

Lightning Strikes



Each in-service aircraft is struck by lightning at least once per year, on average. Even if the level of energy of lightning strikes is high, their effects on an aircraft are limited.

This article explains the lightning phenomenon and why aircraft are prone to lightning strikes. It describes how aircraft are designed to limit the effects of a lightning strike and ensure that the safety of the flight is not impaired. It also recalls several safety precautions to take in flight and on the ground, and what must be done when an aircraft is struck by lightning.

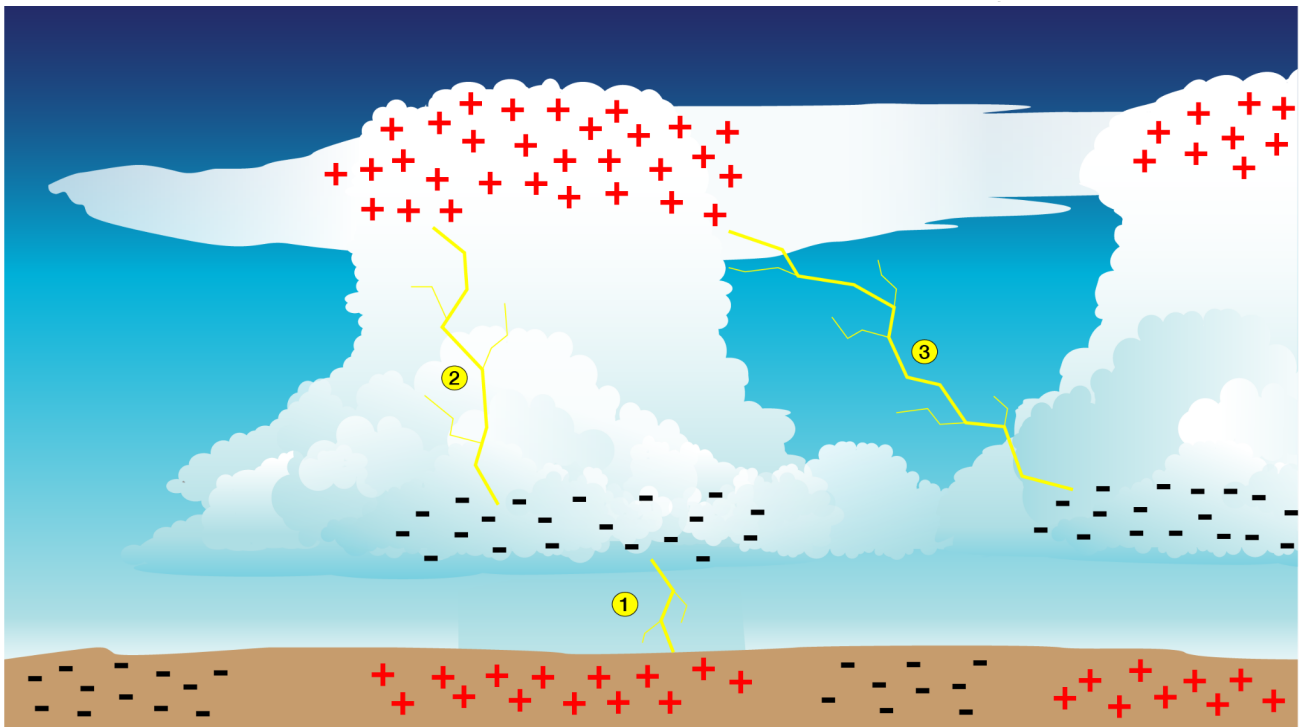
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LIGHTNING PHENOMENON

Within storm clouds, thermal convection causes collisions between ice particles resulting in the transfer of electrons between them. This process leads to the accumulation of electrical charges inside the cloud. When the electrical tension between these charged areas reaches a critical point, it overcomes the insulating properties of the air that separates them, resulting in a lightning discharge. **(fig.1)**. Lightning can happen ① between cloud and ground, ② inside a cloud, or ③ between two clouds. Earth experiences an average of approximately 44 lightning strikes every second.

(fig.1) Typical types of lightning



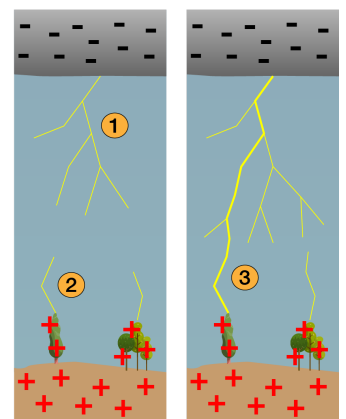
Lightning bolts

A lightning bolt initiates with a column of ionized air **(fig.2)** that generally ① starts from the negative part of the cloud and moves towards the positively charged area. This column is called a 'leader'. As it nears the positively charged area, ② secondary leaders develop from it. ③ When the two leaders come into contact with each other, an electrical current flows to neutralize the opposite electrical charges accumulated in the two areas.

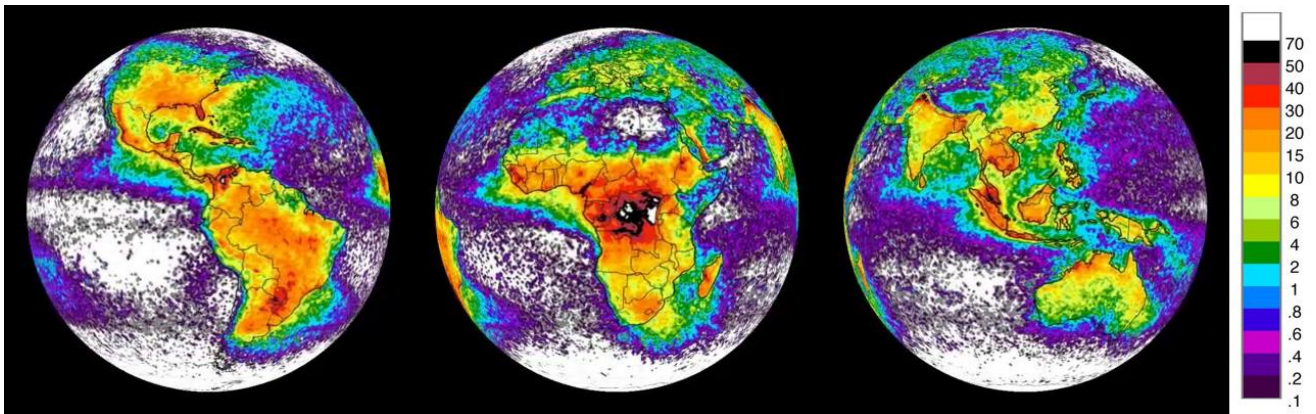
There are often several successive discharges in a single lightning bolt. The discharge current can reach 200 000 A and the temperature inside the lightning channel can reach 30 000 °C. Cloud-to-ground lightning bolts are usually the most powerful.

Worldwide distribution of lightning strikes to ground

The average worldwide frequency is 3 lightning strikes per square km per year (strike/km²/yr). However, there is a strong disparity of this value depending on the location on the planet. Based on a National Aeronautics and Space Administration (NASA) study, the regions more prone to lightning strikes are Central Africa and South America with more than 20 strikes/km²/yr and more than 70 strikes/km²/yr in Central Africa, reaching 158 strikes/km²/yr in Congo. In comparison, oceanic areas have a frequency of less than 1 strike/km²/yr reaching less than 0.1 strike/km²/yr in the polar regions and South Pacific area **(fig.3)**. ■



(fig.2) Lightning initiation



(fig.3) Worldwide lightning distribution from 1995 to 2003 with color range indicating the average annual number of lightning flashes per square kilometre. Credits: National Oceanic and Atmospheric Administration (NOAA) Science and National Aeronautics and Space Administration (NASA).

AIRCRAFT AND LIGHTNING STRIKES

Using the 3 strikes/km²/yr average value and an average aircraft surface of 300 m², an aircraft should theoretically be struck by lightning once every 1 000 years. The operational reality is that an in-service aircraft will be struck by lightning on average once a year, or every 3 000 flight hours. This is 1 000 times the projected value above.

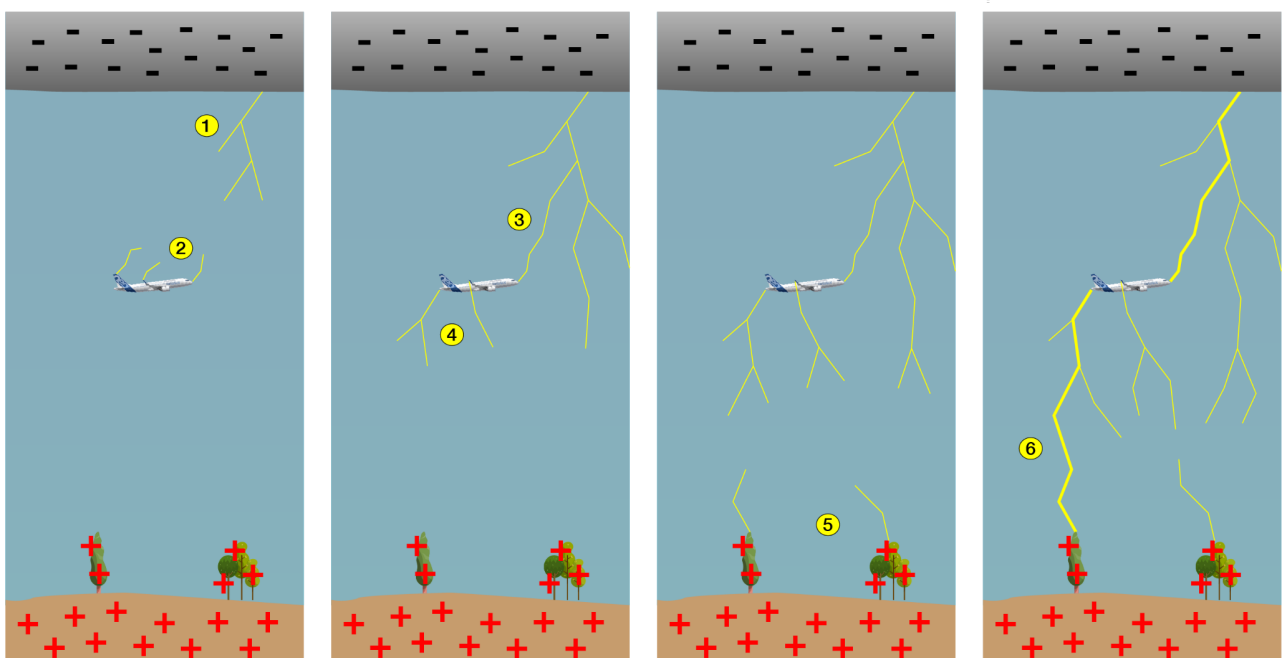
This difference can be explained by the fact that an aircraft will tend to attract lightning in flight when it is in the proximity of a storm's high electrical field **(fig.4)**.

If a lightning leader initiates close to an aircraft **①**, some lightning leaders will also initiate from the aircraft extremities (e.g. nose cone, wing tips, vertical tailplane) toward the lightning leader **②**.

If one aircraft leader joins with the lightning leader, the aircraft becomes part of the lightning channel **③**, and continuing leaders initiate from the other extremities of the aircraft toward the positively charged area (ground) **④**.

When one of these leaders nears this positively charged area, **⑤** new leaders initiate from it and **⑥** create lightning when joining the main leader.

(fig.4) How lightning strikes an aircraft.



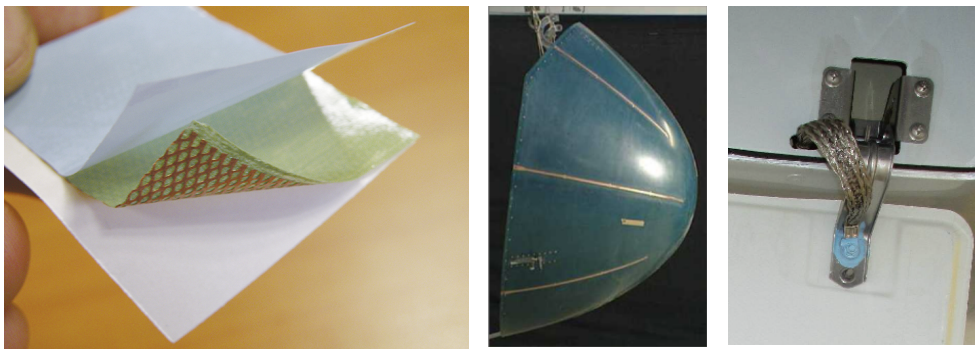
Aircraft design considerations

All large aircraft must be designed and certified to withstand lightning strikes without sustaining significant damage to their structure or effects on their systems that would adversely affect safety for the remainder of the flight. This includes protection of the airframe structure against the direct effects of lightning, and the protection of the electronic circuitry versus lightning current induced effects.

Conductive structure

The aircraft structure is designed to conduct the electrical current induced by a lightning strike. For composite fuselages or components, integrated conductive metallic foils and metallic strips are used to ensure this.

All components of the aircraft structure (metallic or composite) must be bonded together with bonding leads or with fasteners to ensure electrical continuity **(fig.5)**. This will enable the lightning current to travel through the aircraft structure without creating significant damage.



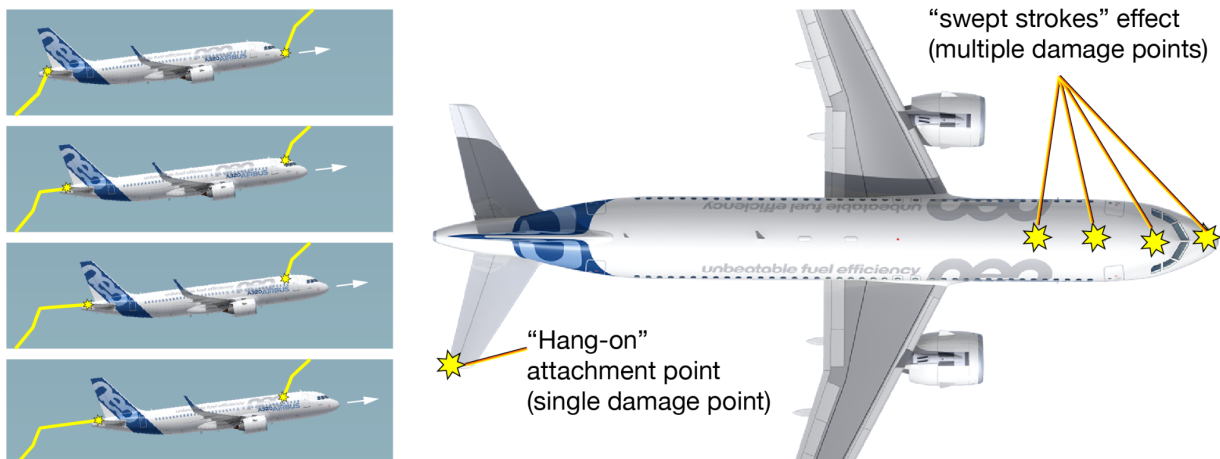
(fig.5) Metallic foil integrated into composite structure (left), conductive metallic strips on the radome (centre), and bonding leads ensure electrical continuity between structural components (right).

Direct effects of a lightning strike are normally limited to the damage caused by the lightning strike at its initial point of contact. The observable effects of a lightning strike include:

- **Metallic components:** Burns, pitting, holes, and melt marks on the aircraft skin or structure, structural deformation, heat damage, and paint discoloration.
- **Composite components:** Paint discoloration, skin punctures, fiber damage (including fiber tufts or fiber delamination), loss or damage of copper foil mesh and metallic strips.

As the aircraft moves during the strike, and due to the pulsating discharge of the electrical current, the lightning attachment points (on entry or exit) can move along the surface of the aircraft creating the so-called multiple “**swept strokes**” (up to 20 strokes) **(fig.6)**. They can also remain fixed on the rearmost parts of the aircraft (known as a “hang-on” attachment point), which is a single attachment point sustaining several discharges.

The level of damage at the attachment points depends on the intensity of the lightning strike.

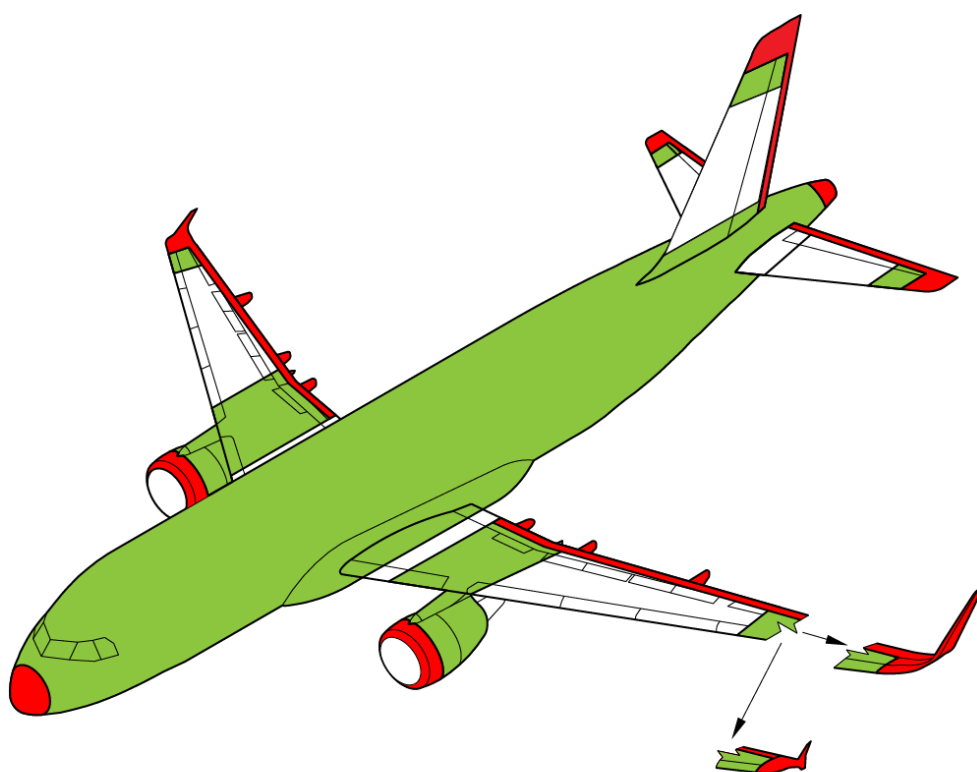


(fig.6) Example of “swept strokes” and “hang-on” attachment points shown on an A320 aircraft with the initial entry point of the lightning current on the nose cone and an exit point on the left side of the horizontal tailplane.

Aircraft Lightning Attachment Zones

Lightning attachment zones are identified depending on the probability and type of lightning attachment on the aircraft structure **(fig.7)**.

(fig.7) Lightning attachment zones shown on an A320 aircraft (AMM extract)



- Zone 1:** Areas where damage is most probable (initial entry or exit points)
- Zone 2:** Areas where damage is probable (swept strokes)
- Zone 3:** Areas where damage is less probable

Protection against the indirect effects of lightning strikes

Electromagnetic fields related to a lightning strike can cause unwanted transient voltages and currents in the aircraft wiring and its systems. As required by the regulations, aircraft must be designed so that there is no perturbation of a critical or essential system in the case of a lightning strike that could temporarily or permanently affect its operation. The level of protection given to a particular system depends on the likelihood of the system being affected by lightning and the impact that a loss of this system would have on the safety of the flight.

Protection from the indirect effects of lightning strikes is ensured by:

- System redundancy
- Physical and electrical segregation of the redundant systems
- Electromagnetic protection on the electrical harness where required, using differential transmission lines, shielding and over-shielding, and specific routing rules
- Electrical isolation or use of lightning surge arrestors specified inside equipment ports depending on their potential exposure to lightning strike effects
- Management of corrupted data by system software. ■



INFORMATION

Detailed information on the lightning phenomenon and its effect on aircraft can be found in the “[Lightning Protection of Aircraft Handbook](#)” created by Franklin A. Fisher and J. Anderson Plumer, available for download on the [FAA Technical library](#).

The standard ED-91A - Lightning Zoning and the SAE Aerospace Recommended Practice (ARP) ARP5414B - Aircraft Lightning Zone, provides information on lightning strike zones and guidelines for locating them on particular aircraft.

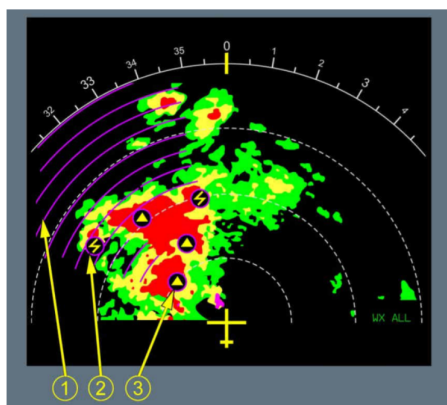
LIGHTNING STRIKE PREVENTION & SAFETY PRECAUTIONS

Most of the reported lightning strike events on aircraft usually occur **in flight between 5 000 ft and 15 000 ft**, or when the aircraft is on the ground.

Lightning Avoidance In-flight

Flight crews should take advantage of all available means to avoid lightning conditions such as weather forecasts, use of the onboard weather radar, and ATC guidance.

Certain weather radars are equipped with a lightning prediction function that provides additional indications to the flight crew of areas within a storm where an aircraft may be more prone to lightning strikes (**fig.8**).



(fig.8) FCOM illustration of the Honeywell weather radar RDR-4000 with ① rain echo attenuation indication, ② lightning prediction, and ③ hail prediction icons



INFORMATION

Information on the use of weather radar and storm avoidance can be found in:

- A220 FCOM1 (section 16-06) and A320/A330/A340/A350/A380 FCTM Aircraft Systems/weather radar
- Safety first article “[Optimum use of weather radar](#)” published in July 2016
- Airbus WIN video “[Operational Use of the Weather Radar](#)” published in November 2017

Safety Precautions when on Ground

In the case of a storm with lightning activity when the aircraft is parked or stored outside for maintenance activities, the maintenance and ground servicing personnel should apply specific safety precautions to limit the consequences of a potential lightning strike.

Aircraft electrical grounding (earthing)

Grounding (earthing) the aircraft reduces the risk of injury to personnel and risk of damage to the aircraft in the case of a lightning strike. If the aircraft is not grounded, the lightning current can exit from any point of the aircraft structure. This is normally close to the landing gears where it can cause significant damage and a risk of serious injury. Any ground servicing equipment (e.g. platforms, access stairs, cargo loaders, ground service carts, cargo loaders, and pushback vehicles) that may be in contact with an aircraft that is not grounded when it is struck by lightning, may also be damaged.

A grounding cable with less than 500 mOhm of resistance and with a minimum cross section of 22 mm² (0.034 in²) must be attached to one of the aircraft grounding points.

Suspension of maintenance and servicing activities

Maintenance or ground servicing operations should be stopped pending the end of the storm and lightning conditions. Even if the aircraft is grounded, the resulting shockwave created by a lightning strike can cause injuries to ground personnel. Anyone working in the vicinity of the aircraft should not touch metal parts equipment or any other item connected to the aircraft.

Disconnection of all external equipment

Disconnection of external equipment (e.g. external power supply, air conditioning carts, and other ground servicing vehicles) prevents damage in the case of a lightning strike.

In lightning conditions, ground operators should disconnect or remove their headsets and communicate with the crew in the cockpit using standard hand signals.

Adherence to local regulations

When available, the operators must review and follow the local airport or airline policy and procedures for managing safety when there is lightning and storms. ■



INFORMATION

More information and guidelines can be found in the International Air Transport Association (IATA) documentation:

IATA Airport Handling Manual, (AHM) 462 "Safe Operating Practices In Aircraft Handling", section 11; 11.3 Weather Terms and Definitions; 11.5 Severe Weather Forecasting; 11.6 Severe Weather Notification; 1.6.2 Notification Methods; 11.7.3 Thunderstorm/Lightning; 11.8 Thunderstorm/Lightning Safety.

IATA Ground Operations Manual, (IGOM) 3.3 Adverse Weather Conditions



MANAGING LIGHTNING STRIKES

When lightning strikes an aircraft, a specific process must be applied to detect any damage caused by the strike, evaluate the damage, and perform the necessary repair before returning the aircraft back into service.

Informing Maintenance of a Lightning Strike Event

In the case of a lightning strike, the flight crew must make a **logbook entry** to inform maintenance personnel of the event, so that they can perform the appropriate inspection and necessary repairs. The flight crew should **provide as much information as possible** such as the landing gear position when the strike happened, a description of any system malfunction during or after the strike, and a list of the ECAM (EICAS for A220) alerts that may have been triggered.

Inspection of the aircraft for damage

Preparation of the inspection

The maintenance personnel should gather all the information provided by the flight crew about the event and print a **Post Flight Report (PFR)** to analyze any effect on the aircraft systems.

Choice of inspection

It is possible to choose between several types of post lightning strike inspection (except for A220 and A300 aircraft). This enables flexibility depending on airline operations, time constraints, human resources, availability of ground support equipment, etc.

Standard post-lightning strike Inspection

The standard inspection after a lightning strike is divided into several phases. The first phase being **initial damage detection** consisting of a thorough inspection of the entire surface of the aircraft and testing certain systems. The following phases are **additional checks** to be performed further to damage detection.

Quick Release Inspection (QRI)

The Quick Release Inspection (QRI) allows the operator to perform a reduced inspection to release the aircraft in a shorter time frame, and postpone the full standard inspection for a limited number of flight cycles when time and logistics permit. The QRI is only available for A300-600, A310, A320 family, A330, A340, A350, and A380 aircraft.

The QRI consists of inspecting the areas that are most prone to lightning strikes and testing certain systems. If no damage is found during the QRI, the aircraft can be dispatched for up to 50 or 200 Flight Cycles (FC) depending on the aircraft type. A full standard lightning strike inspection must be performed on the aircraft before the end of this grace period. If a new lightning strike occurs during the grace period, a new QRI must be performed, but the grace period applicable before a full inspection remains the 50 or 200 FC from the initial lightning strike event.

1-flight-back inspection (2 FC)

This alternative was added in the A320 family AMM to enable further flexibility and allows a maximum of 2 FC (ferry or revenue flight) to return the aircraft to an airfield with sufficient manpower and logistics to perform a standard or quick release

inspection. However, this procedure is not applicable if one of the following conditions occurred:

- The flight crew reported a lightning flash with the sound of detonation
- The flight crew decided to divert the flight after a lightning strike event in flight
- There were injuries to passengers and/or crew members caused by the lightning strike event.

The 1 flight back inspection consists of:

- A visual Inspection of the Air Data/Inertial Reference System (ADIRS) probes and sensors (at touching distance)
- A visual inspection of the flight control surfaces (from a 3m platform or passenger entry stairs)
- A functional check of the aileron and elevator servo controls
- A functional test of the flight control surfaces.

The 1-flight-back inspection was made available for A350 aircraft in the 01-NOV-2023 revision and is under study for A330, A340, and A380 aircraft.

Inspection type	A220	A300	A300-600 /A310	A320 Family	A330/A340 Family	A350	A380
Standard inspection	YES	YES	YES	YES	YES	YES	YES
QRI - Quick Release Inspection	N/A	N/A	50 FC	200 FC	200 FC	200 FC	200 FC
			<i>Note: If a new lightning strike occurred during the grace period, the grace period remains 200 FC or 50FC from the time of the initial lightning strike event.</i>				
1 Flight Back (2 FC)	N/A	N/A	N/A	YES	Under study	YES	Under Study

Damage Evaluation & Repair

Damage due to lightning strikes should be repaired using an approved repair as per local authority regulations. Airbus recommends using the SRM or ASR (for A350) or ASRP (for A220) to evaluate and repair the damage. SRM/ASR/ASRP repairs are certified to be capable of withstanding additional lightning strikes.

Damage outside of the SRM/ASR/ASRP limits

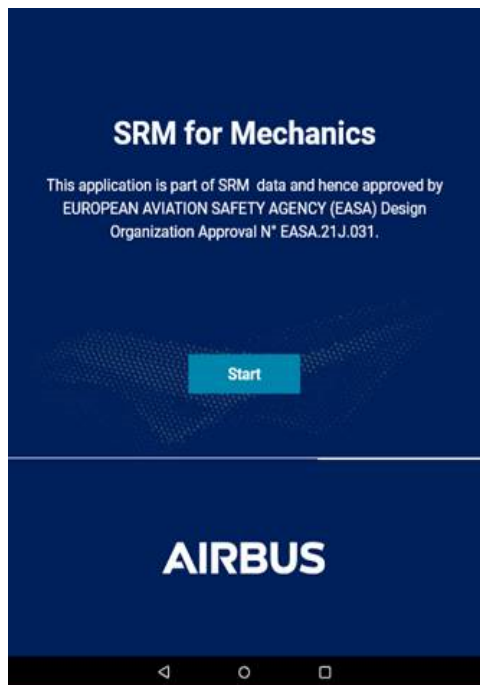
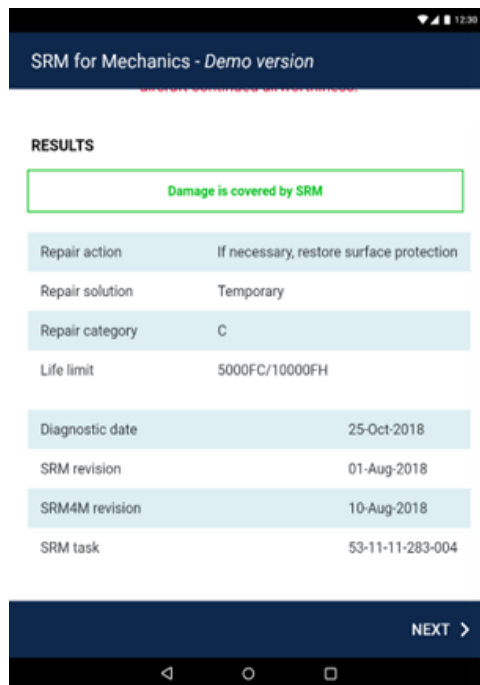
When the lightning strike damage is outside of the SRM/ASR/ASRP limits, it is necessary to obtain repair instructions either from Airbus via a Repair and Design Approval Form (RDAF) or a Repair Engineering Order (REO) for A220 aircraft, or via an instruction provided by an EASA PART 21 approved organization.

To obtain the Airbus RDAF/REO, the operator or repair organization should prepare a damage assessment as required in SRM/ASR/ASRP.



INFORMATION

The “SRM for Mechanics” (SRM4M) mobile application provides a quick and easy way to use the SRM for A320 family aircraft.



(fig.9) SRM for Mechanics (SRM4M) application for Android and iOS

Report lightning strike events to Airbus

Airbus analyzes any reported lightning strike events in order to further increase knowledge in this domain. Operators and repair organizations are encouraged to report lightning strike occurrences to Airbus even if no damage is found on the aircraft after the inspection. Operators can also participate in the forums and working groups organized by Airbus. For example, Airbus hosts a Lightning Strikes Expert Forum in order to exchange experience about managing lightning strikes with all operators. An SRM working group (except A220) also meets regularly since 2014 to exchange experience about structural repair topics. ■



INFORMATION

Further information can be found in the AMM/MP, SRM/ASR/ASRP documents available on the AirbusWorld portal and in the following published documents:

- **OIT 999.0066/15**
- **OIT 999.0003/20 ATA 51 – STRUCTURAL REPAIR MANUALS AND AIRCRAFT STRUCTURAL REPAIR MANUALS CONTINUOUS IMPROVEMENTS**
- **Safety first #18 - Safe Operations with Composite Aircraft**
- **FAST #22 - Lightning Strikes and Airbus Fly-By-Wire Aircraft**

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Aircraft are often struck by lightning. Aircraft manufacturers must demonstrate that their aircraft remain safe after a lightning strike.

Flight crews should avoid areas with lightning conditions as much as possible by using weather forecasts, onboard weather radar, and ATC guidance.

When an aircraft is parked or stored outside in lightning conditions, it is important to apply precautionary measures such as electrically grounding the aircraft, pausing ground or maintenance operations, and disconnecting any external equipment. It is also important that all operators are familiar with the local airport regulations and procedures for severe storms and lightning events, and have their own policies in place for their flight crews, maintenance crews, and ground crews.

For every lightning strike event, it is essential for flight crews to make an accurate logbook entry and for maintenance crews to adhere to the AMM/MP/AMP procedures to perform inspection and damage assessment. Any repair must be done using the SRM (ASR on A350 and ASRP on A220).

Operators should report all their lightning strike events to Airbus, even if there is no damage found in the post lightning strike inspection. This will provide data that contributes to further enhancing industry knowledge on the subject.

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