Lightning Detection From Space
A Lightning Primer

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Introduction

Lightning, the thunderbolt from mythology, has long been feared as an atmospheric flash of supernatural origins: the great weapon of the gods. The Greeks both marveled and feared lightning as it was hurled by Zeus. For the Vikings, lightning was produced by Thor as his hammer struck an anvil while riding his chariot across the clouds. In the East, early statues of Buddha show him carrying a thunderbolt with arrows at each end. Indian tribes in North America believed that lightning was due to the flashing feathers of a mystical bird whose flapping wings produced the sound of thunder.

Today, scientific rather than mystical techniques are used to explain lightning with experimental procedures replacing intuitive concepts. Yet, we remain in awe of lightning which still shines with its mystery, and rightly so. Each year, lightning is responsible for the deaths of a hundred or so people, injuries to several hundred more, and millions of dollars in property damage, in the United States alone.

While these are more than sufficient reasons for NASA to pursue lightning research, lightning has a direct effect on day-to-day operations as well. The avoidance of lightning strikes to a spacecraft during launch relies heavily on the ability of meteorologists to accurately forecast and interpret lightning hazards to NASA vehicles under varying weather situations. Severe hazards for NASA due to lightning have been well documented. One major incident occurred during the 1969 launch of the Apollo 12 mission when lightning briefly knocked out vital spacecraft electronics. Fortunately, the astronauts regained control.

The unmanned Atlas Centaur 67 which carried a Naval communication satellite was determined to have been struck by a triggered cloud-to-ground lightning flash on March 26, 1987. The lightning current apparently altered memory in the digital flight control computer. This glitch resulted in the generation of a hard-over yaw command which caused an excessive angle of attack, large dynamic loads, and ultimately the breakup of the vehicle.

On a smaller scale, two sounding rockets being prepared for launch from NASA's Wallops Island in 1987 were prematurely launched as a direct result of lightning.

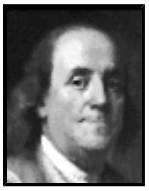
It is now well recognized that lightning strikes near aircraft most often originate from the craft itself. The flash is believed to begin with the inception of a leader, propagating in both directions away from the craft. These are called "triggered" lightning flashes.

It is difficult to obtain accurate statistics on lightning injuries and fatalities since a systematic compilation of information on lightning casualties does not exist. Many case histories show heart damage. Inflated lungs and brain damage have also been observed from lightning fatalities. Loss of consciousness, amnesia, paralysis and burns are reported by many who have survived.

Deaths and injuries to livestock and other animals, thousands of forest and brush fires, as well as millions of dollars in damage to buildings, communications systems, power lines, and electrical systems are also the result of lightning.

Finally, the threat of lightning causes many work stoppages and lost production increasing the time and cost required to prepare NASA spacecraft for flight.

History



Benjamin Franklin performed the first systematic, scientific study of lightning during the second half of the 18th century. Prior to that time, electrical science had developed to the point where positive and negative charges could be separated. Electrical machines could, by rubbing together two different materials, store the charges in primitive capacitors called Leyden Jars from which sparks could be generated and observed.

While others had previously noted the similarity between laboratory sparks and lightning, Franklin was the first to design an experiment which conclusively proved the electrical nature of lightning. In his experiment, he theorized that clouds are electrically charged, from which it follows that lightning must also be electrical. The experiment involved Franklin standing on an electrical stand, holding an iron rod with one hand to obtain an electrical discharge between the other hand and the ground. If the clouds were electrically charged then sparks would jump between the iron rod and a grounded wire, in this case, held by an insulating wax candle.

This experiment was successfully performed by Thomas Francois D'Alibard of France in May 1752 when sparks were observed to jump from the iron rod during a thunderstorm. G. W. Richmann, a Swedish physicist working in Russia during July 1753, proved that thunderclouds contain electrical charge, and was killed when lightning struck him.

Before Franklin accomplished his original experiment, he thought of a better way to

prove his hypothesis through the use of a kite. The kite took the place of the iron rod, since it could reach a greater elevation and could be flown anywhere. During a Pennsylvania thunderstorm in 1752 the most famous kite in history flew with sparks jumping from a key tied to the bottom of damp kite string to an insulating silk ribbon tied to the knuckles of Franklin's hand. Franklin's grounded body provided a conducting path for the electrical currents responding to the strong electric field buildup in the storm clouds.

In addition to showing that thunderstorms contain electricity, by measuring the sign of the charge delivered through the kite apparatus, Franklin was able to infer that while the clouds were overhead, the lower part of the thunderstorm was generally negatively charged.

Little significant progress was made in understanding the properties of lightning until the late 19th century when photography and spectroscopic tools became available for lightning research.

Lightning current measurements were made in Germany by Pockels (1897-1900) who analyzed the magnetic field induced by lightning currents to estimate the current values. Time-resolved photography was used by many experimenters during the late l9th century to identify individual lightning strokes that make up a lightning discharge to the ground.

Lightning research in modern times dates from the work of C.T.R. Wilson who was the first to use electric field measurements to estimate the structure of thunderstorm charges involved in lightning discharges. Wilson, who won the Nobel Prize for the invention of the Cloud Chamber, made major contributions to our present understanding of lightning.

Research continued at a steady pace until the late 1960's when lightning research became particularly active. This increased interest was motivated both by the danger of lightning to aerospace vehicles and solid state electronics used in computers and other devices as well as by the improved measurement and observational capabilities which were made possible by advancing technology.

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