1.3 **LIGHTNING SAFETY FOR SCHOOLS: AN UPDATE**

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1. INTRODUCTION

Lightning has been the most under recognized weather hazard. The U.S. meteorological community recently placed more emphasis on lightning safety. The National Weather Service began an annual Lightning Safety Awareness Week in 2000, which is now held annually on the last full week of June (www.lightningsafety.noaa.gov). Two of the largest U.S. professional meteorological societies, the American Meteorological Society (http://www.ametsoc.org/policy/amsstatements_inforce.html) and the National Weather Association (http://www.nwas.org/), approved lightning safety policy statements in 2002 and 2003, respectively. The American Geophysical Union is currently considering a lightning safety policy statement. All websites in this article are clickable hyperlinks.

2. U.S. LIGHTNING THREAT

Lightning is the second leading cause of storm deaths in the U.S., killing more people than tornadoes or hurricanes (Curran et. al., 1997) (Figure 1). Lightning also inflicts life-long severe injuries on many more than it kills (Cooper, 1995) (Andrews et. al., 1992). Fortunately, the vast majority of lightning casualties (deaths + injuries) can be avoided easily, quickly, and inexpensively through a few simple guidelines. However, these guidelines can be inconvenient, so diligence is required in following them.

The distribution of locations and activities of lightning casualties in the U.S. is shown in Figure 2. In the U.S., the largest number of lightning casualties occurs in open areas, including sports fields. The average cloud-to-ground lightning flash density across the U.S. is in Figure 3 (Orville, 2000); data are from the National Lightning Detection Network. The largest flash densities are in Florida, the Southeast, Gulf States, Midwest, and the Front Range of the Rocky Mountains. However, no place in the U.S. is free of lightning threat.

3. LIGHTNING THREAT AT SCHOOLS

Schools are the third leading source of lightning casualties to youths (age < 18 years) in Florida (Figure 4). This suggests that schools need to implement lightning safety plans to reduce lightning casualties to youths, not to mention protecting their staff and other workers. Most of the lightning casualties in schools are associated with outdoor activities such as sports on athletic fields, recess on playgrounds, marching band, and all other outdoor extracurricular activities. This is consistent with ‘open areas’ being the largest source of general lightning casualties as shown previously in Figure 2. Thus, it is important for coaches, referees, and leaders of other outside school activities to practice good lightning safety. Schools need an effective integrated lightning safety plan. Support from school management is essential in developing these plans.

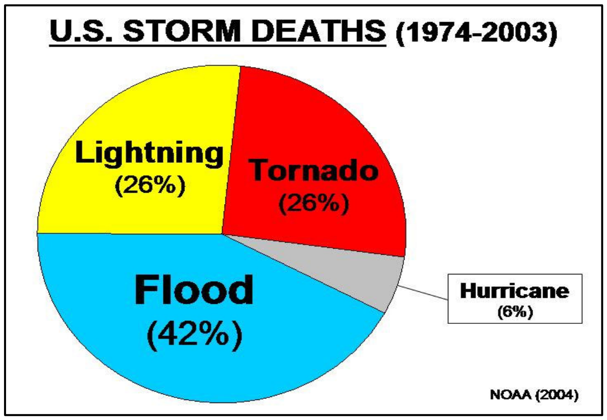

FIGURE 1. Storm deaths in the U.S. (1974-2003) by weather phenomena (NOAA, 2004). Lightning is the second leading cause of storm deaths in the U.S.

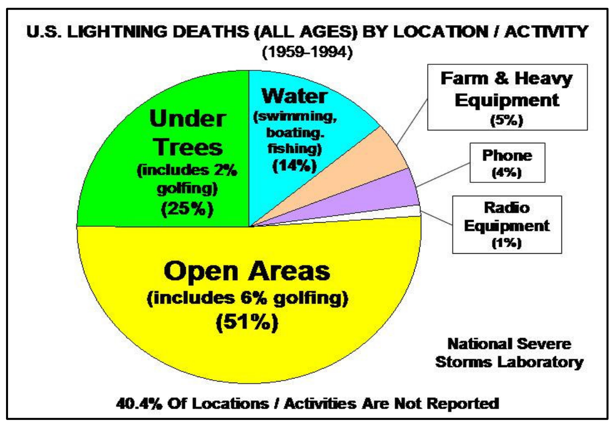

FIGURE 2. Lightning casualties in the U.S. (1959-1994) by location and activity. Open areas have the most lightning casualties. Adapted from Curran et. al. (1997); 40.4% of locations/activities are not reported.

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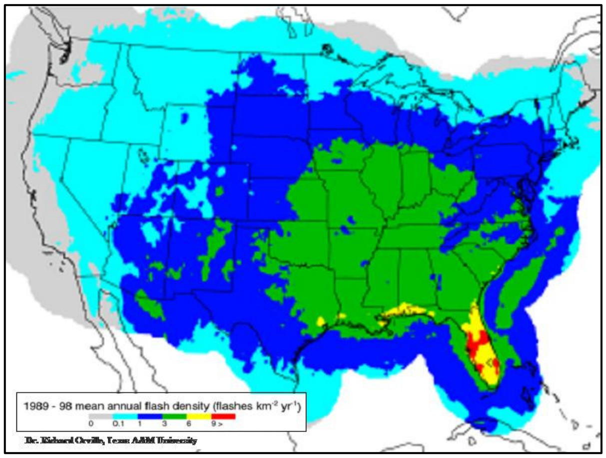

FIGURE 3. Average cloud-to-ground lightning flash density in the U.S. (1989-1998) from the NLDN (Orville, 2000). The largest flash densities are in Florida, Gulf States, Southeast, Midwest, and the Front Range of the Rocky Mountains. No place in the U.S. is free of lightning.

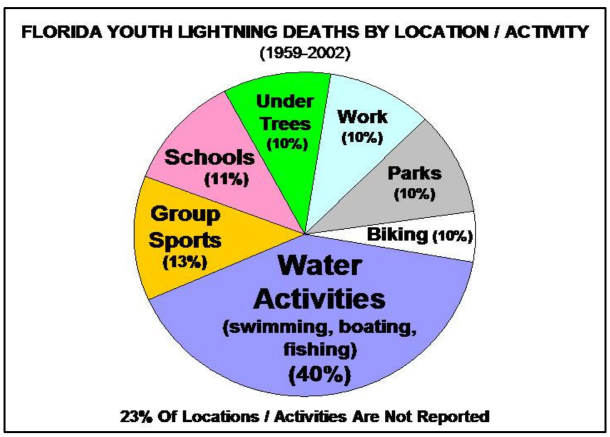

FIGURE 4. Location or activity of lightning deaths to youths (<18 years old) in Florida (1959-2002).

After-school outdoor activities are especially dangerous since this coincides with the diurnal maximum of afternoon thunderstorm activity. This is consistent with the diurnal pattern of lightning deaths (Figure 5). Besides extracurricular activities, other risky school-related activities include waiting outside for school buses, walking or biking home, and walking home after departing the school bus.

The distribution of locations and activities of youth lightning casualties is quite different from that for all ages across the U.S. (Figure 2). This suggests that the content of lightning safety training for youths should differ from that provided to general audiences. The training for youths should specialize in the locations and activities that generate the most casualties for that group. This is in addition to the different training techniques required for effective training of different age groups.

Youths are a large fraction of lightning deaths in Florida (Figure 6). The ten-year age bracket with the largest percentage is 10-19 years old. This bracket has 30% of Florida lightning deaths, despite being only 12.5% of the 80-year age range. This suggests that lightning safety education to youths is important to reduce overall lightning casualties. Schools can play an important role in that lightning safety education. The distribution of lightning deaths by age for Florida youths shows a large increase for above 10 years old (Figure 7). This suggests that lightning safety

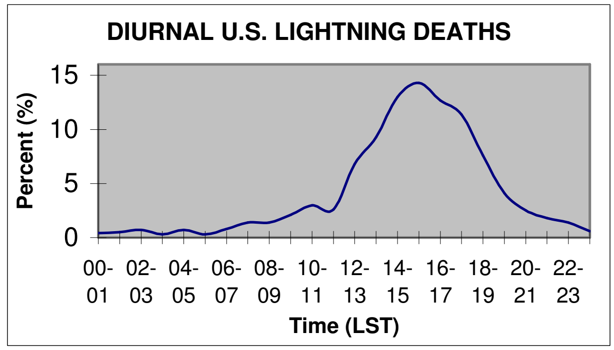

FIGURE 5. Diurnal distribution of lightning deaths in the U.S. (1959-1994). Data from Curran (1997).

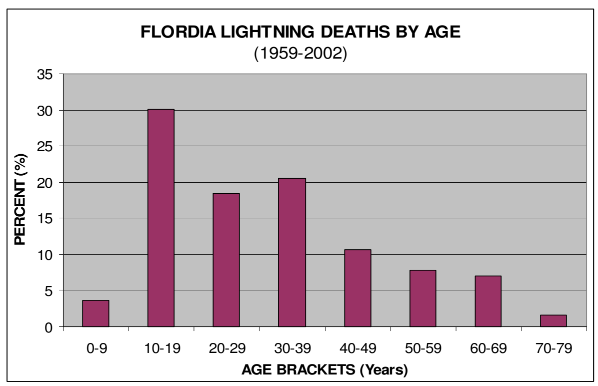

FIGURE 6. Age distribution of lightning deaths in Florida and the U.S. (1959-2002).

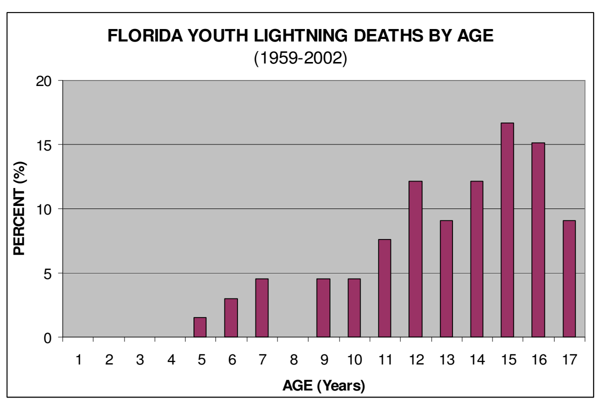

FIGURE 7. Age distribution of lightning deaths to youths (< 18 years old) in Florida (1959-2002).

education would be most effective in elementary schools. Safety education to this younger age group also makes sense before the recklessness and rebelliousness often associated with adolescence makes safety education less effective.

While no other lightning casualty studies have been done exclusively on youths, other lightning casualty studies in Florida have proven to be generally applicable across the U.S. Therefore, it is reasonable to extend the Florida lightning death statistics for schools and youths across the U.S., until other youth-only studies are done. This is especially true for regions where the school year starts/ends before their lightning season ends/starts, as they do in Florida. The school year in Florida is generally early August to early June, while he lightning season usually starts in mid-May and through mid-September. One example of the consistency between Florida and U.S. lightning casualty statistics is the gender distribution of lightning deaths. In Florida, 79% of lightning deaths are male, which is close to 84% across the entire U.S. (Figure 8). Likewise, the age distribution of lightning casualties across the U.S. tends to be weighted towards youths and young adults (Holle, 2005b), as it is in Florida. This suggests that effective lightning safety education should be weighted towards techniques that work best for males and youths.

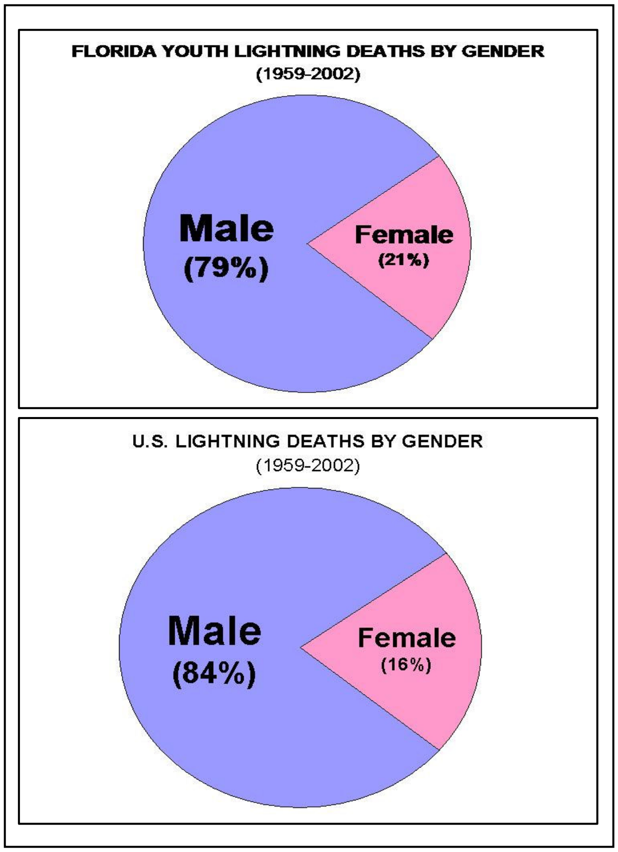

FIGURE 8. Gender distribution of lightning deaths to youths in Florida (1959-2002) and all ages in the U.S. (1959-1994). U.S. data from Curran et al. (1997).

4. ORIGINAL LIGHTNING SAFETY GUIDELINES

Total lightning safety requires four tiers of activities: 1) education, so people are aware of the hazard and know what actions to take when lightning threatens, 2) weather warnings to alert people to take action, 3) protection of facilities and equipment, and 4) mitigation, for when that protection fails. This paper focuses on the first aspect of lightning safety, since education is the key to improving lightning safety.

The following lightning safety guidelines are based on the recommendations from the Lightning Safety Group (LSG), which are the best set of guidelines available (Holle et. al., 1999). The LSG first formed as an ad hoc group at the 78th Annual American Meteorological Society Meeting in 1998. The LSG formed in response to the preexisting lightning safety advice, much of which is often contradictory, incomplete, incorrect, or sometimes even unsafe. The LSG consisted of 16 lightning experts from many diverse disciplines (Table 1). The diversity of members was important since it included not just lightning science and lightning safety experts, but also representatives from real-world applications with lightning experience, who helped ensure the recommendations would be practical in the real world. The LSG published six recommendations, which are an important step in overcoming previous shortfalls and in standardizing lightning safety. The National Collegiate Athletic Association adopted the LSG guidelines (Bennett et. al., 1997), as have several school districts across the U.S. The original guidelines have been widely published (Holle et al., 1999) and are available at various websites.

5. UPDATED LIGHTNING SAFETY GUIDELINES

This article is an update to a similar article originally written for the American Meteorological Society 10th Symposium on Education (Roeder et al., 2001). The original LSG recommendations are adapted here into five levels of decreasing lightning safety (BAMS, 2003) (Roeder, 2003). While consistent with the recommendations in that article, these multi-level guidelines are easier to interpret, learn, and implement than the original LSG recommendations. The authors hope schools will use this information to implement lightning safety plans and teach lightning safety to their students, staff, and local communities. A quick reference guide of the five levels is provided in Table 2.

While no simple lightning safety procedure can guarantee perfect safety, following these guidelines will help avoid the large majority of lightning casualties. The most important principle of lightning safety is that no place outside is safe when thunderstorms are within six miles of your location.

Organizations with recurring outdoor activities, including schools, need to have a lightning safety plan. This plan must be in-place, understood, and agreed to by all participants before it is needed. Adults must be responsible for the lightning safety of the children entrusted to their care.

TABLE 1. LIGHTNING SAFETY GROUP (1998)

MEMBER	AFFILIATION
Brian Bennett	Assistant Athletic Trainer, The College of William & Mary
Leon Byerley	Lightning Protection Technology
Mary Ann Cooper, MD, FACEP	Lightning Injury Research Program, The University of Illinois at Chicago
Ken Cummins, Ph.D.	Vice President Engineering, Global Atmospherics, Inc.
Ronald L. Holle	Research Meteorologist, National Severe Storms Laboratory, NOAA
Ken Howard	Research Meteorologist, National Severe Storms Laboratory, NOAA
Richard Kithil	President/CEO, National Lightning Safety Institute
E. Philip Krider, Ph.D.	The University of Arizona, Department of Atmospheric Sciences
Lee C. Lawry	Product Manager, Global Atmospherics, Inc.
Raúl E. López, Ph.D.	Research Meteorologist, National Severe Storms Laboratory, NOAA
Bruce Lunning, CSP, CPCU, ARM	Senior Loss Control Specialist, St. Paul Fire & Marine Insurance Co.
John T. Madura	Manager, KSC Weather Office, NASA
Marcus McGee	President, Quality Protection Systems, Inc.
William P. Roeder	Chief Staff Meteorologist, 45th Weather Squadron, US Air Force
Jim Vavrek	Science Teacher, Henry W. Eggers Middle School
Christoph Zimmermann	Safety Management, Global Atmospherics, Inc.

TABLE 2. QUICK REFERENCE FOR THE FIVE LEVELS OF LIGHTNING SAFETY.

LEVEL (best to worst)	**BRIEF DESCRIPTION**
Fundamental Principle: **No** place outside is safe with thunderstorms within six miles	
1	Schedule outdoor activities to avoid lightning
2	30-30 Rule: If 30 sec between lightning and thunder, go inside. While inside, stay away from corded telephones, electrical appliances and wiring, and plumbing. Stay inside until 30 min after last thunder.
3	Avoid dangerous locations/activities (elevated places, open areas, tall isolated objects, and water related activities (swimming, boating, near edge of bodies of water). Do **NOT** go under trees to keep dry in thunderstorms!
4	Desperate last resort--Proceed to safest spot available. Use lightning crouch if lightning imminent.
5	First Aid: Immediately start CPR or rescue breathing, as needed. Call 9-1-1. Use an AED (do not delay CPR). Continue CPR/rescue breathing if AED won't activate or is not available.

5.1 Level-1: Schedule Outdoor Activities

In any safety procedure, avoiding the risk is best. Schedule your outdoor activities to avoid the lightning threat. Plan ahead; watch the weather forecast and know your local weather patterns. Forecasts are available from your local National Weather Service office, available by clicking on the desired office on the U.S. map at their Headquarters website (www.weather.gov). While the National Weather Service does not issue specific weather warnings for lightning, look for the words 'thunderstorm', 'lightning-storm', and 'lightning' in the forecast. More and more National Weather Service offices are including information in their products to help people protect themselves against lightning.

While all outdoor school activities are at risk from lightning, activities that are far away from proper shelter are especially risky. Examples include golf teams and cross country teams. Water related activities are also especially risky, e.g. some school sports programs include boating. Indoor pools are also a concern since their plumbing and wiring can conduct the electricity from nearby strikes into the water. A vehicle with a solid metal roof and sides, e.g. a school bus, can be used to pick-up students in activities far away from proper shelter. The vehicle provides some protection against lightning until they can get to proper shelter.

5.2 Level-2: '30-30 Rule'

Use the '30-30 Rule' when outside. When you see lightning, count the time until you hear its thunder. If this time is 30 seconds or less, go inside. Don't hesitate, go inside immediately when required! The lightning casualty stories have many cases where people were nearly to a shelter when they were struck; if they'd started even just a minute earlier, they'd have been safe. If you can't see the lightning, just hearing the thunder is a good back-up rule for going inside. With 30 seconds between lightning and its thunder, you are already in danger, so allow enough time to get to safety. This extra lead-time can be significant for fast moving thunderstorms. For example, if you need 5 min to get to safety, a storm moving 30 mph will travel 2.5 miles. This means you need 13 more seconds (5 sec per mile) between lightning and its thunder to get to safety. This is nearing the limit at which one can usually hear thunder. Therefore, for rapidly moving storms, hearing thunder provides a needed added level of safety. Wait 30 minutes or more after hearing the last thunder before going outside. This time indoors may feel inconvenient after the storm, but is vitally important. Most lightning casualties occur after the storm has passed or dissipated.

The best shelter commonly available against lightning is a large fully enclosed building with wiring and plumbing, e.g. a typical school or house. Once inside, stay away from any conducting path to the outside. Stay off corded telephones. Stay away from electrical appliances, lighting, and electric sockets. Stay away from plumbing. Don't watch lightning from windows or doorways. In large buildings, inner rooms are generally better.

If you can't get to a proper building, a vehicle with a solid metal roof and metal sides offers some protection; e.g. a school bus or typical car. As with a house, avoid contact with conducting paths going outside. If parked, close the windows, lean away from the sides, put your hands in your lap, don't touch the steering wheel, ignition, gear shifter, or radio. In large vehicles, like school buses, moving to the center is better. If driving, it is generally considered safer to keep moving, rather than increase the chance of a collision by parking off the side of the road. Convertibles, cars with fiberglass or plastic shells, and open framed vehicles offer no lightning protection.

Recent research suggests that nearly half of the time, lightning occurs at a distance such that thunder provides sufficient warning for people to recognize the danger (Lengyel and Brooks, 2005). That research work was based on lightning detected by the National Lightning Detection Network. However, that system only detects cloud-to-ground lightning, which is only about 30% of all lightning. The majority of lightning is intra-cloud-lightning, and other types of lightning aloft, which would provide additional opportunity to hear thunder and recognize the threat, especially since lightning aloft precedes about 75% of the first cloud-to-ground flashes. Thus the percent of time when thunder provides sufficient safety warning is likely higher than that cited in this research.

Outdoor sports activities need to be especially sensitive to the need to go inside quickly. Recent studies indicate that far too many sports activities have lightning casualties even during the game (Holle, 2005). The officials are not seeking shelter quickly enough.

5.3 Level-3: Avoid Most Dangerous Locations

If you can't get to a proper lightning shelter and must be outside with thunderstorms in the area, at least avoid the most dangerous locations and activities with the most risk. Note: it is much safer not to be outside under this situation. Remember, no place outside is safe when thunderstorms are in the area. Figure-1 provided the percent of lightning casualties versus location or activity.

Avoid elevated locations, either mountains/hills or elevated places, such as some playground equipment. Avoid open areas, including sports fields, playgrounds, marching band practice fields, and golf courses. Avoid tall isolated objects like trees, flagpoles, etc. Do not go under trees to keep dry! Avoid water-related activities: swimming (including indoor pools), boating, and fishing. Avoid open vehicles like grounds keeping equipment (riding lawnmowers, tractors, etc.), open construction vehicles, golf carts (even with roofs), etc. Avoid unprotected open buildings like picnic pavilions, rain shelters, and bus stops. Avoid large or long metal structures like fences and bleachers. A commonly believed myth is that metal attracts lightning. However, if lightning strikes a large metal object by happenstance, the hazardous electricity can be conducted a long distance, increasing the chance of it killing or injuring more people.

5.4 Level-4: Lightning Crouch—Desperate Last Resort

USE THIS AS A DESPERATE LAST RESORT ONLY! Remember, no place outside is safe with lightning in the area.

If you've made several bad decisions and are outside far away from proper shelter and lightning threatens, proceed to the safest location. If lightning is imminent, it will sometimes give a few seconds of warning. Sometimes your hair will stand upright, skin will tingle, light metal objects will vibrate, or you'll hear a crackling static-like "kee-kee" sound. If this happens and you're in a group, spread out so there are several body lengths between each person. If one person is struck, the others may not be hit and can give first aid. Then use the lightning crouch; put your feet together, squat down, tuck your head, and cover your ears. After several seconds, slowly stand up looking for the signs that lightning is imminent. If you detect any of those signs, immediately drop back into the lightning crouch. If you can stand up without detecting any of the lightning signs, continue heading to the safest spot possible. Remember, this is a desperate last resort; you are much safer having followed the previous steps and not placed yourself into this high-risk situation.

5.5 Level-5: First-Aid

All deaths from lightning are from cardiac arrest or stopped breathing from the cardiac arrest. Immediately start CPR or rescue breathing if the person has no pulse or no breathing, respectively. Next, have someone call 9-1-1 for professional emergency medical care. Then use an Automatic External Defibrillator (AED), if one is available. Do not delay CPR or rescue breathing to look for an AED. If the cardiac arrest is a ventricular fibrillation, the AED will perform vastly better than CPR. However, not all lightning cardiac arrests are from ventricular fibrillation. In that case, the AED won't activate and CPR should be continued until Emergency Medical Technicians arrive and take over the first aid.

6. IMPLEMENTING A LIGHTNING SAFETY PLAN AT YOUR SCHOOL

The following advice is based on real-world experience implementing lightning safety plans at schools. It is absolutely vital to have management support. Without coordination, management might be tempted to hinder your efforts, no matter how well intended or how well designed. In a similar vein, it is important to involve coaches, referees, and leaders of other outside activities in the planning, rather than having them surprised by the final plan being dictated by management, which might cause resistance. Already prepared handouts, posters, brochures, guidelines, etc., can speed the implementation process, as opposed to waiting for others to prepare them.

Be prepared for initial disappointing slowdowns. Besides the normal resistance to change, there are many widely held lightning myths perpetuating the mistaken belief that lightning is not an important hazard or that nothing can be done to reduce the risks. One useful argument is that schools often have plans for hazards with much lower probability than lightning, e.g. tornadoes, hurricanes, earthquakes, etc. Many people do not understand lightning and lightning safety and will be tempted to avoid making a decision by 'passing the buck' up the administrative chain of command seeking guidance from ever higher levels. Each level requires re-presenting your materials and re-fighting the same fights repeatedly, which can be very frustrating. You will have to be fully armed with all the facts and have the counter-arguments to lightning myths and other rebuttals ready. The need to be fully prepared is vital--one unanswered argument can be used to justify dismissing your position.

One of the greatest concerns will likely be over legal culpability. In the past, the attitude has been to do nothing. If a lightning casualty occurs, the defense is lightning is a powerful random 'act of god', a rare and pure accident that cannot be prevented. However, if you try to take action, and the incident still occurs, then you could be sued for poor safety procedures. In short, it is has been perceived that it would be better to let the accident happen, rather than take prudent safety precautions out of fear of being sued. At least one attorney has advised that this is a common misconception and prudent safety actions that failed would not be successfully prosecuted. Fortunately, there appears to be a shift in legal attitudes toward lightning safety. The growing opinion is that we have learned enough about lightning and lightning safety that failing to take reasonable and prudent precautions will make you guilty of negligence and culpable to being sued under that argument. The legal arguments against not taking lightning precautions appears to be weakening, especially if you include disclaimers that lightning risks can only be significantly reduced, but not eliminated, in your plan and education efforts.

Do not underestimate the importance of education for students, teachers, coaches, referees, managers, leaders of other outside activities, and other staff. Without an awareness of the importance of the lightning hazard, your lightning safety plan could wither from lack of support. It is especially vital to involve the sports community. Educating the public can also build support for your lightning safety plan, besides being a good public service.

7. OTHER CONSIDERATIONS

Other issues related to lightning safety include lightning detectors and notification services, lightning protection, and lightning safety education.

7.1 Lightning Detectors And Notification Subscription Services

In recent years, inexpensive hand-held lightning detectors have become widely available. Many people are tempted to use these detectors as an objective tool in lightning safety. However, the performance of these commercial products has usually not been independently and objectively verified. In addition to the unknown performance, there is much anecdotal evidence of the devices not locating lightning accurately, or not detecting weak and/or infrequent, but still potentially deadly lightning at all. There is also much anecdotal evidence of the devices being used improperly. Therefore, the Lightning Safety Group recommends these hand-held detectors not be used, or at most be used as a supplement to the '30-30 Rule'. Professional grade lightning detectors are available commercially. These devices perform well, but are too expensive for most organizations.

Fortunately, automatic lightning notification subscription services are a reasonable solution to the gulf between inexpensive but questionable hand-held lightning detectors and the good performance but prohibitively expensive professional grade detectors. The services use the data from the National Lightning Detection Network (Murphy et al., 2002) (Cummins et al., 1999) to automatically notify you when cloud-to-ground lightning is detected within desired distances of your desired location during your desired time. The performance of the National Lighting Detection Network has been objectively and independently verified to provide good lightning detection and location. A threephase approach is best, such as notification when lightning is first detected within 15 miles, as a heads-up that lightning is approaching or developing nearby so you should review plans and prepare for actions. The next notification is for lightning within a distance that allows enough evacuation time before the lightning is within 6 miles. The final notification is for lightning within 6 miles and all outdoor personnel should already be evacuated to safe shelter. These services will also notify you when lightning has not been detected within your desired distances for your desired time span (typically 30 min). This can serve as an 'all clear' and that outdoor activities may resume with reasonable safety. Notification can be to pagers, cell phones, e-mail, faxes, or whatever electronic system(s) you want. These automatic lightning notification subscription services are useful since they provide objective decision points. However, there is one key weakness. The National Lightning Detection Network only detects cloud-to-ground lightning, which is only about 30% of all lightning. The rest of the lightning is aloft, either in-cloud, cloud-to-cloud, or cloud-to-air lightning, which is not detected by the National Lightning Detection Network. A notification service cannot replace use of the '30-30 Rule', which must be used to warn of lightning overhead. Even though the lightning has been overhead, the next flash could be a deadly cloud-to-ground lightning–it is too risky to assume the lightning aloft will continue to remain aloft.

7.2 Lightning Protection

Lightning protection can improve lightning safety by decreasing the likelihood and intensity of indoor lightning shocks. There are two main forms of lightning protection: 1) lightning rods or air terminals (a network of one or more overhead wires), and 2) surge protection. In addition to increased personnel safety, lightning protection is important to facility protection, including avoiding fires and explosive damage to the building and electromechanical devices, and voltage surge damage to electronics, such as computers.

7.2.1 Lightning Rods And Air Terminals:

The function of lightning rods/air terminals is frequently misunderstood. They do not attract, repel, or prevent lightning, nor do they significantly increase or decrease the chances of a lightning strike. Rather they give a preferred point of attachment for lightning that was going to strike within a few tens of yards anyway. The intercepted lightning then follows a thick metal cable, the 'down conductor', to the grounding system where it is dissipated in the soil. The down conductor must have adequate cross sectional area to ensure low electrical impedance (inductance + resistance). Likewise, tight curves in the down conductor must be avoided (usually no less than eight inch radius of curvature) to reduce inductance impeding the flow of lightning current to the ground. Lightning rods/air terminals and the down conductors must be properly installed and maintained to work well. Corrosion maintenance is often required to ensure a clear conducting path to the ground. This is especially important in warm, moist, salty environments, such as throughout the Southeast and Gulf States in the U.S. Installation is best left to professional electricians trained and experienced in these devices and the applicable standards.

People inside buildings with lightning rods must still obey the indoor lightning safety rules. The down conductor can induce dangerous secondary electric currents in wiring or metal pipes nearby in roofs or walls.

Good lightning protection also requires a single point ground be used (aka common ground) to ensure an equipotential environment. All grounded conductors, such as electric power grounds, phone and cable grounds, electrical conduits, metallic plumbing and structural steel, should be conductively tied to the lightning protection ground at a single physical point. Even if a common ground is used, but not grounded at a single physical point, strong voltages can be induced across the conductors due to the very rapid rise times in lightning. However, with single point grounds, when lightning momentarily raises the building's electrical potential to as much as several megavolts, all points rise together, and no hazardous or damaging potential differences and transient electrical currents are created. This is especially important in large facilities with multiple conducting systems, such as schools.

Lightning protection works only as well as its grounding system. Getting a good electrical ground into soil can be surprisingly difficult. Most lightning protection standards require only low electrical resistance. However, the total impedance is what really counts. Impedance consists of both a time-varying inductance term and a non-varying resistance term. Since lightning has very fast rise times, the inductance term is very important. Unfortunately, the inductance term is often ignored in lightning grounding systems. Increasing the surface area making solid contact with the soil can usually lower impedance of grounding systems. One typical technique is driving metal pipes deep into the ground. One of the best solutions is laying the down conductor into shallow troughs of conducting concrete (concrete with carbon graphite fibers mixed in) extending outward from the site being protective. Not only does this greatly increase the surface area touching the soil for reduced impedance, but it also takes advantage of lightning's natural tendency to spread outward near the surface of the soil (the 'Skin Effect', the time varying equivalent of the better known D.C. 'Faraday Cage'). However, don't have the down conductor pass through or near where people will be, e.g. sidewalks, parking lots, etc. If they are there when the lightning is being discharged into the soil, they can be injured or killed. The low D.C. resistance in most standards does serve an important purpose since some lightning has a relatively long-lived continuing current after the rapidly varying currents. This is especially true for strong positive polarity lightning, which can be more than tens times as powerful and damaging as normal negative polarity lightning.

Unfortunately, alternative devices claiming to work much better than lightning rods are being aggressively marketed. These devices are known generically as Early Streamer Emission (ESE) and Charge Dissipation (CD) devices, but are marketed under continuously varying names. Independent expert panels and empirical evidence soundly reject these devices, finding that they work no better than traditional lightning rods. Thus, the extra cost of these systems is not justified. While you may believe you are saving money, in reality you actually providing inadequate protection for your facility. In general, beware of devices that claim to intercept lightning over a larger area than traditional lightning rods or prevent/reduce lightning.

Lightning protection can help guard against most of the dangerous and damaging electric current from a lightning strike to the building, by preventing most of the electricity from entering inside the building. However, it provides no protection from lightning striking external conducting paths leading inside, such as telephone wires, power lines, and plumbing. Surge protection is required to help mitigate those hazards.

7.2.2 Surge Protection

Surge protection against lightning is extremely challenging, given its very high current (~tens of thousands of amps) and very rapid rise times (~milliseconds). No single device can totally provide lightning surge protection, so a series of devices in the proper sequence is best. Gas discharge tubes are a good first line of defense and can divert much of the lightning current to the electrical ground. However, they are relatively slow devices, so much of the very high frequency current is passed through them. Bulk electronic components (capacitors, resistors, and inductors) can make low pass filters that can dissipate much of the high frequency current, passing only a little current at the highest frequencies. These make a good second line of defense. High-speed microelectronics can eliminate the remaining small power high frequency currents. These devices can only handle small currents and must come last in the series of lightning surge protectors. Multi-level surge protection is especially important for delicate electronics, such as school computer labs. Modern electronics are extremely sensitive to electric surges—even just a few volts of sudden over-voltage can destroy micro-integrated circuits. Don't forget to protect computer modems, which seem to be especially susceptible to electrical surge damage, either because phone lines transmit surges more often and/or an innate sensitivity.

Power companies often offer reliable lightning surge protection at reasonable cost. However, most of these devices provide only the first-line protection that protects electromechanical devices and improve personnel safety. Further surge protection for delicate electronics will likely be needed. Also, these devices often only guard against incoming surges on power lines. They may not guard against surges from other paths, such as telephone wires and plumbing.

As with lightning protection, surge protection works only as well as its grounding system. Grounding systems must also ensure that a common ground is used, to avoid potentially destructive electrical voltages developing in the system. This means all the grounding systems, such as the lightning protection ground, electric power ground, phone and cable grounds, and plumbing must be connected electrically to each other at some point. These points of electrical connection must be physically close to each other to avoid transient voltages across the system due to the fast rise time of lightning. Common grounds are especially important in large facilities with multiple conducting systems, such as schools.

Unfortunately, many manufacturers market surge protectors as effective against lightning that cannot handle either its power and/or fast rise times. They may advertise insurance coverage if you experience damage, but the insurance companies declare bankruptcy as soon as a large claim is filed. Alternatively, they may cite Underwriters Laboratory approval, but that just means the devices aren't dangerous, not that they are effective. As with lightning interceptor devices, buyers must beware.

7.3 Lightning Safety Education

Schools can play a vital role in reducing lightning casualties. Most important is to have a lightning safety plan to protect the students and staff during school activities. The Lightning Safety Awareness Week Working Group plans to post a good example of a school lightning safety plan at the National Weather Service lightning safety website in early 2004 (www.lightningsafety.noaa.gov). Next in importance is educating the students and staff in personal lightning safety, so they can maintain their safety when away from school. Short, pithy, rhyming slogans are often useful in teaching safety to children. One especially effective lightning safety slogan for children is 'When Thunder Roars, Go Indoors!'. Other lightning safety slogans are listed in Table-3. If all schools proactively taught lightning safety to their students, we could drastically reduce lightning casualties by the next generation. Finally, schools can facilitate public lightning safety education by sponsoring outreach events, perhaps in conjunction with the local National Weather Service office or other meteorologists.

TABLE 3. LIGHTNING SAFETY TRAINING SLOGANS

SLOGAN	SOURCE
When Thunder Roars, Go Indoors!	45th Weather Squadron
Lightning Kills--Play It Safe!	Lightning Safety Awareness Week
If You Can See It, Flee It!	National Lightning Safety Institute
If You Hear It, Clear It!	National Lightning Safety Institute
Don't Get Fried, Go Inside!	45th Weather Squadron
Don't Be A Fool, Get Out Of The Pool!	45th Weather Squadron

8. LIGHTNING SAFETY INFORMATION

Agencies interested in lightning safety may find the websites listed in Table 4 useful (see last page). Educators working with younger students will especially appreciate the coloring books on thunderstorm safety downloadable from the National Severe Storms Laboratory. Other weather safety coloring books are also available for download. Another paper on lightning safety education at this conference is Cooper and Holle (2005). Anyone interested in teaching lightning safety are welcome to contact the corresponding author for assistance.

9. SUMMARY

Lightning is an extremely significant weather hazard, but far too often underrated. Lightning is the second leading cause of storm deaths, killing more than tornadoes or hurricanes. Fortunately, the vast majority of the lightning casualties can be prevented easily, quickly, and cheaply by following simple guidelines. Since the most frequent impact of lightning strikes to people is life-long severe injuries, it is especially important to protect youths.

Schools need to play a large role in lighting safety for youths. Youths are a large segment of the population that is killed by lightning and schools are the third leading location/activity for lightning deaths to youths. Therefore, schools can help improve lightning safety through two mechanisms. First, schools should implement lightning safety plans to protect those under their care. These plans should strongly emphasize lightning safety for all outdoor activities. Second, schools should teach the lightning safety guidelines so youths and their parents can protect themselves when not at schools. Finally, schools can also serve another valuable role in lightning safety by helping to educate their local communities.

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TABLE-4. LIGHTNING SAFETY WEBSITES

ORGANIZATION	URL *(all URLs are clickable links)*	COMMENTS
GENERAL		
National Weather Service	www.lightningsafety.noaa.gov	Premier overall lightning safety website. Home of Lightning Safety Awareness Week.
45th Weather Squadron, US Air Force	https://www.patrick.af.mil/45ws/45og/lightningsafety.index.htm (note the 's' in 'https')	None
National Severe Storms Laboratory	www.nssl.noaa.gov/researchitems/lightning.html	None
National Lightning Safety Institute	www.lightningsafety.com	None
'USA Today' Newspaper	www.usatoday.com/weather/thunder/wlightning.htm	None
Struck By Lightning.org	www.struckbylightning.org	New non-profit organization dedicated to lightning safety education
CHILDREN		
Kids' Lightning Safety	www.kidslightning.info	Aka "Sabrina's website"
Kidstorm	www.skydiary.com/kids/lightning.html	None
National Severe Storms Laboratory	www.nssl.noaa.gov/edu/bm/bmmain.html	Downloadable coloring books on thunder-storm safety and other weather safety topics
SPORTS AND OTHER OUTDOOR ACTIVITIES		
American Red Cross--Masters of Disaster	www.redcross.org/disaster/masters/	Children's curriculum
National Collegiate Athletic Association	www.ncaa.org/sports_sciences/sports_med_handbook/1d.pdf	None
National Athletic Trainers Assoc.	www.nata.org/publications/otherpub/lightning.pdf	None
National Outdoor Leadership School	research.nols.edu/wild_instructor_pdfs/lightningsafetyguideline.pdf	None
University Of Florida	www.thomson.ece.ufl.edu/lightning	Boating--lightning safety
National Agricultural Safety Database	www.cdc.gov/nasd/docs/d000001-d000100/d000007/d000007.html	Boating--lightning protection
MISCELLANEOUS		
Lightning Injury Research (University of Illinois at Chicago)	www.uic.edu/labs/lightninginjury	None
Lightning Strike and Electric Shock Survivors, Intl.	www.lightning-strike.org	Support group
Vaisala, Inc.	www.lightningstorm.com	National Lightning Detection Network (formerly Global Atmospherics, Inc.)
National Weather Service Headquarters	www.weather.gov	Local forecasts to schedule outdoor activities. Click on U.S. map for desired National Weather Service office.

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