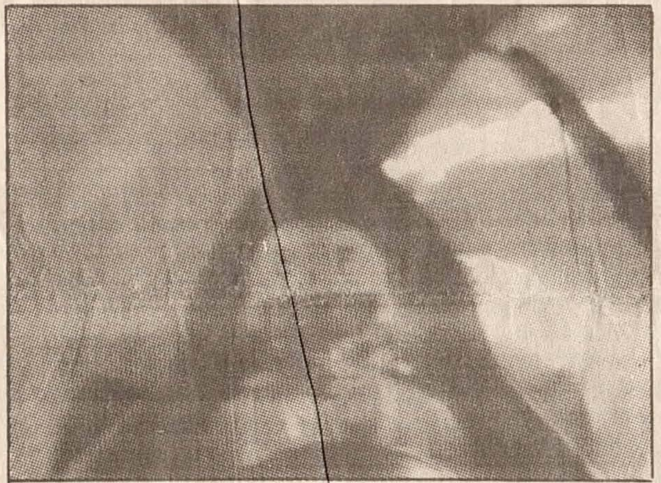
Science / Medicine

Cockpit camera captures the moment as lightning strikes the F-106B fighter jet behind seat of co-pilot Bruce Fisher, a NASA engineer.



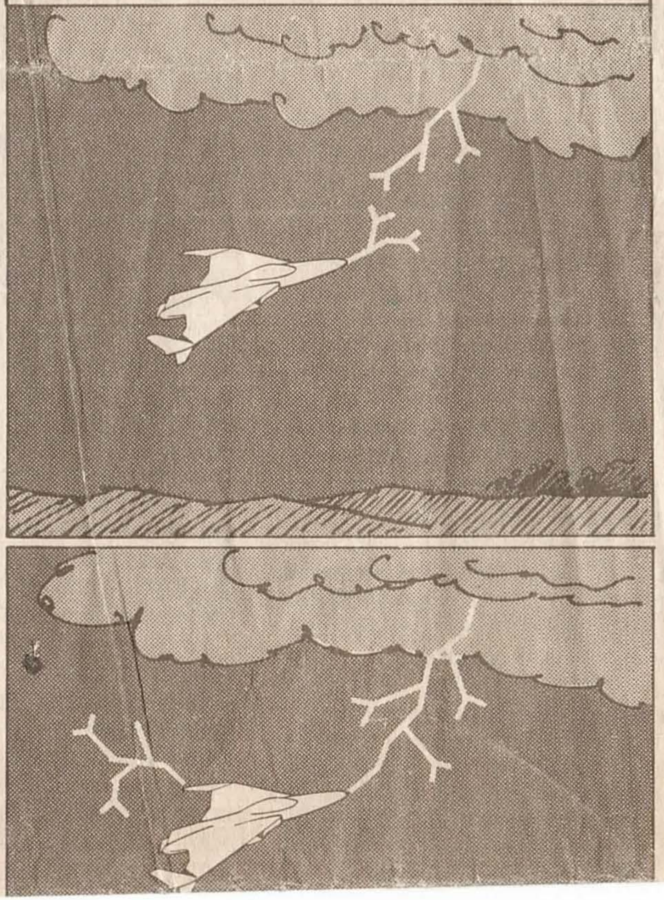
NASA

Wings of Fire

Composite materials being used in new airplanes are strong and light but can be a hazard if

LIGHTNING FOLLOWS 'THE LEADER'

Physicists now believe that lightning strikes begin with "leaders"—regions where electricity has just begun flowing. The leaders grow toward each other simultaneously, forming a path for the electricity. At top, the leader from the nose of the aircraft draws the strike. Center, the plane's metal skin conducts the electricity, until it connects with another leader on the ground, bottom.



81 on board. That disaster, the only one caused by lightning in U.S. commercial aviation, prompted the FAA to require that aluminum wing surfaces of fuel tanks be at least .08 of an inch thick.

Protecting a composite airplane, on the other hand, is more complicated. Engineers are concerned with lightning's direct and indirect effects. Direct effects refer to the damage inflicted by the lightning flash, which is hot—up to 20,000 degrees Celsius—and delivers a shock wave that can dent metal and be heard miles away as thunder. Indirect effects are caused by the huge, rapidly changing currents and electromagnetic fields of a lightning bolt, which can create unwanted currents and voltages in any unprotected electrical wires inside the airplane.

"The concern was if you had a lightning strike that coupled into a wire, a component could be damaged, and feasibly you could damage a 50-cent electronic chip and the airplane would fall out of the sky," said Gary DuBro, assistant director for studies and analysis at the Office of Naval Technology in Arlington, Va.

Some jets, like the Air Force's F-16 fighter and the new Airbus A320 airliner, cannot fly without sophisticated flight computers that continually adjust the engines and control surfaces.

For safety, wires leading to essential electronic controllers are all connected to devices that limit sudden, potentially damaging surges of voltage and current. The wires themselves are usually shielded with metal to further limit surges.

To protect the plane itself from the direct effects of a lightning strike, a thin coating of aluminum, copper, or nickel is applied to all composite surfaces. The idea is to conduct the current from the lightning away from the immediate area of the strike, spreading it out over the fuselage.

Another method of protecting composites starts with fine metal wires, which are woven into the composite material itself. Beech Aircraft Corp. in Wichita, Kan., used this technique on its new all-composite Starship airplane, which had a live encounter with lightning on a test flight in May.

"All we can say is that it did occur and that the

lightning strikes the craft.

By GLENN ZORPETTE

Pilot Robert A. Rivers remembers one thing clearly: They were not the sort of clouds he expected to see lightning leap out of. But it did, and it nearly wrecked his airplane.

Rivers, a research pilot with the National Aeronautics and Space Administration, was approaching the Los Alamitos Army Aviation Facility on Feb. 24, 1987. Behind him was astronaut Brewster H. Shaw Jr., a veteran of two space shuttle flights and Rivers' co-pilot that day.

As the plane, a T-38A jet trainer, passed about 2,500 feet over Seal Beach, Rivers took off his gloves to open a flight manual. About the same time, Shaw's hair began standing on end, not an uncommon occurrence during the static buildup before a lightning strike. Then, at 12:33 p.m., with the plane about 11 miles from the runway at Los Alamitos, there was a bright flash and a loud thump.

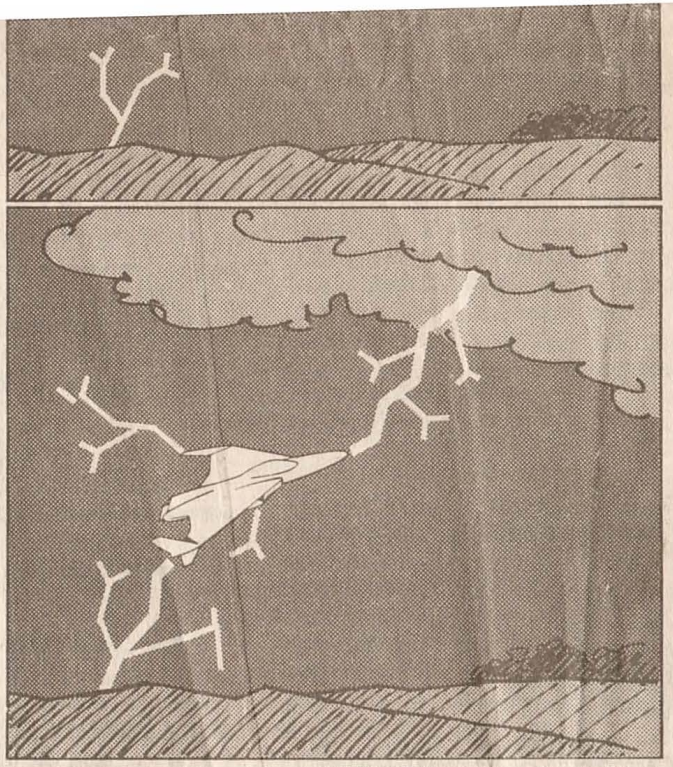
"I remember feeling the shock through my hand on the throttle," Rivers recalled. "We were pretty sure it was a strike." Almost instantly, there was a second thump, and a warning light indicated fire in the right engine. Rivers shut the engine down and managed to land the balky aircraft at Los Alamitos. "I don't think we could have made it much farther," he said.

Leaping out of the burning airplane, the two saw a gaping hole behind the co-pilot's seat. The second thump had been the sound of a fuel tank exploding and ripping off the top of the fuselage.

Although few encounters cause that sort of damage, lightning strikes at least a few planes around the globe every day, according to experts at NASA and the Federal Aviation Administration. The vast majority of strikes are not life-threatening because until recently most airplanes were built of aluminum, which protects them.

But nearly all airplanes designed in recent years use some non-metallic materials called composites, which are plastics reinforced by fibers of graphite or some other material. Composites are stronger and lighter than aluminum but, by themselves, offer little or no protection against lightning.

Therefore, to better protect the next generation of aircraft, researchers have recently undertaken the most ambitious programs ever to understand lightning's effects.



Source: Gary DuBro, U.S. Navy PATRICK LYNCH / Los Angeles Times

Airplanes using composite materials perform better and consume less fuel than comparable all-metal planes. Such features have put the materials into all kinds of new aircraft, from eight-passenger business jets to 350-seat airliners. And most military jets of the next decade, including the so-called stealth aircraft, will rely heavily on composites.

Despite their many advantages, composites lack one important feature: They conduct electricity poorly or not at all. When a metal airplane is hit by lightning, the huge electric current of the bolt typically enters through an extremity like the nose or a wing tip and is immediately conducted through the surface of the plane, spreading out all over like water flowing over the outside of a bottle. Then the current leaves the plane through the tail or some other extremity.

By instantly spreading out the electric current, the metal skin effectively protects the airplane. However, the metal must be thick enough to keep lightning from entering a fuel tank, as it did in a Pan American 707 just before 9 p.m. on Dec. 8, 1963. The plane was hit over Maryland by a bolt that ignited fuel in the reserve tank, blowing the left wing off the plane and killing all

Mike Potts said. An industry source familiar with the event said damage to the Starship was minor.

The use of composites is most pronounced in business jets like the Starship, but airliners also use them. The Boeing 757 and 767 use composites in their noses, nacelles (the rounded engine casings that hang below the wings), in fairings and in all control surfaces on the wings.

U.S. military jets of the 1990s are also going to be built with composites, according to sources at Boeing Advanced Systems, Northrop Corp. and McDonnell Douglas Corp. Both competing designs for the advanced tactical fighter, which will take over as the Air Force's main combat jet sometime in the 1990s, rely heavily on composites. And stealth aircraft, like Northrop's B-2 (or "advanced tactical") bomber, recently unveiled by the Air Force, also use composites.

Stealth aircraft—so named because they are hard to detect—are designed to minimize the reflection of radar waves from their surfaces. Compared to metal, composite materials are poor reflectors of radar waves.

These composite aircraft have had the benefit of a wealth of new information on the effects of lightning on aircraft. Since the late 1970s, several joint research programs have been carried out by the Air Force, the FAA and the National Oceanic and Atmospheric Administration.

But some of the most impressive findings came from the Storm Hazards Program run by NASA's Langley Research Center in Hampton, Va. Pilots and engineers there flew a specially hardened and equipped F-106B airplane, a 1960s-vintage jet fighter, directly into thunderstorms.

From 1980 to 1987, the flight team logged 714 lightning hits, producing the first direct measurements of how fast the electrical fields and currents change on an airplane being hit. Those changes are what cause lightning's indirect effects on airplanes. Based on information from the NASA project, the FAA is setting new regulations for protecting electronic flight systems from lightning's indirect effects.

NASA itself has incorporated the findings into new "launch-commit" criteria for officials at the Kennedy Space Center in Florida to help them determine when it is safe to launch rockets and the space shuttle. The space agency is hoping to avoid another incident like the one on March 26, 1987, when a rocket carrying a Navy communications satellite was hit by lightning just after launch, causing a $160-million loss.

Glenn Zorpette is a free-lance writer in New York City.