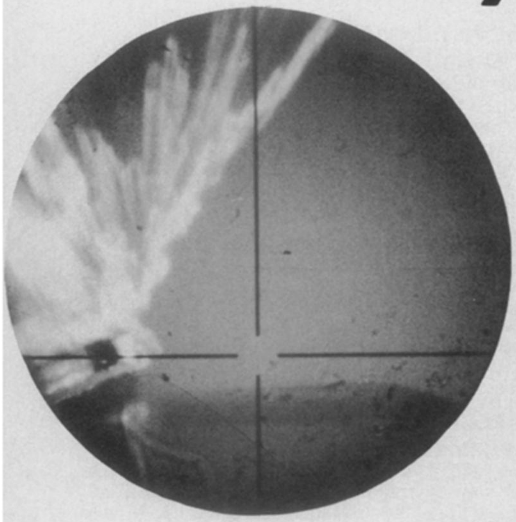
Fly-by-Lightning

The most sophisticated planes are fast, efficient and, researchers fear, highly vulnerable to lightning



Above, a lightning stroke attaches to the engine outlet of a NASA F-106 in flight and sweeps past the camera. NASA Langley

By CHERYL SIMON

Anyone who has endured static crackling over telephone lines, flickering lights and poor radio reception during a thunderstorm knows that a storm, even one miles away, can disrupt electrical systems. Annoying perhaps, but hardly dangerous. But for a pilot operating one of the late model airplanes, the surges of electricity that accompany thunderstorms are at least unnerving, and sometimes catastrophic.

Like many advances in technology, the latest "fly-by-wire" aircraft—planes completely controlled by computers and with light, strong bodies made of composite materials and plastic—present new problems to balance their undeniable assets. They use fuel more efficiently, and operate with far greater precision than is possible with manual controls. They also are far more vulnerable than conventional planes to the effects of lightning.

The metal used in bodies of earlier planes functions as a shield against electrical fields, but materials such as plastics and carbon fiber used in the newest models provide relatively little protection from lightning strikes. To compound the problem, the planes' interiors are filled with sensitive electrical equipment that is all too receptive to transient surges of electricity. Richard Richmond, a civilian researcher at Wright Patterson Air Force Base in Dayton, Ohio, explains that a lightning stroke can create electromagnetic waves that propagate through space. When such a wave strikes a conductor, or a metal body or an electric part, it can induce unexpected and unwelcome electrical signals that affect computer operation.

"The results of a transient could be momentary, with the computer confused for a few microseconds, or something as serious as the aircraft literally falling out of the sky," Richmond says.

While the problem exists for both commercial and military planes, the Air Force has a vested interest in clarifying and solving the problem. Not only are military planes more advanced technologically than most commercial aircraft, but electrical interference also could cause a plane to be incapable of delivering its weapons or to deliver them prematurely. These effects could be similar to those caused by the electromagnetic pulses stimulated by nuclear explosions (SN: 5/19/81, p. 300; 5/26/81, p. 314). The Air Force recently awarded a contract to Boeing Aircraft Co. to study ways to enhance a plane's chances of surviving a brush with lightning.

The urgent need to identify the hazard level posed by lightning's effects on aircraft has inspired an intense inquiry into the basic qualities of lightning a plane is likely to encounter, and into ways to protect the planes so that electricity simply can't get in.

Possible kinds of damage fall into two categories. The most obvious injuries are direct ones, such as a hole burned in an airplane's body or a melted wingtip. Strikes usually inflict little important damage to the structure of the plane, and in fact, lightning tracks across the plane's skin indicate currents lower than the peak currents — usually 200,000 amps — for which planes are designed. However, if even a low discharge dwells over a fuel tank for long enough, the result can be grave indeed. Such was the case in South Carolina in 1978 when lightning struck the metal body of an Air Force C-130E flying through a precipitating but non-thunderous cloud. The current burned a hole through the wing's skin and ignited fuel vapor. The ensuing explosion blew off part of the wing and the plane plummeted to the ground, killing all eight crewmen.

Induced effects are less obvious but are potentially even more dangerous, Richmond says. Lightning need not even touch an aircraft to introduce voltages to wires and integrated circuits.

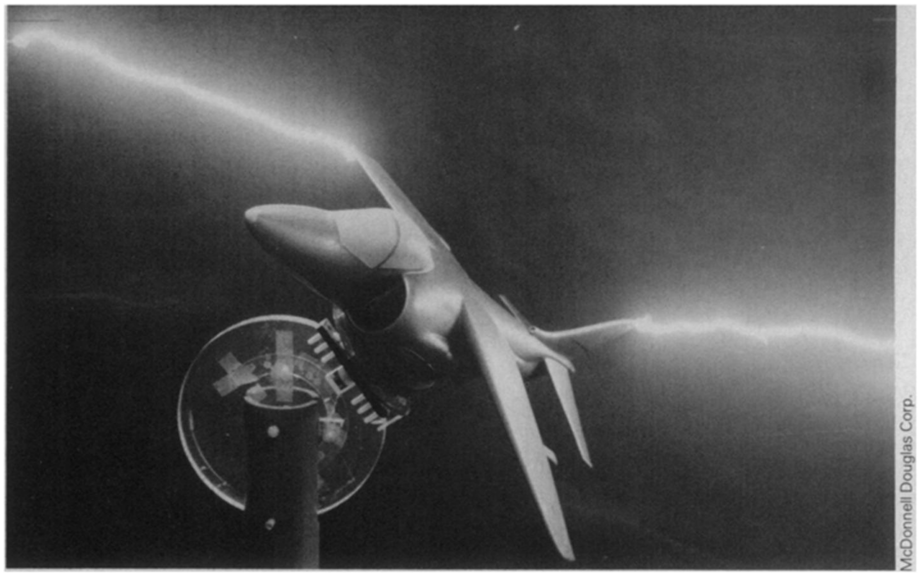
Protection of the planes requires better understanding of both the lightning and the damage it inflicts. In one project, based at the National Aeronautics and Space Administration's Langley Research Center in Hampton, Va., researchers are studying lightning at actual flight altitudes rather than relying on ground-based experiments. When weather conditions promise thunderstorms, an F-106 heavily guarded against damage from lightning and fitted with lightning sensors departs Wallops Flight Center in Virginia and heads for the center of the storm.

During the past three summers, about 165 lightning strikes tore across the plane's aluminum surface. Information about currents and rates of change in electric and magnetic fields — the factor that determines the strength of transient voltages — will be used to learn how the aircraft responds to the lightning. Because of the size and geometry of the F106, the measurements are specific to that plane, "but we hope to be able to make a generic statement about lightning hazard," says Felix Pitts, a NASA Langley researcher.

Pitts says that perhaps 70 or 80 percent of the flashes attach first to the plane's nose, then sweep back along either side of the plane and attach to the fin and wing tip. "Generally the strikes we've had haven't been extremely energetic," he says. While lightning currents are known to reach several hundred thousand amps, most of those recorded during the NASA flight missions have been about 15,000 to 20,000 amps, "but they have been very fast," Pitts says.

Investigators differ over whether data obtained by planes reflect strikes by natural lightning or if the planes themselves are involved in the lightning process. The lightning strikes recorded by most aircraft, says Don Clifford, an aerospace engineer with McDonnell Douglas Aircraft Corp., in St. Louis, are probably a form of lightning other than that which occurs nat-

NASA Marshall Space Flight Center



McDonnell Douglas Corp.

New Mexico Tech.

Top left, photo of cloud tops shows seven simultaneous lightning bolts (bright area at right) during a thunderstorm over Oklahoma in May 1982. Top right, manufacturers subject model planes to high voltage bolts to learn how lightning moves across a plane's body. Above, instruments in a 40-foot cylinder record data on lightning triggered experimentally at New Mexico Tech.

urally during thunderstorms. Most of the reported strikes occur in nonthunderous clouds composed of ice and electrically volatile, super-cooled water droplets. He speculates that when a plane passes through a cloud, it may leave a wake, in effect a trailing conductor that triggers a lightning flash. "You perturb the natural environment and things apparently happen to the airplane that wouldn't happen in the cloud if the airplane wasn't there," Clifford says. "Most pilots will agree to that based on their experience, but a lot of the scientific community isn't convinced yet that an airplane actually triggers lightning."

Lightning triggered by planes also may occur at a much lower level of intensity than natural lightning because the aircraft may cause a charge to be released at a lower voltage level than it would if left alone.

Clifford says the main focus now is not protection from structural damage but protection against electrical interference. "It's possible that small currents are as damaging as large ones. That's what we don't know for sure," he says. Because the next round of electronic systems, now being developed, will be even more sensitive than those now in use, the effort to meld basic and applied lightning research is speeding up.

In designing planes, aircraft engineers prepare for the worst possible case of cloud-to-ground lightning, the searing flashes that split trees and jeopardize golfers unwittingly trapped on an exposed green. While there also are lightning flashes within clouds and from one cloud to another, the cloud-to-ground strokes are thought to pose the greatest risks to planes because they propagate either below or off to one side of a thunderstorm, Richmond says. These are the zones where a pilot is most likely to seek refuge from a storm. Planes are designed to withstand voltages up to 200,000 amps from a cloud-to-ground strike, and there is some evidence that most lightning strikes, especially at higher altitudes such as those sought by the NASA pilots, are much weaker because current intensity decreases with distance from the ground, Clifford says. While this suggests that planes may be overdesigned, engineers need more information about ways that current intensity relates to the size and effect of voltages that affect computer operation.

Richmond, a physicist, is working with a team of French scientists and with researchers at the New Mexico Institute of Mining and Technology's Langmuir Laboratory in Socorro, N.M., to trigger lightning and ultimately to measure how much electricity leaks into an aircraft fuselage. In field experiments, a small solid fuel rocket toting a wire is launched into thunderclouds overhead. The scientists can predict with "a reasonable amount of confidence" when and where a lightning strike will occur, Richmond says.

Lightning is triggered near a 60-foot-tall scaffold bearing a cylinder-shaped instrument package simulating a fuselage. When the lightning strike jumps from the wire to the cylinder, sensors measure the currents and the electromagnetic fields. The data collected will be used to describe the threat lightning poses to aircraft in flight and to develop ways to test the aircraft and pinpoint areas on a plane that are most vulnerable. Finally, designers will determine how best to protect the plane from both damage to its structure and to its electrical systems. Though much of the research focuses on military planes, commercial aircraft manufacturers are encouraged to use the findings.

The prescription for the ailment could be as simple as plugging leaks around doors and windows or spraying the plane's body with a thin coating of aluminum. Strips that conduct electricity down the aircraft's body also can minimize the risk, and individual computer parts can be shielded from outside surges of electricity.

Most pilots enter thunderstorms with about the eagerness that a diver knowingly plunges into a school of barracudas. In fact, the Federal Aviation Administration forbids commercial pilots to fly within 20 miles of thunderstorms, and military pilots are required to maintain a 10-mile clearance. Richmond points out that even though a certain component on a plane cannot withstand a full lightning current, it does not necessarily mean that the plane is unsafe to fly in a "normal environment." But an estimated 2,000 thunderstorms are in progress around the world at any moment, and the possibility that a plane will encounter lightning cannot be ruled out. Says Richmond, "Frequently they end up in storms even when they didn't intend to, primarily on takeoff and landing, because the options for avoiding storm conditions are reduced there." □