Lightning Strike Experience in the NASA F-106B Storm Hazards Program

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INTRODUCTION

A heavily instrumented F-106B aircraft is being flown in thunderstorms to gather data for characterizing lightning at aircraft operating altitudes (Figure 1). Conventional weather finding techniques have been supplemented with UHF lightning mapping radar to select the most active storm cells and the most likely altitude for obtaining direct lightning strikes to the airplane. One hundred seventy-six (176) strikes have been obtained in a three-year period, mostly at an altitude of above 25,000 feet.

Although current transport aircraft usually survive relatively unscathed from the effects of direct lightning strikes, manufacturing trends to composite structures and flight critical digital systems in newer aircraft make imperative the need for a reassessment of the lightning hazard at flight altitude. Design and testing of systems that can benefit from the lighter weight structures and more versatile control systems require the existence of a statistical data base defining the lightning hazard. In addition to the electromagnetic characteristics of nearby flashes and direct strikes, there is also a need for a comprehensive treatment of their effects on structures and the electronic systems vital to flight. The NASA Storm Hazards Program is providing useful data in all these areas.

Initial penetration flights of the NASA-owned and operated F-106B aircraft were conducted in 1980 in Oklahoma under the guidance of the National Severe Storms Laboratory's Rough Rider Project team. Later tests were conducted from Langley Research Center with radar support from NASA Wallops Island Facility.

Figure 1. Lightning Research

The technique evolved for operations at Langley in 1982 is depicted in Figure 2. The National Weather Service WSR-57 weather radars at Patuxent River, Maryland; Hatteras, North Carolina; and Volens, Virginia, were continuously monitored during the day to detect the occurrence of third level radar echoes within 150 miles of Langley. Altitude of storm cell tops were determined by the Wallops SPANDAR radar, a high resolution S-Band radar, and the most likely cells were surveyed for electrical activity using conventional indicators, i.e., short-range time-of-arrival direction finders, and long-range

	1980	1981	1982
FLIGHTS	40	48	49
PENETRATIONS	69	111	239
STRIKES	10	10	156

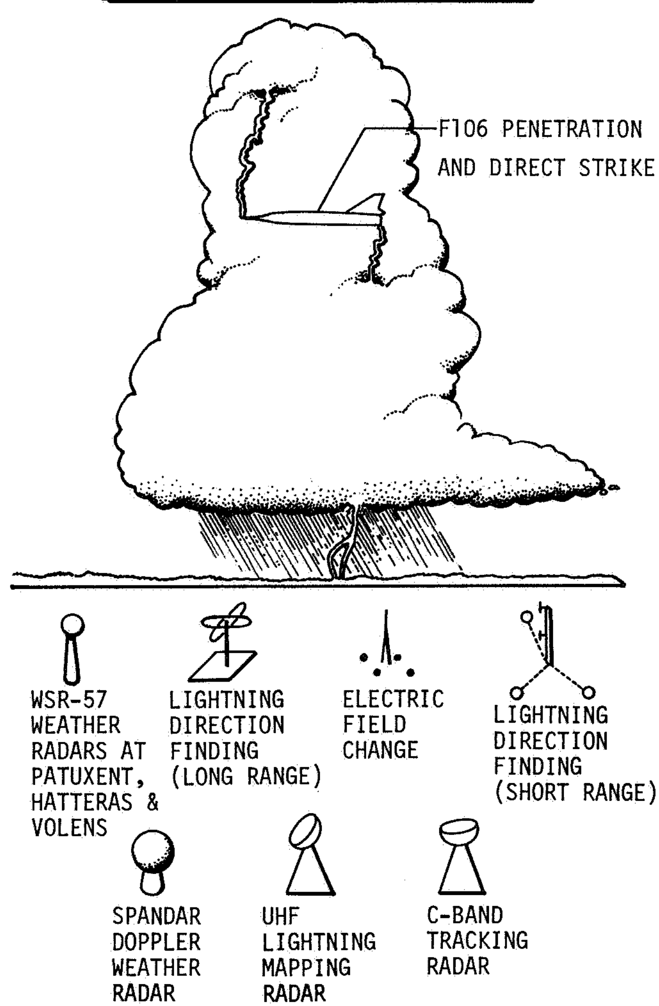

Figure 2. Storm Hazards '82 Operations

magnetic field direction finders. For about one month in 1982, a UHF lightning mapping radar at Wallops was used with good effect to provide three-dimensional data on lightning. A C-Band tracking radar provided aircraft position data to Wallops personnel; the aircraft Inertial Navigation System (INS) position was downlinked to personnel at Langley. Aircraft operational control was exercised either from Wallops or Langley depending on the situation. The aircraft carried its own weather radar, and the pilot always exercised a final option on selecting penetration locations and heading.

In 1980 and 1981, ten lightning strikes to the airplane were received each year. During this time, most penetrations were accomplished at 10,000 - 15,000 feet altitude in accordance with the history of lightning strikes to aircraft as summarized in Figure 3. In 1982, most penetrations were flown between 25,000 and 35,000 feet altitude, with a dramatic increase to 156 in the number of strikes. The distribution of strikes with altitude is shown in Figure 4 for 168 of the strikes. In addition to the altitude change, several other factors that were changed in the 1982 operation contributed to this large increase. These include:

1. More storms available through extension of the aircraft operating range from 100 nautical miles to 150 nautical miles from Langley.

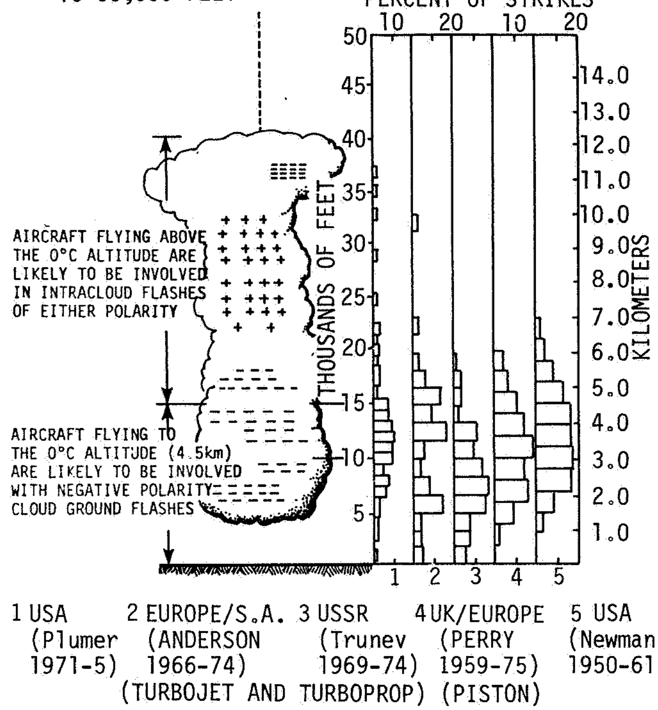

Figure 3. History of Lightning Strike Incidents vs. Altitude

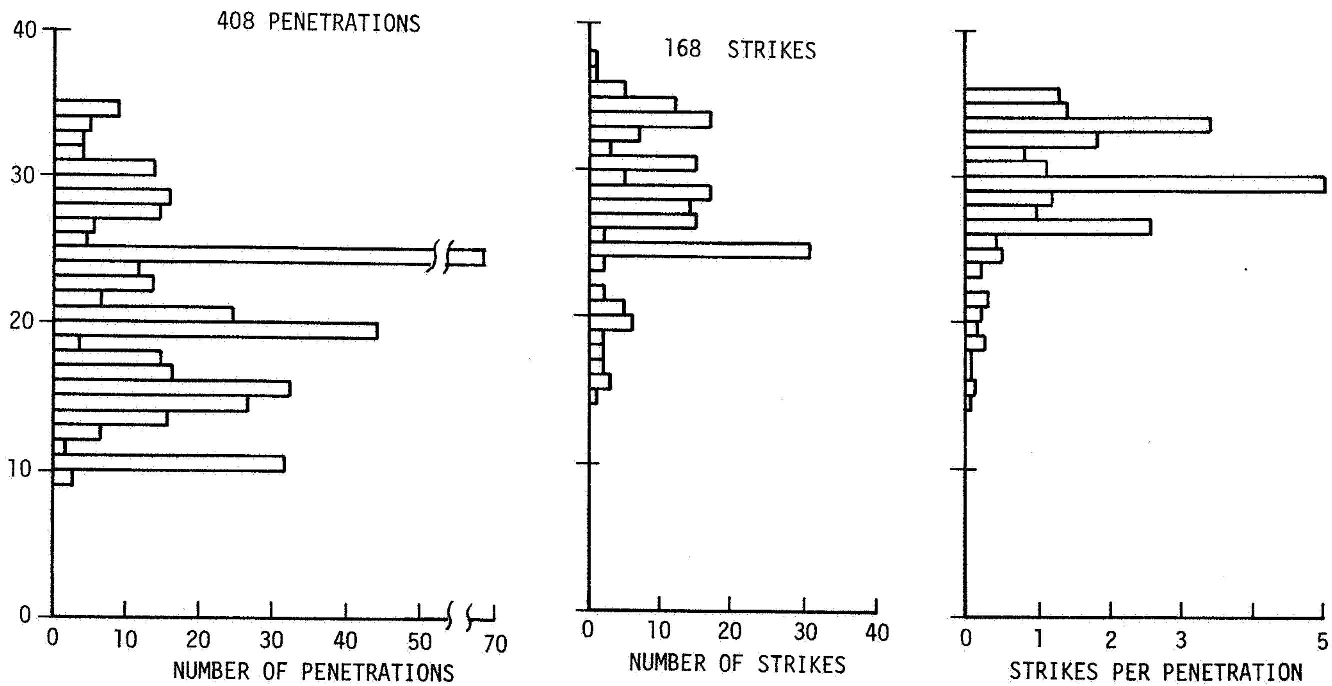

Figure 4. Storm Hazards Program History of Lightning Strike Incidents vs. Altitude, 1980, 1981, & 1982

2. Existence of more moderate level thunderstorms during daylight hours within 150 miles of Langley than heretofore.

3. More efficient use of flight time through the addition of the second control center at Langley to supplement the Wallops control providing greater geographic coverage and equipment redundancy.

4. Improved location of lightning activity through the addition of the UHF lightning mapping radar from late July through August.

5. Addition of the long-range lightning direction finding system in early August.

6. Less equipment outages (In 1981, the F-106B was grounded for two months due to engine problems).

However, it is felt that the principal change was due to flying higher. This was borne out by the activity shown on the airborne field mills, which was also downlinked to the Langley control center. Typical results are shown in Figure 5 which indicate few separated charges down low (17,000 feet), but the existence of many more charge centers at higher altitudes. The sequence shown in Figure 5 is believed to be typical. At 25,000 feet, significant changes in field charge were indicated, and a positive nearby flash and a negative direct strike were recorded. Later, and down low at 17,000 feet, very little field mill activity was observed. Still later, back up high (24,000 feet), many changes in charge level were observed including another negative charge strike. Although there are significant changes in aircraft position within the storm during the data interval shown, these data represent the general experience, and the physical ramifications of this behavior

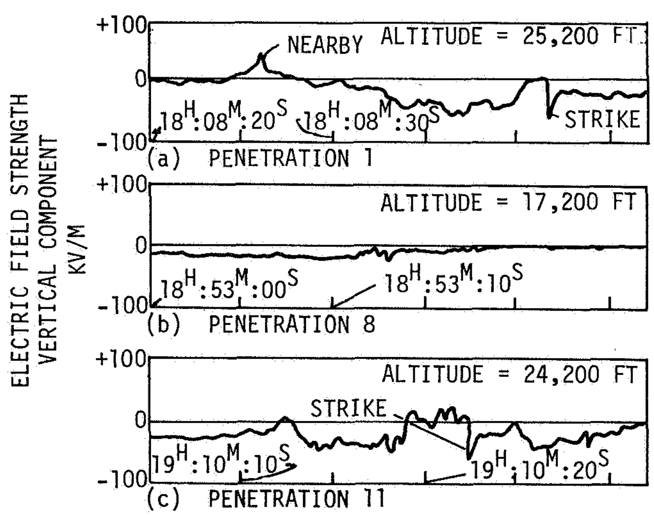

Figure 5. Electric Field Strength Measured During Three Storm Penetrations From Flight 82-027, July 11, 1982

are represented in the distribution of strikes with altitude (Figure 4).

A typical measured electromagnetic sensor response to a direct lightning strike is compared with a numerical model simulation in Figure 6, using a finite element representation of Maxwell's partial differential equations of the basic airframe. In general, the agreement is good, although higher order terms in the prediction need further analysis.

To date, about 138 strikes have been obtained above 25,000 feet, mostly intracloud strikes. Peak amplitudes range from less than 1,000 amps to about 15,000 amps. Next year, some effort will be made to obtain data from cloud to ground strikes, using the advanced lightning finding techniques already described, and operating at altitudes of 10,000 feet or below.

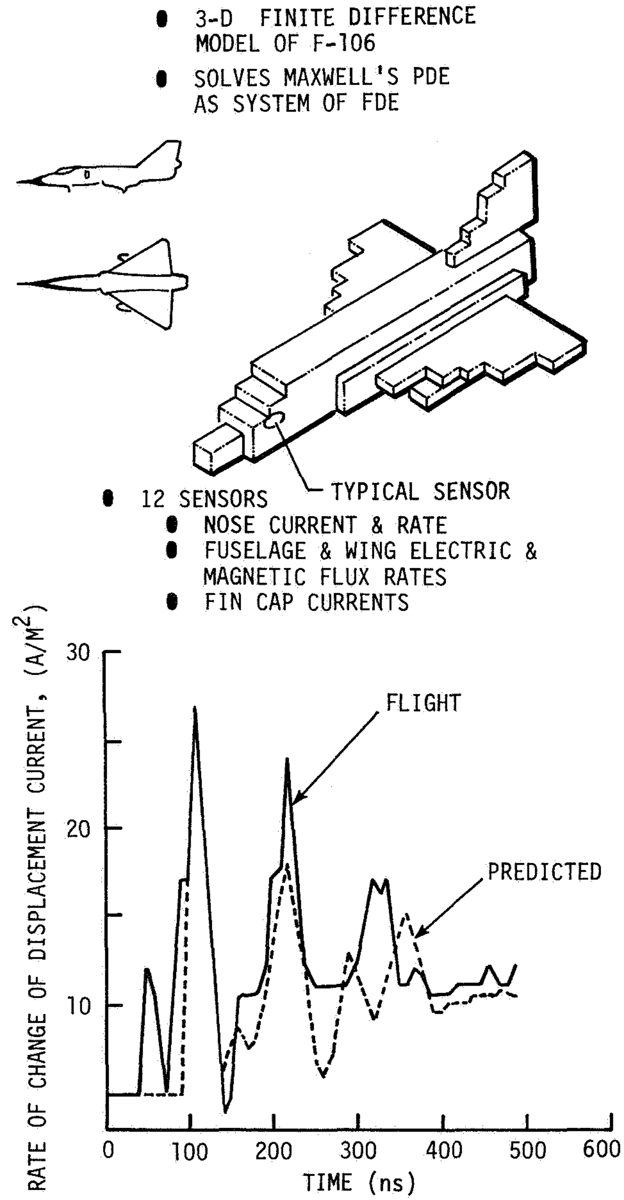

Figure 6. Comparison of Theoretical Prediction with Flight Measurements