CISA CYBER+INFRASTRUCTURE SAFECOM® NCSWIC®

ESSENTIALS OF ALERTS, WARNINGS, & NOTIFICATIONS

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Cybersecurity and Infrastructure Security Agency
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Executive Summary

The Department of Homeland Security (DHS) Cybersecurity and Infrastructure Security Agency (CISA) developed this *Essentials of Alerts, Warnings, & Notifications (AWNs)* document to provide an overview of existing AWN systems. Fundamental AWN elements, evolutions in the AWN landscape, future considerations, privacy and security concerns, and next steps for the community are discussed, while summaries of national, local, and private AWN systems are outlined in the appendices. This document is designed to offer public safety officials, Smart City planners, and alert originators the information and tools needed to familiarize themselves with AWN systems.

Effective and timely AWNs can assist the public to make informed, life-saving, and property-preserving decisions before, during, and after hazardous events. Alert originators, content, and distribution are the foundational elements of AWN systems. Nationally available AWN systems include the Integrated Public Alert and Warning System (IPAWS), Emergency Alert System (EAS), Wireless Emergency Alerts (WEA), and National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). Regional, state, local, tribal, and territorial AWN systems include reverse 911 systems, outdoor sirens, digital signs, sensor networks, and other localized systems.

How to Use this Document

This document is intended for **public safety officials**, **Smart City planners**, and **alert originators**. They can use this document to familiarize themselves with:

- The fundamentals of AWN systems
- The evolving AWN landscape
- Future considerations and next steps for the AWN community
- Examples of national, local, and private AWN systems

This document does not contain AWN system best practices, requirements, comprehensive operating procedures, or governance considerations, but instead identifies resources for further study.

Legislative, social, and technological advances are the driving forces behind AWN landscape changes and future considerations. Prevalence of social media networks and other crowdsourcing communication channels provide alert originators with opportunities to reach a wide range of recipients, but the privacy concerns and security risks posed by these new platforms should also be addressed. Research on how the public responds to AWNs and how to improve AWN effectiveness also influences alert originators' decision making. Proposed legislative changes based on academic research and technological advancements further require alert originators to reconsider dissemination procedures and strategies.

This document does not contain specific AWN system requirements, operating procedures, or governance considerations. Private systems mentioned in this document are used as *demonstrative examples only* and are not to be taken as endorsement by CISA. For best practices that relate to multiple aspects of AWNs, refer to CISA's *Ten Keys to Improving AWNs*, a companion document that is intended to provide a set of best practices for alert originators.

Table of Contents

Tables

Fundamentals of Alerts, Warnings, & Notifications

Alert originators disseminate alerts, warnings, and notifications (AWN) to provide potential threat and safety-related information to advise and protect the public.[1] Effective and timely AWNs provide the public with information they can use for informed decision making and prompt them to take life-saving and property-preserving actions. Successful AWN disseminations can prevent hazard escalations, reduce impact of disasters, and speed recovery efforts.[2]

Alert Originators

Public safety officials and designated alerting authorities at any level of government may issue emergency messages to the public prior to or during incidents. AWNs may also originate from private, non-governmental sources, which in some cases are better geotargeted and more immediate. As a result, counties and states often employ private systems to disseminate AWNs to residents. Large, non-governmental organizations – including academic institutions and businesses – typically have their own mass communication programs capable of broadcasting AWNs. Less constrained by style requirements and character limits, social media posts complement AWNs distributed through official government channels by providing additional information to the public. More information on private AWN systems can be found in Appendix C: Diverse Social Media Platforms.

Alert Content

As **Table 1** illustrates, these communications serve different purposes depending on timing. Prior to an incident or during an ongoing, immediate threat, communications tend to provide information on the specific hazard, location, timeframe, magnitude, and suggested actions.[3] In response to an imminent threat, communications often focus on immediate actions. As the incident stabilizes and threats are contained, additional messages may highlight recovery and restoration efforts. Government-to-government AWN communications also occur as a part of incident response and coordination, but are outside the scope of this paper.[4]

Table 1. Alerts, Warnings, and Notifications Prior to, During, and After an Incident

Type	Timeframe	Purpose	Examples
Warnings	Prior to incidents	Distribute guidance to prepare for an anticipated incident	Weather watches/warnings, fire warnings, volcano warnings, evacuation orders
Alerts	At the beginning and during incidents with an ongoing, immediate threat	Gain the attention of the public and draw their attention to a risk or hazard	Active shooter and other civil dangers, hazardous materials concerns, 911 outage, America's Missing: Broadcast Emergency Response (AMBER) alerts
Notifications	During and after immediate threats	Instruct immediate protective actions and provide ongoing communications relevant to an event to reduce milling and encourage public action. Convey time-sensitive information on response and recovery-related services	Protective actions, evacuation routes, boil water advisories, return from evacuation notices, area accessibility updates, all-clear notices

[1] DHS, "National Emergency Communications Plan," 2019, pg. A5-1.
[2] DHS, "IPAWS Toolkit for Alerting Authorities," pg. 4. Last accessed January 7, 2020.
[3] Ibid, pg. 25, 26.
[4] For example, FEMA operates the National Warning System (NAWAS). NAWAS is a telephone network for exchanging AWN among government entities, including state and local emergency operations centers, public safety answering points, and National Weather Service offices. Government exchanges of warning information may lead to public alerting, but the public alerting would be through the public-facing systems described in this paper.

Alert Distribution

AWN distribution is a multi-step process guided by predetermined policies and procedures. The process itself is also multi-faceted, as numerous elements impact the success of a message's delivery and potential to save lives and protect property. Composition of alert messages, dissemination software and channels, public perception of a hazard, and threats a community faces are some of the many factors that impact this distribution process.

General Process of Alerting

The alerting process begins with the detection or prediction of a hazard capable of impacting life and/or property. Active modeling and monitoring (human and sensors) provide alert originators with incident details and situational awareness. After validating the aggregated information, alert originators should make decisions based on predetermined policies, procedures, and other localized government emergency plans to determine the best course of action.

Nationally Available AWN Systems

Federal, state, local, tribal, and territorial alerting authorities can access several national-level systems for disseminating AWNs, including the:

- Integrated Public Alert and Warning System (IPAWS)
- Emergency Alert System (EAS)
- Wireless Emergency Alerts (WEA)
- National Oceanic and Atmospheric Administration (NOAA) National Weather Services (NWS)

These systems are the nation's critical pathways for reaching the public during emergencies. An overview of these systems is provided below in **Table 2**.

Table 2. Summary of Nationally Available AWN Systems

System	Owner	National Alerting Capability	Key Functions	Audiences/Mediums
IPAWS	Federal Emergency Management Agency (FEMA)	Yes (via EAS and WEA)	▪ Provides public safety officials an integrated way to send alert and warning messages to the public using EAS, NWS, WEA, and other systems ▪ Serves as the only means to send WEA	EAS, NOAA All Hazards Radio, Social Media, Internet Content Providers, State and Local Systems
EAS	Broadcasters that receive messages from FEMA	Yes	▪ Automatically interrupts regular programming ▪ Is the primary system for national level alerts	Radio, TV
WEA	Commercial Mobile Service (CMS) Providers that receive messages from FEMA	Yes	▪ Broadcasts alerts to any WEA-enabled mobile device in a targeted area	Mobile Phones, Cellular-capable Devices

System	Owner	National Alerting Capability	Key Functions	Audiences/Mediums
NOAA NWS Dissemination Services	NOAA	No	▪ Interrupts routine NWS broadcasts and sends a special tone activating local weather radios ▪ Allows local or state officials to activate the system for non-weather emergencies ▪ Provides an alternate source for emergency notifications for radio and television broadcasters and other EAS participants	NOAA All Hazards Radio, NOAA Weather Wire Service (NWWS), NOAAPORT, Emergency Managers Weather Information Network (EMWIN), Weather.gov

State and local usage of EAS is entirely voluntary; WEA is a voluntary program for wireless providers.[5] To use these systems, jurisdictions must install hardware, software, or other infrastructure upgrades. Therefore, the requirements, capital, and maintenance costs vary from system to system. The audience, stakeholders, architecture, and operation of each system are detailed in Appendix A: Nationally Available AWN Systems.

Regional, State, Local, Tribal, & Territorial AWN Systems

In addition to these federal systems, many regions, states, and local jurisdictions have implemented their own AWN systems. These systems do not support the receipt and rebroadcast of national alerts unless they are integrated with IPAWS and are able to use the FEMA Common Alerting Protocol (CAP) to send public alerts and warnings.[6] Typical localized systems include reverse 911 systems, outdoor siren systems, digital signs, and various types of natural hazard sensor systems. To improve the effectiveness of localized AWNs, the policy, planning, and guidance for these technologies should be addressed in state and local emergency alerting plans. Examples of localized systems can be found in Appendix B: Other AWN Systems.

Evolving AWN Landscape

Societal changes, the public's expectations, and technological advances are three main drivers guiding the evolution of the AWN landscape. The public's perception of AWNs and hazards, how they receive AWNs, what information they receive, and how they decide to act are key factors that have and will continue to impact the development of AWN capabilities. Regulatory and legislative changes are additional factors that shape AWNs, aiming to establish baselines or consistency and address areas previously lacking measures and standards.

Specifically, rapid technology development is changing multiple aspects of AWN, from alert originating software to new hazard monitoring and dissemination methods. For instance, sensor networks are creating new AWN possibilities (e.g., artificial intelligence alert systems), which are addressed in more detail in Appendix C: Diverse Social Media Platforms. Other technologies, such as opt-in databases, Global Positioning System (GPS)-enabled devices, and geo-fencing, are improving AWN geotargeting capabilities. Similarly, smart home devices are developing new AWN dissemination outlets and channels. As technology continues to evolve, the specificity levels and volume of public AWN information will continue to increase.

[5] Chemical Stockpile Emergency Preparedness Program, "A Guide to Implementing the Integrated Public Alert and Warning System (IPAWS)," February 2019. Last accessed January 7, 2020.
[6] Ibid.

Policies, Laws, and Regulations

The State Emergency Communications Committee (SECC) from each state are responsible for developing their state's EAS plan, detailing technical, administrative, and other pertinent procedures unique to the state[7, 8], while the Federal Communications Commission (FCC), FEMA, and NOAA NWS collaboratively maintain both EAS and WEA through their guidance and requirements.[9]

The Integrated Public Alert and Warning System Modernization Act of 2015 directed FEMA to modernize the integrated U.S. public alert and warning system,[10] and the National Defense Authorization Act for Fiscal Year 2020 brings additional requirements to the AWN landscape. Under this bill, the federal government has the authority to originate an alert warning of a missile launch to the public through a public alert and warning system.[11] FEMA will also be responsible for developing minimum requirements for state, tribal, and local governments to participate in the public alert and warning system in coordination with the National Advisory Council and in consultation with the public.[12]

FCC Rulings and Requirements

The FCC has several Report and Orders and Notice of Proposed Rulemaking (NPRM) that expand WEA's content and capabilities. In the 2016 *In the Matter of Wireless Emergency Alerts* Report and Order and Further Notice of Proposed Rulemaking (FNPRM), the FCC ruled to increase many of WEA's capabilities, including expanding alert message character limits from 90 to 360 characters for 4G Long-Term Evolution (LTE) and future networks. The order requires participating wireless providers to support embedded information such as web links and establishes a new class of alerts called "Public Safety Messages."[13] In addition, WEA multimedia, multilingual and geotargeting capabilities were expanded under a 2016 FCC ruling.[14] The order went into effect November 30, 2019.[15] The FCC also began seeking comments on the WEA's feasibility to include multimedia content with the messages, as the FCC currently has no technical requirements on embedding multimedia in WEA messages.[16]

The FCC introduced additional updates in the 2018 WEA Report and Order, requiring participating wireless providers to deliver alerts to areas that match the target area specified by alert originators. Specifically, the FCC required participating wireless providers to deliver WEA to the target area "with no more than one-tenth of a mile overshoot."[17] Research from Carnegie Mellon University, which contributed to this revision, demonstrated a "lossless" compression method that could transmit alert messages within the targeted area also complying with current service standards.[18] Researchers were able to reduce the size of geotarget polygon representation to 10 to 25 percent of the original size, occupying nine to 61 characters, thus making it possible to embed geotarget information in the alert text without losing other information.[19]

The 2018 Order also requires WEA-capable mobile phones to preserve alert messages on devices for at least 24 hours after they are received. As a result, the FCC now requires CMS providers to log and maintain basic alert message attributes. Additionally, these logs must be available to the FCC and FEMA

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7 Lisa M. Fowlkes, "State Emergency Managers: Know Your State Emergency Alert System Plans," June 2, 2019.
8 To see EAS plans from states and territories, see https://www.fcc.gov/public-safety-and-homeland-security/policy-and-licensing-division/alerting/general/state-eas-plans.
9 FCC, "Wireless Emergency Alerts," last accessed January 30, 2020.
10 U.S. Congress, Senate, *Integrated Public Alert and Warning System Modernization Act of 2015*, S 1180, 114th Cong., 1st sess., introduced in Senate May 4, 2015.
11 U.S. Congress, Senate, *National Defense Authorization Act for Fiscal Year 2020*, S 1790, 116th Cong., 1st sess., introduced in Senate June 11, 2019.
12 Ibid.
13 FCC, "Improving Wireless Emergency Alerts and Community-initiated Alerting," September 29, 2016.
14 81 FR 75710
15 FCC, "FCC Fact Sheet Wireless Emergency Alerts Second Report and Order and Second Order on Reconsideration," January 8, 2018.
16 FCC, "Parties Asked to Refresh the Record on Facilitating Multimedia Content in Wireless Emergency Alerts," March 28, 2018.
17 FCC, "FCC Bolsters Effectiveness Of Wireless Emergency Alerts Action Will Improve Geographic Targeting of Alerts," January 30, 2018.
18 DHS S&T, "Opportunities, Options, and Enhancements for the Wireless Emergency Alerting Service," December 2015.
19 FCC, "Attachment 1 Record Supports Polygon and Alert Message in 360 Characters," last accessed January 7, 2020.

upon request, as well as to state and local alerting authorities that offer confidentiality protection at least equal to that provided by the *Freedom of Information Act* (FOIA).[20]

The FCC expands the capabilities of alerting systems through rulemakings such as NPRMs and has issued several key Report and Orders to strengthen EAS and WEA. The latest EAS Report and Order increases the effectiveness and efficiency of EAS by establishing the Alert Reporting System (ARS). The ARS combines the existing EAS Testing Report System with the new addition of a comprehensive online EAS filing system, allowing better access and use of EAS information between the FCC, FEMA, and other authorized entities.[21]

Privacy and Security Concerns

Despite the appeal of popular and emerging technologies, alert originators must make careful considerations before utilizing these tools, as each tool poses its own unique security risks. Alert originators should also understand the technological benefits and risks of each platform and establish specific policies and procedures that account for the public's perception of each technology's impacts on privacy and civil liberties.

Social media platforms are commonly targeted by cyber criminals. A multitude of cyber attacks (e.g., data breach, denial-of-service) could paralyze these platforms, rendering these potential dissemination channels useless to alert originators. Cybercriminals could also target AWN organizations that have official accounts on social media platforms, resulting in a variety of consequences ranging from account compromise to potential damage, both financial and otherwise, to the owning organization(s).

Revelations of prominent social media platforms handling users' data improperly altered the public's perception of social media. For example, according to polls, 74 percent of Facebook's users have either adjusted their privacy settings, taken a break from using the platform, or deleted the application altogether.[22] In another poll, around half of the users indicated they do not trust social media platforms to protect their data.[23] Despite the advantages these platforms offer, successful dissemination of AWNs could be hindered if the public trust in social media platforms continues to dwindle.

Internet of Things (IoT)-enabled devices pose similar privacy and security concerns. These threats, as well as the public's perception of them, will affect how alert originators can utilize IoT networks. According to the Federal Trade Commission (FTC), IoT intensifies security risks as connected devices could be impacted by cyberattacks.[24] The IoT manufacturers also lack incentives to keep the devices secure through support software updates because IoT chips are low-cost and disposable.[25] As a result, the inherently interconnected nature of IoT networks could cause significant communication and security breakdowns during the dissemination of AWNs.

According to a global consumer survey, the public is cautious of using IoT devices, particularly smart home devices, compared to other IoT devices and other general online activities.[26] On one occasion, a smart home device recorded its owners' private conversations and sent the recording to an acquaintance.[27] As these systems can provide secondary notification methods for additional information, they should not be excluded from AWN networks. However, the AWN community should thoroughly examine the potential costs of utilizing such technologies before designating them as official dissemination channels.

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[20] 47 CFR 10.320
[21] FCC, "FCC to Make Emergency Alert System More Effective," April 10, 2018.
[22] Andrew Perrin, "Americans are Changing Their Relationship with Facebook," *Pew Research Center*, September 5, 2018.
[23] Lee Rainie, "Americans' Complicated Feelings about Social Media in an Era of Privacy Concerns," *Pew Research Center,* March 27, 2018.
[24] FTC, "Comments on the Benefits, Challenges, and Potential Roles for the Government in Fostering the Advancement of the Internet of Things," *Comments of the Staff of the Federal Trade Commission's Bureau of Consumer Protection and Office of Policy Planning*. June 2, 2016.
[25] Ibid.
[26] Fen Zhao, "Will Smart Home Tech Make Us Care More about Privacy?," June 3, 2018
[27] Niraj Chokshi, "Is Alexa Listening? Amazon Echo Sent Out Recording of Couple's Conversation," *The New York Times*. May 25, 2018.

Considerations for the Future

The National Academies of Science, Engineering, and Medicine (NASEM) provides recommendations for improving and advancing AWN effectiveness. NASEM encourages increased integration of public and private communication mechanisms and information sources within existing AWN systems to increase cross-system functionality and reach a broader audience. NASEM research also suggests that AWN systems should have a "technologically agnostic architecture" to encourage rapid adoption of new technologies and support the continuous broadcasting of life-safety information.[28] Therefore, national alerting capabilities like WEA and IPAWS must continually adapt to the ever-evolving technological ecosystem. Understanding social behaviors will similarly inform communication officials and aid AWN advancement efforts.

NASEM identified five challenges to building a better alerting system:[29]

- *Slow adaption of alerting systems*: High equipment and training costs discourage jurisdictions from adopting new alert systems. Different jurisdiction sizes and staffing levels also hinder adoption of new systems.
- *Limited information about natural hazards*: Alerting agencies rely on weather forecasts and information provided by NWS and NOAA; effective AWNs depend on the maintenance and advancement of data collection and modeling technologies.
- *Ever-changing technology*: AWN technologies must evolve alongside outdated legacy equipment, as these systems remain in the AWN ecosystem and are not easily replaceable. Similarly, new technology deployment must occur in parallel with the user's ability to train with and adapt to these systems.
- *Difficulty of interdisciplinary research and converting research to practice*: Emergency managers, researchers, and technologists have little opportunity for collaboration with one another, which hampers AWN research and advancement.
- *Incentives to participate*: As the AWN ecosystem continues to expand, openness among stakeholders regarding how the components and systems work together to ensure successful AWN dissemination will become more challenging. How to incentivize stakeholder participation and openness is another key consideration for the future of AWN.

Policies, organizational aspects, human factors, procedures, and technologies are five AWN facets defined by the Communications Security, Reliability and Interoperability Council (CSRIC). In their report *Re-imagining of Emergency Alerting*, CSRIC detailed four trends based on a comprehensive evaluation of emergency alerts and emerging technologies.[30]

- *Technology advances are a catalyst for ongoing improvement to public alerting*: As alert-capable devices continue their technological advancements, interoperability across alerting modes and consistency in information delivered will both improve. Devices themselves will also be able to leverage their location awareness to increase the alert message's potential to save life and property. To judge the need for advancement in alerting capabilities, the government, the alerting community, and academics need to examine technology advancement on a regular basis.
- *IoT is an emerging enabler that may enhance the life- and property-saving potential of alerts*: The exchange of data resulting from connectivity between devices may improve the life and property saving potential of alerts. However, enabling IoT for alerting requires further consideration on defining and managing capabilities. Specifically, what IoT capabilities can be

[28] NASEM, "Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions," *The National Academies Press* (2018): 3.
[29] Ibid, 56.
[30] CSRIC Working Group 2, "Final Report—Comprehensive Re-imagining of Emergency Alerting," June 2018.

leveraged for alerting, how these capabilities are managed and coordinated, and how to validate and disseminate the data needs to be defined before implementation.

- *Advancements in social science are a catalyst for ongoing improvement to public alerting*: Just like advancements in technology, advancement in social science significantly impacts the AWN community. Social factors drive the public's decisions on whether to take protective actions. Crowdsourcing on social media facilitates dynamic exchanges between the public and emergency officials in real time. The government, the AWN community, and academic bodies should also regularly convene and assess the need to update alerting capabilities based on new social science findings.
- *Accessibility is inclusive of all alert recipients to ensure the greatest possible understanding of alert information and to maximize any necessary protective action-taking by the public*: Multimedia presentation of alerts should be enhanced with traditional and emerging technologies to convey equivalent information in different languages and account for recipients with different intellectual, cognitive, and other abilities.

Next Steps

Other recommended steps to improving AWN awareness and understanding include the following:

- Read the *Essentials of AWNs* companion document, the *Ten Keys to Improving AWNs*, for detailed AWN best practices. Discuss the documents internally among AWN personnel, as well as technology personnel.
- Conduct engagement and open dialogue with:
    - Neighboring jurisdictions to establish a mutual understanding of AWNs and strengthen coordination;
    - State and local governments to better understand jurisdictional uniqueness and use new insights to update existing AWN policies;
    - Local Critical Infrastructure and Key Resources (CIKR) to ensure clear understanding of AWN qualifications and maintain clear communication channels, especially during potential threats;
    - Industry professionals and academia to stay connected with the latest AWN social science findings and technological advancements; and
    - Federal government agencies such as CISA for AWN guidance, reference, and support, as well as FEMA for IPAWS-specific resources.
        - CISA technical assistance that can be customized for specific stakeholder needs regarding alerts and warnings is available through the *Emergency Communications Technical Assistance/Statewide Communication Interoperability Planning Guide*.
- Review and update existing organizational AWN policies and establish new procedures following dialogue and engagements. Develop a set schedule for annual review and refinement of policies. Conduct regular engagements with entities mentioned above as well as other relevant AWN stakeholders to improve organizational AWN posture.
    - The FEMA IPAWS Management Office recommends effective AWN programs to include policy, procedures, and protocols measured through four characteristics:
        - Effective documentation process to inform and control message origination and distribution;

- Coordination of alerting plans and procedures with neighboring jurisdictions;
- Operators and alert originators receive periodic formal training; and
- Message origination, distribution and correction procedures are in place.

For additional information, Appendices A and B provide details regarding national and local AWN systems and supplement the above content regarding the current AWN landscape. Appendix C: Diverse Social Media Platforms contains examples of social media and emerging technologies. Finally, Appendix D: Additional Commercial Systems Examples contains examples of commercial AWN systems.

Appendix A: Nationally Available AWN Systems

Integrated Public Alert and Warning Systems (IPAWS)

The IPAWS is the modern national alert and warning system used by alerting authorities to send emergency alerts to citizens through multiple systems, thereby distributing messages as broadly as possible.[31] IPAWS integrates the Emergency Alert System (EAS) and Wireless Emergency Alerts (WEA). The National Oceanic and Atmospheric Administration National Weather Service's (NOAA NWS) Dissemination Services is a future planned IPAWS capability. IPAWS can also integrate other state, territorial, regional, local, and tribal systems if they can decode messages formatted using the IPAWS Common Alerting Protocol (CAP).

The Federal Emergency Management Agency (FEMA) operates and directs the IPAWS – Open Platform for Emergency Networks (IPAWS-OPEN). This system provides integrated services and capabilities to federal, state, local, tribal, and territorial alerting authorities that enable them to alert and warn their respective communities via multiple communication methods. IPAWS-OPEN ensures the delivery of real-time data and situational awareness to the public, to public emergency responders in the field, at operation centers, and across all levels of response management.[32]

Audience

IPAWS can reach all WEA, EAS, and NOAA service audiences. It can also integrate any state, local, or private systems that use the CAP message format.[33] In addition, IPAWS is working with major internet content providers, including social media and search sites, for distribution through additional online channels.[34]

Architecture

Alerting authorities use IPAWS-compatible software to compose and distribute alerts via the IPAWS-OPEN alert aggregator using CAP standards. The alert aggregator verifies the credentials of the message and then distributes it to the public through the integrated alerting systems. The integrated alerting systems receive the CAP message, decode it, and reformat it if needed to distribute the message to the system's end users. The sections on EAS, WEA, and NOAA NWS Services detail the specific information flows for sending an alert through IPAWS.

Emergency Alert System (EAS)

The EAS is an alerting system for issuing warnings via broadcast, cable, satellite, wireline radio and television stations. The system is an evolution of a broadcast-based alerting system first established in 1951 with periods of overhaul and modernization. It is the primary system for the President to deliver an emergency message to the entire nation simultaneously within ten minutes.[35,36] Such a message would interrupt regular programming across all broadcast mediums and may use voice, video, and/or text.[37] EAS focuses on broadcast mediums like radio and TV stations because they typically continue to operate when other means of alerting the public are unavailable or congested.[38]

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[31] DHS, "IPAWS Toolkit for Alerting Authorities," pg. 4, last accessed January 7, 2020.
[32] FEMA, "Emergency Alerting: Integrated Public Alert Warning System - Open Platform for Emergency Networks (IPAWS-OPEN)," July 2017.
[33] DHS, "IPAWS Toolkit for Alerting Authorities," pg. 4, last accessed January 7, 2020. Also, often state, local or private systems require data entry into another field and do not use the CAP text, so operational guidance is key to integration effectiveness.
[34] Ibid, pg. 23.
[35] GAO," Emergency Alerting: Capabilities Have Improved, but Additional Guidance and Testing Are Needed," April 2013, pg. 3.
[36] FEMA, "Emergency Alert System," last updated October 22, 2019, last accessed January 7, 2020
[37] FCC, "Emergency Alert System (EAS)," last updated December 19, 2019, last accessed January 7, 2020.
[38] FEMA, "IPAWS Toolkit for Alerting Authorities," last accessed January 7, 2020. pg. 20.

While the primary purpose is for the transmission of national emergency messages, the President has never used EAS or its predecessor systems to deliver a national message.[39] State and local alert originators have used EAS for severe weather alerts via feeds from NWS. [40] However, state and local usage of EAS transmission is entirely voluntary. Other alerts may be used for day-to-day emergencies that pose a threat to life and property, such as earthquakes, fires, hazardous materials incidents, power failures, industrial explosions, and civil disorders.[41]

Audience

Part 11 of the Federal Communication Commission's (FCC) rules codify the requirements for EAS participants. Participants generally include:[42]

- Analog radio and television stations
- Wired and wireless cable television systems
- Direct Broadcast Satellite (DBS)
- Digital Television (DTV)
- Satellite Digital Audio Radio Service (SDARS)
- Digital Cable and Digital Audio Broadcasting (DAB)
- Wireline video systems operators

Participants are required to comply with FCC-developed EAS rules and regulations.[43] Any member of the public watching or listening to these different types of media would receive the alerts. EAS participants relay warnings in their primary broadcast language;[44] the diversity of languages further broadens the reach of EAS. However, since EAS only includes television and radio stations, a large portion of the public would likely not receive an EAS alert – the alert would only reach those who are watching television or listening to the radio at the time of the alert.[45]

Architecture

At the national level, FEMA originates an Emergency Action Notification (EAN) from its operations center to the National Public Warning System (NPWS) – previously known as the Primary Entry Point (PEP) – stations. These private or commercial radio broadcast stations cooperatively participate with FEMA to provide emergency alert and warning information to the public before, during, and after incidents and disasters.[46] Sirius satellite radio and the NPR satellite network receive a feed directly from the FEMA Operations Center. The EAS also has the NWS as an additional source of alerts. EAS equipment at State and Local Primary Stations can directly monitor the NWS for local weather and other emergency alerts. Local broadcast stations, cable systems, and other EAS participants can then rebroadcast the alerts to relay local emergency messages to the public.[47]

The IPAWS Program Management Office (PMO) expanded the number of participating broadcast stations across the nation to directly cover over 90 percent of the U.S. population. The NPWS station expansion ensures that under all conditions the President can alert and warn the public.[48] All other EAS participants that are not national, state, or local primary stations are participating national stations (PNS)

[39] FCC, "Emergency Alert System (EAS)," last updated December 19, 2019, last accessed January 7, 2020.
[40] Ibid
[41] Telecommunications, 47 CFR § 11.55 (2014).
[42] FCC, "Public Safety Tech Topic #21 – Emergency Alert System (EAS)."
[43] Ibid.
[44] Telecommunications, 47 CFR § 11.55 (2014).
[45] Government Accountability Office, "Emergency Alerting: Capabilities Have Improved, but Additional Guidance and Testing Are Needed," April 2013, pg. 20.
[46] FEMA, "The National Public Warning System," last updated October 22, 2019. Last accessed January 7, 2020.
[47] Ibid
[48] Ibid

and monitor a local primary station.[49] At present, the United States is divided into approximately 550 EAS local areas, each of which contains at least two local primary stations.

Wireless Emergency Alerts (WEA)

Wireless Emergency Alerts (WEA), formerly referred to as the Commercial Mobile Alert System,[50] are emergency messages that commercial wireless networks broadcast to WEA-enabled mobile devices in a locally targeted area. WEAs automatically appear on mobile device screens with a unique ring tone or vibration to draw attention to the alert. Originally, the messages were limited to 90 characters, as they were intended to quickly convey basic information to a wide audience, who could then gather more information through other sources. However, the FCC adopted rules to update and strengthen the system. The updated rules will:

- Require participating wireless providers to support inclusion of embedded phone numbers and URLs in all WEA alerts, including WEA America's Missing: Broadcast Emergency Response (AMBER) alerts, which will enable the public to click to see a photo or call authorities – effective November 1, 2017;[51]
- Increase the maximum length of WEA messages from 90 to 360 characters for 4G LTE and future networks – effective December 13, 2019;[52]
- Create a new class of alerts ("Public Safety Messages") to convey essential, recommended actions that can save lives or property (e.g. emergency shelter locations, a boil water order) – effective December 13, 2019;
- Require participating wireless providers to support transmission of Spanish-language alerts – effective December 13, 2019;
- Enable state and local authorities to easily test WEA, train personnel, and raise public awareness about the service – effective December 13, 2019; and
- Require participating wireless providers to deliver the alerts to more granular geographic areas. For participating providers, this means delivering the alert to the entire target area with no more than 0.1 mile overshoot – effective December 13, 2019.

WEAs are important because mobile devices are nearly ubiquitous. The FCC continues to improve and expand WEA capabilities through its reports and orders. However, all short message service (SMS) messaging is a "best effort" service and there is no guarantee that it is received or opportunity to resend the message if it does not reach a recipient.

Audience

All the major U.S. cell carriers are participating in part in WEA on a voluntary basis. Most smart phones are WEA capable; however, not all handsets currently on the market are capable of receiving WEAs.

Architecture

WEAs use SMS-Cell Broadcast (SMS-CB), which is designed to broadcast a text message to multiple phones at once. Broadcasting a text makes SMS-CB distinct from typical texting (SMS-Point to Point), which is a one-to-one service. By broadcasting using SMS-CB, WEAs can avoid causing congestion on the control plane.[53] From an information flow perspective, the alerting authority sends an emergency

[49] FCC, "Public Safety Tech Topic #21 – Emergency Alert System (EAS)."
[50] FCC, "FCC Renames CMAS as Wireless Emergency Alerts (WEA)," February 25, 2013.
[51] 81 FR 75710
[52] FCC, "New WEA Enhancements Available Dec. 13, 2019," November 25, 2019.
[53] Telecommunication networks can be separated into three "planes", and the control plane controls how telecommunication traffic will be forwarded between nodes. For more, see DHS S&T's *Wireless Emergency Alerts System Enhancement Recommendations*.

message through IPAWS. A Commercial Mobile Service (CMS) Provider Gateway then routes the message to the target cell based on details provided by the alerting authority. A cell, which may be one or more towers, provides some geotargeting as cells cover a specific geographic area. The provider network then broadcasts WEA messages directly to mobile phones connected to the particular cell.

National Oceanic and Atmospheric Administration (NOAA) National Weather Services (NWS) Dissemination Services

The National Oceanic and Atmospheric Administration (NOAA) has several services that provide alert and warning information to the public, including NOAA All Hazards Radio (also referred to as NOAA Weather Radio [NWR]), the NOAA Weather Wire Service (NWWS), its Weather.gov website, the Emergency Managers Weather Information Network (EMWIN), and NOAAPORT. Each of these services can relay weather or non-weather emergency messages (NWEM).[54] The NOAA National Weather Service (NWS) facilitates all automatically relay weather emergencies. All NWEMs originate from alerting authorities and HazCollect.

Emergency weather reported through NOAA NWS Services include multitudes of severe weather events such as hurricanes, tornados, and winter storms. In addition, NOAA NWS may issue special weather or marine statements. For each type of weather event, NOAA may originate a message that falls into one of four categories:[55]

- *Outlook/Statement*: There is a 30 percent chance that a hazardous weather event may develop.
- *Watch*: There is a 50 percent chance that a hazardous weather event may develop.
- *Warning*: There is an 80 percent chance that a hazardous weather event is imminent, or an event is already occurring; the event poses a threat to life or property.
- *Advisory*: There is an 80 percent chance that a hazardous weather event is imminent, or an event is already occurring; the event is likely to cause significant inconvenience and could pose a threat to life or property if proper precautions are not taken.

Architecture

State or local alerting authorities send messages through IPAWS or via phone to their National Weather Forecast Office. The message then passes to HazCollect, which distributes the message across all NWS services.

HazCollect

HazCollect is a system to distribute NWEMs through all NWS distribution channels, including NOAA All Hazards Radio, EMWIN, NOAA FOS, NWWS, and NOAAPORT. NWEMs may address incidents such as wildfires, hazardous materials releases, terrorist incidents, AMBER alerts, or public health emergencies.[56] The ability to relay NWEMs through HazCollect provides an important alternative to the EAS. It also provides redundancy for feeding alerts to the EAS participants who generally monitor NOAA Weather Radio for emergency alerts as a secondary source.[57]

NOAA All Hazards Radio

NOAA All Hazards Radio is a national network of radio stations operated by NOAA NWS. The network includes 1,025 transmitters located across 50 states, coastal waters, Puerto Rico, the U.S. Virgin Islands, and the U.S. Pacific Territories.[58] The system broadcasts on seven frequencies in the Very High

[54] GAO, "Emergency Alerting: Capabilities Have Improved, but Additional Guidance and Testing Are Needed," April 2013, pg.10.
[55] NOAA, "National Weather Service Reference Guide," September 2011, pg. 16.
[56] Ibid
[57] Ibid. pg. 11
[58] NOAA, "NOAA Weather Radio," last accessed January 7, 2020.

Frequency (VHF) band ranging from 162.400 to 162.500 megahertz (MHz).[59] During an emergency, the system interrupts regular broadcasts with a special activation tone on a transmitter-by-transmitter basis to activate weather radios that are in a given area or programmed to receive communications for an area. The radios then alert listeners with hazard information. Newer radios detect a digital-over-audio protocol called Specific Area Message Encoding (SAME), which allows the users to program their radios for specific geographic areas of interest and concern.

National Weather Wire Service (NWWS)

The NWWS is the primary telecommunications network for NWS forecasts, warnings (including non-weather warnings), and other products to the media, emergency management agencies, and private weather services. Major NWS forecast offices serve as uplink sites and send NWS data, including alerts and warnings. The uplink sites and users receive the entire NWWS data stream as part of the broadcast.[60] Commercial software then enables users to select, manipulate, alarm, and display the information on a variety of devices.[61] The system is the most reliable and timely warnings system that NOAA offers. NWWS is designed to deliver watches and warnings in ten seconds or less 98 percent of the time.[62]

Weather.gov

Weather.gov is an internet site with real-time data, similar to EMWIN data, as well as real-time warnings. Any user with Internet access can use the Weather.gov site to view alerts and warnings for their particular geographic area (see alerts.weather.gov). However, the website can become congested during severe weather events due to heavy traffic or communications issues. Communication issues may also make the website inaccessible on the user end.

Emergency Managers Weather Information Network (EMWIN)

The Emergency Managers Weather Information Network (EMWIN) provides the emergency management community access to a live stream of NWS warnings, watches, forecasts, and other relevant products. The stream is available via radio, satellite, or File Transfer Protocol (FTP) on the Internet.[63] EMWIN users are free to rebroadcast the information they receive to others. Initial receivers of the data from satellite (typically private and government emergency management groups and municipalities) can rebroadcast the data using local or NWS-owned frequencies. [64] Municipalities can augment the transmission with other data, such as local road conditions or school closings. Users can automatically pull the data from the Internet via FTP and then distribute it via other means, such as emergency operations center communication channels with the public.

NOAAPORT

NOAAPORT provides a satellite broadcast of the full suite of NWS products, including radar images and other graphical features as well as alerts and warnings for the nation. The media, emergency management agencies, and private weather services are all typically users of NOAAPORT. A vendor provides the NOAAPORT satellite feed, which consolidates feeds from all the Weather Forecasting Offices for distribution to users. Users must have satellite receiver equipment, available from a variety of vendors, to receive the broadcast. Users also need software to process and work with the data.[65]

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[59] Ibid.
[60] National Weather Service, "Dissemination of Marine Weather by the NWS."
[61] NOAA, "National Weather Service Reference Guide," September 2011, pg.90.
[62] NWS, "10-715 NOAA Weather Wire Service (NWWS) Dissemination" February 1, 2018..
[63] Weather Message Software, "Emergency Managers Weather Information Network," last accessed January 7, 2020.
[64] NWS, "EMWIN," last accessed January 7, 2020.
[65] NWS, "NOAAPORT," last accessed January 7, 2020.

Appendix B: Other AWN Systems

Unlike the national systems, like Emergency Alert System (EAS) and National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Services, which include many satellite and broadcast methods to reach the public, many of the regional, state, and local systems depend on state and local infrastructure to deliver alerts and warnings. For example, these systems may depend on local infrastructure for power or communications, which may not operate during a local emergency that affects infrastructure.[66]

Emergency Telephone Notification Systems (ETNS)

Emergency telephone notification systems (ETNS) automatically call a set of phone numbers to relay alert and warning information.[67] These systems typically use a database and software from a vendor to track phone numbers and associate them with an address. Alert originators can use the addresses to target alerts to certain areas. ETNS may deliver emergency messages for a variety of incidents, including hazardous material spills, evacuations, and boil water advisories.

One example of an ETNS is Reverse 911, which is a product of Airbus Group, Inc. (formerly EADS North America). Another similar system is CodeRED, though many providers offer similar technology. Such systems allow an alerting authority to record a message and send it to all phones simultaneously in a preprogrammed geographically targeted area. When a resident or client answers the phone, the recording identifies itself as Reverse 911 and then provides the emergency message.[68] For example, officials in Niles, WI issued a reverse 911 alert warning its residence of sporadic 911 outages.[69] Police in Idaho Falls, ID used this same technology to warn the public to stay inside and lock their doors during a Special Weapons and Tactics (SWAT) incident.[70]

An important consideration with ETNS is that residents without conventional phone lines are not prepopulated in a vendor's database. Therefore, wireless or Voice over Internet Protocol (VoIP) users have to register their phones and associate it with an address for ETNS to deliver alert messages prior to an event, as vendor databases typically include address information for traditional landlines.

Siren Warning Systems

Outdoor siren warning systems sound loud tones or provide a one-way voice communication within a local area, typically activated using radio/remote control.[71] These systems are primarily used to warn people who may be outside during quick manifest, severe weather conditions (e.g., tornados).[72] Alerting authorities may also use sirens for other emergencies, such as hazardous materials spills, to quickly signal the need to evacuate to the surrounding community.[73] For instance, officials in Boone County, MO, have positioned 80 sirens throughout the county to maximize coverage in populated areas, noting that these sirens are for warning people outdoors only. On the other hand, people indoors should focus on monitoring other sources, in particular NOAA All Hazards Radio.[74]

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66 Ben Jones, "Tornado Sirens Giving Way to New Warning Technology," *USA Today*, April 22, 2013.
67 National Emergency Number Association (NENA), "Minimum Standards for Emergency Telephone Notification Systems," June 12, 2004.
68 "Southern Nevada on the Alert (REVERSE 911)," last accessed January 7, 2020.
69 Tom Robb, "Outgoing Niles Police Department Calls Hit by Outage," *Journal & Topics*, June 5, 2018.
70 "Man Pronounced Dead Following SWAT Situation," *EastIdahoNews.com*, May 25, 2018.
71 American Signal Corporation, "Outdoor Warning Siren Systems," last accessed January 7, 2020.
72 Ibid
73 Ibid
74 Missouri Storm Aware, "Missouri Storm Aware – Tornado Sires," last accessed January 7, 2020.

Digital Signage

Digital signage such as variable-message signs (VMS) change their displays to show alerts and warnings when issued by alerting authorities. Pedestrians or drivers then see the messages on the signs and take protective actions in response. The permanent VMS often seen on the highways display public safety and weather-related alerts in addition to traffic related messages.[75]

Other types of digital signage, such as the electronic billboards, also display messages to raise awareness on matters pertaining to public safety. These billboards typically receive content from a media player which receives the content from a server, though systems vary. A variety of localities use these signs. For example, in Los Angeles digital signs displayed alerts during the manhunt for Christopher Dorner, a suspect in killing several police officers.[76] The Federal Bureau of Investigation (FBI) also uses digital signs to post wanted ads to generate tips from the public to assist in the apprehension of fugitives. Over the past decade, the scope of the program has grown. The FBI has signed agreements with many media companies, providing the Bureau with quick access to more than 6,700 digital billboards across the country. Close relationships have been forged, and wanted posters are often live within minutes of an FBI request.[77] Jurisdictions also frequently use digital signs to display America's Missing: Broadcast Emergency Response (AMBER) alerts.

Avalanche Warning Systems

The United States Forest Service (USFS) operates 14 avalanche centers across the country including Alaska, the Pacific Northwest, and the East Coast.[78] Based on weather information from the NWS, these centers issue avalanche forecasts and provide condition observations to the public.[79] In consultation with the regional avalanche centers, the National Avalanche Center created three criteria for issuing avalanche warnings: 1) avalanche warnings are always issued when the avalanche danger is extreme; 2) avalanche warnings are issued when the avalanche danger is high in many areas; and 3) avalanche warnings can be issued when non-recreationalists or people who would not otherwise access the avalanche advisory are expected to be impacted.[80] Many of the regional centers also provide education and offer resources from the National Avalanche Center to further prep the public to inform them on avalanche safety.

Earthquake Warning Systems

The United States does not have a national earthquake warning system. As a result, the United States Geological Survey (USGS) is working to develop a nationwide system in coordination with several academic and other organizational partners, by leveraging federal and state investments in existing seismic networks.[81] An earthquake early warning (EEW) is not a forecaster or predictor of earthquakes, but rather a high-tech way to warn people how many seconds remain before the next quake hits.[82] While not fully operational, a demonstration system, ShakeAlert, can send notifications to select users in California with potential magnitude, intensity, and seconds remaining before impact.[83] An EEW system can only provide a warning seconds to minutes ahead of an earthquake. While the timeframe is short, it does allow citizens and some critical infrastructure providers to take immediate protective actions. For example, trains can stop, citizens can seek protective shelter, and equipment can be shut down.[84]

[75] State of New York Department of Transportation Office of Traffic Safety and Mobility, "Variable Message Sign Guidelines," December 2018.
[76] "Clear Channel Outdoor Expands Digital Sign Network in Los Angeles Area," *Business Wire*, February 3, 2014.
[77] "FBI, Billboards Celebrate 10 Years of Partnership," *Sign Value*, January 18, 2017.
[78] National Avalanche Center, "U.S. Avalanche Centers," last accessed January 7, 2020.
[79] NWS, "Avalanche Safety," last accessed January 7, 2020.
[80] Mount Washington Avalanche Center, "Avalanche Watch and Warning Criteria," last accessed January 7, 2020.
[81] USGS, "Early Earthquake Warning Current Status," Last accessed January 7, 2020.
[82] Glen Farley, "ShakeAlert earthquake early warning system rolls out in Washington," April 11, 2017.
[83] USGS, "Earthquake Early Warning," last accessed January 7, 2020.
[84] USGS, "West Coast States Work on Early Warning System for Earthquakes," April 6, 2017.

ShakeAlert continues to refine its system; its latest operation phase includes delivering public alerts by Wireless Emergency Alert (WEA) and the MyShake smartphone app in California.[85]

EEW systems work by relaying information from sensors located near faults to an alert center. The alert center processes and then distributes this information to the public. Since earthquakes travel at the speed of sound and communications can travel at the speed of light, communications can arrive seconds to minutes ahead of the damaging earthquake waves.[86] On March 27, 2017, the U.S. House of Representatives passed a bill introduced by Rep. Peter DeFazio that instructs the federal government to identify funding and develop a plan for an early warning system for the Cascadia Subduction Zone, a large fault that runs along the coast from Northern Vancouver Island to Cape Mendocino, CA. Scientists say the fault has generated major earthquakes in the past and someday will create at least a magnitude nine quake that will have devastating effects for the Pacific Northwest.[87]

Technological advancement continues to drive for better EEWs. A recent study demonstrated that the Micro-Electro-Mechanical System (MEMS) accelerometers in smartphones can detect earthquakes greater than magnitude five when located near an epicenter. Smaller quakes are more difficult to detect because of daily noise (devices constantly being jostled and tilted), but with technology advancing rapidly, these sensors could soon identify smaller earthquakes.[88] Early Warning Labs, LLC is another vendor that seeks to provide better EEW capabilities to the west coast states. The company's sensors not only provide early alerts, but audio warnings through fire alarm systems and Amazon or Google smart home devices.[89]

Flood and Landslide Warning Systems

In addition to EEWs, wireless sensor networks are also assisting alert originators to automatically monitor and report on floods and landslides. Iowa's flood center employs more than 200 ultrasonic sensors to monitor water levels in streams across the state.[90] These sensors collect and automatically send data to the Iowa Flood Information System (IFIS), as well as assist in information and advanced hydrological modelling.[91] Harris County, TX also employs 163 sensor-equipped gages to facilitate real-time observation of water levels.[92] The Lower Colorado River Authority of Austin, TX partnered with the Department of Homeland Security's (DHS) Science and Technology Directorate's (S&T) First Responders Group to develop and test flood sensors that will monitor flood-prone areas in real time; these sensors are expected to be 20 times less expensive than market rate.[93]

Landslide sensor networks are another example of AWN systems that can provide real-time notifications. By using relatively inexpensive mobile phone connections and sensors that were calibrated to measure soil moisture, the research team at the University of Alabama in Huntsville, AL was able to field test the sensor network to predict landslides.[94] Internationally, similar types of technology are already being deployed. Loughborough University (England) and the British Geological Survey together created Slope ALARMS, a sensor that monitors and quantifies acoustic emissions from the slopes; field tests of this technology are currently underway.[95] In Mandi, India, the local government began to install inexpensive sensors to form an early landslide warning system for ten of its landslide-prone areas on their national highway.[96]

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[85] ShakeAlert, "ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States," last accessed January 7, 2020.
[86] USGS, "Earthquake Early Warning," last accessed January 7, 2020.
[87] "DeFazio's earthquake early warning system bill passes U.S. House," *KATU2*, March 28, 2017.
[88] Seismological Society of America, "Tiny sensor used in smart phones could create urban seismic network," *ScienceDaily*, September 29, 2013.
[89] Josh Haskell, "Earthquake Early Warning App Sends Alert Through Building Fire Alarms, Home Devices," *ABC7*, February 26, 2018.
[90] Senix, "Water Level Sensors Provide Real-time Flood Warnings in Iowa," April 17, 2018.
[91] Ibid.
[92] Harris County Flood Control District, "Harris County Flood Warning System," last accessed January 7, 2020.
[93] DHS, "S&T Uses Internet of Things to Improve Flood Alert Technology," July 26, 2017.
[94] The University of Alabama in Huntsville, "Landslide Sensors at UAH May Save Lives Worldwide," October 24, 2013.
[95] Slope ALARMS, "About," last accessed January 7, 2020.
[96] "Landslide Sensors on Mandi Highway Soon," *The Tribune India*, June 21, 2018.

Hurricane Warning Systems

The USGS actively deploys storm-tide sensors throughout the projected paths of hurricanes. These sensors record water levels and barometric pressure every 30 seconds and wave height (where applicable) every two seconds.[97] The Federal Emergency Management Agency (FEMA), the NWS, the National Hurricane Center[98], and the U.S. Army Engineer Research and Development Center utilize data gathered from these sensors, as well as state responders and emergency management officials.[99] The Air-Launched Autonomous Micro Observer (ALAMO) is a sensor device that can be parachuted to profile measurements of upper ocean temperature and salinity and assist in predicting hurricane strengths.[100] Typical hurricane forecast models focus on atmospheric measurements and observation, even though hurricanes are created, in part, by underwater properties.[101] Researchers sponsored by the Office of Naval Research field tested these specialized sensors during Hurricane Irma.[102] ALAMO's ability to measure oceanic characteristics can help public safety officials achieve better situational awareness and, in turn, provide more accurate information to the public.

Another system that assists in oceanic data information collection, delivery, usage, and prediction is the U.S. Integrated Ocean Observing System (IOOS). Comprised of buoys, satellites, tide gauges, radar stations, and underwater vehicles, IOOS provides scientists a common platform to track, predict, manage, and adapt to changes to the oceanic environment.[103] Through a partnership between federal, regional, and private sector stakeholders, the system provides both real-time and long-term observations that assist researchers to better understand climate variability and trends.[104] The IOOS is crucial to the accuracy and success of current and future AWNs through its multitude of capabilities.

Tsunami Warning Systems

The NOAA Tsunami Program is responsible for monitoring tsunami activities and the earthquakes that trigger them within the U.S., its territories, and in other international regions. The National Tsunami Warning Center stationed in Alaska monitors tsunami activities for the U.S. west coast, Alaska, and Canada, while the Pacific Tsunami Warning Center stationed in Hawaii monitors seismic activities and potential threats for the Hawaiian Islands, the U.S. Pacific and Caribbean territories, the British Virgin Islands, and other nations in the surrounding regions.[105]

Tsunamis are typically caused by underwater earthquakes. As it is not possible to predict the earth's next movement, warning centers depend on data and observation from different entities to determine the existence and impact of tsunamis. The NOAA Tsunami Program relies on USGS and its partners' seismic networks for such information as location, depth, and magnitude to determine whether a tsunami was generated after an underwater earthquake.[106] After an earthquake has occurred, warning centers can validate a tsunami's existence through observation of sea-level data and disseminate, refine, or cancel messages.[107] NOAA's National Data Buoy Center and networks of coastal water-level stations are also integral parts of the national tsunami monitoring effort. As the operator for the network of Deep-Ocean Assessment and Reporting of Tsunami (DART) system, the National Data Buoy Center monitors and reports in real-time of tsunamis in the sea along with its international partners.[108] Maintained by NOAA's

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[97] USGS, "USGS Installs Storm-Tide Sensors Along Gulf Coast for Hurricane Nate," October 7, 2017.
[98] The U.S. National Hurricane Center is also a part of the World Meteorological Organization's Tropic Cyclone Programme, where Regional Specialized Meteorology Centers and Tropical Cyclone Warning Centers around the world monitors other types of tropical storms like cyclones and typhoons. For more information, visit https://www.wmo.int/pages/prog/www/tcp/.
[99] Ibid.
[100] Woods Hole Oceanographic Intuition, Air Launched Autonomous Micro Observer (ALAMO), "About," last accessed January 7, 2020.
[101] Warren Duffie Jr, "Powerful Prediction: Finding a Better Way to Forecast Hurricane Strength," September 9, 2017.
[102] Ibid.
[103] National Ocean Service, "What is IOOS®?" Last accessed January 7, 2020.
[104] John L. Wilkin, Leslie Rosenfeld, Arthur Allen Rebecca Baltes, Antonio Baptista, Ruoying He, Patrick Hogan, Alexander Kurapov, Avichal Mehra, Josie Quintrell, David Schwab, Richard P, Signell and Jane Smith, "Advancing coastal ocean modelling, analysis, and prediction for the US Integrated Ocean Observing System," 2017.
[105] NOAA, "U.S. Tsunami Warning System," last modified September 29, 2017.
[106] Ibid.
[107] Ibid.
[108] Ibid.

Center for Operational Oceanographic Products and Services (CO-OPS), the networks of coastal water-level stations are used to confirm tsunami arrival time and height.

Wildfire Warning Systems

The NWS coordinates closely with federal and state wildland managers to provide Red Flag Warning, Fire Weather Watch, and Extreme Fire Behavior alerts to warn fire departments of the conditions and potentials of dramatic increases in wildfire activity.[109] A Red Flag Warning signifies conditions that are highly unfavorable for prescribed burns[110] and could lead to especially dangerous wildfire growth.[111] Such alerts are issued when it is highly possible that the Red Flag criteria will be met in the next 24 to 48 hours.[112] The NWS issues Fire Weather Watch when the Red Flag criteria will be met in the next 12 to 72 hours,[113] and Extreme Fire Behavior alerts when a wildfire may behave erratically and sometimes dangerously based on meeting one or more of the predetermined criteria.[114]

Winter Weather Warning Systems

Local NWS offices issue winter weather advisories, watches, and warnings based on local criteria. Forecasters observe weather conditions and patterns conducive for a variety of winter weather, including Nor'easters, ice storms, ground blizzards, and extreme cold and wind chills, and issue the type of weather alert accordingly.[115] These alerts are then disseminated via the appropriate NWS channels, as well as social media and other public platforms, to inform the public of potential, impending, and imminent winter weather events.

Volcano Warning Systems

Similar to tsunami monitoring, volcano monitoring requires a combination of different geological surveys on a continuous basis in order to forewarn volcanic activities. USGS developed the National Volcano Early Warning System (NVEWS) with its affiliated partners to provide early warning through surveys of the country's most hazardous volcanos.[116] USGS Volcano Observatory scientists send out volcano-alert notifications with defined alert levels and color codes.[117] To improve the nation's volcano monitoring and early warning capabilities, as well as strengthening existing ones, the U.S. Senate passed the National Volcano Early Warning and Monitoring System Act on May 17, 2018.[118] The Act requires that the resultant system include a 24/7 national volcano watch office, support a national volcano data center, provide external research and monitoring technology grants, and champion the modernization of current capabilities through emerging technologies.[119]

[109] NWS, "Understanding Wildfire Warnings, Watches and Behavior," last accessed January 7, 2020.
[110] Also known as controlled burn, fire managers use prescribed fire after careful planning and under controlled conditions to treat the land for resource benefits or other reasons. For more information, see National Park Service educational series on wildland fire.
[111] NWS, "What is a Red Flag Warning?" last accessed January 7, 2020.
[112] NWS, "Fire Weather Watch and Warning Definitions," last accessed January 7, 2020.
[113] Ibid.
[114] NWS, "Understanding Wildfire Warnings, Watches, and Behavior," last accessed January 7, 2020.
[115] NWS, "Winter Weather Warnings, Watches and Advisories," last accessed January 7, 2020.
[116] USGS, "National Volcano Early Warning System – Monitoring Volcanoes According to Their Threat," last accessed January 7, 2020.
[117] USGS, "Volcano Notification Deliver Situational Information," last accessed January 7, 2020.
[118] U.S. Senate Committee on Energy & Natural Resources, "Senate Passes Cantwell's Volcano Early Warning and Monitoring Bill," May 17, 2018.
[119] American Geosciences Institute, "Senate Passes Bill to Improve National Volcano Early Warning and Monitoring Capabilities," May 20, 2018.

Appendix C: Diverse Social Media Platforms

In addition to national alerts, warnings, and notification (AWN) systems, social media platforms and different types of sensor systems are becoming increasingly integrated into the overall public safety ecosystem. By utilizing social media platforms as complementary dissemination channels, alert originators not only boost the possibility of reaching a wider audience, but they also increase their outreach towards diverse populations, especially those with language barriers and disabilities. Moreover, the public can also provide additional information such as multimedia content from their perspectives during an incident, further strengthening alert originators' situational awareness. A sampling of such platforms is provided below:

- **PulsePoint** is a smart phone application that lets users view their local emergency medical services' (EMS) and fire departments' calls for public assistance. The application notifies users of nearby individuals in cardiac arrest who need Cardiopulmonary Resuscitation (CPR),[120] and provides a distinct alert to display the locations of the closest Automatic External Defibrillators (AED) to assist those individuals in distress.[121]
- **Nextdoor** is a neighborhood-based social network platform that also acts as a private AWN system. Around 2,500 public agencies across the country actively participate in Nextdoor's platform to provide residents with notifications (e.g., press releases, weather/safety alerts).[122] Residents also share public safety information on this platform. Since Nextdoor is more localized, alert originators could use the platform to conduct area- or neighborhood-specific public outreach during an incident.
- **Google Public Alerts** is another example of a private AWN system with a diverse and massive audience. The universal presence of Google and its products can assist alert originators in reaching their target audiences in the event that other channels are overloaded during emergency situations. The system integrates with Google Search, Google Maps, and Google Now to provide warnings and related protective actions to the public before incidents occur.[123] Google Public Alerts also requires data to be in the Common Alerting Protocol (CAP) format and prefers its public safety partners to be certified Integrated Public Alert and Warning System (IPAWS) alerting authorities.[124]
- **Facebook's Safety Check** feature is activated when the platform receives alerts of emergencies and hazards, and its users in the affected area are also reporting about the incident.[125] Specifically, the feature allows users to indicate their safety and monitor their friends and families' status. The Safety Check feature is a part of Facebook's Crisis Response, an information hub allowing users to connect with one another to exchange information during an incident, and coordinate recovery efforts afterwards.[126] Data aggregated on users' first-person accounts can provide crucial insights to alert originators and strengthen overall situational awareness.

[120] Susan Scutti, "App Crowdsources First Responders to Come to the Rescue," *CNN Health*, October 25, 2016.
[121] PulsePoint, "Designated to Put AEDs in Motion," last accessed January 7, 2020.
[122] Nextdoor, "Nextdoor for Public Agencies," last accessed January 7, 2020.
[123] Google, "Google Public Alerts," last accessed January 7, 2020.
[124] Google, "Introduction to Google Public Alerts," last accessed January 7, 2020.
[125] Facebook, "Crisis Response," last accessed January 7, 2020.
[126] Ibid.

Appendix D: Additional Commercial Systems Examples

Below are additional examples of commercial systems utilized at various levels and sectors of the government.

Name	Description
AlertSense	AlertSense allows individuals within an impacted area to be alerted simultaneously through multiple communication channels, including geotargeted reverse dial 911 calls to residents, Wireless Emergency Alerts (WEA) to mobile phones, and alerts to subscribers through preferred contact paths and posts to social media.
Blackberry AtHoc	AtHoc provides a comprehensive crisis communication and mass notification solution that unifies all channels and devices, empowering organizations, people, and communities to communicate and collaborate during critical events.
Everbridge	Everbridge Mass Notification provides analytics, Geographic Information System (GIS) targeting, flexible group management, distributed contact data, language localization, and multiple options for contact data management. It can also help organizations optimize voice and Short Message Service (SMS) routing.
Hiplink IPAWS Dispatch	The HipLink interface enables the Integrated Public Alert and Warning System (IPAWS) module to send direct emergency messages to the Federal Emergency Management Agency (FEMA) with defined communication pathways by an authorized user. This feature allows agencies to target with Geographical Alerts, WEA, Emergency Alert Systems (EAS), Non-Weather Emergency Messages (NWEM), Collaborative Operating Group (COG)-to-COG, and Public Feeds.
Hyper-Reach	Hyper-Reach Express (with IPAWS) uses local, selected cell towers to send messages to all mobile devices within range of the selected towers (chosen via geotargeting from Google mapping) including non-residents.
iNOTiFY	Using the iNOTiFY browser and smart phone interfaces, emergency managers can communicate privately with their Emergency Support Function (ESF) teams using rich media – text, audio, and pictures – presented on a map display.
NIXLE-New Jersey	Nixle is utilized by agencies and organizations around the country. In New Jersey, Nixle Connect allows the New Jersey State Police and the state's Office of Emergency Management to send messages to the public by text/SMS, email, and Internet posts.
Ping4Alerts!	Ping4alerts! is an emergency communications platform that allows public safety agencies to send high-precision, location- based geo-fencing emergency alerts to people in their community.
SAF-T-Net	Continuously monitored by a staff of degreed meteorologists, advanced computer processing analyzes the weather 24/7, searching for dangerous conditions such as strong winds, hail and tornadoes. When severe weather activity is detected in a specific alert location, Alabama SAF-T-Net dispatches a notification to an individual's mobile device, email account or home phone.
Swift911	Swift911 delivers messages via multiple contact methods including: voice, text, email, fax, and social media, and syndicates messages via Rich Site Summary (RSS) feeds, Common Alerting Protocol (CAP) format, and IPAWS.
Wide Area Alert Network (WAAN)	Navy installations worldwide use the WAAN as an effective and reliable mass notification system to maximize the potential to warn and direct affected personnel during a crisis through multiple systems: Giant Voice (GV), Interior Voice (IV), Computer Desktop Notification, and Automated Telephone Notification.
Wireless Emergency Notification System (WENS)	Inspiron Logistics' WENS uses true SMS and voice messaging as the basis for communication for emergency notification, mass notification, campus notification, and pandemic alerts. This system was designed to work in the event of the most extreme-case scenarios.

Appendix E: Acronym List

Acronym	Definition
AED	Automatic External Defibrillator
ALAMO	Air-Launched Autonomous Micro Observer
AMBER	America's Missing: Broadcast Emergency Response
ARS	Alert Reporting System
AWN	Alert, Warning, and Notification
CAP	Common Alerting Protocol
CIKR	Critical Infrastructure and Key Resources
CISA	Cybersecurity and Infrastructure Security Agency
CMS	Commercial Mobile Service
COG	Collaborative Operating Group
CO-OPS	Center for Operational Oceanographic Products and Services
CPR	Cardiopulmonary Resuscitation
CSRIC	Communication Security, Reliability, and Interoperability Council
DAB	Digital Cable and Digital Audio Broadcasting
DART	Deep-Ocean Assessment and Reporting of Tsunami
DBS	Direct Broadcast Satellite
DHS	Department of Homeland Security
DTV	Digital Television
EAN	Emergency Action Notification
EAS	Emergency Alert System
EEW	Earthquake early warning
EMS	Emergency Medical Services
EMWIN	Emergency Managers Weather Information Network EMWIN
ESF	Emergency Support Function
ETNS	Emergency Telephone Notification System
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FNPRM	Further Notice of Proposed Rulemaking
FOIA	Freedom of Information Act
FTC	Federal Trade Commission
FTP	File Transfer Protocol
GIS	Geographic Information System
GPS	Global Positioning System
GV	Giant Voice
IFIS	Iowa Flood Information System
IOOS	Integrated Ocean Observing System
IoT	Internet of Things
IPAWS	Integrated Public Alert and Warning System
IPAWS-OPEN	IPAWS-Open Platform for Emergency Networks
IV	Interior Voice

Acronym	Definition
LTE	Long-Term Evolution
MEMS	Micro-Electro-Mechanical System
MHz	Megahertz
NASEM	The National Academies of Sciences, Engineering, and Medicine
NAWAS	The National Warning System
NOAA	National Oceanic and Atmospheric Administration
NPRM	Notice of Proposed Rulemaking
NPWS	National Public Warning System
NVEWS	National Volcano Early Warning System
NWEM	Non-Weather Emergency Message
NWR	NOAA Weather Radio
NWS	National Weather Service
NWWS	NOAA Weather Wire Service
PEP	Primary Entry Point
PMO	IPAWS Program Management Office
PSA	Public Service Announcement
RSS	Rich Site Summary
S&T	Science and Technology Directorate
SAME	Specific Area Message Encoding
SECC	State Emergency Communications Committee
SDARS	Satellite Digital Audio Radio Service
SMS	Short Message Service
SMS-CB	SMS-Cell Broadcast
USFS	United States Forest Service
USGS	United States Geological Survey
VHF	Very High Frequency
VMS	Variable-Message Sign
VoIP	Voice over Internet Protocol
WAAN	Wide Area Alert Network
WEA	Wireless Emergency Alert
WENS	Wireless Emergency Notification System

Appendix F: Disclaimer of Liability

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