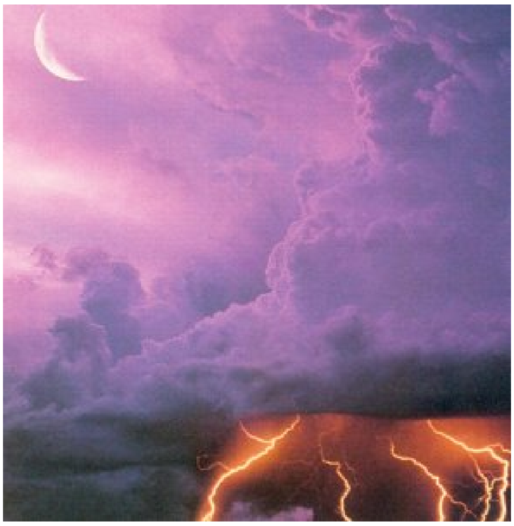
THUNDERSTORMS KILL!

Original idea from Dan Manningham

Thunderstorms kill. They kill with wind, rain, ice, hail, lightning, downbursts & tornadoes. They kill up to 10 miles beyond the confines of the Cloud itself. They kill everywhere, even the best pilots… get it?



Look! There's no excuse for this. Pilots are still flying into thunderstorms, and then acting surprised when they get hurt. Everyone knows that an airplane is not match for a thunderstorm. Everyone knows that thunderstorms kill. There's no excuse.
Forget about what other guys are doing. Forget about those hangars rumors, and form your own conclusions. Forget about expecting ATC to tell you to avoid buildups; that's not its job.
Consider this, you may be able to drive through a stop sign or a red light without any harm whatsoever. You can cross a rail road track when the gates are down and live to brag about it. You can do either one several times if you are lucky. You can also fly into or near a thunderstorm and survice. Maybe you have already. Maybe you have been lucky. All of those activities are possible, but they are not safe. Traffics, trains and thunderstorms kill. Not each and every episode takes a victim, but like a serial killer, these powerful forces persistently stalk one more quarry. And then one more. NEVER fly in, over, under or near a thunderstorm because it is a killer, and you might be the next casualty. Avoid, always avoid…

ORIGINS

Thunderstorms generally build in one of 3 specifics ways:
First they can develop in warm air-masses where surface heating is sufficient to drive large parcels of moist air aloft. These "air mass" thunderstorms tend to stand as individual powerhouses, although they can, be large and numerous when conditions are right. Air-mass thunderstorms have ripped airplanes apart in flight, flash frozen entire flocks of high-flying geese, dumped 3 feet of hailstones on the ground and shattered boulders with lightning.

Secondly, squall line thunderstorms form as cold air pushes warm, moist air aloft, beginning the convective process. Squall lines develop as a definable row of storms, usually moving rapidly as an advancing front. Squall-line storms can build to enormous size and violence. They have claimed hundreds of airplanes over the years and have, if anything more fury and power than air-mass storms. They have crushed buildings, sunk ships at sea, destroyed the largest military dirigibles ever built and ravages farmland.

A third type of thunderstorm development is the Mesoscale Convective Complex (MCC). The MCC consists of a very large grouping thunderstorms formed in a rough circle. For reasons not fully understood, the MCC seems to be self-perpetuating so that the storms feed on each other. A well developed MCC may cover a diameter of 100 miles and persist for 12 to 16 hours or longer. Individual thunderstorms with an MCC can be among the most violent known, and they have lots of neighbors! MCCs have dumped several feet of water, washed airplanes completely off airport property, spawned hundreds of tornadoes in a small area and devastated entire cities.

A thunderstorm brings together in one place just about every known weather hazard to aviation. A single thunderstorm cell can hold 500 000 tons of water in the form of liquid droplets and ice crystals. The total amount of heat energy released when that much water is condensed amounts to approximately 3 x 10^{14} calories. Equated with known energy sources, this falls just below an entry-level hydrogen bomb. Even a small thunderstorm would have the caloric equivalent of a Hiroshima-type atomic weapon. All of that energy in a small area produces some predictable and spectacular results.

Weather can be divided into 2 categories: that which can be safely flown through and that which cannot. In the former category are rain, snow, fog, chop, cold and heat. The latter category-"cannot"-is limited to only a few, namely icing greater than certification limits and thunderstorms-all thunderstorms.

IDENTIFICATION

Still, pilots may ask, *"Just what constitutes a thunderstorm?"* It is a question that lawyers love to postulate at the trial that results from your decision to flirt with one. Meteorologists may quibble about the need for a "ground truth" report of observed lightning before they will classify a storm as a thunderstorm. As a pilot, you can consider any localized convective cell over approximately 15,000 feet high as a thunderstorm whether there is thunder or not.

Further, any cell that paints level two or greater on your radar (yellow or red) can be considered a thunderstorm for flying purposes. Certainly, any cell that emits lightning, hail or tornadoes is, by definition, a thunderstorm. You will want to recognize that shifting surface winds, low-level wind shear, rain, virga and reports of icing in convective clouds are all symptoms of what we are referring to as thunderstorms. Thunder and lightning are the final and conclusive evidence, but they are not necessary to suggest avoidance. If you have to ask if it's a thunderstorm, you should make avoidance your highest priority.
The thunderstorm occupies a unique place in the pantheon of aviation meteorology because it is the one weather event that should always be avoided. Why always? Because thunderstorms are killers. And they do so in an ingenious variety of ways.

WIND AND TURBULENCE

Thunderstorms are diabolical machines producing several different lethal products, including at least four types of destructive wind. The first of these winds is called a gust front.
Gust fronts extend outward from the storm cloud and may reach as far as 20 miles ahead of the storm itself. Gust-front winds increase the average velocity of prevailing winds by 15 to 20 knots, but have registered as high as 100 knots. Further, gust-front winds may cause changes in wind direction of up to 180 degrees.

Updrafts and downdrafts are the vertical winds of thunderstorms. They can reach velocities as high as 6,000 fpm-well above the performance capabilities of virtually all civil aircraft. Further, this turbulence is not necessarily contained within the cumulonimbus cloud. Severe turbulence from updrafts and downdrafts can be encountered anywhere below a thunderstorm, up to 10,000 feet above a thunderstorm and as far as 20 miles laterally from a severe storm.

The other two forms of severe thunderstorm wind-downbursts and tornadoes-are so unique that they deserve a separate description.
Still, basic windshear from thunderstorm activity is more than adequate to wreck your airplane, as witnessed by the crew of L'Express Flight 508 (LEX 508) on July 10, 1991. They heard on ATIS that thunderstorms were overhead, and they saw several cells out through the windscreen and on radar. Some airplanes in the area were diverting (destined to survive to fly another day), and others were ignoring the signs and making the approach. The Captain of LEX 508 opted for the latter.
The initial encounter with wind shear occurred approximately seven miles from the runway. This encounter produced a 45-degree roll to the left, which was almost immediately followed by a pitch-up to a near-vertical attitude. The airplane then began an uncontrollable loss of airspeed and altitude. Just prior to impact, the captain retarded both throttles. The airplane struck the roof of a house, then two cars, and finally came to rest in the living room of a second house. There were only two survivors-the captain and one passenger. The copilot and 12 other passengers perished as a direct result of intentional flight too close to a thunderstorm, along with the ensuing windshear encounter that resulted in loss of control of the aircraft.

MICROBURST

In April 1974, Ted Fujita, Ph.D., a meteorologist from the University of Chicago, was studying aerial photographs of tornado damage. He noticed several debris patterns on the ground that resembled a starburst pattern, appearing as if a high-pressure hose had been aimed at the surface.
Dr. Fujita theorized that these patterns were caused by very localized, high-energy downdrafts, and he coined the term "downburst." He later added the term "microburst" to define the same event on a somewhat smaller scale.
On June 24, 1975, an Eastern Airlines Boeing 727 (Eastern 66) was approaching New York's John F.

Kennedy International Airport for a landing on Runway 22L. Two large thunderstorm cells dominated the area of the approach path, with one severe cell directly astride the final approach path to that runway. Other airplanes were continuing the approach, and the Eastern crew simply continued its approach along with the rest. Radar would have shown a powerful cell directly over the approach path, and the cumulonimbus clouds themselves were clearly visible. Still, when others are doing it, there is a temptation to press on.
At 700 feet agl, the airplane flew into rain. At 500 feet, the rain became heavy. The airplane began sinking at 400 feet, and the speed dropped from 138 KIAS to 122 KIAS in seven seconds. Four seconds later, the airplane crashed into the approach lights 2,400 feet short of the runway, killing 112 people.
The tragedy of Eastern 66 may have been the first known accident caused by a downburst. Still, pilots have known since the 1920s (and before) that thunderstorms kill, and Eastern 66 simply demonstrated one previously unknown way. Since that time, numerous fatal accidents known to have been caused by downbursts have occurred. Examples are Continental 426 at Denver, Pan Am 759 at New Orleans, Continental 63 in Tucson, Royal Jordanian 600 in Doha, Qatar and many more.

Characteristics of microbursts include:

- SIZE: Approximately 6,000 feet in diameter above the ground with a horizontal extent on the surface spreading to approximately 2 1/2 miles outward from the center.

- INTENSITY: Vertical winds as high as 6,000 feet per minute above the ground becoming strong horizontal winds with as much as an 80 knot variation on the surface. The downward airstream may extend as low as treetop level.

- TYPES: Wet and dry. In wet areas of the US, microbursts are normally accompanied by heavy rain. However, dry areas provide falling rain drops with sufficient time and distance to dissipate before reaching the ground (VIRGA).

- LIFE: The life cycle of a microburst from the initial downburst to dissipation will seldom be longer than 10 minutes with maximum intensity winds lasting approximately 2 minutes. Multiple microburst activity in the same area is not uncommon and should be expected.

- SIGNS: Dry microbursts often generate a ring of dust on the surface. Opposite direction winds over a short distance, accompanied by cell activity, are also a clear indication of a microburst.

During landing and takeoff, microburst windshear effects can cause a sufficient reduction in aircraft performance to create a severe hazard due to the possibility of ground contact. Flight in the vicinity of suspected microburst activity should always be avoided.

SQUALL LINES

A "squall line" is a non-frontal, narrow band of active, or very active, thunderstorms. They often develop ahead of a cold front in moist, unstable air, but may develop in unstable air far from any front. The line may be too long, to easily detour and too wide and severe to penetrate. They often contain severe steady state thunderstorms and present the single most intense weather hazard to aircraft. They usually form rapidly, generally reaching maximum intensity during late afternoon and the first few hours of darkness.

TORNADO

Tornadoes are the result of great instability in the atmosphere, most often thunderstorms. The exact mechanisms that cause a tornado are not fully understood, but the effects are. Tornadoes can be a few feet in diameter or as much as a half-mile. The most violent thunderstorms draw air into their cloud bases with great vigor. If the incoming air has any initial rotating- motion, it often forms an extremely concentrated vortex from the surface well into the cloud. Meteorologists have estimated that winds in such a vortex can exceed 200 pressure inside the vortex can be quite low.

Their funnels normally advance at a moderate speed, but the winds within the funnels can be extreme. The strong, winds gather dust and debris, and the low pressure generates a funnel-shaped cloud extending downward from the cumulonimbus base. If the cloud does not reach the surface, it is a funnel cloud; if it touches the land surface, it is a tornado; if over water, it is a water spout. Experts making educated guesses about the damage patterns of tornadoes say the probable wind speed inside a severe tornado is in the range of 500 mph. Very large tornadoes have been tracked for over 200 miles. One such twister killed 689 people on March 18, 1925. On April 4, 1974, tornadoes killed more than 300 people and injured over 600-many in Xenia, Ohio, a city that was devastated that night.

Nobody was able to identify any specific aircraft accidents attributable to tornadoes, but they are known to be one more threat from thunderstorms. If you fly too close, you could become a unique statistic.

Tornadoes have occurred with isolated thunderstorms, but more frequently form with steady state thunderstorms associated with cold fronts or squall lines.
Reports or forecasts of tornadoes indicate that atmospheric conditions are favorable for violent turbulence. Since the vortex extends well into the cloud, any pilot inadvertently caught on instruments in a severe thunderstorm could encounter a hidden vortex.
Families of tornadoes have been observed as appendages of the main cloud extending several miles outward from the area of lightning and precipitation. Thus, any cloud(s) connected to a severe thunderstorm carries a threat of violence. Frequently cumulonimbus mammatus clouds occur in connection with violent thunderstorms and tornadoes. These clouds display rounded, irregular pockets from their base and are sign-posts of violent turbulence. Surface aviation observations specifically mention this and other hazardous clouds. Tornadoes occur most frequently in the Great Plains states east of the Rocky Mountains; however, they have occurred in every state.

WATER INGESTION

Thunderstorms lift and condense incredible amounts of water. In some areas of a thunderstorm, the precipitation from all that lifted moisture can be heavy-very heavy. It can fall in torrents of liquid water so dense that lift is severely compromised, and turbine engines may flame out. Some piston engines may shut down due to saturated intake filters producing an overly rich mixture.

On April 26, 1990, the pilot of a Learjet 25D attempted to overfly a thunderstorm at 41,000 feet, with minimal clearance from the storm top. Directly over the storm, the airplane encountered severe turbulence, causing the right engine to flame out. With only partial power, the airplane descended into the storm, experiencing pitch excursions of +25 to –10 degrees and rolls to 90 degrees. At 33,000 feet, the left engine failed in heavy rain, and the airplane eventually was destroyed in an off-airport landing. It is likely that a 10-minute diversion away from that storm would have precluded all of the above, as well as the obligatory explanations to the FAA, to the NTSB, to local law enforcement authorities, to the insurance company, to the employer, to fellow pilots and to the brother-in-law.

ICE

Thunderstorms lift tons of water into the upper atmosphere, where it becomes supercooled water. Now, just imagine what that means to your airplane at or near the freezing level.
Ice. Incredible amounts of ice. Many pilots have reported ice accretion of several inches in a few minutes. It's not surprising, since thunderstorms are nearly perfect icing makers.
Updrafts in a thunderstorm support abundant liquid water. The water becomes supercooled when carried above the freezing level. When the temperature in the upward current cools to about - 15 degrees Centigrade (C), much of the remaining water vapor sublimates as ice crystals. Above this level the amount of supercooled water decreases.
Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level, but at high levels, icing may be either rime or mixed rime and clear. The abundance of supercooled water makes clear icing occur very rapidly between 0 degrees and -15 degrees Celsius, and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.

In 1959, a Navy T-28 penetrated the topmost spire of a small thunderstorm at 23,000 feet and emerged from the other side in less than a minute with one-half inch of ice over the entire airplane, including the canopy. The year 1994 witnessed an accident that appears to have been caused by icing in or near a thunderstorm. In that accident, an ATR-72 crashed, killing all aboard.

Thunderstorm ice is distinct precisely because it can accumulate at extraordinary rates, often forcing the airplane to a lower altitude where the ice can dissipate, but heavy rain and turbulence can cause engine and/or airframe damage. Ice is just one more excellent reason to avoid all thunderstorms by a wide margin.

LIGHTNING

But winds and icing are not the only arrows in a thunderstorm's quiver. Others are equally powerful and destructive, like lightning. Remember, also, that lightning is the exclusive product of thunderstorms.
If you see lightning, you have received absolute proof of a thunderstorm, with all of its potential threat. Conversely, if you avoid thunderstorms by an adequate margin, you will avoid lightning strikes. You have good reason to do so.

A lightning "bolt" that pierces the sky is actually a channel of pulsating electrical energy about two inches wide. Powerful strokes can extend up to 20-miles long, heating the air to 50,000°F-five times the temperature of the sun's surface. When it strikes, that bolt can deliver 125-million volts of electricity, with the power of 20,000 amperes or more. When hit by lightning, a tree's sap will instantly boil, causing the tree to explode. Some bolts have opened 10-foot craters in the ground, turning sand instantly to glass. Large boulders have been split in two. People have been blinded, maimed and killed.

But lightning doesn't really damage airplanes. They remain unscathed, right? Don't count on it. In 1962, a Boeing 707 exploded over Elkton, Maryland when lightning ignited the fuel. Of course, that can't happen to modern airplanes and modern fuel. Right? By the way, how are your fuel tank bonding straps? Tank covers? Inspection plates and gaskets? Fuel vents? Nacelle fuel lines and fittings? Incidentally, in 1987, a NASA T-38 suffered a lightning-induced fuel tank explosion that left a gaping hole in the wing. You can never be too careful.

On November 21, 1981, a Bell 206 was blown from the sky by a lightning bolt and landed in the Hudson River. A Navy F-14 pilot was flash-blinded by lightning, forcing his (non-pilot) backseater to manage the airplane for several minutes until the pilot regained partial vision. No one knows how many other airplanes have been lost or damaged by lightning, but NASA research confirms that airplanes actually trigger lightning. Ironic, isn't it?
Experience proves that lightning can flame-out turbine engines, fry electronic components, weld gears together, melt electric motors, ruin generators, cook inverters, pit bearings, blow fuses, blind or cause permanent retinal damage to pilots, pit and crack radomes, shatter composites (including rotor blades and airplane control surfaces) and destroy digital data buses and databases.
Fortunately, if you avoid thunderstorms by a suitable margin, you will avoid all lightning. Easy, eh?

A few pointers on lightning:

- The more frequent the lightning, the more severe the thunderstorm.
- Increasing frequency of lightning indicates a growing thunderstorm.
- Decreasing frequency of lightning indicates a storm nearing the dissipating stage.
- At night, frequent distant flashes playing along a large selector of the horizon suggest a probable squall line.

HAIL

If you manage to miss the wind shear, ice, tornadoes, microbursts and lightning, the threat of hail always looms. Several years ago, a DC-9 crew flew their airplane into a thunderstorm and suffered the total loss of both engines when large hailstones completely destroyed the compressors.

In May 1975, a Boeing 727 encountered hail at 22,000 feet. The outside windshields were broken, and the radome disintegrated. The radar antenna, itself, was severely damaged. Engine intakes were peened flat, as were the tail and wing leading edges. The hail broke through the fuselage and the front radar pressure bulkhead, causing a depressurization.
A DC-8 encountered hail and lightning in clear air and sustained damage as described by the captain after to the ground from the number-three engine, and several pieces of metal were hanging loose or missing. The leading edges of the wings and tail were beaten in as with a hammer."

Hail can be (and often is) thrown into clear -air as far as 10 miles from a large thunderstorm. And you cannot see it coming. Happily, if you avoid thunderstorms by a suitable margin, you will avoid any hail damage. Isn't that a nice coincidence?

LOW CEILING AND VISIBILITY

Visibility generally is near zero within a thunderstorm. Ceilings and visibility can become restricted in precipitation and dust between the cloud base and the ground. The restrictions create the same problem as all ceiling and visibility restrictions, but the hazards are increased many fold when associated with the other thunderstorm hazards of turbulence, hail, and lightning which make precision instrument flight virtually impossible.

EFFECT ON ALTIMETERS

Pressure usually falls rapidly with the approach of a thunderstorm, then rises sharply with the onset of the first gust and arrival of the cold downdraft and heavy rain showers, falling, back to normal as the storm moves on. This cycle of pressure chance may occur in 15 minutes.
If the altimeter setting is not corrected the indicated altitude may be in error by over 100 feet.

PRECIPITATION STATIC

Precipitation static, a steady, hi-h level of noise in radio receivers, is caused by intense corona discharges from sharp metallic points and edges of flying aircraft. It is -encountered often in the vicinity of thunderstorms. When an aircraft flies through clouds, precipitation, or a concentration of solid particles (ice, sand, dust, etc.), it accumulates a charge of static electricity. The electricity discharges onto a nearby surface or into the air causing a noisy disturbance at lower frequencies. The corona discharge is weakly luminous and may be seen at night.

WEATHER RADAR

Weather radar detects droplets of precipitation. Strength of the radar return (echo) depends on drop size and number. The greater the number of drops, the stronger the echo; the larger the drops, the stronger the echo. Drop size determines echo intensity to a much greater extent than does drop number.
Meteorologists have shown that drop size is almost directly proportional to rainfall rate; the greatest rainfall rate is in thunderstorms. Therefore, the strongest echoes are thunderstorms.
Hailstones usually are covered with a film of water and, therefore, act as huge water droplets giving the strongest of all echoes. Showers show less intense echoes, and gentle rain and snow return the weakest of all echoes.
Since the strongest echoes identify thunderstorms, they also mark the areas of greatest hazards. Radar information can be valuable both from ground-based radar for preflight planning and from airborne radar for severe weather avoidance.

Thunderstorms build and dissipate rapidly, and they also may move rapidly. The best use of ground radar information is to identify general areas and coverage of echoes. Remember that weather radar detects only precipitation drops; it does not detect other weather phenomena. The most intense echoes are severe thunderstorms. Remember that hail may fall several miles from the cloud and hazardous turbulence may extend as much as 20 miles from the cloud.

It is time for pilots to stop flying in the vicinity of thunderstorms and then feigning surprise at the consequences. That act of surprise is nothing more than a public admission of ignorance.
If you choose to flirt with a thunderstorm, you can reasonably expect wind shear beyond the performance capability of your aircraft, and possibly beyond its structural limits.
You also can expect sufficient rain to drown the engines, all the potential consequences of a severe lightning strike, major airframe and engine damage from hail or ice accretion far beyond the limits of any airframe or engine deice or anti-ice system, as well as all of the effects of a downburst. Your only justifiable surprise should be if you survive.

Thunderstorms are a severe hazard to your health, your life and your career. Only one, absolute form of protection is available to you: Avoid, always avoid.

SUMMARY

Never regard any thunderstorm as "light" even when radar returns show the echoes are of light intensity. Avoiding thunderstorms is still the best policy.

Don't land or take off in the face of an approaching thunderstorm. A sudden wind shift or low level turbulence could cause loss of control.

Don't attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence under the ston-n could be disastrous.

Do avoid any thunderstorm identified as severe or giving an intense radar echo. This is especially true under the anvil of a large cumulonimbus cloud.

Weather radar is intended for avoidance only. All areas of steep gradient should be avoided by twenty miles at all altitudes.

Flight over the top of thunderstorms is not recommended. If necessary, clear the tops of thunderstorm clouds by 5,000 feet.

For flight planning, coordinate with flight dispatch. Fuel conservation is secondary to safety, comfort, and schedule.

Below the freezing level - avoid contoured areas by at least 10 miles. Above the freezing level - avoid contoured areas by at least 20 miles.