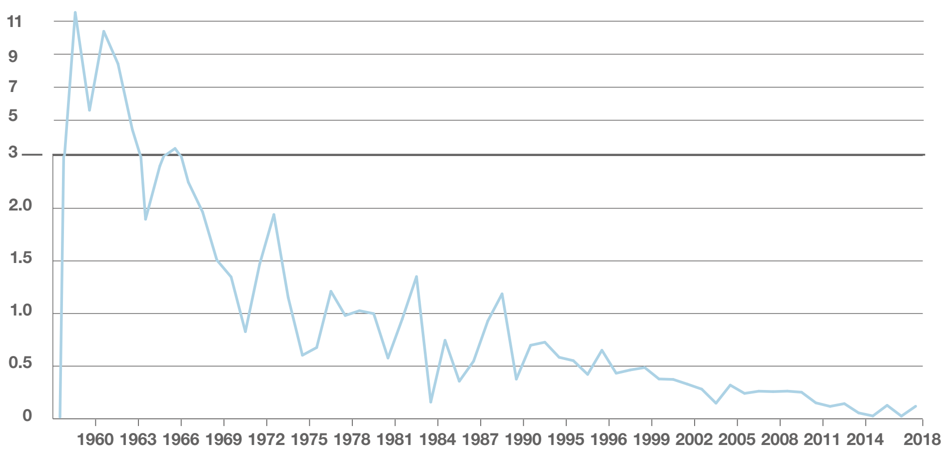
Rates of fatal accidents as well as hull-losses are steadily decreasing over time

The values of peak accident rate evidenced in the 1960s, when the number of flights was much lower than today, illustrate the difficulty of considering accident data from a period with a low volume of industry activity.

Today, approximately 35 million flight cycles per year are completed by jet aircraft, making a sound statistical basis for analysis.

Yearly fatal accident rate

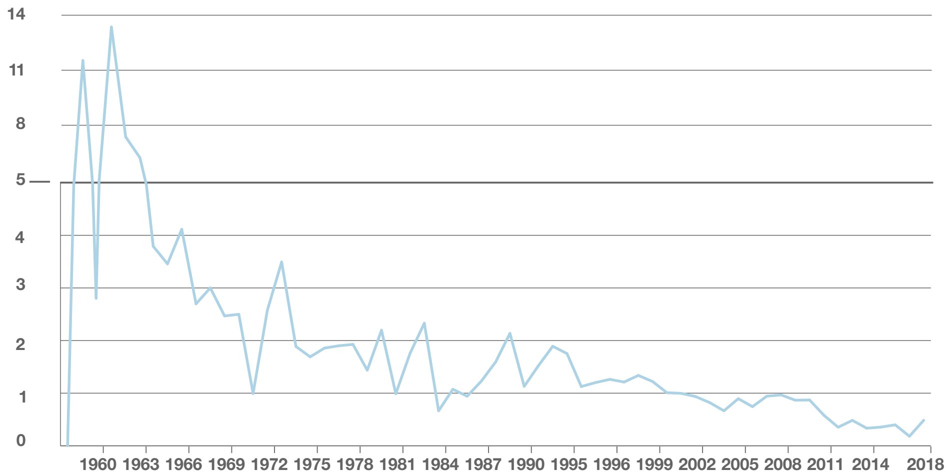
Yearly fatal accident rate per million flights



Fatal

Yearly fatal hull loss

Yearly hull loss rate per million flights



Hull loss

2.3 Evolution of the commercial air transport fleet

Airbus aircraft flew 78% of the flights made by fourth generation jets in 2018

In 2018, nearly 35 million flight departures were made globally. Of these, 17.6 million were made with fourth generation jets, of which Airbus models accounted for 13.7 million.

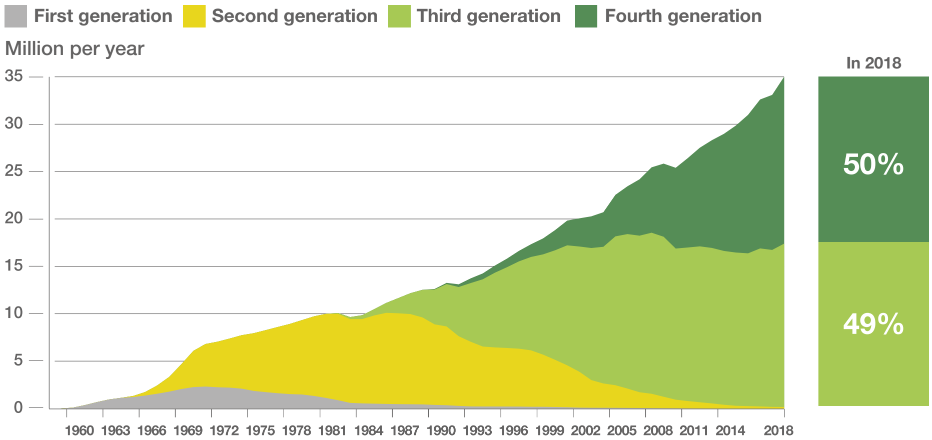
The huge reduction in accident rate evidenced on the previous pages has only been achieved by a long and ongoing commitment by the commercial aviation industry to place safety at the heart of its mission. Whilst a significant part of this success is due to effective regulation and a strong safety culture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

The first generation of jets were 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, Sukhoi Superjet and the Mitsubishi MRJ.

Yearly number of flights by aircraft generation millions per year



Industry status at end 2018	Generation 1	Generation 2	Generation 3	Generation 4
Aircraft in-service	3	230	12,043	13,696
Total accumulated flight cycles (million)	40.6	254.7	394.0	181.9
Flight cycles in 2018 (million)	0.0	0.2	17.2	17.6

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, 707, 720, DC-8, Convair 880/890

Caravelle

2 More integrated auto-flight

From 1964

More elaborate auto-pilot and auto-throttle systems

Concorde, A300B2/B4, Mercure, F-28, BAe146, VFW 614 727, 737-100 & -200, 747-100/200/300/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, F-70, F-100, 328JET, 717, 737 Classic & NG/MAX, 757, 767, 747-400/-8, Bombardier CRJ, Embraer ERJ, 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, 777, 787, Embraer E-Jets

A350 XWB

2.4 Impact of technology on aviation safety

CFIT accidents

-85% from second to third generation

LOC-I accidents

-75% from third to fourth generation

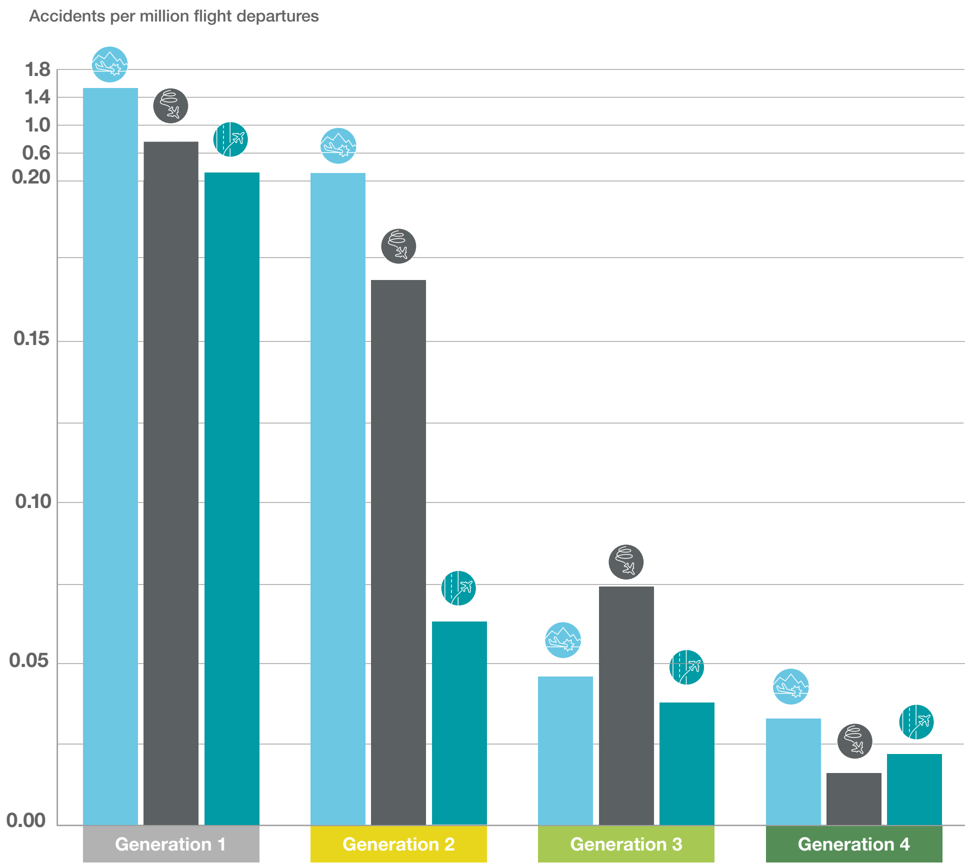
Comparison of accident rates by generation of aircraft provides a clear illustration of the value of our industry's investments in technology for Safety.

Studying the statistics over the life of each generation of jets shows that an 85% reduction in fatal CFIT accidents has been achieved between the second and third generation of jets. In addition to this achievement, the fourth generation of jets has added a 75% reduction in fatal LOC-I accidents compared to the third generation. These are great achievements, which we can properly put into context by studying the overall reduction in the fatal accident rate per generation.

The lowest sustained fatal accident rate of first generation jets was around 3.0 accidents per million flights, whilst for the second generation it was around 0.7, meaning a reduction of fatal accidents of almost 80% between generations. In comparison, third generation jets now achieve about 0.2 accidents per million flights, a reduction of around a further 70%.

Finally, fourth generation jets have the lowest accident rate of all, at a stable average rate of about 0.1 fatal accidents per million flights, which is a further 50% reduction compared to the third generation.

Average fatal accident rate by accident category 1958-2018

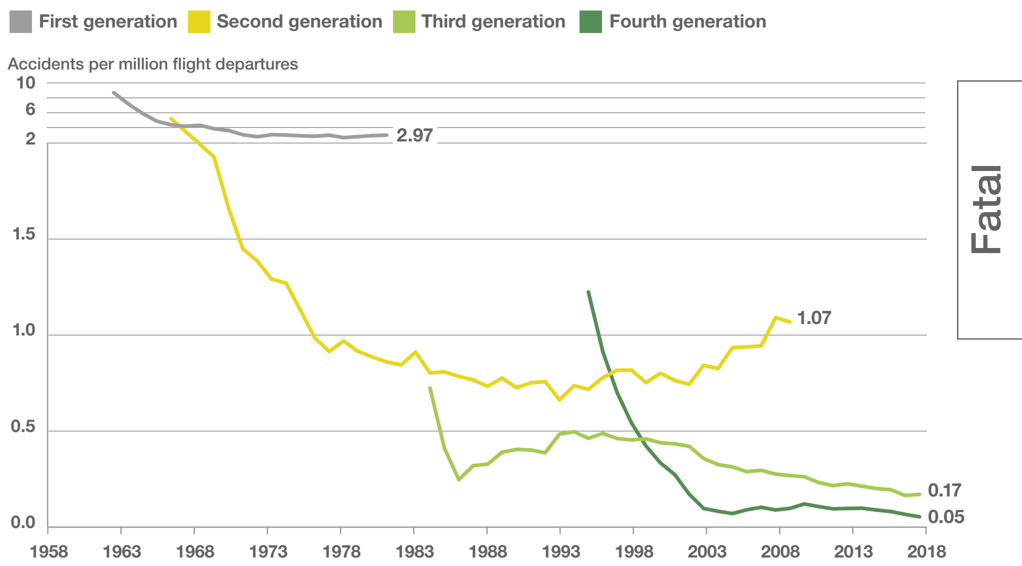


2.5 Evolution of accident rates by aircraft generation

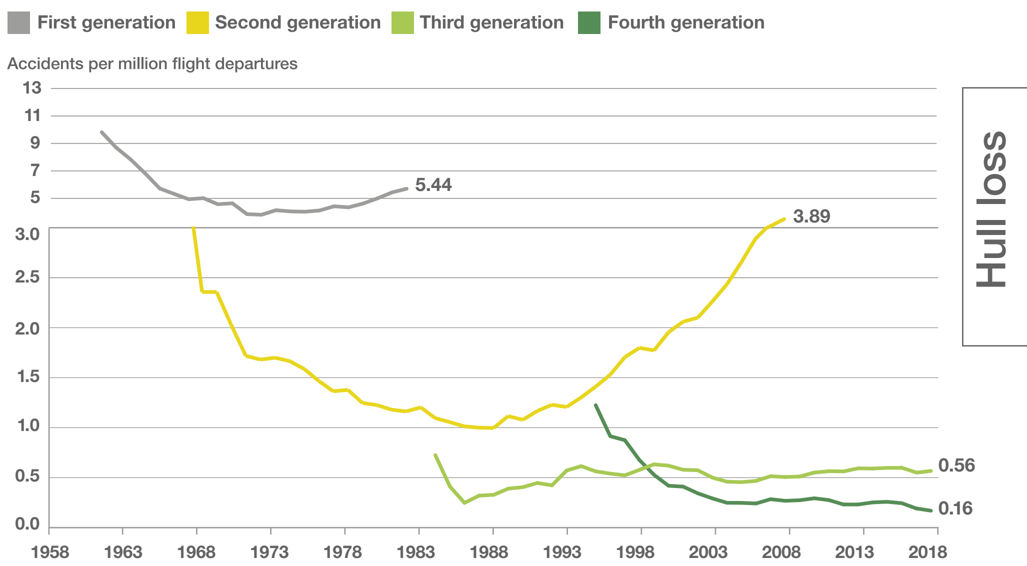
Advances in technology have decreased accident rates for each generation

The graphs above and below highlight the long-term trend of reduced fatal and hull loss accident rates, achieved through investment in technology between generations.

10 year moving average fatal accident rate by aircraft generation



10 year moving average hull-loss rate by aircraft generation



3.0 Commercial aviation accidents over the last 20 years

A/THR
REV
FULL
A/THR
REV
FULL
40
35
30
25
20
15
10
5
0
0
CG 30
1 DN
CG 35
2 DN
CG 40 43
3 DN
ENG 1
ENG 2

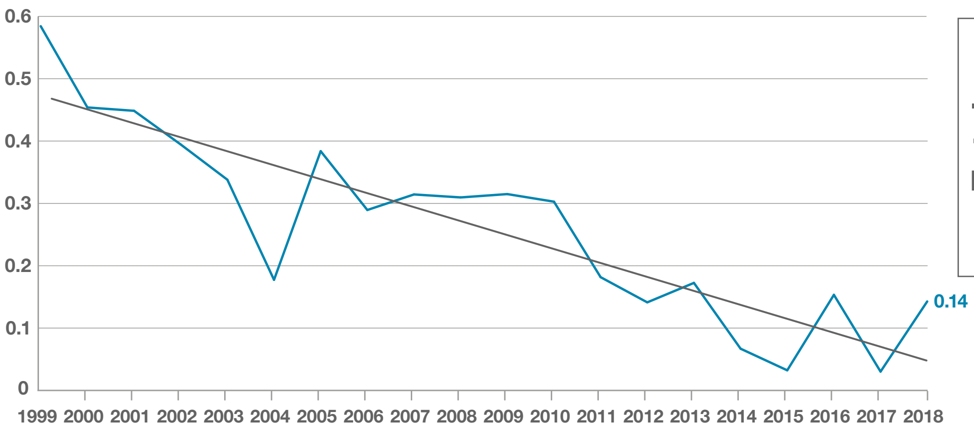
3.1 Evolution of the yearly accident rate

Since 1999, the aviation industry has succeeded to reduce the fatal accident rate by around 95%

The hull loss rate has also been reduced significantly, by around 70%.

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

Yearly fatal accident rate per million flights



Fatal

Yearly hull loss accident rate per million flights

Hull loss

3.2 Ten year moving average of accident rate

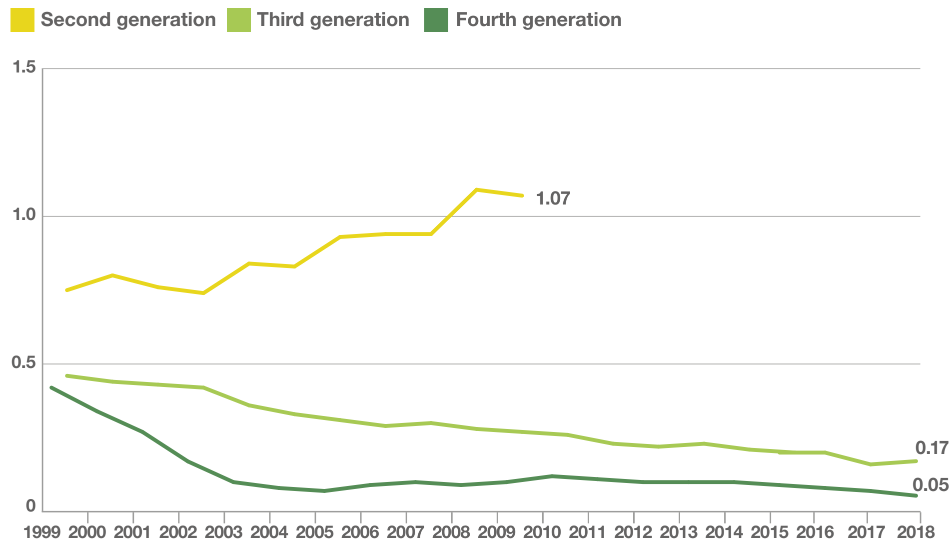
Accident rates for fourth generation of aircraft are around 50% lower than for the third generation

The third generation of aircraft helped to reduce accidents rates by introducing Glass Cockpits with Navigation Displays and Flight Management Systems.

The fourth generation of aircraft have incorporated these advances, and included Fly-By-Wire technology which makes Flight Envelope Protection possible.

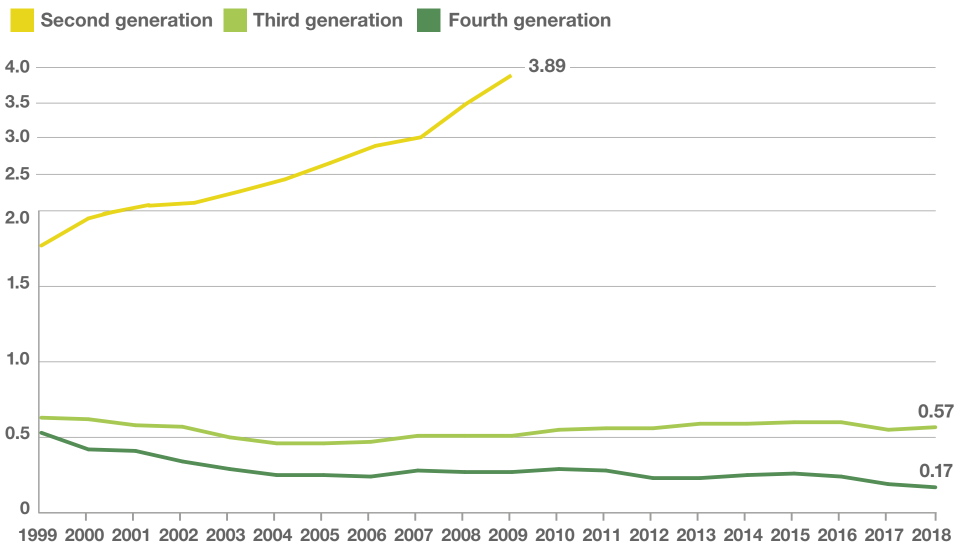
Fatal

10 year moving average fatal accident rate by aircraft generation per million flights 1999-2018



Hull loss

10 year moving average hull loss accident rate by aircraft generation per million flights 1999-2018



3.3 Accidents by flight phase

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

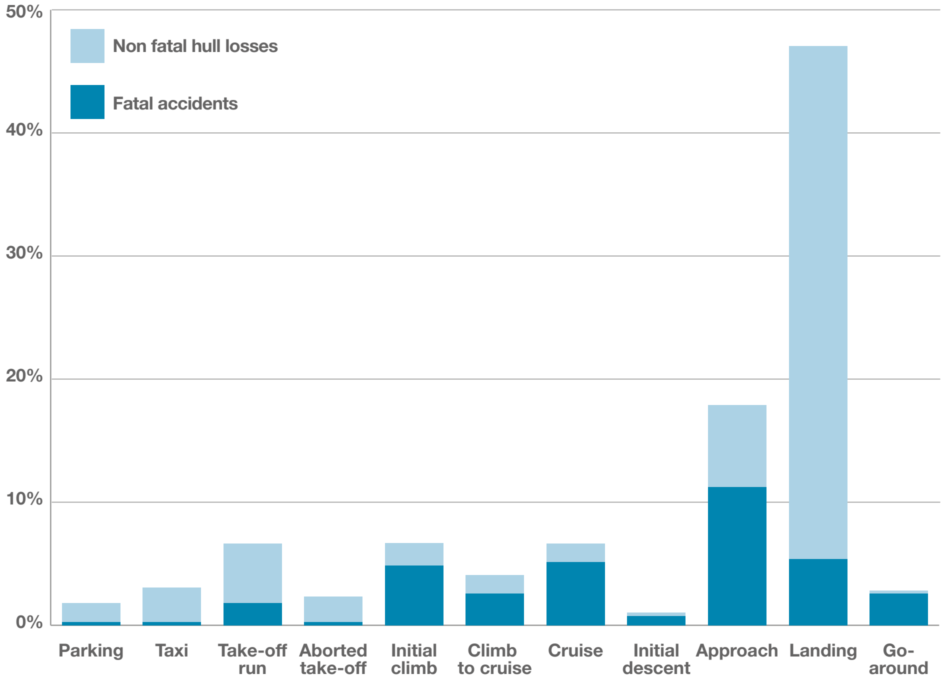
The percentages of accidents occurring in approach & landing highlight that these phases are operationally complex with high crew workload, which can be further aggravated by disadvantageous weather or traffic conditions.

It is not a surprise that the largest percentages of both fatal accidents and hull losses are seen to 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 by flight phase as a percentage of all accidents 1999-2018



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 single biggest cause of fatal accidents over the last 20 years is LOC-I

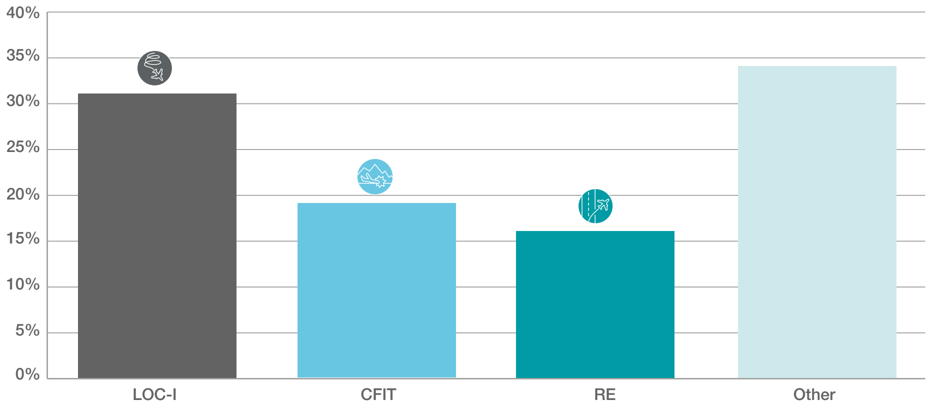
LOC-I accidents have been shown to be significantly reduced by technologies already existing on fourth generation aircraft.

CFIT accidents continue to be reduced in number 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 by numbers, and the single biggest cause of hull losses. Emerging technologies (energy-based and performance-based) are very promising for addressing longitudinal events.

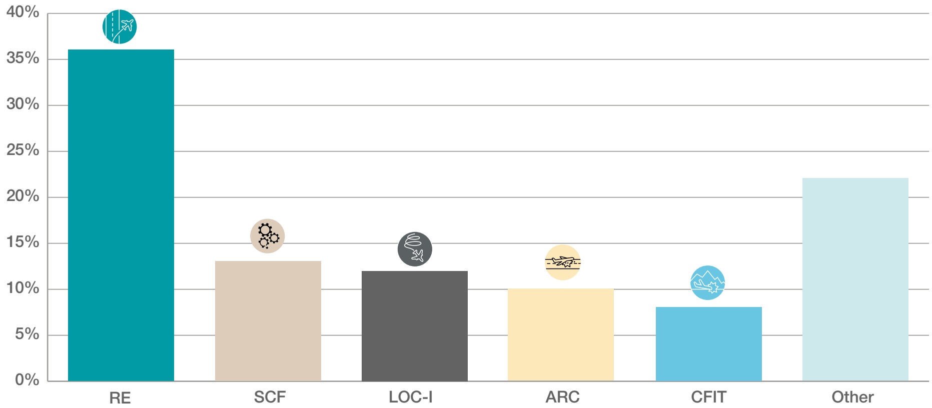
Fatal

Percentage of fatal accidents by accident category 1999-2018



Hull loss

Percentage of hull losses by accident category 1999-2018



3.5 Evolution of the three main accident categories

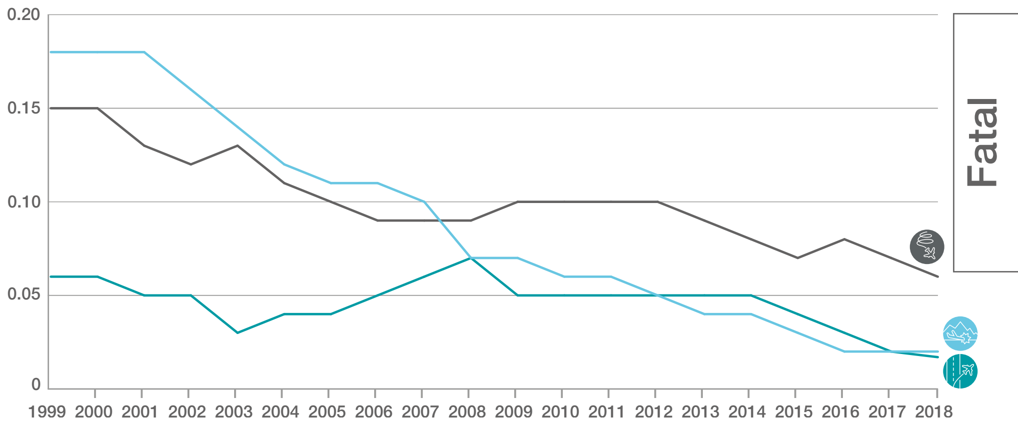
In the last 20 years, the rate of CFIT reduced by a factor of 7, LOC-I by 2

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.

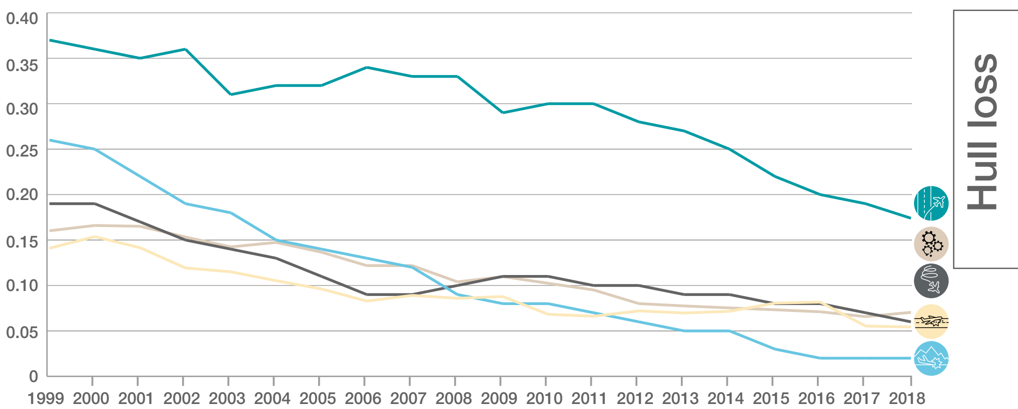
Regarding LOC-I, in 2018 the proportion of flights flown by generation four aircraft equipped with technology to reduce LOC-I accidents was 48%. Since the rate of LOC-I accidents is 75% lower on fourth generation aircraft than on third generation aircraft, we can expect the rate of LOC-I accidents to further decrease as the number of generation 4 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 5% 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 by accident category per million flights



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



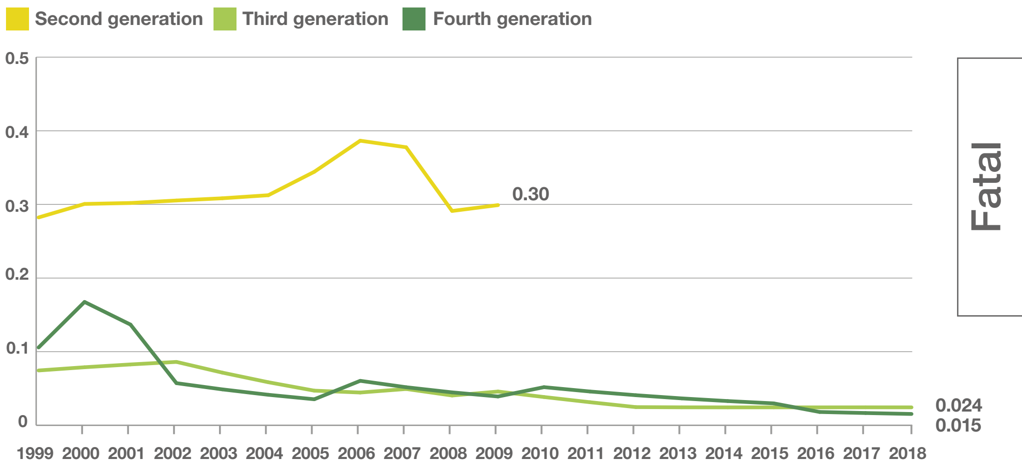
3.6 Controlled Flight Into Terrain (CFIT) accident rates

The introduction of Glass Cockpits, FMS & Terrain Awareness and Warning Systems has reduced CFIT accident rates by 85%

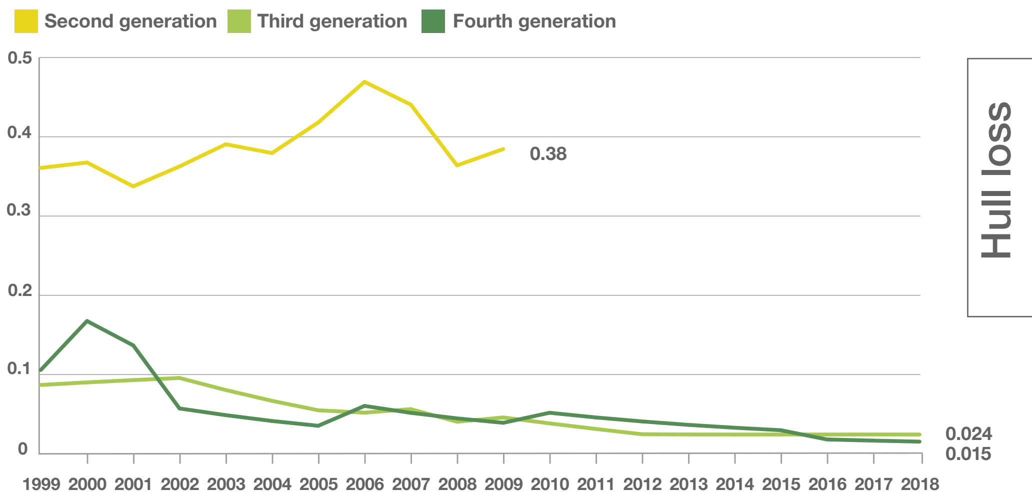
Technologies to reduce CFIT were introduced progressively with Ground Proximity and Warning Systems and then Terrain Awareness & Warning System (TAWS).

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 rate by aircraft generation per million flights



10 year moving average CFIT rate by aircraft generation per million flights



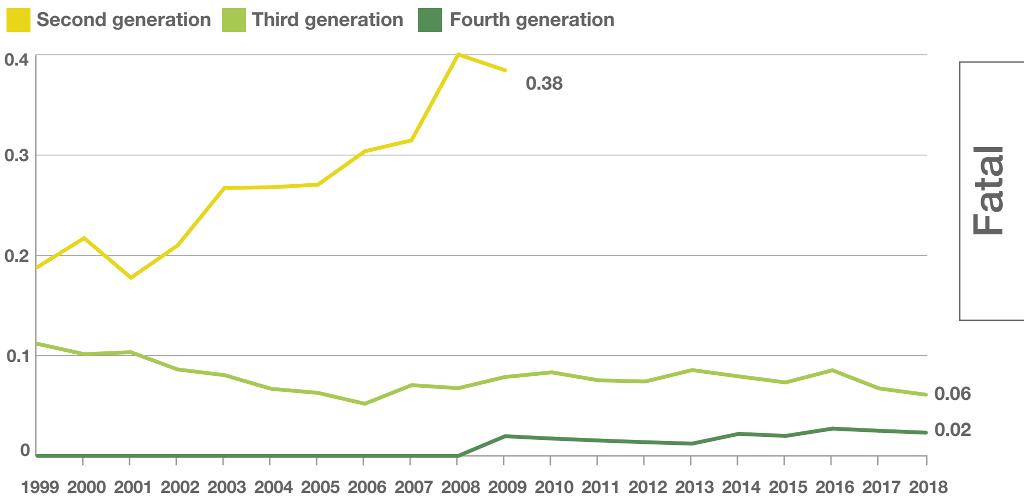
3.7 Loss Of Control In-flight (LOC-I) accident rates

Flight envelope protection has reduced LOC-I accident rates by 75% compared to third generation aircraft

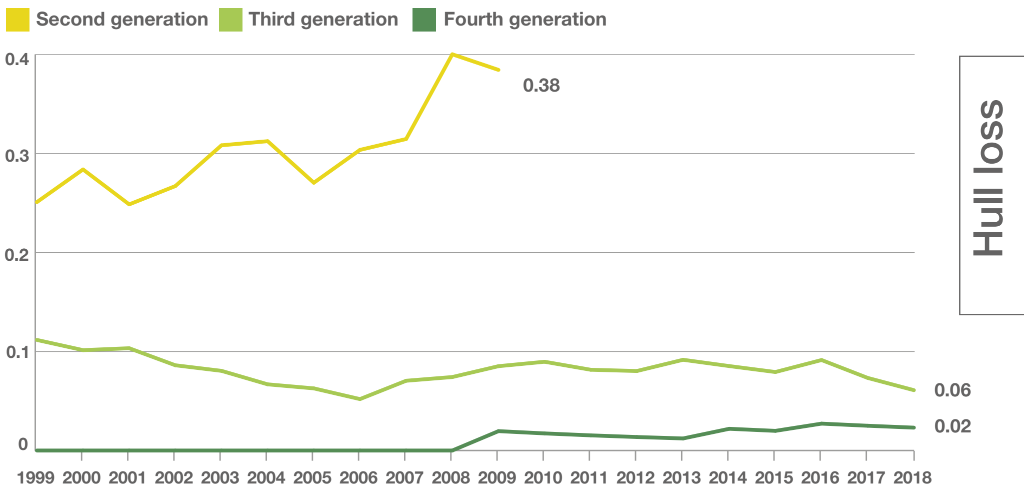
The fourth generation of aircraft has accumulated 30 years of experience since the A320 aircraft entered into service in 1988.

This represents a significant experience with more than 178 million accumulated flight cycles. This strong statistical basis illustrates the significant safety benefit of flight envelope protected aircraft to address LOC-I.

10 year moving average LOC-I rate by aircraft generation per million flights



10 year moving average LOC-I rate by aircraft generation per million flights

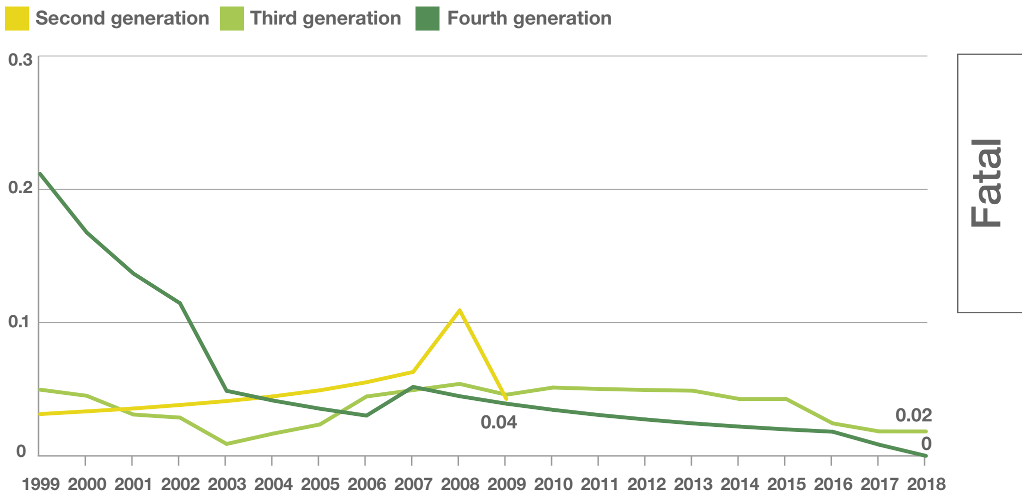


3.8 Runway Excursion (RE) accident rates

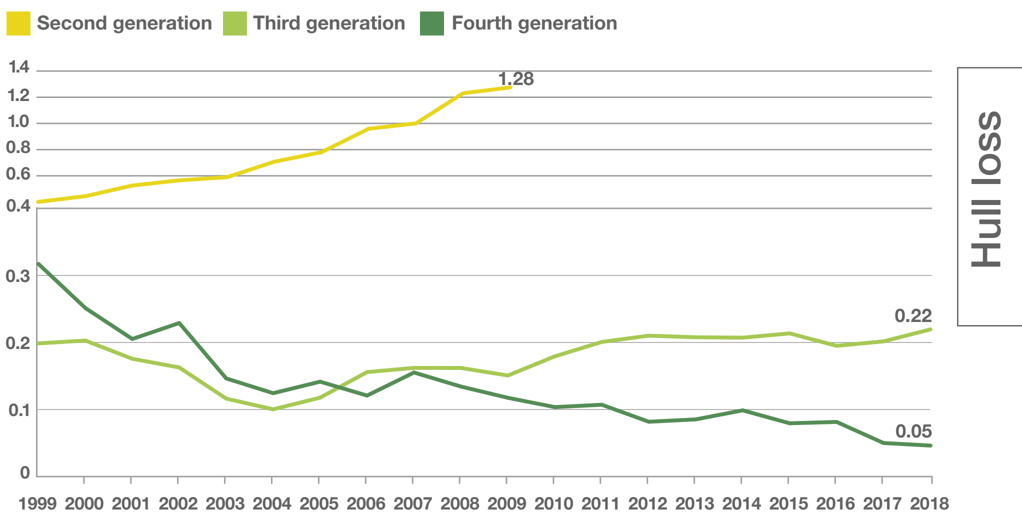
New technologies to reduce RE accidents have recently been introduced

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 rate by aircraft generation per million flights



10 year moving average RE rate by aircraft generation per million flights



List of tables and graphs

AIRBUS

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Concept design by Airbus Multi Media Support 20183228. Photos by Airbus, H. Goussé, M. Shen, F. Lancelot, A. Doumenjou.

Reference: X00D17008863 Issue 3. May 2019.
Printed in France by Art & Caractère.

This brochure is printed on Stucco.
This paper is produced in factories that are accredited EMAS and certified ISO 9001-14001, PEFC and FSC CoC. It is produced using pulp that has been whitened without either chlorine or acid. The paper is entirely recyclable and is produced from trees grown in sustainable forest resources.

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.

The printer, Art & Caractère (France 81500), is engaged in a waste management and recycling programme for all resulting by-products.