Overview and Executive Summary

Considerable research and evaluation have gone into improving natural and man-made hazards warning methods and technologies for campus and community populations over the past two decades. The oldest technology for public warning has been the electric air siren developed in the early 20th century. More recently, research has led to the development of newer electronic telecommunications technology warning systems. Electrical and Electronic Sirens are still widely used for outdoor warning, but have a number of limitations for warning the campus community and adjacent areas. This document will explore those technologies and methodologies as a multifaceted and coordinated, comprehensive systems approach to natural and man-made hazards warning possibilities.

Electronic Siren and Public Address outdoor warning technologies

The University of Colorado at Boulder installed two Whelen tone and voice sirens in the 1990's primarily for flash flood hazard warning. Flash floods of Boulder Creek represent the greatest threat for flash flooding in the State of Colorado [due to geographic and meteorological conditions present in the drainage area] to the campus and surrounding community. Boulder Creek and other tributaries bisect the campus and community. Sophisticated urban drainage and flood warning detection devices for water flow rate increases in the drainage area would give very little time [less than 20 minutes in worst-case scenarios] to warn and evacuate or shelter the affected areas immediately adjacent to the flood path which includes University family housing dwellings, research facilities, maintenance and support facilities, etc.

The Boulder Creek Flash Flood Risk is the largest in the State of Colorado

The irony is that only one such devastating “500 year” level flash flood ever occurred on the Boulder Creek drainage in the late 19th century when the campus was only occupying land on high ground south of Boulder Creek and out of “harm’s way.” There have been lesser floods in the 1930’s and most recently in 1969. There is still a potential risk of at least one percent for a 500 year or larger flash flood each year should certain meteorological conditions occur. A similar devastating flood occurred in 1976 near Estes Park Colorado on the Big Thompson river, which killed more than 150. Warning systems were not
available and a State Trooper lost his life trying to drive down the canyon and warn residents. This is no longer the case and preparedness, mitigation and response training have been implemented. Flash floods are especially deadly as they dislodge propane tanks, houses, vehicles, large rocks, bridges and other natural debris and carry it downstream where further damages are caused and debris gorges and blocks the water flow diverting water and debris into unanticipated areas. Victims who fall into the raging waters of a flash flood rarely drown as they are battered to death by the debris.

http://www.boulderoem.com/warning-systems/245-outdoor-warning-sirens

Renowned natural hazards expert, Dr. Gilbert White, [who founded the internationally acclaimed University of Colorado at Boulder Natural Hazards Research and Applications Center] devoted much of his academic career warning of the high life safety risk to campus and community posed by a major flash flood of Boulder Creek and associated tributaries. Despite his warnings, much construction occurred both on and off-campus in the flood path over the past seven decades as the campus was “landlocked” and lacked sufficient acreage to build outside the boundaries.

- **Outdoor Sirens and Public Address Systems rarely warn persons inside buildings**

The University of Colorado at Boulder’s Department of Public Safety noted that during monthly siren testing exercises, most of the campus community who were outside of buildings ignored the warnings. Those inside buildings could not hear the sirens and public address announcements. Sirens rarely can be heard if someone is inside a home or building, or inside moving vehicles with windows rolled up, stereo and air conditioning on. Those who are at home and asleep are very unlikely to hear them unless the device is immediately adjacent to their residence.

- **Community Disaster Education public and private partnerships educate students, faculty/staff**

Residents and office personnel who were surveyed stated they rarely could hear the sirens inside, and even then didn’t know what they meant or what they were expected to do if they did hear sirens. Consequently, the American Red Cross, the Department of Public Safety and the Boulder Office of Emergency Management partnered to produce public information videos, brochures, and to conduct training exercises for residents, staff, and students to familiarize them with expected preparedness, mitigation and response during warnings.

At CU and in the City of Boulder area, sirens are tested monthly during flash flood season along with programs and media coverage on public safety education concerning the tests and appropriate responses when warnings are issued. In areas where natural hazards are uncommon (such as Boulder) it is even more difficult to raise awareness levels about potential high risk natural hazards such as flash floods. It is essential to conduct a public safety awareness campaign in the campus community, especially for international and non-english speaking students, faculty and staff, that educates them on what sirens mean and what the public should do in response to a specific natural hazard or other warning [e.g., shelter-in-place, evacuate to higher ground, etc.] Otherwise the public will likely ignore the warning or may take inappropriate action.

*Most sirens were never intended to be heard, (nor are they generally capable of being heard) inside buildings, but are primarily for warning those in outside venues.*
Among the larger vendors of outdoor warning sirens/public address systems are Whelen Engineering:

http://www.whelen.com/_MASSNOTIFICATION/massnotification.php

and Federal Signal Corporation:


- Expected Response to Warning Siren and Public Address systems often does not occur

The public often may not understand what they are supposed to do when they hear a siren even though the Emergency Management Office and public safety community may have a presumption that the "public should know how to respond," (e.g., tune to radio, tv, or internet for more information). The use of various types of siren warning tones to denote certain types of hazard warning has been largely a failure as very few people know or understand the difference, much less what they should do to respond when a warning is initiated. Moreover, there is no uniform standard in place nationally that codifies such meanings, nor any significant education program to promulgate such information. Although residents of a given area where certain natural hazards are common [e.g., tornadoes] may understand what a siren alert means, those who are visitors or transient populations, or non-English speaking communities may have no concept of what the warning tones indicate, much less what reaction or response they should take.

There are cases in which sirens have been used predominately to warn of tornadoes, where an appropriate response would be to shelter-in-place in a residence or public building. However in the case of a flash flood in the same area, such action may be inappropriate if the home or building is in the floodpath and thus "in harm's way." It was reported that there is at least one case where this actually happened and some members of the public who were endangered, assumed that the sirens were for a tornado warning when in fact it was for a flash flood. Consequently they took inappropriate action and sheltered in a basement, and were injured or killed by failing to evacuate.

Public address voice announcements are more helpful when used with siren tones to clarify what hazard the warning is for. Other potential failings of outdoor warning siren/public address systems include echoes and poor audibility during wind, storms, or other high noise environments resulting in confusion and ignoring the warnings.

Often the public will ignore warnings thinking they are “just another test” and may fail to listen to radio or television to see if there is an actual warning. This is sometimes called the “crying wolf” syndrome so it is important for the voice messaging portion to include language indicating that the warning is only a test. Moreover the siren tones should be immediately followed by voice announcements indicating the nature of the hazard, when it will occur, and what action to take to avoid being “in harm’s way” [e.g., “move to high ground on foot for flash flood” or “move into basement of sturdy buildings for tornado” etc.]

- Sirens should not be used for alerting fire and rescue responders

The use of sirens for alerting fire and rescue responders has been (or should be) largely replaced with radio paging systems. Sirens should not be used for that purpose to avoid further confusion of the public.
Different tones for various natural or man-made hazards does not work

It has been suggested that standards for assigning specific siren tones to specific natural or man-made hazards [e.g., “whoop” only for tornadoes, “hi-lo” only for flash flood, “wail” only for nuclear attack, etc. Proponents of such applications for the sirens suggest that public education and standards should be promulgated nationally so that the public does not have to know that in one area siren tones mean one kind of warning, which may be totally different for another area. Regrettably this has never been pursued or promulgated effectively, so it is unlikely that it ever will be and probably would still not be effective due to a lack of uniform national standard meanings and a lack of comprehensive public education.

Sirens are very expensive and are primarily most useful in urban areas (or in small rural communities) with concentrated populations. They are not effective or practical in sparsely populated rural areas.

In order to effectively cover a given geographic area, a radius extending from the siren position to about 2000 or more feet must be engineered depending on the audio decibel output of the siren and other environmental factors such as terrain, building proximities, etc., which in densely populated areas can become very expensive, and still have limited effectiveness.

“Code Blue ®” emergency callbox systems for outdoor public address warnings

Those campuses with “Code Blue ®” or other emergency callbox systems can also be equipped with public address speaker systems which deliver more effective and localized announcements that provide comprehensive distribution and thus are more clearly heard due to a wider proliferation in strategic geographic locations. Consequently there is less sound distortion and more even distribution of sound throughout the geographic campus areas. The flashing LED strobe beacon can be activated to flash when a public address announcement or warning is being delivered to give a visual warning that an emergent situation is occurring. Many campuses have multiple callboxes numbering in the 100’s or more mounted in parking structures, on outside pedestals and even inside buildings. Some are tied into fire alarm warning systems and to public address systems inside buildings for more effectiveness. Emergency callbox phones can also house automatic external defibrillator [AED] kits for medical emergencies. See Code Blue website:

http://codeblue.com/product/pas-1-d/

Multi-faceted warning systems

A more effective and proven approach is to install a multi-faceted warning system which may include outdoor warning sirens/public address systems, but also uses “fan-out” [or “robo-caller”] automated emergency telephone warnings to wired telephones, which can be rapidly delivered at a rate of about 2000 calls per minute or more depending on the system and geographic scope of the area to be alerted for a hazard.

The National Emergency Number Association (NENA) has written detailed recommended standards for the use of such systems [*the author was a contributor and task force committee member of the NENA committee that compiled this document] which can be viewed at the NENA website:

http://www.nena.org/
These "9-1-1 callback" or "**Reverse 9-1-1®**" (**a copyrighted trade name of a specific vendor) technologies have been found to be very successful in alerting campus and local populations with warnings and specific instructions of what they should do to respond in a timely manner (e.g., wildfires, flash floods, hazardous materials emergencies, terrorist attacks, campus shootings, lockdowns, etc.)

Systems such as those provided by Intrado ® may utilize the 9-1-1 telephone number data base which includes not only published numbers but the 35% of the data base that are non-published. 9-1-1 data base files are also the most frequently updated and accurate files of any such system. Systems that do not use the local telephone service provider 9-1-1 data base may have many errors and omissions which could result in significant segments of the public not being notified of emergent situations. Intrado is among the foremost Next Generation 9-1-1 Systems providers [NG9-1-1].

http://www.intrado.com/solutions/ILEC/

Such systems should detect whether the call is received in person, or whether the line is busy, marking it for a later retry, or whether it went to an answering machine/voice mail, etc. It also should document the delivery of each call and record the action in a data base for liability and review purposes. Systems should also sense text telephone/TTY-TDD systems for hearing-impaired subscribers and may deliver coded warnings to those devices in some cases. Language barriers for non-English speaking populations are also of concern and subscribers should be able to request to receive a message in their native language, or may be told to call a certain number for a translation of the warning.

"Call-blocking" features of some wired phones will not permit delivery of emergency warnings and must be disabled for subscribers to hear warning messages. Sometimes the news media will advise the public to call their wired telephone service provider and deactivate their call blocking feature to receive warning messages. Our experiences with the system over the past ten years have been very positive, particularly for warning the public of wildfire, tornado, flood evacuations, fugitive and criminal-at-large alerts, lost/missing children and at-risk adults, etc.

- **wireless smart phones with text messaging**

Technology exists for a similar warning methodology for **wireless smart phones with text messaging**, which are becoming more numerous than wired phones. Such services may require user subscription in order to be included in emergent notifications, as there is no automated data base for wireless phones due to their mobile and transient characteristics; conversely wired phones using 9-1-1 subscriber data bases are generally automatically included. Both wired and wireless phones can be included in the subscription warning systems, but **users must subscribe themselves** in order to be notified in an emergency.
Examples of such service providers can be viewed at:
http://www.coderedweb.com/

http://www.colorado.edu/alerts/

Identification of unsubscribed wireless phones being operated within the "polygon" of the warning area may be dependent on the ability to determine the physical location of the phone through "wireless phase II 9-1-1 technology" which presently uses cell tower orientation or trilateration and in some cases GPS positioning. Not all areas and public safety answering points/9-1-1 communications centers are equipped with phase II technology, but eventually will be. Some cell phone providers have been somewhat reluctant to support such technology despite Federal mandates, so delays in implementation are still of concern.

- **Cable TV-interrupt systems**
  Cable TV-interrupt systems also permit flashing warning messages via crawlers or program interruption to subscribers, but presumes that the subscriber's tv is operational at the time. Systems are being developed that will turn on tv sets when an alert is issued, so viewers can receive the warning even at night while they may be sleeping.

- **National Weather Service automated radio alert systems**
  National Weather Service weather alert radio that sends tones to open radio receivers allowing subscribers to hear warning messages.

- **Emergency Alert System (EAS)**
  EAS delivers messages to broadcast media outlets such as radio and television, cable, etc., and can be tailored to deliver local warning messages.

- **Links to building public address systems**
  Public Address building systems (e.g., in schools, outdoor emergency callbox “blue light” phones often installed on college campuses, fire alarm systems, businesses, government buildings, etc.) further enhance rapid delivery of warning messages sent from public safety communications centers.

- **Mass E-mail and text messaging to personal computers and mobil smartphones**
  Some higher education institutions also deliver mass e-mail warning messages to the campus community, but servers must be geared to rapidly deploy high volumes for such messages in very short times or they will not be timely in providing adequate warning before the hazard occurs. Similarly, web pages can be used to flash warning messages, but are passive, so must be selected for users to receive the warning or have technology that overrides and turns on computers to display the warning message.

A national task force has been examining the best methodologies for public warning and the consensus favors a multifaceted systems that reach the largest spectrum of individuals through a variety of media technologies and outlets.
University of Colorado Natural Hazards Center Research on Warning methodologies

http://www.colorado.edu/hazards/

University of Colorado at Boulder Natural Hazards Research and Applications Center sociologists and behavioral scientists such as Dr. Dennis S. Mileti, have determined that warnings received by individuals often are questioned or doubted, due to a denial process, and must be verified through checking with multiple other credible resources such as radio/tv, checking with a family member or friend, observing the hazard visually, or even videotaping the hazard instead of seeking shelter or evacuating, etc., before they will accept that the warning is valid and requires immediate response. Many have died from delays caused by such verification behavior.

http://urbanearth.gps.caltech.edu/dr-dennis-s-mileti/

Denials include:

- “It will not happen here or to me.”
- “If it does happen here it will not affect me.”
- “If it does affect me, there is nothing I can do about it anyway.”

The longer the delay in verification, the more likely it is that the individuals in “harm’s way” will be injured or killed by the hazard. Consequently they should receive identical warnings, and instructions as to what the hazard is, when it will arrive, what areas are affected, and most of all what specific action they should take [e.g., move to higher ground, shelter in place, etc.]

All warning messages should include the following information

- Warning message delivering authority [e.g., University Police Chief, fire chief, sheriff, Red Cross, et al],
- nature of hazard [wildfire, tornado, flash flood, campus shooting, etc.]
- urgency [immediate, delayed]
- time of hazard arrival
- location affected by hazard, specific geographic areas, streets, etc.
- specific mitigation and response instruction [e.g., “Shelter-in-place,” “evacuate to]_____[locations]"
- Deliver the message in appropriate language for non-English speaking populations

The more specific and detailed the message is, the more likely it is that the warning will be heeded. This verification and denial process has been known to delay reactions and appropriate responses and cause harm to individuals who fail to act quickly. A multifaceted warning system that sends the same message through a variety of different technologies and information channels, is more likely to be responded to than those that are inconsistent or unverifiable, or only use one or two channels to deliver such messaging.
Public education programs for community disaster education and awareness (e.g., those of the American Red Cross and FEMA), along with campus Community Emergency Response Team [CERT] training are key elements in making communities more "disaster resistant" by knowing what the warning methodologies are, and how to respond to various hazards when warnings are issued. Regular tests and drills that involve the public help to improve education and understanding of appropriate response to actual emergencies. Scenario participation or “hands-on” exercises are most effective in creating awareness and empowerment of individuals among adults and children for actual response to emergent situations.

http://www.redcross.org/prepare/disaster

- **Involve Children and Seniors, Minorities**

Be sure to include children, seniors and minorities in training programs through schools, churches, youth organizations, senior groups and minority community groups and associations. The American Red Cross has excellent programs for all age groups and minorities in the Community Disaster Education programs and internet online resources. Community Emergency Response Teams also make excellent Community Disaster Education [CDE] Instructors and should be trained to provide their neighborhoods and workgroups with CDE information and classes.

Remember to include non-English speaking international students and families who may have little familiarity with hazards indigenous to the campus area, [e.g. middle-east students may not have ever seen or understand the dangers of a flash flood, hurricane, tornado or earthquake.

Areas that seldom experience natural or man-made hazards are even more difficult to orient and persuade as the public has more doubt or significantly less familiarity with risks versus those who routinely experience events such as tornadoes, floods, severe storms, etc.

Implementation of these multifaceted methodologies and technologies operating in parallel have been found to be highly effective in providing credible, broadly disseminated, and validated emergency messaging.

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