ALLIANCE FOR INNOVATION AND INFRASTRUCTURE

Consensus Around Technologies

The Key Communications Technologies that Need to be Adopted to Improve Efficiency and Reduce Excavation Damages

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Introduction

Excavation damage to underground utility lines causes significant economic harm to the nation. With over $30 billion annual economic harm from damage incidents[1] and an additional $61 billion in systemic waste,[2] excavation damage needs to be addressed by both private actors and public authorities. The costs will likely increase as a result of the 2021 Infrastructure Investment and Jobs Act, which will infuse billions of dollars into infrastructure and construction spending. This type of spending is highly correlated to excavation damage and therefore likely to result in even more damage to subsurface utilities that will generate added costs in the coming years.

As we describe in this paper, broad consensus from industry and public entities has formed around a number of innovative technologies, best practices, and communication techniques to reduce excavation damage. While there is significant consensus, what is still lacking are the necessary action steps to achieve reforms in practice. In this paper, we seek to highlight the consensus around some of the available technologies and communication techniques and then discuss recommendations to advance them into practice systemically.

Background of Survey

We have reviewed the recommendations of three groups that have been important in setting, implementing, and overseeing damage prevention policies and processes in the United States. Those are the National Transportation Safety Board (NTSB), the Common Ground Alliance (CGA), and the Pipeline and Hazardous Materials Safety Administration (PHMSA). We also reviewed the recommendations of a newer group, the Infrastructure Protection Coalition (IPC), which arose in 2021 with a nationwide report on the damage prevention system. While there are other stakeholders and entities, such as state governments and researchers, these four groups represent a wide cross-section of the parties that play a significant role in damage prevention, including independent government agencies, direct supervisory regulators, industry stakeholders, and regular users of the 811 system. Before looking to the consensus around their technology and communication recommendations, we first give a brief background on each of the groups.

National Transportation Safety Board (NTSB)

The NTSB is the nation's top independent investigative body for all transportation accidents, including pipelines. NTSB also conducts academic research, promotes technology and best practices, and works with industry and government actors. As far back as 1994, the NTSB "brought together about 400 representatives from pipeline operators, excavators, trade associations, and local, State, and Federal government agencies to identify and recommend ways to improve prevention programs."[3] At the time, there were few organizations uniting

stakeholders or voicing issues in the damage prevention space. NTSB noted that different industry groups had their own basic standards, but that "Participants at the Safety Board's 1994 workshop…developed detailed lists of elements they believed are essential for an effective one-call notification center, other elements a center should have, and elements it could have." In other words, NTSB helped write the basic tenets of effective damage prevention still upheld today as voiced by a broad and diverse set of stakeholders.

Common Ground Alliance (CGA)

Formed in 2000 as an offshoot of the seminal 1999 Common Ground Study[4] by the Office of Pipeline Safety (a precursor to PHMSA), CGA is made up of 16 diverse stakeholder groups (ranging from excavators and locators to facility owners and public entities).[5] CGA has become nationally influential for damage prevention research and education, and its Best Practice Guides are accepted as the authoritative source for industry standards. These best practices are themselves the product of consensus, requiring unanimous approval by all 16 stakeholder groups in addition to the practice being proven effective and in actual use by a CGA member in the field. CGA also has seven committees, each "comprised of members from the 16 active stakeholder groups within the CGA. These committee members operate on a consensus basis – ensuring that all CGA initiatives carry the support of the entire damage prevention community."[6] In addition to promulgating best practices, through its various committees, CGA conducts independent research and produces white papers, technology reports, and damage information reporting.

Pipeline and Hazardous Materials Safety Administration (PHMSA)

As the top regulatory damage prevention authority, PHMSA studies, regulates, and allocates resources to stakeholders across the damage prevention process.[7] In addition to administering over a dozen grants aimed at effective damage prevention and implementation of innovative technology, PHMSA has set forth the Nine Elements of Effective Damage Prevention, which it developed from decades of study and stakeholder engagement.[8] The agency directly oversees and certifies every state's damage prevention laws, and PHMSA personnel work directly with stakeholders to conduct training and learn about practices and technology in the field. In 2016, Congress requested PHMSA to study improving damage prevention technology, intending that the report summarize existing technology and recommend needed reforms. The following year, PHMSA completed the study, which relied on "existing data and information, and consulted with numerous key stakeholders."[9] Other research is conducted by PHMSA in consultation with hundreds of stakeholder groups and builds on the agencies deep subject matter expertise.

Infrastructure Protection Coalition (IPC)

As mentioned above, there is an additional group we reference in this paper, which only came into being in the last two years. A coalition comprised of longstanding industry groups, the IPC was established in response to years of waste and inefficiency within the damage prevention system.[10] This group is composed of five contractor associations representing thousands of entities and tens of thousands of employees, including the American Pipeline Contractors Association (APCA), Distribution Contractors Association (DCA), National Utility Contractors Association (NUCA), National Underground Locator Contractors Association (NULCA), and the Power & Communication Contractors Association (PCCA). The group launched with a

comprehensive nationwide study on costs and efficiency concerns within the damage prevention process. In its inaugural report, IPC made 13 national recommendations to reduce excavation damages and improve efficiency.

Consensus Around the Adoption of Technology

We have reviewed what each of these four groups have said about damage prevention and the recommendations that they have made to see what consensus exists among them. The key takeaway is that they all agree on the importance and value of technology in reducing excavation damage. According to CGA, "three of the four best opportunities for improving the U.S. damage prevention system revolve around technological improvements." They go on to say that "Perhaps the single most important takeaway…is the extent to which technological solutions for some of our most entrenched problems already exist."[11]More recently, CGA has again stated, "The technologies to help us achieve zero damages exist."[12] Likewise, PHMSA and the NTSB have stated, "Technological developments, especially mobile devices, are constantly changing the game to the betterment of damage prevention" and that an investigative "report must include an analysis of…what can be done to foster development of better technologies,"[13] respectively.

A number of technologies and practices emerge consistently across the literature, industry groups, and government reports. These technologies center around the importance of communication and focus on technology-based communications devices, techniques, or platforms. Among these are:

Electronic White-Lining (EWL). The use of a web-based locate request that allows excavators, contractor, or homeowners to enter ticket information directly and draw a precise, overhead, virtual delineation of the proposed excavation area.

- NTSB has long been a proponent of physical white-lining. While the agency has not weighed in on virtual white-lining, its investigative reports frequently point to destroyed markings and lack of electronic or photographic record as a potential contributing factor for damage, an issue that an electronic white-lining record would address.[14]
- CGA elevates EWL as a Best Practice,[15] identifies it as the first step in the ideal dig of the future,[16] states that it has one of the highest returns on investment (ROI),[17] and surveys show that locators believe it is highly effective,[18] with 79 percent of CGA members responded that software, including electronic white-lining, can have the greatest impact on reducing damage.[19] CGA also states that "most 811 centers now receive the majority of their incoming notices electronically rather than by telephone and can support electronic white-lining..."[20]
- PHMSA describes electronic white-lining among improving damage prevention technologies,[21] and that the use of EWL in the damage prevention process leads to "efficiencies [which] will result in cost savings, improved locate accuracy, and improved safety."[22]
- IPC recommends that electronic white-lining be required nationwide.[23]

Electronic Positive Response. The use of a web-based platform accessible to the excavator or homeowner listing each utility/facility owner that has been notified of an excavation project, relevant contact information, and a live-status update on whether the site has been marked for each of the facilities and what if any conflicts exist.

- NTSB has highlighted the importance of positive response and the need for "a time-saving alternative" to check up-to-date ticket status,[24] which electronic positive response would address.
- Even before CGA officially formed, the Common Ground Study cast a vision for excavators to receive positive responses "directly from the facility owner/operator's locator personnel, through the one-call center's database."[25] CGA has formally adopted electronic positive response as a Best Practice[26] and a technology the dig of the future relies upon.[27]
- PHMSA defines nine elements of successful damage prevention leading off with "enhanced communication between operators and excavators" which is facilitated primarily through one-call centers. For that communication to be effective and enhanced, an electronic platform and up-to-date communication is needed, as through electronic positive response.[28]
- IPC recommends that electronic positive response be required nationwide.[29]

Enhanced Positive Response (EPR). The use of an electronic positive response platform that allows the uploading of additional relevant information directly into the one-call center platform, giving the excavator, locator, and others access to additional information such as facility maps, ticket information, virtual manifests, or digital photographs along with notification of the completion of the locate job. This ensures as much relevant information as possible is available and accessible relating to the presence and location of any underground facilities, which can be accessed from the job site on a web-enabled mobile device. *(Hereafter, when a recommendation for EPR is mentioned, it is important to remember that EPR includes electronic positive response as one of its elements.)*

- NTSB has discussed the benefit of a preserved electronic record of an excavation site marking.[30] Similarly, NTSB investigations rely on photographs of the pre-incident scene to determine if positive responses were made by all notified utilities.[31] Drawings that show some buried infrastructure but not all are also emphasized as lacking completeness and creating risk, highlighting the importance of complete and enhanced information being available to excavators.[32]
- CGA names enhanced positive response a Best Practice,[33] has highlighted it in every annual Technology Report,[34] and believes that it is the second step of the ideal excavation project of the future.[35] Surveys demonstrate that 79 percent of CGA members responded that software, including enhanced positive response, can have the greatest impact on reducing damage.[36] CGA also states that, "Most 811 centers now receive the majority of their incoming notices electronically rather than by telephone and can support…automated/enhanced positive response systems."[37]
- PHMSA has identified enhanced positive response as its top recommendation after studying damage prevention technology[38] and describes that it "eliminates

misunderstanding", "increases communication," "promotes accountability," and "creates a shared responsibility environment."[39]

- IPC emphasizes in its recommendations the need for "GIS System Adoption by Asset Owners" to map all of their assets digitally and require one-call notice with GPS coordinates,[40] which is one element that can be included in an enhanced positive response package. A repeated emphasis throughout its reports is on "contractor wasted time waiting for asset owner compliance with locate request or taking 'defensive excavation' practices at additional cost and lost productivity in an attempt to avoid unlocated facilities" which may be avoided with enhanced communication of digital records, photographs, and information shared with the excavator.[41]

Predictive Analytics. The collection of data and use of software to manage locate requests, particularly to optimize high-volume influxes of requests and to manage high-risk excavation tickets.

- NTSB has repeatedly emphasized the importance of data collection to be integrated into damage prevention processes to avoid future damage.
- CGA has called the industry to "utilize technology/software to account for variability in demand" calling this an "opportunity for systemic improvement with the greatest ROI potential."[42] CGA goes on to state that "Predictive analytics and other technologies can be leveraged to better account for influxes of locate requests, and to identify projects where damages are likely to occur – both of which are likely to reduce damages."[43] Surveys demonstrate that 79 percent of CGA members responded that software, including ticket management, can have the greatest impact on reducing damage.[44] CGA also identifies predictive analytics on its wish list of technology.[45]
- PHMSA identified predictive analytics tools as its number two recommendation,[46] stating the need to "Evaluate and implement predictive analytic tools, which use data to identify and proactively address high-risk excavations." Elements three and nine of PHMSA's effective damage prevention program highlight "Operator's Use of Performance Measures for Locators" and "Data Analysis to Continually Improve Program Effectiveness."[47]
- IPC, across its nationwide assessment, continually emphasized data collection and "effective metrics" for preventing damage, streamlining efficiency, and improving the locate process. Its analysis includes evaluation of unnecessary locates and "a calculation of frequency of wasted time incurred by locators and excavators due to infrequent compliance or inefficient locate process."[48]

While this is not an exhaustive list of recommendations by the four groups being discussed, it represents technologies that are agreed upon by broad stakeholder consensus as needed improvements in the damage prevention process. What is striking about this consensus is that it arises from both regulatory parties and private sector stakeholders, yet no substantial action has taken place through regulation or organic implementation by stakeholders to mandate adoption in practice. It perhaps shows that when strong consensus forms, a sort of bystander effect occurs,

where no party takes steps to resolve the issue – with regulators waiting on industry to act, and industry waiting for a regulatory requirement before acting. This is why, "the real challenges lie in overcoming barriers to adoption and finding ways to integrate the technologies into the damage prevention ecosystem."[49]

More Can Be Done to Drive Adoption of Technology

It is instructive to examine the damage prevention groups we have discussed with specific regard for their action steps to implement the technologies they have recommended. We look first at what each group has or hasn't done in recent years, then explore options at their disposal to create momentum and achieve implementation of the technologies we have discussed and they have supported, around which there appears to be broad consensus.

National Transportation Safety Board (NTSB)

Today, the primary impact the NTSB has on damage prevention is pipeline accident investigations and safety recommendations. Although the agency's transportation jurisdiction covers pipelines, but not other subsurface utilities, their recommendations are highly applicable to the entire damage prevention process as it relates to other infrastructure. In fact, NTSB recommendations on white-lining from 1997 still serve as the basis for today's CGA best practices guide. While the NTSB does not investigate every pipeline issue, when it does, its recommendations carry significant weight both with respect to pipelines and other underground facilities.

Moving forward, there are two primary ways that NTSB can make a positive impact for damage prevention. The first is more passive, while the second could be acted on quickly. By its nature, NTSB is largely backward-looking with respect to accident investigations, but it does provide forward-looking recommendations.[50] To make a recommendation, the agency would need to wait for a significant excavation incident affecting pipelines, then investigate it and make recommendations.

Without waiting for future accidents, the NTSB could act more quickly by utilizing its Most Wanted List (MWL), which "highlights transportation safety improvements needed now to prevent accidents, reduce injuries, and save lives." The NTSB uses the MWL to focus their advocacy efforts throughout the year, and historically has used it for "Excavation Damage Prevention to Underground Facilities."[51] By specifically naming damage prevention technologies in this list, NTSB could exercise its significant influence. Additionally, future pipeline investigations should answer whether these key technologies and practices could have prevented or mitigated the damage.

Common Ground Alliance (CGA)

CGA's consensus-driven groups have found that the number one challenge identified by over half of locators surveyed is "the area to be marked is not clearly defined."[52] When the question came to what policy would bring about accurate and on-time locates, the number one response was mandatory white-lining, with 97 percent of locators saying it would be somewhat or very effective.[53] In that survey, CGA did not differentiate between physical or virtual white-lining, but

the same survey found that 97 percent also saw "increased communication between the excavator and the locate technician" as very or somewhat effective. Uniting these findings, it is clear that EWL addresses the locators' views by helping clearly define the area to be marked, simplify white-lining, and increase communication. With the demand for improved communication between parties, it is also no surprise that electronic white-lining, electronic positive response, and enhanced positive response (which do just that) are formally adopted best practices and found throughout CGA's reports, while predictive analytics has been put forward as a solution with great return on investment being reviewed by multiple committees.

When it comes to achieving reforms and implementing technology, CGA has not always been quick to act. In 2020, CGA recognized the need for "systemic change" and called for more implementation of technology.[54] In 2021, the organization formed new workings groups to study implementation barriers[55] and identify solutions. Creating new working groups has helped gain an understanding of the issues but has not seemed to translate into action or clear progress in implementation of the technologies that they support. Nevertheless, CGA has begun to seriously examine barriers to technology implementation and in its latest report, stated:

> It is past time to advance the pace of technology adoption, application and integration in U.S. damage prevention. The technologies to help us achieve zero damages exist. The barriers facing the industry are not technological. They are driven by financial assessments that do not take into consideration the long-term benefits of investing up front, along with political and institutional challenges. Leaders in damage prevention must prioritize strategic technology investments in order to meaningfully advance the industry.[56]

In order to help make that needed advancement happen, CGA could strengthen certain of its existing best practice statements. One option would be providing a distinct best practice statement for electronic white-lining that is separate from the standard for physical white-lining, while a best practice on predictive analytics could help one-call centers and locators improve their operations. CGA could also incentivize its members to adopt certain technology through certification badges, discounted dues, or other programs.

Pipeline and Hazardous Materials Safety Administration (PHMSA)

After two decades of research and work directly with stakeholders and local/state level authorities, PHMSA's number one element of effective damage prevention programming is "enhanced communication between operators and excavators," along with "use of technology to improve all parts of the locating process" as number eight. Since conducting its critical 2017 study – where EPR and predictive analytics are its first and second recommendations – PHMSA has continued to regulate and work with stakeholders, but has not completed further comprehensive damage prevention studies. In 2021, PHMSA added a new grant to help improve pipeline modernization and safety and is expected to expand its grant programming to emphasize enhanced positive response.[57] The agency has primarily focused on state enforcement programs, seeking to ensure the parties causing damage are penalized. This has not been combined with significant movement to push the implementation of technology, nor has PHMSA updated its effective elements of damage prevention or reviewed state programs to recommend critical technology or program reforms since 2014.[58]

PHMSA has a number of options at its disposal to improve technology implementation for damage prevention. Similar to NTSB, while the agency's primary authority centers on pipelines, PHMSA recommendations and resources influence the entire damage prevention process, therefore impacting the safety of other underground facilities. To make progress, PHMSA could use incentives, such as prioritizing its grant programs to applicants seeking to develop and deploy electronic white-lining, enhanced positive response, or predictive analytics programs. The agency can also update and refine its effective elements of damage prevention to incorporate consensus technologies, while also reviewing every state to encourage them to implement technology. Finally, PHMSA could take regulatory action to require that certain technologies be used for excavation work near pipelines or set a new higher standard for state certification that requires state damage prevention authorities to issue rules that mandate EWL, EPR, and similar technologies.

Infrastructure Protection Coalition (IPC)
In the last two years, IPC has initiated greater conversation around excavation damage prevention, but it is too soon to see if their efforts will move the needle. Still, the 2021 report by IPC tells us two things: first it reinforces that a consensus truly exists around the need for the implementation of various technologies discussed herein, and second, it tells us that progress is slow as evidenced by the group forming and speaking up in the first place.

Overall, NTSB, CGA, PHMSA, and newcomers like IPC, are some of the leading voices and most authoritative sources on damage prevention in the United States today. Not only do they represent stakeholders from every stage of damage prevention, but they hold the power, authority, and influence to effectuate change. If consensus technologies and best practices are going to be enacted systemically, it is these groups that will drive it.

Recommendations

NTSB
Include the technologies discussed in this paper in the next annual Most Wanted List. Any pipeline accident investigations in the future should investigate the impact EWL, EPR, and predictive analytics might have had in preventing or mitigating the accident.

CGA
Create a new best practice statement for EWL that is distinct from physical white-lining, or at a minimum strengthen the white-lining best practice to primarily emphasize EWL and only point to physical pre-marking if EWL is not available through one-call center. Consider designing a best practice statement around the use of predictive analytics. Implement a certification program for members to receive a badge, dues credit, or some other incentive for implementing key best practices such as electronic white-lining, electronic positive response, enhanced positive response, and predictive analytics. Hold dialogues with relevant members (one-call centers, utilities, locators, and excavators) specifically aimed at leveling barriers and achieving the above listed technologies at a systemic level, while committing to a timeline.

PHMSA

Ensure all grant programs prioritize incorporation of the technologies discussed in this paper. Establish EWL and EPR as minimal enforceable standards through regulatory action or certification. Update the Nine Elements of Effective Damage Prevention and conduct a state-by-state review on the progress of implementation of each technology outlined above.

Conclusion

Damage prevention in the United States includes a range of challenges, yet these challenges also provide immense potential for gains in safety, efficiency, savings, and process improvement from top to bottom. The reforms discussed in this paper are not only possible, but critically needed and eminently implementable. As CGA states, "it is past time to advance the pace of technology adoption, application and integration in U.S. damage prevention."[59]

Because technology is a "primary driver in greater efficiency and improved safety," the goal of improving damage prevention must include getting more technology in actual use.[60] This is a point on which all parties agree. Not only have federal agencies and respected trade organizations found agreement on certain technologies that would reduce excavation damage, but virtually no one is voicing opposition to this consensus. Questions remain about costs or implementation methods, but no organized opposition or criticism exists against electronic white-lining, electronic positive response, enhanced positive response, or predictive analytics. By contrast, these are all highly praised and elevated as the top recommendations in numerous government and private reports.

As PHMSA reports, "Stakeholders generally recommended that future technology be developed to allow a variety of systems and equipment to work together to improve damage prevention programs." But as the literature makes clear, the technology needed to change the game is here already. The time is now to get these implemented nationwide.[61,62] If action is not taken, time will pass, and damages will continue. In fact, in 1997, the NTSB's seminal damage prevention study concluded: "that many essential elements and activities of a one-call notification center have been identified but have not been uniformly implemented."[63] In the intervening 25 years, the damage prevention sector has grown in incredible ways, established deep and effective relationships and consensus, and produced cutting-edge technology and best practices. History does not have to repeat itself, and armed with consensus and proven technology, industry participants and regulators can promote implementation today.

What is needed is a mechanism for implementation that will overcome both "real or perceived barriers to adoption of new technologies."[64] Both private sector groups like CGA and IPC and federal agencies like NTSB and PHMSA have done a lot on paper; but constant research and publishing of best practice guides and technology reports has not achieved needed systemic reform. Member organizations should consider creating incentives for stakeholders to adopt these core technologies. Likewise, PHMSA should orient its grant programs to help facilitate the adoption of these consensus communication technologies and then begin to raise its standards for enforcement to ensure the systemic reforms are taking place. If the private sector continues

failing to bring about full adoption of available technology to reduce damage incidents, PHMSA and state authorities should consider regulating new enforceable minimum standards centered around these key technologies.

Consensus is incredibly valuable. But once it has formed and been so thoroughly validated, action is the only option remaining. We look forward to seeing that action and the improvements in safety, efficiency, and value the damage prevention process will gain in the future.

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About Aii

The Alliance for Innovation and Infrastructure (Aii) is an independent, national research and educational organization that explores the intersection of economics, law, and public policy in the areas of climate, damage prevention, energy, infrastructure, innovation, technology, and transportation.

The Alliance is a think tank consisting of two non-profits: the National Infrastructure Safety Foundation (NISF), a 501(c)(4) social welfare organization, and the Public Institute for Facility Safety (PIFS), a 501(c)(3) educational organization. Both non-profits are legally governed by volunteer boards of directors. These work in conjunction with the Alliance's own volunteer Advisory Council.

Board of Directors

Citations and Notes

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[2] Infrastructure Protection Coalition. (2022). *811 Emergency Reports*. https://www.ipcweb.org/?dt=1658781680088.

[3] National Transportation Safety Board (NTSB). (1997). *Safety Study, Protecting Public Safety Through Excavation Damage Prevention*. https://www.ntsb.gov/safety/safety-studies/Documents/SS9701.pdf p. vi.

[4] Office of Pipeline Safety. (1999). *Common Ground, Study of One-Call Systems and Damage Prevention Best Practices*. U.S. Department of Transportation. https://primis.phmsa.dot.gov/comm/publications/CommonGroundStudy090499.pdf.

[5] The 16 stakeholder groups are: Electric, Emergency Services, Engineering/Design, Equipment Manufacturer, Excavator, Gas Distribution, Gas Transmission, Insurance, Locator, Oil, One-Call, Public Works, Railroad, Road Builder, State Regulator, and Telecommunications. *See*, https://commongroundalliance.com/Membership-Engagement/Membership.

[6] Common Ground Alliance (CGA). (2022). Working Committees. https://commongroundalliance.com/Membership-Engagement/Committees.

[7] Alliance for Innovation and Infrastructure (Aii). (2022). *Excavation Damage to Underground Infrastructure: A Look at the Federal Damage Prevention Approach*. https://www.aii.org/wp-content/uploads/2022/04/A-Look-at-Federal-Damage-Prevention.pdf.

[8] Pipeline and Hazardous Materials Safety Administration. (2019). *Nine Elements of Effective Damage Prevention*. U.S. Department of Transportation. https://primis.phmsa.dot.gov/comm/DamagePrevention9Elements.htm.

[9] *Id*. at p. 4.

[10] *Supra* note 2.

[11] Common Ground Alliance (CGA). (2021). *Technology Report 2021: Technology Advancements & Gaps in Underground Safety*. https://commongroundalliance.com/Portals/0/2021%20Technology%20Report.pdf?ver=2021-05-27-165320-157.

[12] Common Ground Alliance (CGA). (2022). *Technology Report 2022: Technology Advancements & Gaps in Underground Safety*. Volume 5. https://commongroundalliance.com/Portals/0/Tech%20Report-print-final.pdf?ver=2022-07-26-103127-027.

[13] National Transportation Safety Board. (2010). Pipeline Accident Brief. https://www.ntsb.gov/investigations/AccidentReports/Reports/PAB1303.pdf.

[14] Additionally, while to-date only advocating for physical white-lining, NTSB has long stressed the importance of site markings. As far back as 1997, NTSB advocated this critical best practice, which has gone on to serve as the basis for the CGA best practice on white-lining. The agency's emphasis on the importance of pre-marking and on the use of technology strongly reinforce that electronic white-lining is the best practice, although NTSB has not explicitly updated its position on pre-marking in decades.

[15] Common Ground Alliance (CGA). (2022). *Best Practices Version 18.0, Chapter 5 White Lining*. https://bestpractices.commongroundalliance.com/5-Excavation/502-White-Lining.

[16] *Supra* note 11.

[17] Common Ground Alliance (CGA). (2021). *Pathways to Improving U.S. Damage Prevention*. Next Practices Initiative. https://commongroundalliance.com/Portals/0/Next%20practices%20Pathways%20Report%202021_FINAL4.pdf?ver=2021-10-12-180926-957.

[18] Common Ground Alliance (CGA). (2020). *Insights into Improving the Delivery of Accurate, On-Time Locates*. CGA White Paper. https://commongroundalliance.com/Portals/0/Library/2020/White%20Papers/CGA%20Locator%20White%20Paper%20-%20FINAL%2010.21.20.pdf?ver=2020-10-22-131342-877.

[19] *Supra* note 12.

[20] *Id*.

[21] Pipeline and Hazardous Materials Safety Administration (PHMSA). (2017). *A Study on Improving Damage Prevention Technology*. U.S. Department of Transportation. https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/news/18351/reporttocongressonimprovingdamagepreventiontechnologyaug2017.pdf.

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[23] Infrastructure Protection Coalition. (2022). *811 Emergency: $61 Billion Lost to Waste, Inefficiency in System to Protect Underground Utilities*. https://www.ipcweb.org/images/reports/US-RPT.pdf. National Recommendation 10.

[24] *Supra* note 3.

[25] *Supra* note 4.

[26] Common Ground Alliance (CGA). (2022). *Best Practices Version 18.0, Chapter 3, 3.27 Electronic Positive Response*. https://bestpractices.commongroundalliance.com/-3-One-Call-Center/327-Electronic-Positive-Response.

[27] *Supra* note 11.

[28] *Supra* note 8.

[29] *Supra* note 23. National Recommendation 9.

[30] Direct communication with multiple NTSB staff, directors, and board members.

[31] *See* e.g., National Transportation Safety Board (NTSB). (2019). *Pipeline Accident Report, Pacific Gas & Electric Third-Party Line Strike and Fire San Francisco, California*. https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR2102.pdf.

[32] National Transportation Safety Board (NTSB). (1994). *Pipeline Accident Report, UGI Utilities, Inc., Natural Gas Distribution Pipeline Explosion And Fire Allentown, Pennsylvania*. https://www.ntsb.gov/investigations/AccidentReports/Reports/PAR9601.pdf.

[33] Common Ground Alliance (CGA). (2022). *Best Practices Version 18.0, Chapter 3, 3.31 Enhanced Positive Response*. https://bestpractices.commongroundalliance.com/-3-One-Call-Center/327-Electronic-Positive-Response.

[34] Common Ground Alliance (CGA). (2022). *Technology Advancements & Gaps in Underground Safety*. Technology Hub. https://commongroundalliance.com/Publications-Media/Technology-Reports.

[35] *Supra* note 11.

[36] *Supra* note 12.

[37] *Id*.

[38] *Supra* note 21.

[39] Pipeline and Hazardous Material Safety Administration (PHMSA). (2017). *PHMSA Pipeline Safety R&D Forum*. https://primis.phmsa.dot.gov/rd/mtgs/111616/Eric%20Swartley.pdf.

[40] *Supra* note 23.

[41] *Id*.

[42] Common Ground Alliance (CGA). (2021). *Report to the Industry*. Next Practices Initiatives. https://commongroundalliance.com/Portals/0/NextPracticesReportToIndustry_Final_03.01.2021.pdf?ver=2021-03-09-154941-650.

[43] *Id*.

[44] *Supra* note 12.

[45] *Id*.

[46] Robertson, Annmarie. (2017). *PHMSA Damage Prevention Initiatives and Technologies*. U.S. Department of Transportation. https://www.epa.gov/sites/default/files/2017-05/documents/damage_prevention_robertson.pdf.

[47] *Supra* note 8.

[48] Supra note 23.

[49] *Supra* note 12.

[50] Alliance for Innovation and Infrastructure (Aii). (2022). *Federal Damage Prevention Overview*. https://www.aii.org/wp-content/uploads/2022/04/Federal-Damage-Prevention-Overview.pdf.

[51] National Transportation Safety Board (NTSB). (2022). *Most Wanted List Archive*. https://www.ntsb.gov/Advocacy/mwl/Pages/mwl_archive.aspx.

[52] *Supra* note 18.

[53] *Id*.

[54] *Supra* note 1.

[55] One such barrier is state legislation, "Many one call centers, in cooperation with their facility owner members, have tried to leverage predictive analytics and other technologies to provide excavators with a realistic timeframe for marking or try to normalize demand – but state laws are almost always a barrier to stakeholder efforts to add flexibility into the process." Next Practice Status."

[56] *Supra* note 12.

[57] U.S. Congress. (2022). *Explanatory Statement for The Department of Transportation and Housing and Urban Development, and Related Agencies Appropriations Bill*. United States Senate Committee on Appropriations. https://www.appropriations.senate.gov/imo/media/doc/THUDREPT_FINAL2.PDF. P. 91.

[58] Pipeline and Hazardous Materials Safety Administration (PHMSA). (2019). *Characterization of State Damage Prevention Programs*. U.S. Department of Transportation. https://primis.phmsa.dot.gov/comm/sdppcdiscussion.htm.

[59] *Supra* note 12.

[60] Supra note 11. p. 6.

[61] Alliance for Innovation and Infrastructure (Aii). (2020). *Its Time for Nationwide Adoption of Enhanced Positive Response*. https://www.aii.org/time-nationwide-adoption-enhanced-positive-response/.

[62] Alliance for Innovation and Infrastructure (Aii). (2022). *Its Time for Nationwide Adoption of Electronic White-Lining*. https://www.aii.org/its-time-for-nationwide-adoption-of-electronic-white-lining/.

[63] *Supra* note 3. p. 20.

[64] *Supra* note 12.

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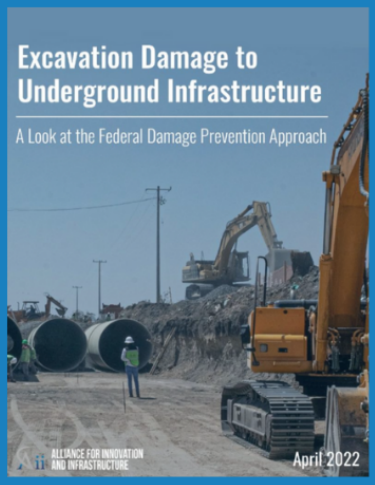

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