

UNITED STATES NAVY INSERVICE
AIRCRAFT LIGHTNING STRIKE AND DAMAGE SURVEY

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ABSTRACT

The Naval Air Development Center has surveyed the number of lightning strikes and damage to Naval aircraft, covering a period from 1 January 1961 to 31 December 1980. This survey provides information on lightning strike rate per 10,000 flight hours, number of lightning strikes occurring annually, number of lightning strikes per month, number of lightning strikes at various altitudes, and lightning damage and/or strike location for various aircraft types. Additional efforts underway at the Naval Air Development Center include the investigation to determine feasibility of utilizing Boeing's lightning data logger to gather phenomenological information, the evaluation of a storm warning/avoidance system, and conducting a lightning and P-static transient protection devices survey. Continuous monitoring of lightning strike and damage data will enhance the understanding of the lightning threat to Naval aircraft and will benefit the eventual solutions toward preventing damage effects to structure and avionics.

INTRODUCTION

The susceptibility of complex electronics equipments to degradation due to self-interference and/or interference from a non-hostile source is documented by a rising volume of data. The Navy has launched a multi-pronged effort to deal with this problem in its many aspects. There are a number of arenas in which the effort will take place: (a) out in the field where deployed equipments are exposed to the real world electromagnetic environment; (b) the testing lab where this environment is partially simulated to provide more specific data on a particular aspect of the problem; (c) on the drawing board where new designs are conceived in an attempt to obviate some portion of the total problem.

Lightning strikes comprise one aspect of the Electromagnetic Interference (EMI) problem that has serious implications. The present survey of lightning strike data represents a first attempt to gather both physical and statistical evidence in order to quantify and better define the characteristics of lightning.

The data presented herein are a first step in that they derive from a general incident reporting system used for reporting on an extremely broad range of incidents affecting a large number of Naval

platform types, i.e., ships, missiles, aircraft, etc. This has led to a certain non-uniformity in the quality and completeness in the reporting of individual incidents. In particular, not every report will indicate each important aspect of the lightning strike such as altitude, weather conditions, exact locations, etc., and therefore, though we have reports of some 606 total incidents as indicated in Figure 1, subsequent figures may have fewer entries, indicating that some individual reports failed to include the particular parameter under consideration.

Lightning discharges in the vicinity of, and directly striking, aircraft pose a serious safety and operational problem. The type of aircraft appears to make little difference; almost every airplane in the Navy inventory will be struck by lightning at least once in its lifetime. The data indicates that certain aircraft, because of their mission profiles, are more likely to encounter lightning strikes with some regularity. The degree of vulnerability to mission disruption occasioned by lightning strikes is substantial and will surely escalate unless methods are developed to obviate this hazard.

DATA SUMMARY

The lightning data presented summarizes the Navy experience in the period January 1961 through December 1980. During this period there have been a total of 606 incidents. They have taken place in all conceivable combinations of season, altitude and geography. The great majority of strikes, 98%, resulted in "limited" or no physical damage to the aircraft; however, in numerous cases electronic equipments were adversely affected, and in three cases aircraft were lost. The following can be inferred from the data:

1. 88% of strikes occurred at less than 25,000 ft. altitude.
2. 60% of all strikes were on patrol type aircraft.
3. 34% of all strikes were in the southeastern United States, 15% in the southwestern United States, and 10% in the South China Sea.
4. 98.2% of all strikes result in no or only minimal damage to aircraft.
5. There is no month in which strikes are extra-

ordinarily prevalent, though the incidence in August, the highest month, is 11% and in the lowest month, December, it is 6%.

6. The cost of a lightning strike per incident is \$18,200 (this includes the loss of a major aircraft; Without that the average cost is \$11,000). This cost has not been adjusted for inflation.

7. The areas of an aircraft most likely to sustain damage are Nose Radome (25%), Wing (20%), Antenna (17%), and Tail (16%). A close examination of the latest year's data indicates the need to more closely scrutinize prior years' data. Of the 31 recorded incidents, eight resulted in mission abandonment and still others, beyond the eight, resulted in the disablement of mission sensitive electronics, i.e., HF communications, radar, etc.

The number of lightning strikes per 10,000 flight hours is .12 for the naval aircraft surveyed in the time period 1961-1980. The total number of strikes is based on approximately 40×10^6 flight hours. This means there was one strike for approximately every 64,000 hours of flight time. This finding is substantially below the findings for other similar studies indicating that in the early years lightning strikes were probably unreported. For example, a British commercial aircraft study indicated one strike per 2400 hours of flying time. Other comparable studies on specific aircraft range from one strike per 2700 hours to one strike per 33,000 hours.

Analysis of Navy patrol aircraft indicates one strike for every 3700 hours flying time. This is similar to the experience of the commercial airlines.

DATA ANALYSIS

Figure 1, Number of Lightning Strikes Per Year, shows the number of lightning strikes on an annual basis for naval aircraft. The gradual trend toward a greater number of strikes in the 1970's is attributed to better reporting and an increase in the number of aircraft and flights. The average number of strikes per year over the last six years is 58, which is comparable to the United Kingdom's statistic of 58 strikes per year.

Figure 2, Months vs Number of Lightning Strikes, illustrates the number of strikes per month. There does not appear to be any pattern except there were fewer strikes during the April to June and October to December time periods. This could be the result of several factors (i.e., fewer flights).

Figure 3, Number of Lightning Strikes Monthly per Aircraft Series, shows the number of lightning strikes with respect to aircraft function groups in the current inventory. Since the patrol series logs many more flight hours, 344 strikes is not considered unusual and does not indicate that the aircraft is intrinsically more susceptible to lightning strikes

because of its design. Rather, it follows from the longer flights and extended periods spent at the altitudes where most strikes occur (see Figure 4).

Figure 4, Number of Lightning Strikes vs Altitude, shows that 87% of the strikes occur below 25,000 feet. It clearly indicates that aircraft whose missions require that they fly at these lower altitudes should have increased lightning protection. The majority of hits occur between 5,000 and 10,000 feet. This agrees with the United Kingdom and Canadian findings.

Figure 5, Geographical Area vs Number of Lightning Strikes. The data used to develop Figure 5 was divided into ten broadly defined geographical areas. The figure shows that the majority of strikes occur in the warm/tropical climates. Further breakdown by month would have most likely indicated that strike frequency increases during those months when cloud cover and seasonal storm activity was highest, assuming hours flown remained constant.

Figure 6, Aircraft Damage vs Number of Lightning Strikes. The Navy has categorized the aircraft damage caused by lightning into five categories. Alpha or A damage is the code for the loss of an aircraft. Fortunately, only three such occurrences are on record. 98% of the strikes caused no or only limited damage. Although it is not reported here, the limited damage strikes result in a termination of the mission in many of the reported incidents. This generates a fleet readiness problem of a magnitude large enough to require continued investigation of lightning protection techniques.

Figure 7, Cost of Lightning Strike Damage vs Year. The costs shown represent the amount of money required to repair only the structural damage caused by the lightning strike, or to replace a lost aircraft due to a lightning strike. No attempt is made to adjust dollars for inflation, nor has an attempt been made to quantify the cost of either a mission abort or the value of the lives lost in the loss of an aircraft.

Figure 8, Aircraft Type Grouping of Lightning Damage and Strike Location. Lightning damage and/or strike location is presented for various types of aircraft. The majority of lightning strikes did damage to the avionics equipment. Protrusions, from the aircraft, i.e., radome, antenna, etc., sustained the most damage. With the increasing use of electronics for flight controls and weapons delivery, lightning damage, if not prevented, will cause an increasing number of mission aborts.

CONCLUSIONS

1. Further data refinements need to be pursued. The existing data can support additional conclusions if it is properly reduced. Additional data gathering is required inasmuch as it is evident that not all strikes are being reported.

2. Lightning strike data needs to be gathered on a continuing basis to:

- a. Provide better knowledge of lightning vulnerability.
- b. Provide a source of feedback to the lightning community to indicate what design techniques are working and what areas need further effort.

3. These data expose only the tip of the iceberg in that they explore only the tangible damage to aircraft. The extent to which lightning strikes damage electronic equipments and/or disrupt their proper operation either permanently or just temporarily represents an area of increasing concern as missions become reliant, to a very large and increasing extent, on the proper operation of those equipments.

FUTURE WORK

The present effort has been directed towards identifying the boundaries in which this problem exists. With that established, several follow-on and/or complementary efforts have been initiated: (1) a uniform reporting format is being developed to insure that all important aspects of the strike are described by the respondent; (2) the Boeing "Data Logger" is being evaluated for feasibility for installation into selected aircraft. This will provide detailed information about lightning waveforms, cur-

rent and voltage amplitudes, frequency spectrum, etc.; (3) A joint Air Force/Navy/NOAA effort involving flights of an instrumented aircraft in and around lightning active areas to measure various lightning data in greater detail than permitted by the data logger; and (4) an analytic effort funded by NASA, ONR investigating the waveform, peak voltage, current, and E&M field intensities present at VHF frequencies in the vicinity of lightning discharges.

Beyond these efforts are others coming on stream that will address the problem of hardening susceptible aircraft areas, components, and equipments to the threat imposed by lightning.

The collection of lightning strike data will be continued indefinitely in order to further refine and develop the conclusions drawn and to be drawn from the data. The continuation of the data gathering effort will also provide a needed control to ascertain whether any deployed attempts at lightning hardening have been successful. From time to time it is expected that the updated and augmented data will be made available to the EMC community.

REFERENCES

1. Lightning Strike Data, Navy Safety Center, Norfolk, Virginia 23511 (January 1961-December 1980).

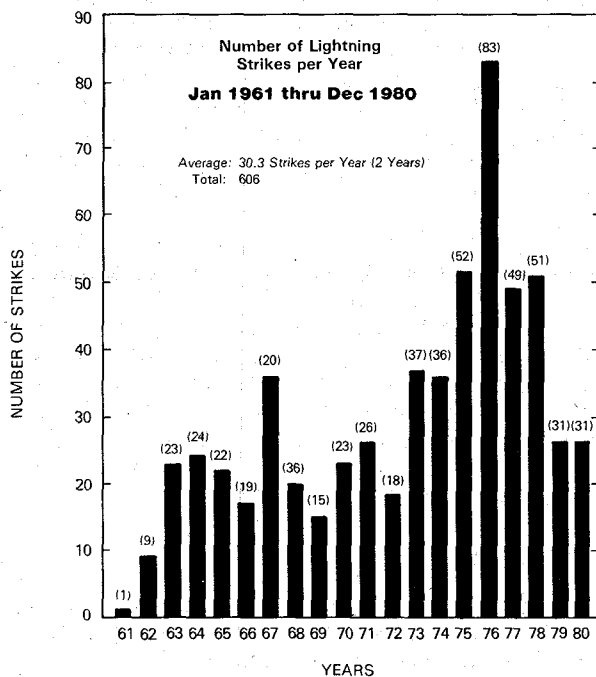


Figure 1

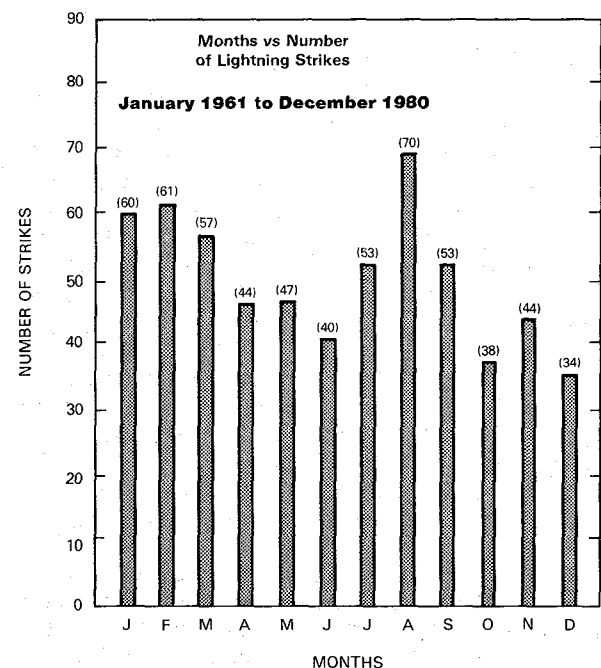
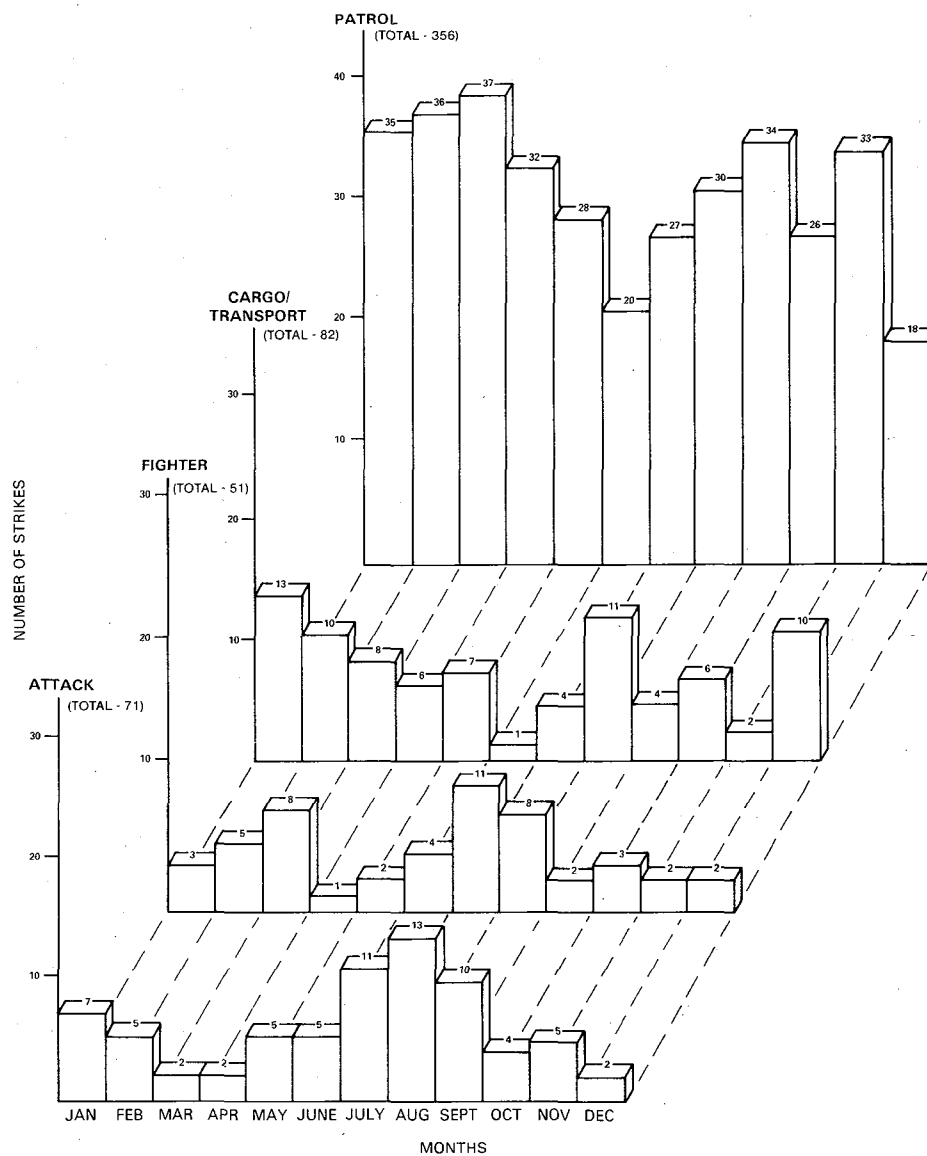


Figure 2



Number of Lightning Strikes Monthly per Air Craft Series
Jan 1960 Thru Dec 1980

Figure 3

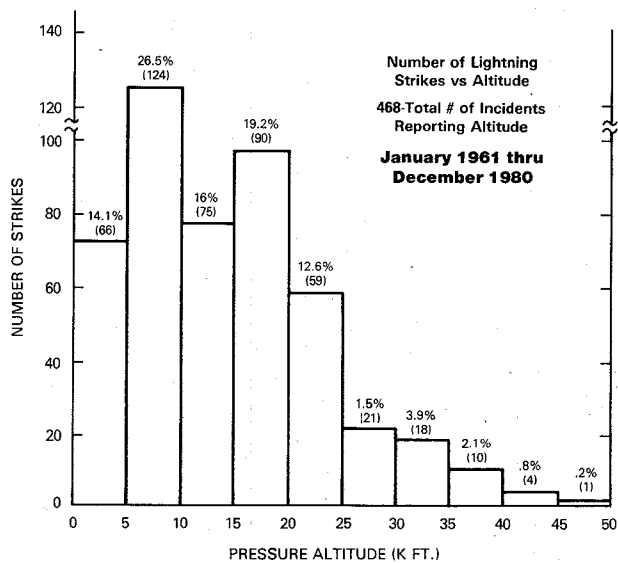


Figure 4

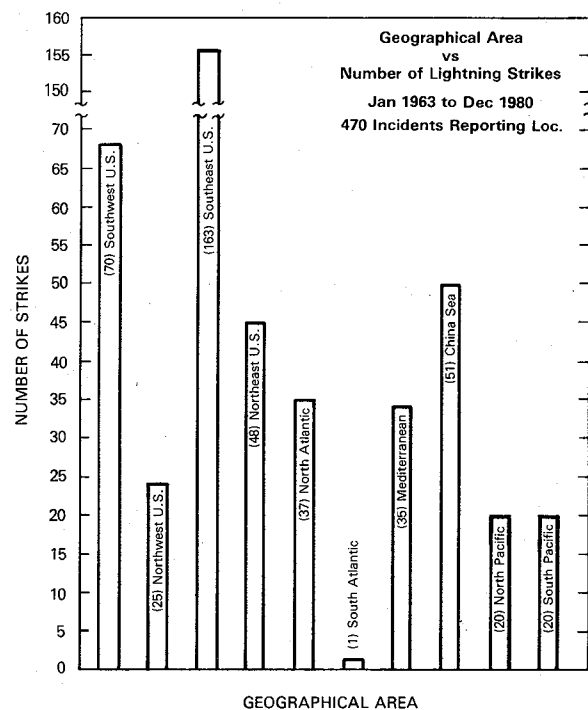


Figure 5

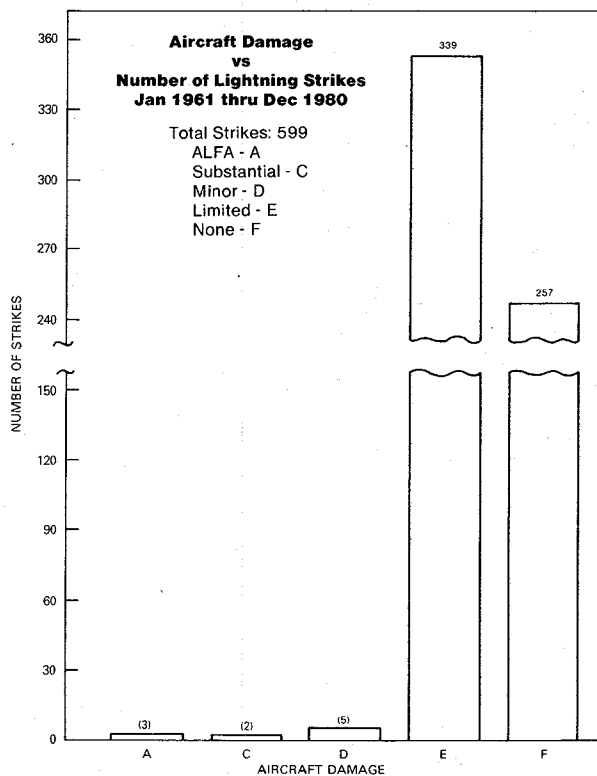


Figure 6

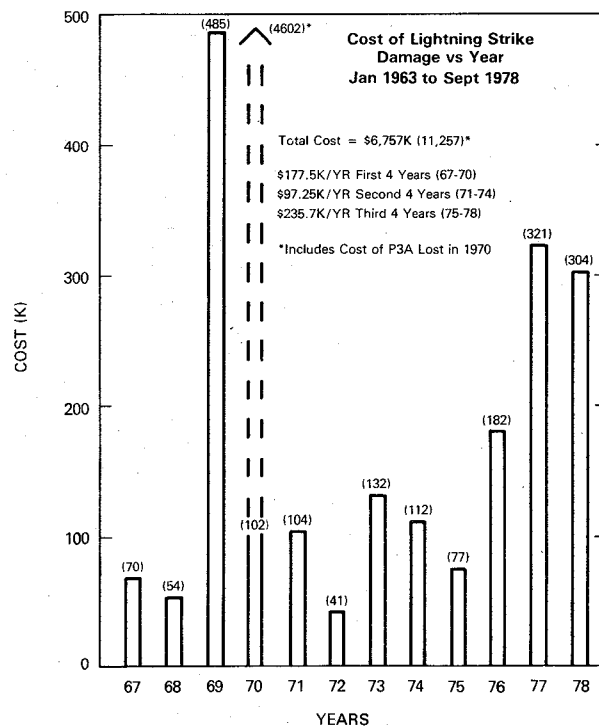


Figure 7

A/C TYPE GROUPING OF LIGHTNING DAMAGE AND STRIKE LOCATION

A/C Type	N/R	W	R	A	T	F	P	AT	Strike Location
Attack	20	8		3	16	3	4	17	Nose Radome, Fuel Probe, Wing, Fuselage, Tail Assy.
Cargo/Transports	23	17		8	13	6	0	0	Nose, Wing, Radome, Antenna, Fuselage, Nose Radome
E ²	0	0	0	0	0	0	0	0	
Fighters	19	10	0	2	12	4	1	15	Nose, Wing, Radome Fuselage, Antenna, Tail, Fuel Probe
Patrol	81	85		25	59	62	0	46	Fuselage, Nose, Radome, Wing, Tail, Antenna, Nose Radome
Rotary Wing (Helicopter)	0	0	2	0	0	0	0	0	
Trainer	1	1		2	1	1	0	2	Nose, Antenna, Radome
Total	144	122	2	50	101	76	5	104	

Legend: A/C-Aircraft
 N/R-Nose and/or Radome
 W-Wing
 A-Avionics
 T-Tail or Tail Assy.
 F-Fuselage
 P-Probe, Fuel
 AT-Antenna
 R-Rotor Blade

Figure 8