DOT/FAA/AR-04/13

Office of Aviation Research
Washington, DC 20591

General Aviation Lightning Strike Report and Protection Level Study

August 2004

Final Report

This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-04/13		

4. Title and Subtitle	5. Report Date
GENERAL AVIATION LIGHTNING STRIKE REPORT AND PROTECTION LEVEL STUDY	August 2004
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
J.B. O'Loughlin and S.R. Skinner	
9.Performing Organization Name and Address	10. Work Unit No. (TRAIS)
National Institute for Aviation Research Wichita State University 1845 Fairmount Avenue Wichita, KS 67260-0093	11. Contract or Grant No. 00-C-WSU-00-28
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591	Final Report 14. Sponsoring Agency Code AIR-100

15. Supplementary Notes

The FAA William J. Hughes Technical Center Technical Monitor was Anthony Wilson.

16. Abstract

This report analyzed 95 lightning strike reports from general aviation business jet aircraft that occurred over a 5-year period. The analyses was conducted to determine which variables most affect the severity of indirect lightning effects damage of in-service aircraft and their systems and to assess the effect of the level of lightning and High-Intensity Radiated Fields (HIRF) protection design and implementation.

After validating the data, three variables were studied with respect to lightning damage: aircraft age, aircraft flight hours, and the level of lightning and HIRF protection. The level of protection for each aircraft model in the database was categorized as no protection, avionics protection, or full protection.

The study found that fully protected aircraft had a significantly lower percentage of electrical failure and interference due to lightning strikes when compared to aircraft with no protection or only avionics protection. The number of electrical failures reported did not increase over the age of the aircraft.

17. Key Words	18. Distribution Statement
Aircraft age, Airworthiness, Flight hours, Lightning strike reports, Protection level study	This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classified (of this report)	20. Security Classified (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	32	

Form DOT F1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

The authors acknowledge the technical assistance, guidance, and review given this study by the EMC engineering staff of Bombardier Aerospace, Cessna Aircraft, and Raytheon Aircraft Corporation, without whose support this effort would not have been possible.

Special thanks is also given to the Wichita State University graduate research assistants, Syed Ghayur, Ghulam Awan, Najma Begum, and Fayyaz Khan, who carefully and laboriously collected and organized the data and professionally and methodically worked through numerous iterations and revisions to help produce this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The lightning strike data analysis for the Federal Aviation Administration and the National Institute of Aviation Research was conducted to study and review lightning strike reports from incidents involving general aviation business jet aircraft. A lightning strike database was compiled from forms filled out by pilots and maintenance personnel along with the corresponding maintenance history of that aircraft. The general purpose of the study was to develop a better understanding of the factors that are most influential in affecting the probability of electrical damage of in-service aircraft and their systems due to a lightning strike, to assess the cost-effectiveness of design changes, and to improve reporting and data collection procedures.

There were 95 incident reports on various aircraft models in the database that were used in the study. After validating the data, three variables were studied with respect to lightning damage: aircraft age, aircraft flight hours, and the level of High-Intensity Radiated Field (HIRF) protection. The level of HIRF protection for each aircraft model in the database was categorized as full protection, avionics protection, or no protection.

Reporting of lightning strike incidents has drastically improved over the last 5 years, indicating the effectiveness of lightning strike incident-gathering procedures. Also, aircraft delivered over the last 10 years have been increasingly equipped with HIRF-protected systems. The data revealed that aircraft were most vulnerable to a lightning strike when flying in clouds and rain. The study found that the amount of HIRF protection in an aircraft had a significant impact on the extent of damage resulting from a lightning strike. Compared to unprotected aircraft, HIRF-protected aircraft had a significantly lower percentage of electrical failures or electrical interference events due to lightning strikes. The study indicated that the age of the aircraft had no observable impact on the percentage of electrical failures due to lightning strikes. The percentage of electrical failures from lightning strikes increased for those aircraft with more flight hours.

1. INTRODUCTION.

A lightning strike can impose severe damage to critical and essential systems of any aircraft. Much design and implementation has been done to minimize lightning strike damage to the electrical systems of large commercial air transport and cargo aircraft. A lightning study was previously conducted on commercial airline fleets [1], and plans are in progress to expand the project to include operators of turboprop and regional jet aircraft [2].

A comparative study of the general aviation (GA) lightning strike report data had not been performed that identifies, compares, and analyzes the vulnerability of these aircraft to lightning strikes. For these reasons, and at the request of the Federal Aviation Administration (FAA), a lightning strike database was compiled from lightning strike reports involving GA business jet aircraft.

Due to the physically smaller size and cross-sectional areas of GA aircraft, their structures must carry higher current densities than larger aircraft, and their electrical systems and wiring will be exposed to larger electromagnetic fields that may actually exceed those occurring in large commercial aircraft [2]. Therefore, it is important that GA designers and EMC engineers be aware of these differences.

1.1 PURPOSE.

The historical lightning strike data analysis for the FAA and the National Institute of Aviation Research was conducted to study and review lightning strike reports from incidents involving GA business jet aircraft. A lightning strike on an aircraft could impose severe damage to critical and essential systems of the aircraft. Previously, a lightning study was conducted on commercial airline fleets [1], but nothing had been done to analyze the lightning strike data with regard to GA aircraft. A comparative study of this data had not been performed that identifies, compares, and analyzes aircraft vulnerability to lightning strikes. The general purpose of the study was to develop a better understanding of the factors that are most influential in affecting the probability of electrical damage of in-service aircraft and their systems due to a lightning strike, to assess the cost-effectiveness of design changes, and to improve reporting and data collection procedures.

A lightning strike database was compiled from GA lightning strike forms, which were filled out by pilots and maintenance personnel along with the corresponding maintenance history of that aircraft. These forms were adopted from FAA-recommended forms on lightning strikes, developed by Lightning Technology Incorporated [3].

1.2 DEFINITIONS.

Aircraft models in the lightning strike database were divided into three categories (no protection, avionics protection, and full protection) on the basis of their High-Intensity Radiated Fields (HIRF) protection.

- No Protection Category—Those aircraft that were manufactured without any protection of the aircraft systems against the indirect effects of lightning.

- Avionics Protection Category—Those aircraft that were manufactured with protection of the aircraft avionics systems against the indirect effects of lightning.

- Full Protection Category—Those aircraft that were manufactured with protection of the aircraft avionics systems and electrical systems against the indirect effects of lightning.

Damage due to an aircraft lightning strike is categorized as either a direct effect or an indirect effect [1]. For example, if a lightning strike attachment damages an antenna mounted on the outer structure of an aircraft, this is categorized as direct effect damage from the lightning strike. On the other hand, if the lightning strike attachment to an aircraft induces a high-intensity radiated electromagnetic field that produces electrical current surges in the electrical wiring, resulting in a malfunction of electrical equipment, that failure is categorized as indirect effect damage from the lightning strike, as the failure was not due to physical damage from a direct attachment. This study concentrated only on indirect effect lightning damage reports.

2. DATA QUALITY.

There were 95 incident reports on various aircraft models in the database that were used in the study. An initial evaluation was performed to ensure that the data in the database were representative of all in-service aircraft in the field. Two variables used for verifying the data were flight hours and strike zones, as discussed in the following sections.

2.1 FLIGHT HOUR DISTRIBUTION.

A comparison of flight hours was performed between aircraft involved in lightning strike incidents and all in-service aircraft of the same model to verify that the data in the lightning strike database was representative of all aircraft in the field.

Figure 1 shows the age distribution of aircraft in the lightning strike database, and figure 2 shows the age distribution of all in-service aircraft. As shown, the database has a reasonably good spread of data between young and old aircraft when compared to the number of aircraft in the field. The data in the figures show a decreasing percentage of in-service aircraft with respect to flight hours and a corresponding decrease in the number of strike reports with respect to flight hours.

2.2 ZONE DISTRIBUTION.

The second parameter studied to verify the data quality was zone distribution of aircraft with respect to a lightning strike. A detailed diagram of a lightning strike zone for a straight-wing business jet is shown in figure C-1 in appendix C. Based on the information from the document "ARP-5414 Aircraft Lightning Zone," [4] the aircraft is primarily divided into three zones, depending upon the aircraft susceptibility to a lightning strike. A detailed description of these zones is given in appendix C.

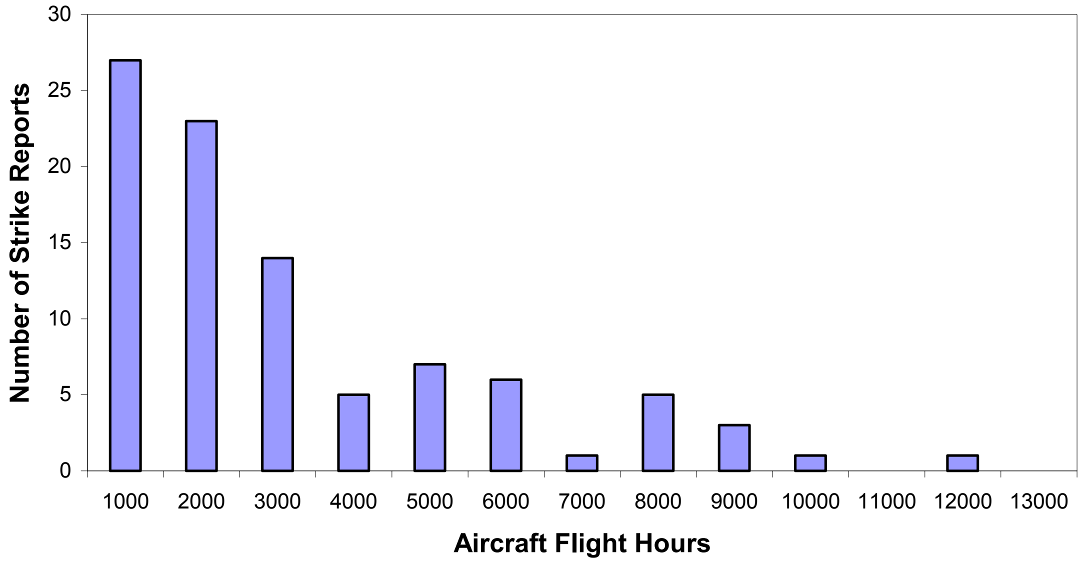


FIGURE 1. DISTRIBUTION OF LIGHTNING STRIKE REPORTS BY FLIGHT HOURS

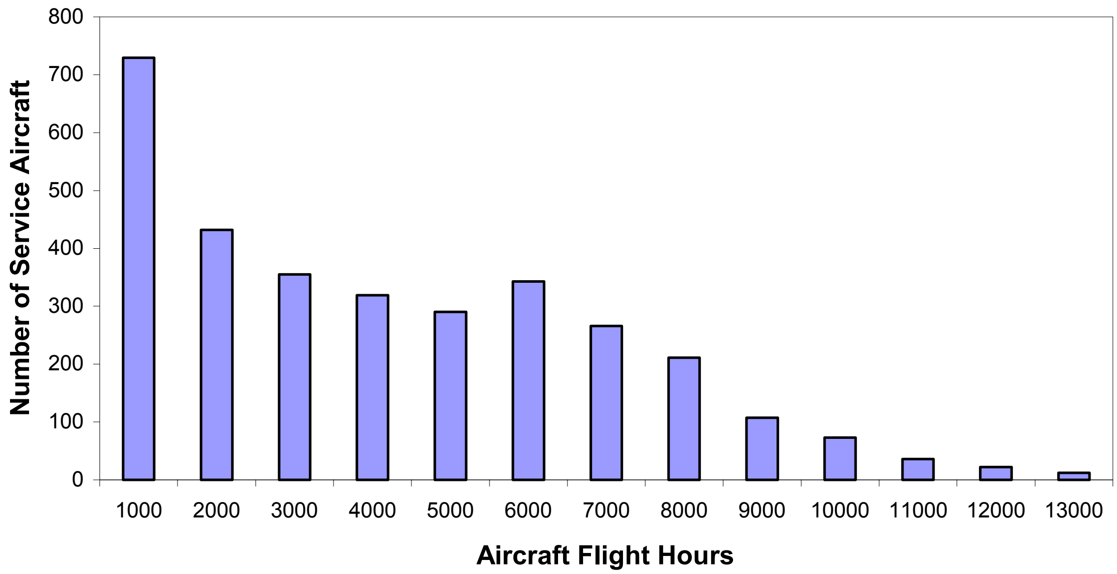


FIGURE 2. DISTRIBUTION OF IN-SERVICE AIRCRAFT BY FLIGHT HOURS

The zone distribution of surface damage by lightning strike from the Electromagnetic Effects Harmonization Working Group (EEHWG) Document WG-46 [5] and the lightning strike database is shown in table 1. This table indicates that zone 1, the radome and the wing tips, was the most frequented area of lightning attachment. Zone 2 includes the areas on the bottom of the fuselage and wing tips, while zone 3 includes the large areas under the wings. As shown in the table, the zone distribution in the database is in accordance with the rest of data obtained from EEHWG Document WG-46.

TABLE 1. ZONE DISTRIBUTION OF LIGHTNING STRIKE ON VARIOUS AIRCRAFT

Company	Zone 1 (%)	Zone 2 (%)	Zone 3 (%)
Boeing Data	87	12	1
Airbus Data	66	34	0
Dassault Data	55	22	23
Fokker Data (jets)	53	41	6
McDonnell Douglas Data	69	27	4
Lightning Strike Database	77	20	3

3. ASSUMPTIONS AND RELIABILITY.

This section describes some of the assumptions that were made to facilitate the data analysis. This section also shows that these assumptions did not affect the reliability of the data.

3.1 MODEL DISTRIBUTION.

The database contains 95 incident reports on various aircraft models. Figure 3 shows the percentage of total aircraft produced for each model, which reported a lightning strike to the database.

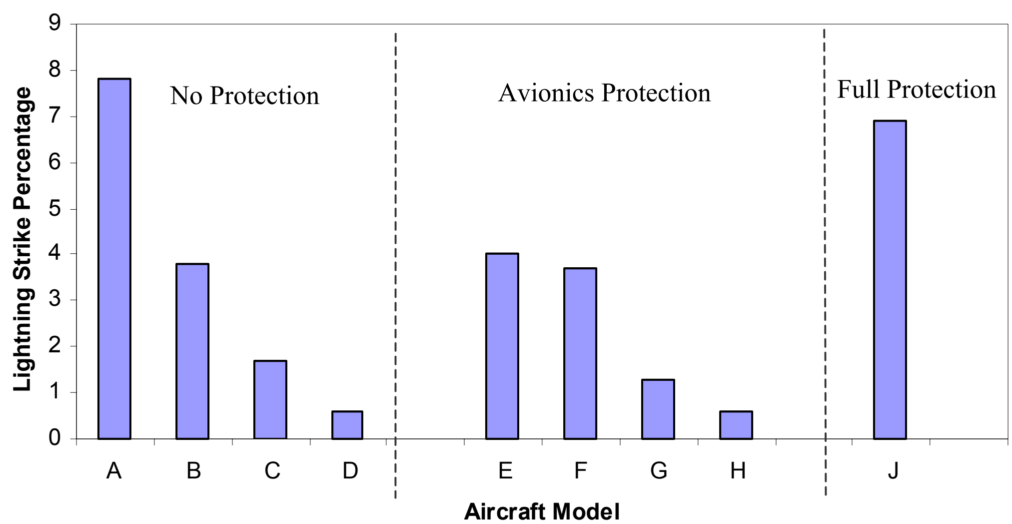


FIGURE 3. PERCENTAGE STRIKES ON EACH MODEL

The percentage is calculated by

$$Strike\ Percentage\ on\ Model\ X = \frac{L}{M} \times 100$$

where L is number of lightning strike reports for model X, and M is the number of aircraft produced for model X.

The uneven distribution of these models could be attributed to the manner in which these aircraft are flown. All aircraft models (A-J) were GA business jets. Larger aircraft models, A and J in this study, are more susceptible to trigger a lightning strike since they are flown in more severe weather conditions. Thus, a higher percentage of lightning strikes were recorded for these models. Smaller aircraft are usually not flown during severe weather conditions, thus lowering their exposure to the risk of a lightning strike.

3.2 AIRWORTHINESS DATE VERSUS DELIVERY DATE.

The analysis required a birth date to identify the age of the aircraft. The delivery date is often hard to determine due to the limited system accessibility. On the other hand, the airworthiness (AW) date is easy to access and incorporate in the lightning strike database. In most cases, the disparity between the AW date and delivery date was not more than a month, as shown in figure 4, and is negligible over the life of the aircraft. Normally, aircraft with a difference of more than 2 months were demonstration aircraft and were flown in the time between the AW date and the delivery date. This makes the AW date a more reliable parameter to use for the age of the aircraft.

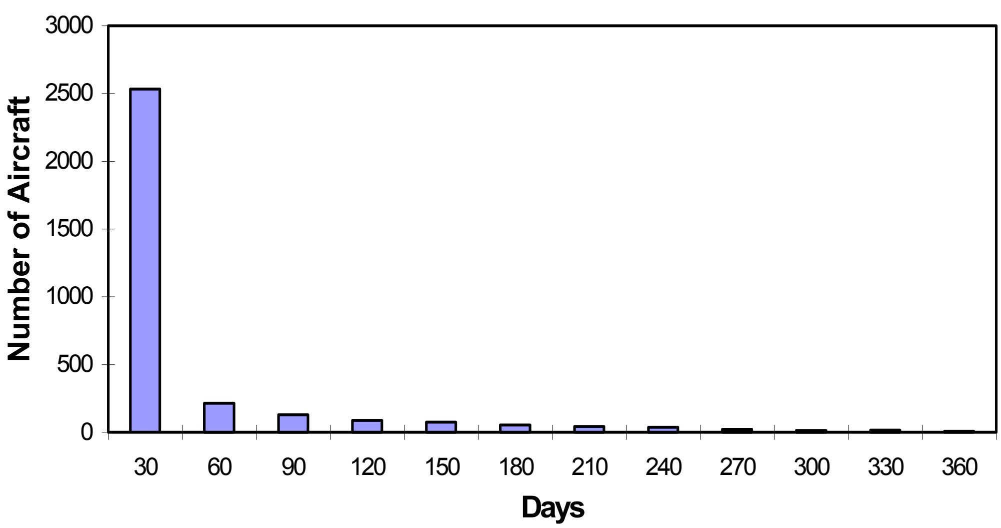


FIGURE 4. DISPARITY BETWEEN AW DATE VS DELIVERY DATE

3.3 LIGHTNING STRIKE REPORTING.

A comparison was done on the aircraft delivered each year with the lightning strike occurrence on those aircraft. Figure 5 shows the number of aircraft delivered and the number of lightning strike reports on those aircraft versus the AW date. This graph shows a decrease in lightning strike reports for those aircraft that were produced during the last few years. These aircraft are relatively new and will have flown fewer flight hours, thus lowering the likelihood of getting struck by lightning.

Figure 6 shows the percent of aircraft that filed a lightning report versus the AW date. Like figure 5, the percentage of aircraft produced that filed a strike report has reduced in the last 3 years. As shown in figures 5 and 6, the reporting of lightning strike incidents has improved on the aircraft delivered during the last 10 years. This could be attributed to a combination of mandated reporting and data collection procedures for aircraft lightning strikes being streamlined over the last 5 years. This would seem to be verified by figure 7.

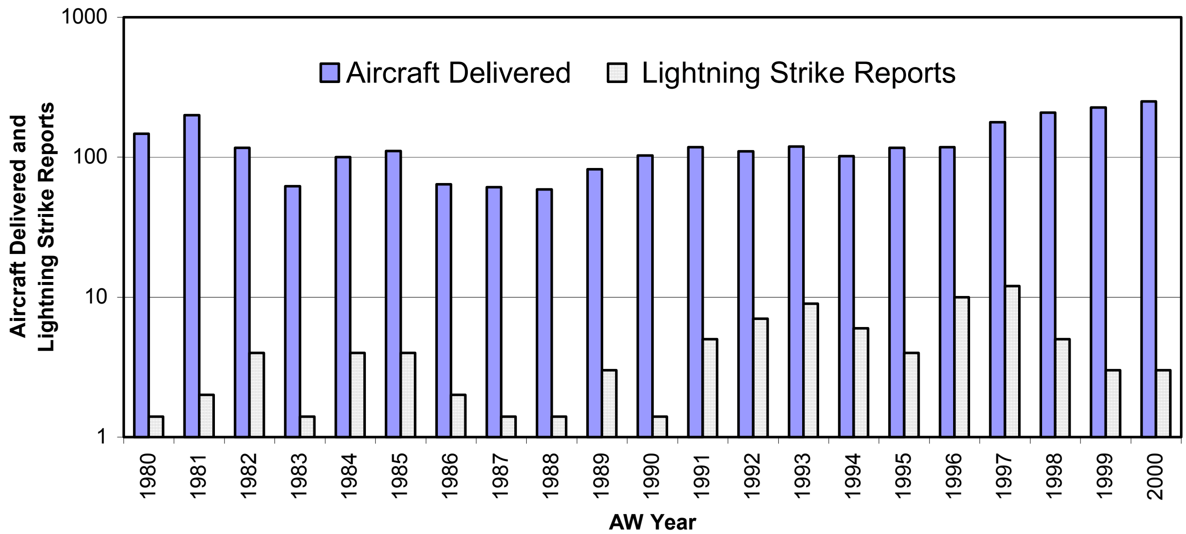


FIGURE 5. AIRCRAFT DELIVERED/LIGHTNING STRIKE REPORTS BY AIRWORTHINESS YEAR

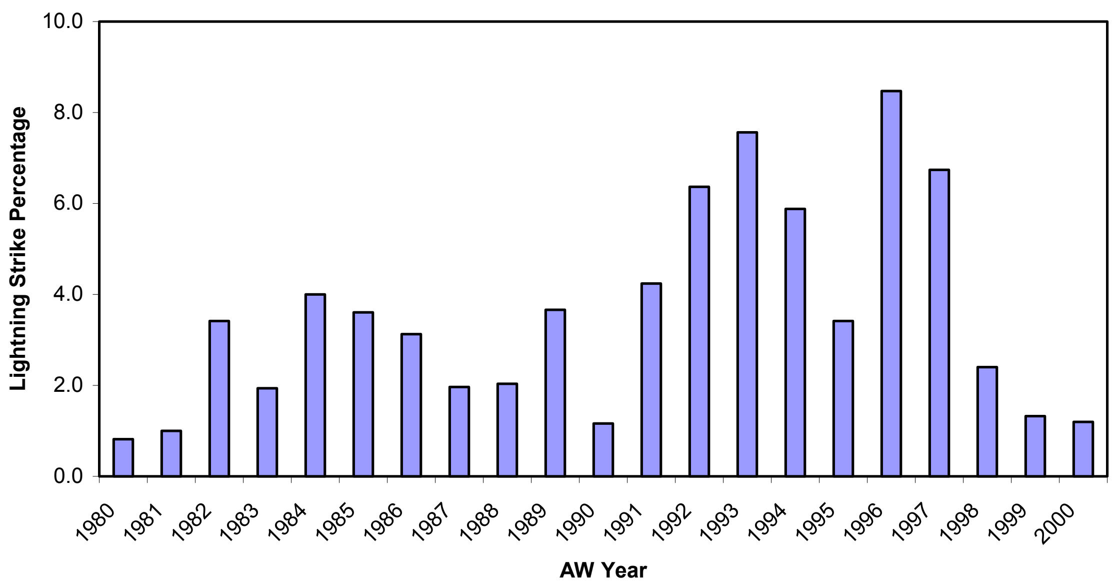


FIGURE 6. PERCENTAGE OF THE AIRCRAFT IN THE DATABASE TO TOTAL AIRCRAFT DELIVERED BY AW YEAR

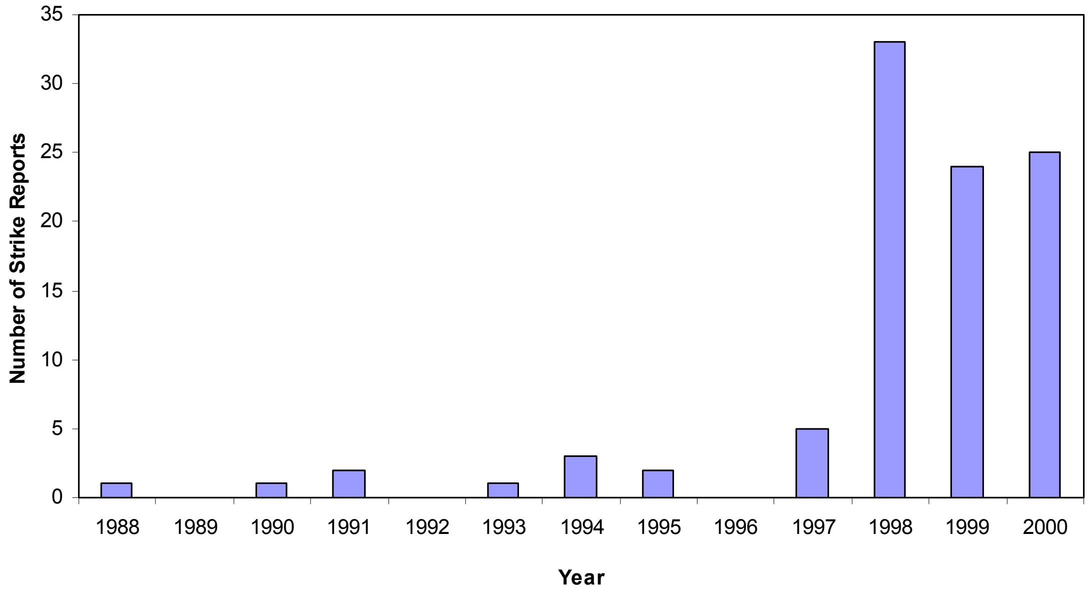


FIGURE 7. NUMBER OF STRIKE REPORTS PER YEAR

3.4 LIGHTNING AND HIRF PROTECTION ON AIRCRAFT.

The need for full lightning and HIRF protection (Title 14 Code of Federal Regulations 25.1316 and Advisory Circular 20-136) on aircraft has intensified with the introduction of advanced electrical systems on aircraft. As shown in figure 8, aircraft delivered over the last 8 years have been increasingly equipped with HIRF-protected systems. The significant advantages of having HIRF-protected aircraft are analyzed in section 4.

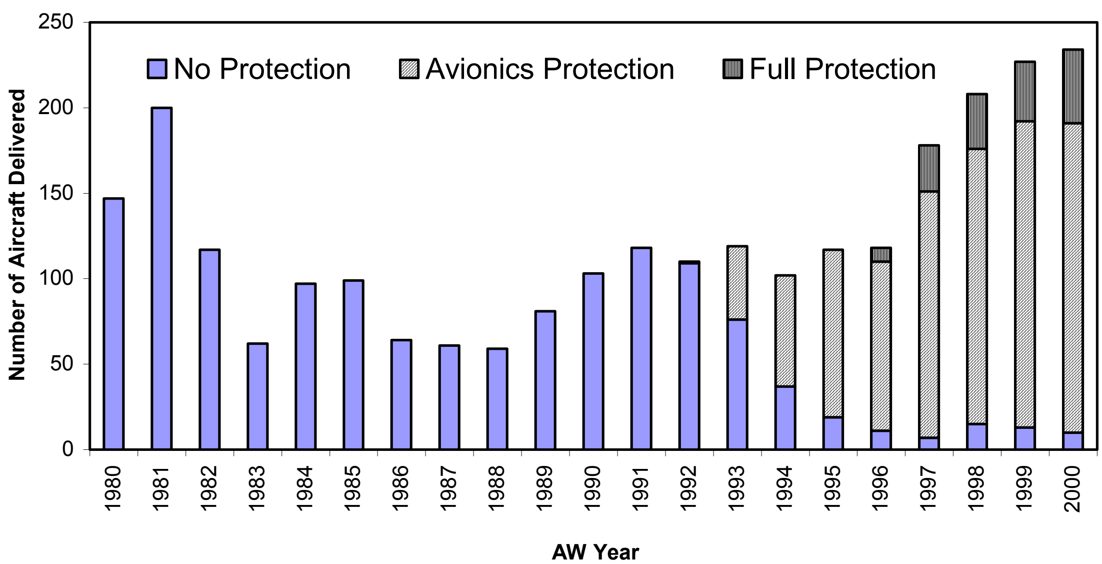


FIGURE 8. AIRCRAFT DELIVERED VS AW YEAR OF THE AIRCRAFT

4. ANALYSIS AND RESULTS.

The data in the lightning strike database were analyzed to determine the environmental conditions that affected the occurrence of a lightning strike and the factors that were most influential in affecting the probability of electrical failure or interference due to a lightning strike. The variables studied with respect to the lightning damage were the aircraft flight hours, age of the aircraft, and the level of protection.

4.1 ENVIRONMENTAL CONDITIONS.

Figure 9 shows the environmental conditions at the time when the aircraft were struck by lightning. For some aircraft, the weather conditions at the time of the lightning strike were not reported, indicated by the No Information column in figure 9. As shown in the figure, the number of lightning strikes was higher during rain than any other conditions.

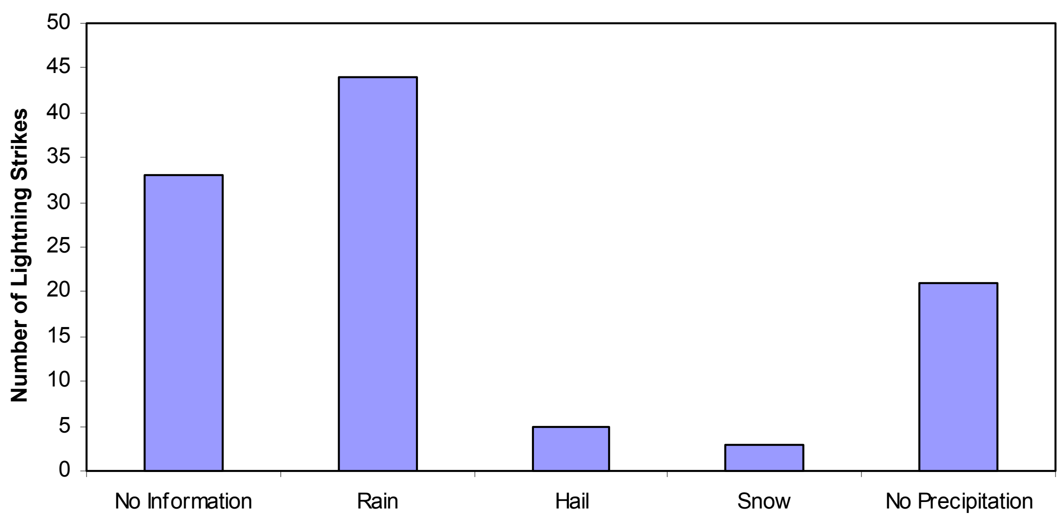


FIGURE 9. NUMBER OF LIGHTNING STRIKES VS CLIMATIC CONDITIONS

The position of the aircraft with respect to the clouds at the time of lightning strike is shown in figure 10. For some aircraft, the information regarding their position in the clouds was not reported, as shown in the figure. Most of the aircraft were in the clouds at the time of the lightning strike, which implies that the majority of lightning strikes experienced by aircraft are intracloud flashes. Intracloud flashes are less in magnitude of intensity but occur more frequently than cloud-to-ground lightning and high-altitude lightning. The above information indicates that the aircraft is most vulnerable to a lightning strike when flying in clouds while encountering rain.

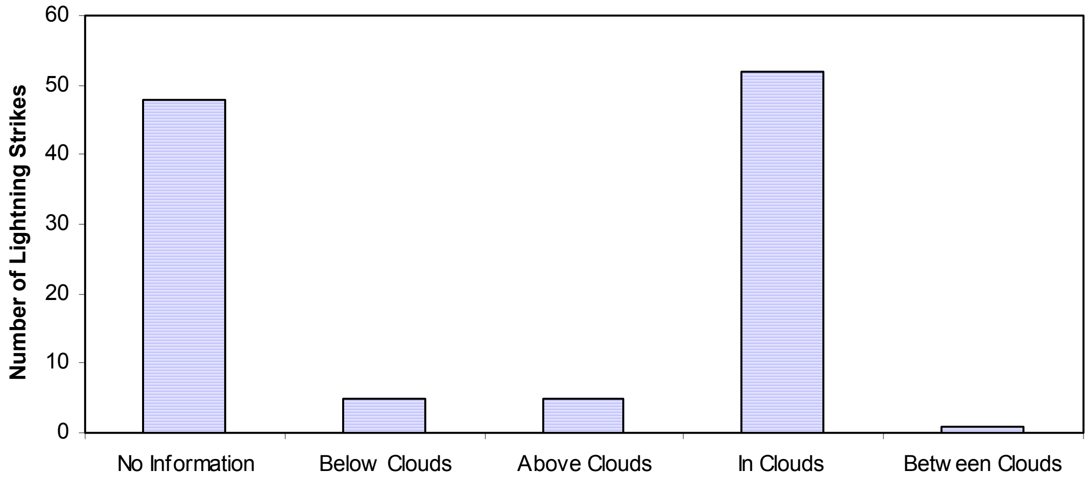


FIGURE 10. NUMBER OF LIGHTNING STRIKES VS AIRCRAFT POSITION

4.2 ELECTRICAL FAILURES AND INTERFERENCES.

In the lightning strike reporting form, pilots report the electrical failures and interferences that resulted from lightning strikes. Figure 11 shows the distribution of electrical failures and interferences that occurred during lightning strikes on various aircraft models. This figure indicates that the majority of the reports are for aircraft in the no protection category, followed by avionics protection and full protection categories. Aircraft in the full protection category reported no electrical failures and only one instance of electrical interference.

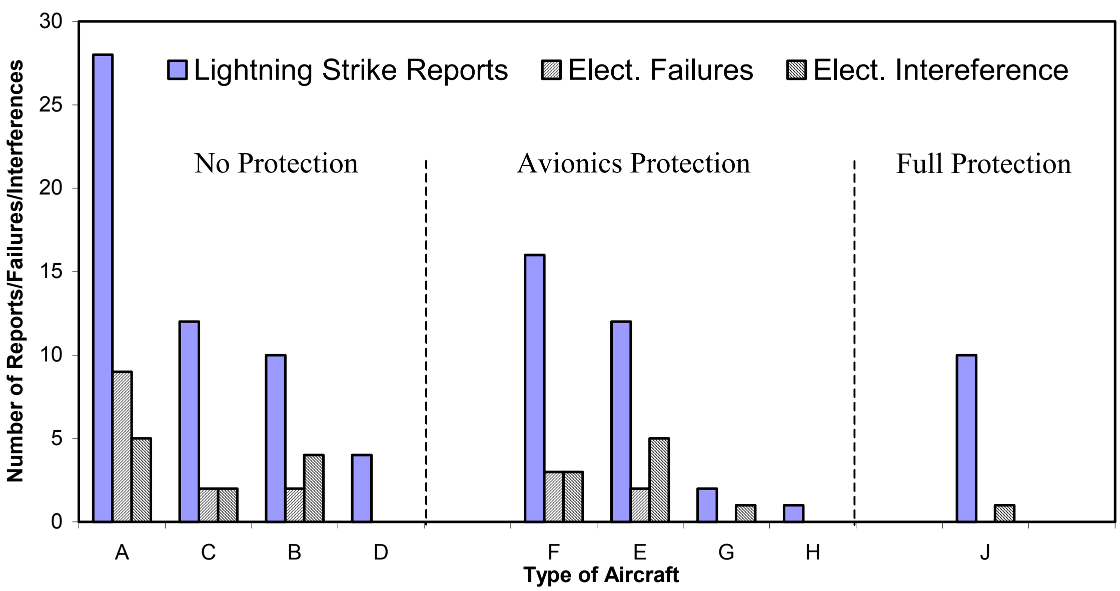


FIGURE 11. ELECTRICAL FAILURES AND ELECTRICAL INTERFERENCES BY AIRCRAFT MODEL

4.3 EFFECT OF LIGHTNING PROTECTION ON AIRCRAFT.

Figure 12 shows the number of lightning strike reports summarized for each protection category along with their associated electrical failures and electrical interferences. There was no report of an electrical failure on a fully protected aircraft, and only one incident of electrical interference was reported. There were also fewer incidents of electrical failures and electrical interferences in avionics-only protected aircraft when compared to the aircraft with no protection.

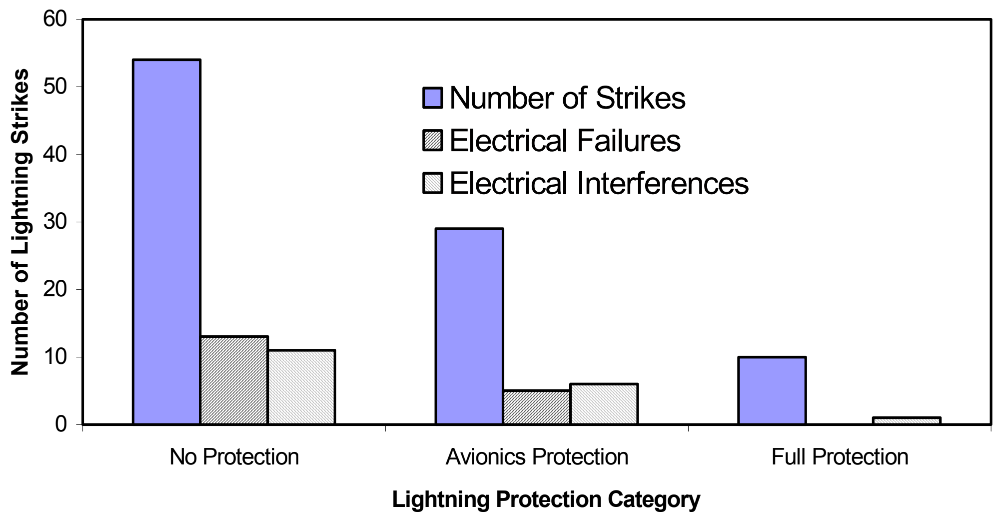


FIGURE 12. AIRCRAFT PROTECTION VS ELECTRICAL FAILURES AND ELECTRICAL INTERFERENCES

4.4 EFFECT ON UNPROTECTED VERSUS PROTECTED SYSTEMS.

An avionics-protected aircraft is equipped with both protected and unprotected systems. In the case of fully protected or unprotected aircraft, the protection level of the system is evident. In order to analyze the effectiveness of HIRF protection of systems onboard the aircraft, a comparison was made between protected and unprotected systems.

The failure rate of fully protected systems was found to be significantly lower than the failure rate of unprotected aircraft systems, as shown in figure 13. The failure rate was due to the effectiveness of the protection level installed in the systems onboard the aircraft. This illustrates that an unprotected system onboard an aircraft is much more susceptible to lightning strike damage than a protected system.

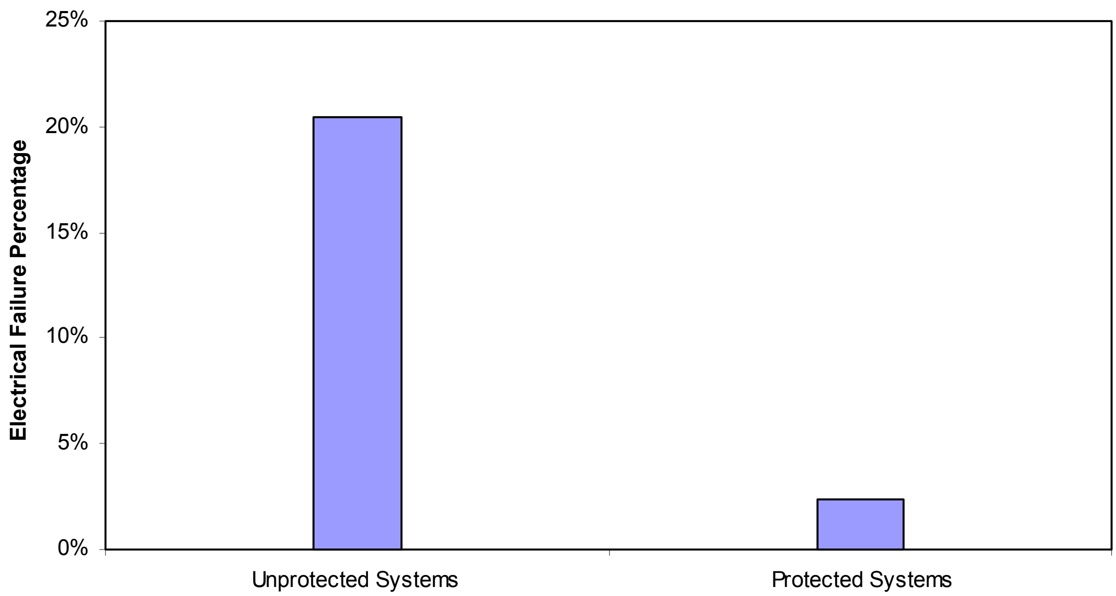


FIGURE 13. ELECTRICAL FAILURE PERCENTAGE VS PROTECTED AND UNPROTECTED SYSTEMS

4.5 EFFECTS OF AIRCRAFT AGE AND FLIGHT HOURS.

The study of the effects of lightning damage on the aircraft was done by comparing the percentage of electrical failures versus the age of the aircraft. This percentage was calculated by

$$\textit{Electrical Failure Percentage for model } X = \frac{A}{B} \times 100$$

where A is the number of electrical failures reported on aircraft of age *X*, and *B* is the number of lightning strike reports on the aircraft of age *X*.

Figure 14 displays the percentage of electrical failures versus the age of the aircraft. For those aircraft in this study, the general trend indicated that the failure rate did not increase as the aircraft becomes older. This may be expected for well-maintained aircraft with little corrosion, because some failures may go unreported for poorly maintained aircraft.

Further study with respect to the age of the aircraft was done on the aircraft in the avionics-protected category to see if the protection degraded over the age of the aircraft. Figure 15 graphs the number of lightning strike reports filed and the corresponding number of electrical failures and electrical interferences on avionics-protected aircraft over the age of the aircraft. This figure indicates that the number of electrical failures due to lightning strikes was relatively constant over the age of the aircraft. This may result for the same maintenance reasons associated with fully protected aircraft.

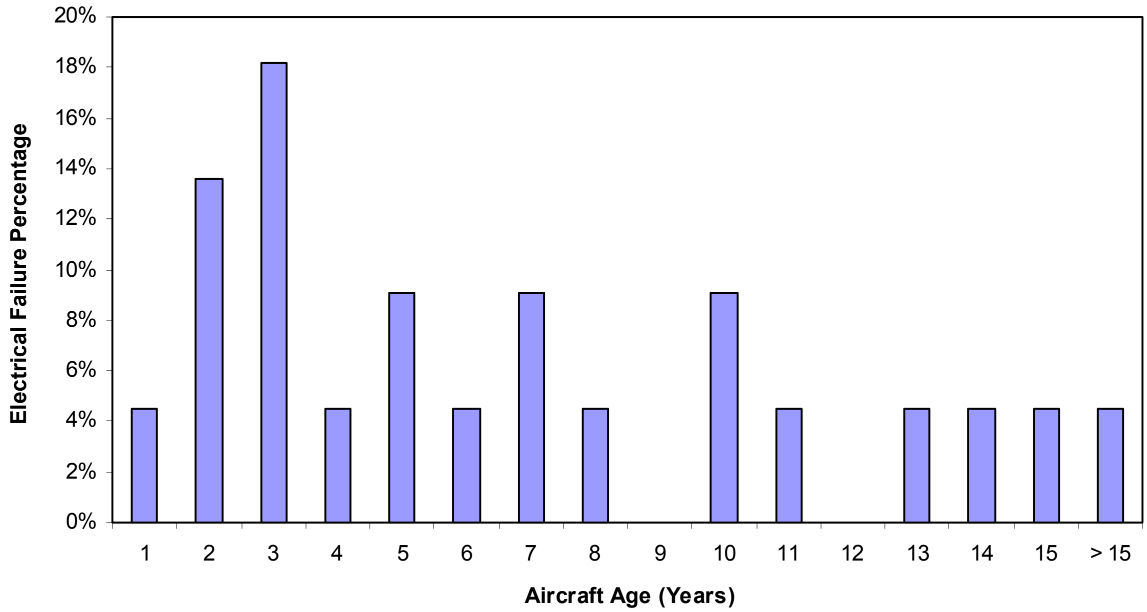


FIGURE 14. ELECTRICAL FAILURE PERCENTAGE VS AIRCRAFT AGE

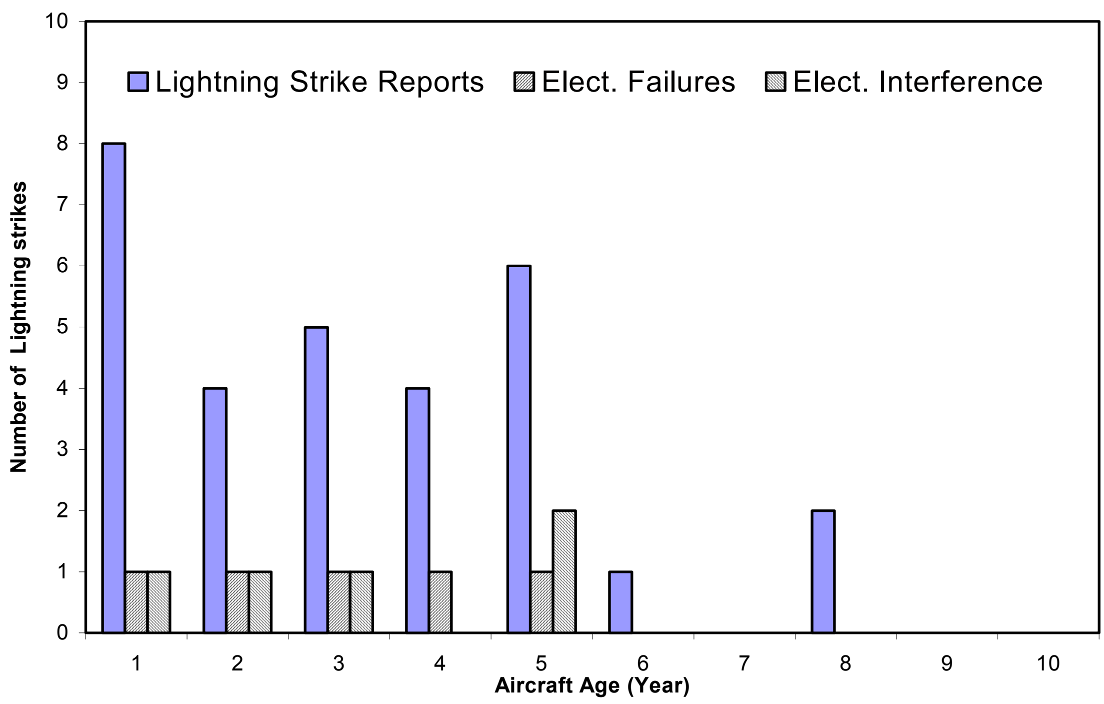


FIGURE 15. ELECTRICAL FAILURES AND ELECTRICAL INTERFERENCES ON AVIONICS-PROTECTED AIRCRAFT VS AIRCRAFT AGE

The effect of lightning damage versus aircraft flight hours was analyzed by comparing the percentage of electrical failures versus the flight hours on the aircraft. This percentage was calculated by

$$\% \, Electrical \, Failure = \frac{C}{D} \times 100$$

where C is the number of electrical failures reported on aircraft having Q flight hours, and D is the number of lightning strike reports on aircraft having Q flight hours.

Figure 16 shows the percentage of electrical failures versus the flight hours on the aircraft. The major contributors to these failures were aircraft with no protection. Analysis showed the percentage of electrical failures increased with flight hours for aircraft with no more than 5000 flight hours. But the failure rate percentage seemed to decrease above 5000 flight hours.

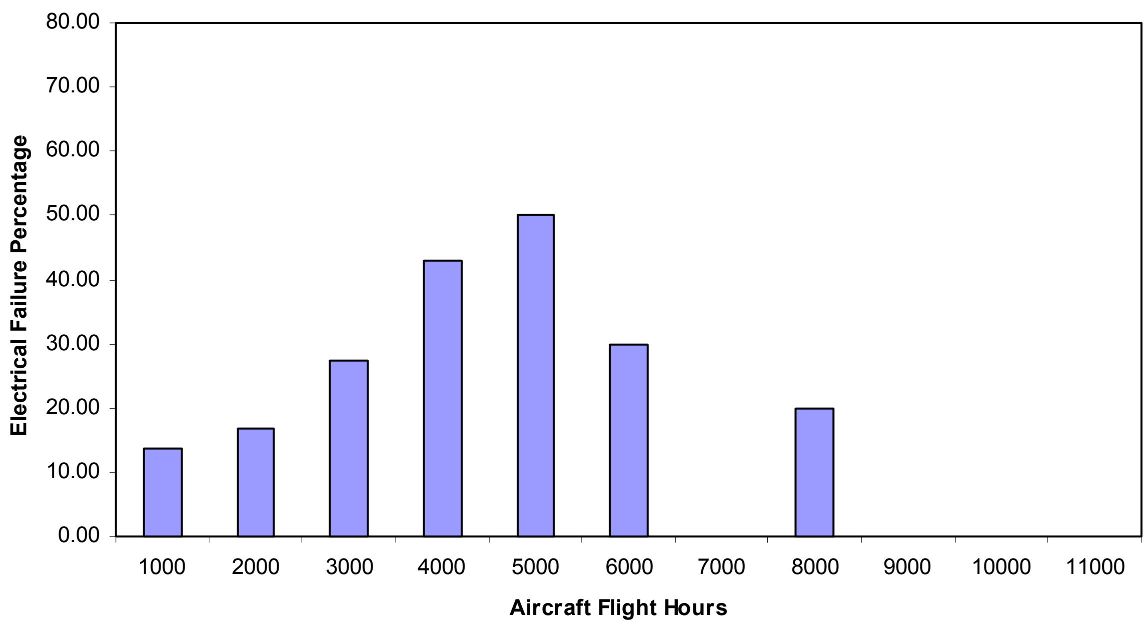


FIGURE 16. ELECTRICAL FAILURE PERCENTAGE VS AIRCRAFT FLIGHT HOURS

To find the reason for this increase, and then decrease, in electrical failure percentage as flight hours increased, the reporting of lightning strikes and failures were further investigated. The graph shown in figure 17, similar to figure 15, was prepared using the number of incidences rather than percentages, as shown in figure 16.

As shown in figure 17, the number of failures is relatively constant over the number of flight hours, but the number of nonfailure reports is decreasing. It appears that those aircraft with more flight hours often did not report the lightning strike unless a failure was associated with that lightning strike.

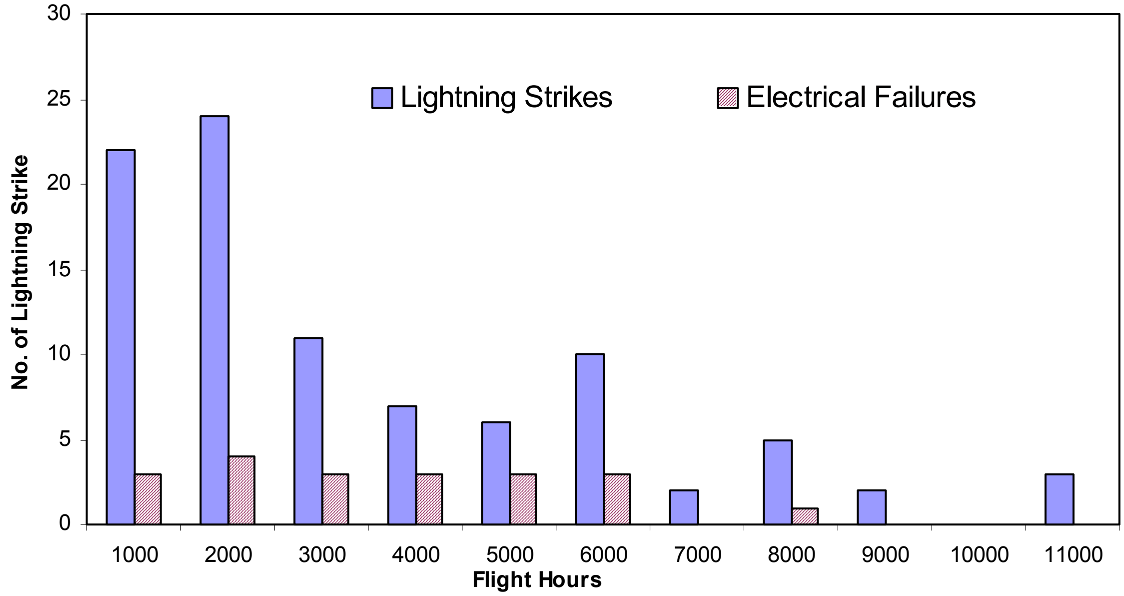


FIGURE 17. ELECTRICAL FAILURES VS FLIGHT HOURS

At the same time, lightning strikes were reported more consistently on aircraft that have fewer flight hours. This was an interesting result since this behavior differs from the results found with the aircraft age. These results were investigated by contacting different appraiser companies. They were of the opinion that besides other factors, flight hours have a larger impact on the depreciation of an aircraft than age. If an aircraft of lesser value is struck by lightning, it may not be reported unless it is associated with an electrical failure.

In contrast, an older aircraft that is properly maintained and has fewer flight hours may be reported for a lightning strike, even though the strike did not cause any electrical failures or interferences. The possible reason for the slight increase in nonfailure reports for aircraft with more than 5000 flight hours could be that they were overhauled. This overhaul would increase the value of the aircraft and make it more likely that a nonfailure lightning strike would be reported.

To verify that the lightning and HIRF protection is not degrading as the number of flight hours increases, a study with respect to the flight hours was done on the aircraft in the avionics-protected category.

Figure 18 shows electrical failures and lightning strikes on avionics-protected aircraft versus the flight hours on the aircraft. This graph shows the same trends as figure 17, indicating that no degradation of the protection is occurring. Because the fully protected aircraft did not experience a failure, a similar study could not be performed.

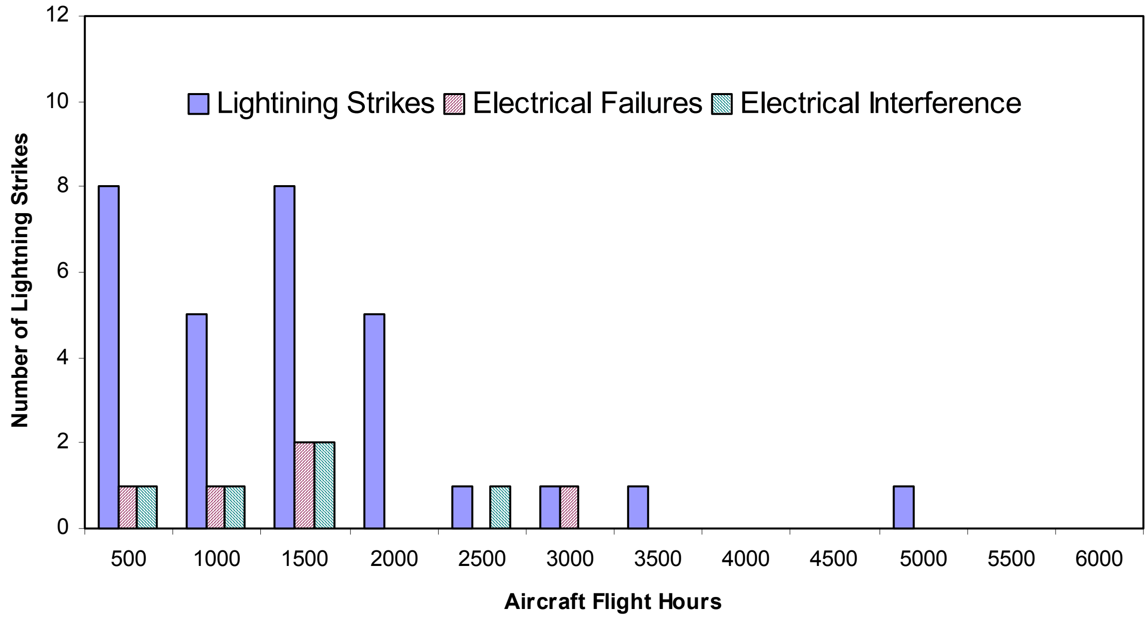


FIGURE 18. ELECTRICAL FAILURES AND ELECTRICAL INTERFERENCES ON AVIONICS-PROTECTED AIRCRAFT VS FLIGHT HOURS

5. OBSERVATIONS.

Based on the study of the incidents reported in the lightning strike database, the overall observations are given below.

- Reporting of lightning strike incidents has drastically improved over the last 5 years, indicating the effectiveness of lightning strike incident-gathering procedures.
- Aircraft delivered over the last 10 years have been increasingly equipped with High-Intensity Radiated Fields (HIRF)-protected systems.
- Data in the database revealed that aircraft were most vulnerable to a lightning strike when flying in clouds and rain.
- The study found that the amount of lightning and HIRF protection in an aircraft had a significant impact on reducing the extent of damage resulting from a lightning strike.
- Compared to lesser or unprotected aircraft, lightning and HIRF-protected aircraft had a significantly lower percentage of electrical failures or electrical interferences due to lightning strikes.
- The percentage of electrical failures due to lightning strikes on HIRF-protected systems (2%) was much less than unprotected systems (20%), thus indicating the effectiveness of HIRF protection.

- The results of the study indicated that the age of the aircraft had no observable impact on the percentage of electrical failures due to lightning strikes.

- The percentage of electrical failures from lightning strikes increased for those aircraft with more flight hours. After analyzing the data, the most likely reason for the increase appeared to be that aircraft with more flight hours generally did not report a lightning strike unless a failure was associated with it.

6. RECOMMENDATIONS.

During the study of the lightning strike database, it was observed that some important parameters were not included on the lightning strike form used by pilots and maintenance personnel. (See appendix A for a sample of the lightning form presently being used by the industry and appendix B for the recommended sample form.) These additional parameters could be beneficial for future analysis of aircraft lightning strikes. The following suggestions have been made for parts 1 and part 2 of the lightning strike form to improve data collection.

1. Change **Date** to **Strike Date** to avoid confusion with **Entry Date.**

2. Change **Level Flight** to **Cruise** to avoid confusion between **Level Flight** and **Level off.**

3. Add the following fields:

    - **OAT** (Outside Air Temperature): This will help to determine the critical temperature zone for the occurrence of lightning strikes.

    - **Geographical strike location** (latitude and longitude): This will help to determine the vulnerable geographical locations for the occurrence of lightning strikes.

    - **Altitude** (feet).

    - **Speed** (knots): If the speed of an aircraft and length of the affected surface are known, then the duration of the lightning attachment could be calculated to determine the severity of the strike.

    - **List affected systems**: This will help in evaluating the cause of the interference and failure on a particular system that failed during the lightning strike.

    - **Estimated cost of repair**: This will help in justifying the design changes to the aircraft and reduce the operating costs for the owner.

    - **Severity of damage (light, moderate, and heavy)**: This will also help in justifying the design changes to the aircraft and reduce the operating costs for the owner.

7. REFERENCES.

1. McDowall, R.L., "Data From the Airlines Lightning Strike Reporting Project, Part 1: Pilot Reports," Galaxy Scientific Corporation.

2. Plumer, J.A., "Lightning Strikes/Static Discharge Incident Report, Part I & II," Lightning Technologies Inc., Email Correspondence, June 18, 2001.

3. Plumer, J.A., "Lightning Protection of Aircraft," Lightning Technologies Inc., 1990, pp. 69-70.

4. Society of Automotive Engineers, Inc. (SAE) Aerospace Recommended Practice –5414, "Aircraft Lightning Zoning," 1999, pp. 24-25.

5. Electromagnetic Effects Harmonization Working Group (EEHWG) Document WG-46, "Report on Aircraft Lightning Strike Data."

8. GLOSSARY.

Aircraft Age—Aircraft age is defined as the time between the airworthiness date and the present date.

Aircraft Flight Hours—Hours reported flown since Airworthiness Date.

Airworthiness Date—The date when it is determined that an aircraft, or one of its component parts, meets its type design and is in a condition for safe operation.

Attachment Point—Any spot where the lightning flash enters or exits from the aircraft.

Avionics-Protected Systems—Those aircraft that have been engineered and manufactured with protection of the aircraft avionics systems against the indirect effects of lightning.

Cloud-to-Ground Lightning—A lightning flash from a cloud to the ground.

Direct Effect of Lightning Strike—Physical damage effects at the point of lightning flash attachment to the aircraft.

Full Protection—Those aircraft that have been engineered and manufactured with protection of the aircraft avionics systems and electrical systems against the indirect effects of lightning.

HIRF-Protected Systems—Systems on aircraft protected from High-Intensity Radiated Fields.

High-Altitude Lightning—It is a short-lived, diffused light stream occurring above thunderclouds.

Indirect Lightning Effect—When lightning strikes an aircraft inducing high-intensity radiated electromagnetic fields that produce electrical current surges in the aircraft wiring that results in a malfunction of electrical equipment.

Induced Voltage—Voltage produced in a circuit by changing magnetic or electrical fields.

Intracloud Flashes—Lightning between charge centers within a cloud.

Lightning Attachment Point—Any spot where a lightning flash initially attaches to, or enters, the aircraft.

Lightning Flash—The total lightning event that could occur within a cloud, between clouds, or between the cloud and the ground. It can consist of one or more return strokes, plus intermediate or continuing currents.

Lightning Strike Database—A database compiled from general aviation lightning strike forms, which were filled out by pilots and maintenance personnel along with the corresponding maintenance history of that aircraft.

Lightning Strike Zone—Aircraft surface areas and structure classified according to the possibility of lightning attachment dwell time and current conduction.

No Protection—Those aircraft that were manufactured without any protection of the aircraft systems against the indirect effects of lightning.

APPENDIX A—PRESENTLY USED LIGHTNING STRIKE REPORTING FORM

LIGHTNING STRIKE/STATIC DISCHARGE INCIDENT REPORTING FORM
Part 1

1. Flight Crew must complete Part 1.

NOTE: Entire report must be filled out following any lightning strike incident. If lightning strike is discovered after the fact, complete as much of report as possible. File form immediately following incident. Attach additional sheet(s) to provide complete description.

A. Flight Information:
Flight Number ________ Date ________ Model ________ Unit/Serial Number ______________

B. Airplane Orientation:
Takeoff ________ Climb __________ Level Flight __________
Descent ________ Approach ________ Other _______________

C. At time of flight, airplane was:
Above Clouds ______ Within Clouds _______ Below Ceiling _________

D. Precipitation at Strike:
Rain _________ Sleet __________ Hail __________ Snow __________ None ______

E. Lightning in Vicinity:
Before ________ After _________ None ______

F. Static in Comm/Nav
Before ________ After _________ None _______

G. Was St. Elmo's fire (bluish electrical discharge or corona) visible before strike?
Yes ______ No ______

H. Interference/Outage report. Include any disturbances in avionics and/or electrical systems, such as dimming of cabin lights, total system outage, etc.

Engines	Interference ____	Out ____	Ok ____
Navigation	Interference ____	Out ____	Ok ____
Radar	Interference ____	Out ____	Ok ____
Communication	Interference ____	Out ____	Ok ____
Flight Control	Interference ____	Out ____	Ok ____
AC Power Systems	Interference ____	Out ____	Ok ____
DC Power Systems	Interference ____	Out ____	Ok ____

I. Additional Comments and descriptions:

Part 1 completed by: ______________________________________ Date ___________ Phone ___________

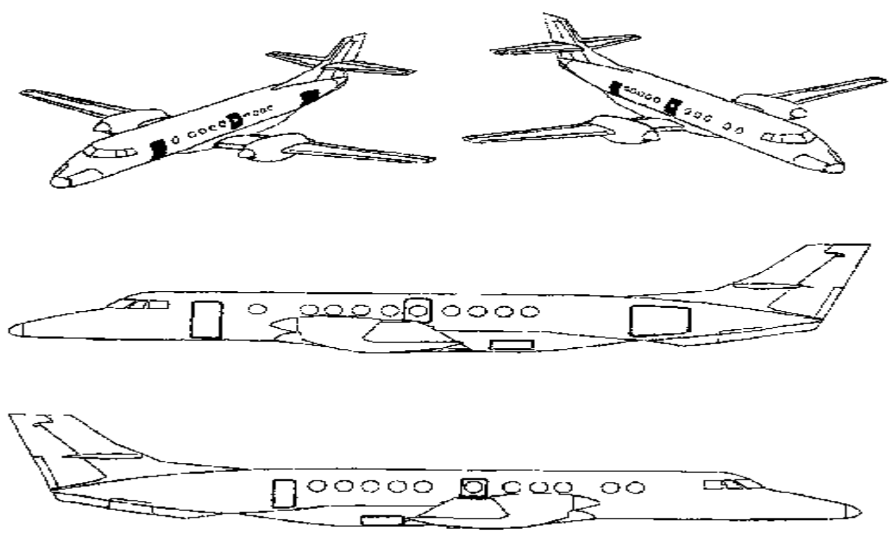
LIGHTNING STRIKE/STATIC DISCHARGE INCIDENT REPORTING FORM
Part 2

1. Ground Crew must complete Part 2.

NOTE: Attach additional sheet(s) to provide complete description. Photos and sketches of damage are recommended and must be itemized and referenced in their description.

NOTE: If damage is severe, please report the lightning strike as soon as possible.

A. List any sweeping points, such as burn marks, divots, etc., and skin penetrations on airplane skin believed to be the result of the lightning strike. Itemize and reference location(s) of damage on drawing provided. Indicate top, bottom, left or right



B. Describe damage to structure and external components caused by previously mentioned damage points. In the case of skin penetration(s), indicate hole diameter(s). List all damage to radome and any other composite structure, such as fairings, control surfaces, etc. If lightning diverter strips are damaged, include lightning diverter strip location(s) on radome. For damage to composite structure, paint thickness must be included in description.

C. List any damage to avionics and electrical components believed to be the result of the lightning strike, including damaged wiring, disengaged circuit breakers, etc. Include manufacturer, model number and serial number of damaged units where applicable.

D. Additional comments and descriptions:

Part 2 completed by: ____________________________________ Date __________ Phone ____________

APPENDIX B—RECOMMENDED SAMPLE OF LIGHTNING STRIKE REPORTING FORM

LIGHTNING STRIKE/STATIC DISCHARGE INCIDENT REPORTING FORM
Part 1

1. Flight Crew must complete Part 1.

NOTE: Entire report must be filled out following any lightning strike incident. If lightning strike is discovered after the fact, complete as much of report as possible. File form immediately following incident. Attach additional sheet(s) to provide complete description.

A. Flight Information:
Flight Number _____Strike Date _____Model _____ Unit/Serial Number _______
Altitude _____ft Airspeed _____ Kts Geographical Location ______

B. Airplane Orientation:
Takeoff ______ Climb _____ Cruise _____ Descent ____
Approach _____ Other _____

C. At time of Strike, aircraft was:
Above Clouds____ Within Clouds ______ Below Ceiling ______

D. Precipitation at Strike:
Rain _____ Sleet _____ Hail ______ Snow ____ None_____

E. Lightning in Vicinity:
Before _____After _____ None _____

F. Static in Comm/Nav:
Before _____After _____ None_____

G. Was St. Elmo's fire (bluish electrical discharge or corona) visible before strike?
Yes_____ No_____

H. Interference (**I**) or Outage (**O**) report. Check all the following, which apply and list affected Systems, such as dimming of cabin lights, total system outage, etc.

Engines	I____	O__________________________
Navigation	I____	O__________________________
Communication	I____	O__________________________
Flight Instruments	I___	O__________________________
Flight Control	I___	O__________________________
AC Power Sys	I___	O__________________________
DC Power Sys	I___	O__________________________

I. Additional Comments and descriptions:

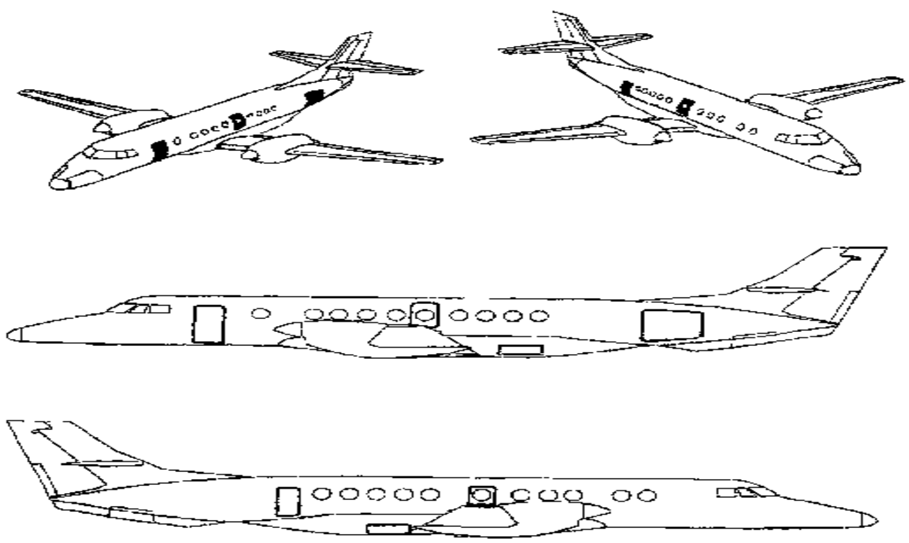
Part 1 completed by: ______________________________ Date _________ Phone ________

LIGHTNING STRIKE/STATIC DISCHARGE INCIDENT REPORTING FORM
Part 2

1. **Ground Crew must complete Part 2.**
   NOTE: Attach additional sheet(s) to provide complete description. Photos and sketches of damage are recommended and must be itemized and referenced in their description.

   NOTE: If damage is severe, please report the lightning strike as soon as possible. Inspection by Engineering Representative(s) may be required.

   A. List any sweeping points, such as burn marks, divots, etc., and skin penetrations on airplane skin believed to be result of the lightning strike. Itemize and reference location(s) of damage on drawing provided. Indicate top, bottom, left or right.



   B. Describe damage to the structure and external components caused by previously mentioned damage points. In the case of skin penetration(s), indicate hole diameter(s). List all damage to radome and any other composite structure, such as fairings, control surfaces, etc. If lightning diverter strips are damaged, include lightning diverter strip location(s) on radome. For damage to composite structure, paint thickness must be included in description.

   C. List any damage to avionics and electrical components believed to be the result of the lightning strike, including damaged wiring, disengaged circuit breakers, etc. Include manufacture, model number and serial number of damaged units where applicable.

   D. Estimate cost of repair

   E. Mention severity of damage (light, moderate, heavy)

   F. Additional comments and descriptions:

PART 2 COMPLETED BY: _________________________ DATE_______ PHONE________

APPENDIX C—DESCRIPTION OF AIRCRAFT LIGHTNING ZONES [C-1]

Zone 1: The initial attachment points of the lightning flash and first return strokes.

Zone 2: An aircraft in motion experiences more attachment points than the initial attachment point with a relatively stationary flash channel. The aircraft motion causes the lightning flash to attach and dwell at various surface locations, so this zone is called the swept-stroke zone.

Zone 3: An area that may carry large amount of current by conduction between areas of direct or swept stroke attachment points.

Zones 1 and 2 are further divided as 1A, 1B, 1C, 2A, and 2B. The definitions of these zones are as follows:

Zone 1A: First return stroke zone with a low expectation of hang on.

Zone 1B: First return stroke zone with a high expectation of hang on.

Zone 1C: First return stroke zone of reduced amplitude with a low expectation of hang on.

Zone 2A: Swept stroke zone with a low expectation of hang on.

Zone 2B: Swept stroke zone with a high expectation of hang on.

REFERENCE

C-1. Society of Automotive Engineers, Inc. (SAE) Aerospace Recommended Practice –5414, "Aircraft Lightning Zoning," 1999, pp. 24-25.

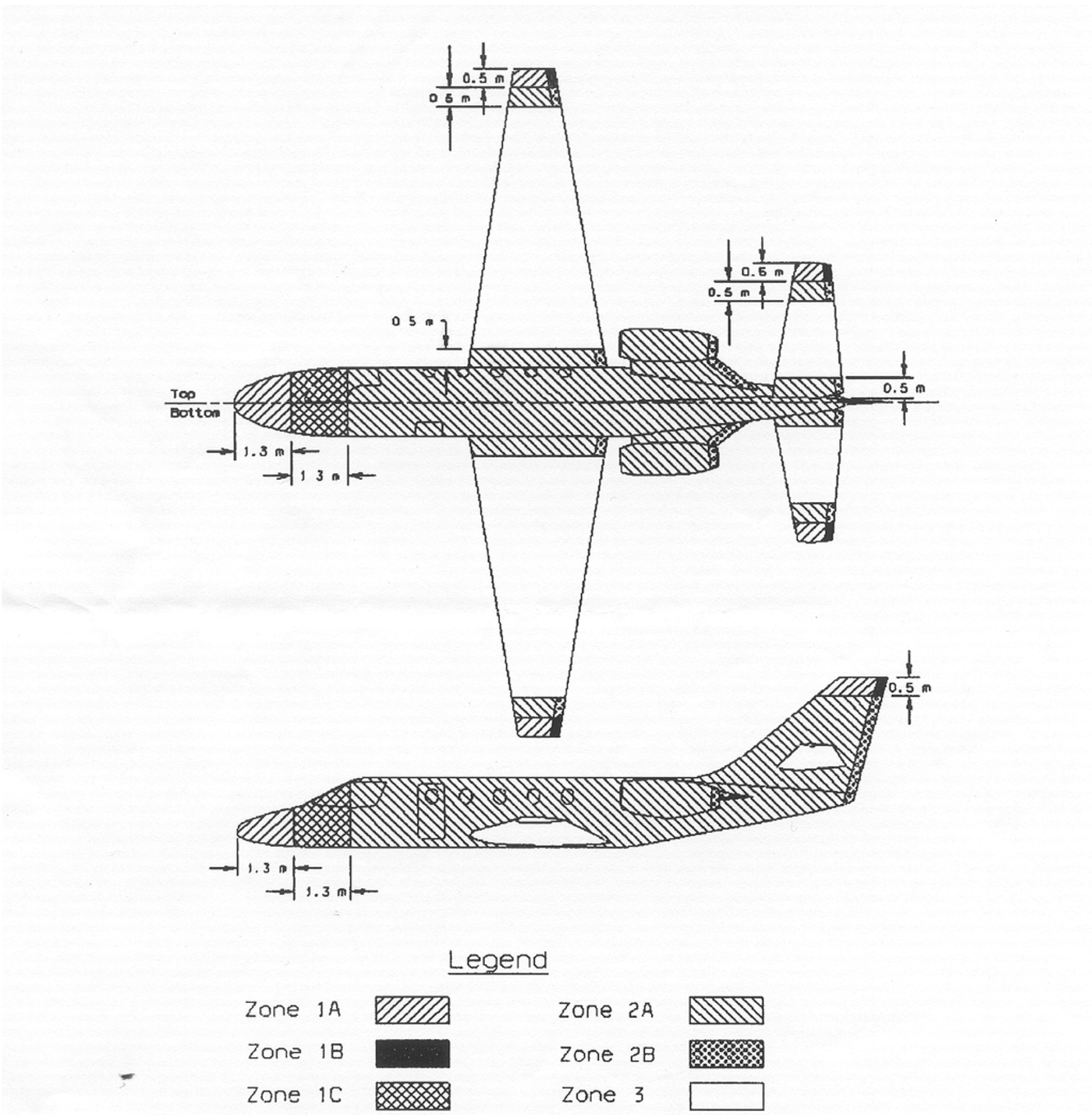


FIGURE C-1. LIGHTNING STRIKE ZONE DETAILS FOR STRAIGHT-WING BUSINESS JET AIRCRAFT