Improving Damage Prevention and Infrastructure Resilience:

Utilizing Existing Infrastructure and Technology for Proactive Real-Time Monitoring

Introduction

Damage to underground infrastructure remains a critical challenge in the United States. Many strategies are being discussed at conferences and piloted in the field to tackle the issue, from improving state laws to spreading awareness.[1] However, the fact remains that damages to underground infrastructure cost the nation $50 billion to $100 billion every year.[2] One of the leading causes is failure to engage in the damage prevention system by notifying 811 ahead of excavation work. This "no call" damage, means infrastructure owners and operators lack awareness of potentially risky excavation work around their assets.

Recent advancements in some of the very infrastructure assets commonly struck by excavation work demonstrate an opportunity for practical solutions in damage prevention. Distributed Fiber Optic Sensing (DFOS) is one of these emerging technologies and can become an important tool for real-time monitoring of specific utilities and rights-of-way containing more than one utility.

Fiber Optic Sensing

Fiber optic cable is often found in buried conduits, which can contain multiple pipes, cables, and wires. Fiber now forms the backbone of the telecommunications network, connecting homes and businesses to the data centers that host the internet, largely replacing copper wire. Optical fibers are essentially long strands of ultra-pure glass. Infrared light signals pulse through the fibers within a cable to deliver data and internet. Within one cable, the fiber count may range from dozens to even thousands of optical fibers. These fibers transmit data in a single direction from end to end, fulfilling a singular purpose. With the same technology, however, a single fiber can enable multi-use applications. One fiber within a cable can detect its surroundings to produce additional valuable insights. In other cases, specialized sensing fibers can be inserted into buried conduits to provide support of applications requiring higher sensing performance.

DFOS converts the fiber into an array of thousands of sensing points for every mile along its path. A small device attached to the end of a fiber optic cable can be used to capture reflections from laser pulses to precisely measure vibrations, strain, and temperature changes along the cable.[3, 4] These disruptions would otherwise be considered noise, but proven technology and algorithms are increasingly extracting learnings from them.

As a distributed infrastructure solution, fiber optics can not only measure that these disruptions are occurring but pinpoint the origin anywhere along the line across 60 miles or more.[5] The technology can even classify the source of the disruption through categorization. This enables asset owners/operators, local governments, transportation departments, researchers, and more to remotely discern anything from earthquakes to traffic patterns, excavation work to manhole cover openings, and more with a high degree of confidence.

These capabilities mean that existing fiber optic or specialized fiber cable can become a continuous sensor that accurately measures external events anywhere along itself and the immediate location adjacent to the fiber path. A network of these fibers can provide continuous real-time coverage for threats and disruptions. Advanced algorithms differentiate between routine ground movements, like road traffic, and actual threats, like unplanned excavation.

One of the most considerable advantages of fiber optic cable is its ability to integrate seamlessly into existing fiber-optic and conduit infrastructure. Because cables can contain many individual fibers, there are opportunities to "turn on" this technology even in existing infrastructure.

"Dark" fibers that do not currently have any telecommunications running through them can be utilized as fiber optic sensors by installing an interrogator at one end of the fiber. There are frequently dark fibers or conduit space for specialized fibers available along main infrastructure corridors, where optical fiber can be used most effectively and help measure and protect many different utilities simultaneously.[6, 7]

Fiber Optic Sensing in Damage Prevention

Fiber optic sensors have significant potential in utility and structural applications, measuring structural health and corrosion, particularly in new infrastructure.[8] It can also be used in railways to track trains and monitor wear in metro systems, enhancing safety further. Some companies in the oil and gas industry have embraced fiber optic sensors to monitor temperature fluctuations, track inline inspection tools, and detect geotechnical activity or leaks in pipelines.[9] Fiber optic sensors are also capable of enhancing security, alerting illegal valve activity on pipelines, and detecting facility incursions like "hot tapping" of pipelines.[10]

While DFOS enhances pipeline protection, its applications in damage prevention extend beyond pipelines. Fiber optic lines are themselves a facility that is often damaged in excavations, making up almost half of all facilities damaged in 2023.[11] By using a single fiber as a sensor, excavation activity can be precisely detected and alerted before a line is accidentally damaged. By automatically pinpointing exact locations of potential threats in real time, DFOS minimizes response time and decreases risk of serious incidents. This is particularly useful for preventing damage when excavators fail to notify an 811 center before digging.

Lone Star DFOS Highlight

The Texas811 call center is currently exploring DFOS technology, using it to prevent damage alongside infrastructure corridors, where fiber optic cable is already installed. They explain:

> The Fiber Optic Sensing software detects unique vibration signatures near a protected underground facility that it recognizes as excavation activity and sends a notification to Texas811 regarding the detected excavation activity.
>
> The notification is compared to the Texas811 ticket database to determine if there is an active one-call at the location of the detected excavation activity. If there is an active one-call ticket, no further action is taken. [Now Texas811 and asset owners have situational awareness]
>
> If there is not an active one-call ticket, Texas811 sends an alert to the facility operator notifying them of unauthorized excavation activity near their protected underground facility.

The alert is sent electronically or verbally to the facility operator including the type of excavation, manual or mechanical, as well as GPS coordinates of the detected activity.

The facility operator responds to the excavation site to intervene before damage occurs.[12]

This type of system can be deployed with other call centers and help reduce damages. No-call damages currently make up more than 25 percent of all facility damages according to the Common Ground Alliance, the largest single cause.[13]

Technological Approach

DFOS is one of several technological advancements in damage prevention, alongside enhanced positive response and electronic white-lining, enabling a more robust, comprehensive approach. Ideally, improvements in damage prevention also come from policy, education, and technology together, but fiber optic sensing represents a cost-effective, problem-solving innovation for damage prevention. DFOS becomes even more effective when paired with other technological advancements like Artificial Intelligence (AI). AI is already being used in many DFOS systems to more effectively categorize data, leading to fewer false positive alerts and enhanced insight.[14] Drones or other verification technologies can easily be paired with DFOS to increase efficiency, improve safety outcomes, and reduce human workload and associated risks.

Policy Recommendations and Conclusion

Policymakers should consider encouraging DFOS adoption in damage prevention, providing incentives for pipeline operators and other utilities to integrate existing or newly installed fiber optics into monitoring systems. Given its multi-benefit uses and cost-effectiveness, fiber optic sensor installation should be considered for future base-line standards safety practice for new pipeline construction. This could be considered by the Pipeline and Hazardous Materials Safety Administration or state-level agencies for rulemaking or grant programs. In addition to its multi-use functionality of transmitting data and serving as a continuous distributed sensor, another dimension of multi-use is that the same fiber can protect other assets in the same right-of-way, concurrently serving electric, gas, and water infrastructure for early identification of leaks, preventative maintenance, damage prevention, and enhanced life safety.

Although technology is continuously improving, DFOS technology is already preventing damage and is a lower-cost alternative to other sensor technology. Developing coordination platforms and integrating DFOS data into call center practices should also be encouraged to maximize effectiveness. Damage prevention One-Call centers can run pilot programs to gain an understanding of the technology and realize its benefits, as Texas 811 has done. Adoption of new technology can be challenging but ultimately will lead to less damage and enhanced safety.

Distributed Fiber Optic Sensing represents a transformative and additive opportunity in damage prevention. By enabling real-time monitoring of utilities and structural integrity of infrastructure, DFOS can significantly reduce immediate damage but also enable preventative maintenance. Texas 811 is working with utility member companies for fiber optic sensors deployment, providing a model for nationwide adoption. Damage prevention stakeholders and policymakers should take proactive steps towards learning about and adopting this innovative technology.

Citations and Notes

---

[1] Dierker, B. & Rogers, O. (September 2024). *2024 Damage Prevention Report Card: Tracking innovation in state dig laws to promote communication and collaboration among stakeholders*. Alliance for Innovation and Infrastructure. Aii.org.

[2] Zeiss, G., & Shinoaki, S. (2020, August 6). *Reducing Damage to Underground Utility Infrastructure during Excavation*. https://gita.memberclicks.net/assets/FINAL White paper_ Reducing Damage to Underground Utility Infrastructure during Excavation V5-2-2.pdf.

[3] Known as a data acquisition system, sometimes called an interrogator.

[4] Interrogators have negligible power needs, while no electricity is needed for the sensing cable. This technology also has virtually no maintenance requirements, making it more practical than installing cameras or dozens of electronic sensors which necessitate both calibration and replacement.

[5] Patel, P. (2023, August 14). *Fiber-Optic Cables Are Natural Earthquake Detectors*. IEEE Spectrum. https://spectrum.ieee.org/earthquake.

[6] Fiber Optic Sensing Association. (2023, March). *Comment of the Fiber Optic Sensing Association: NTIA broadband programs* [Public comment]. Retrieved from https://fiberopticsensing.org/wp-content/uploads/sites/2/2023/03/FOSA-NTIA-BB-comment_.pdf.

[7] Where dark fiber may not be present, utilities may choose to place conduit and optical fiber adjacent to the new utility infrastructure for this specific purpose. Open conduit slots can also help provide for growth and future technology integration where existing need is not identified today.

[8] Bado, M. F., & Casas, J. R. (2021). A review of recent distributed optical fiber sensors applications for Civil Engineering Structural Health Monitoring. *Sensors*, *21*(5), 1818. https://doi.org/10.3390/s21051818.

[9] Islam Ashry, Yuan Mao, Biwei Wang, Frode Hveding, Ahmed Y. Bukhamsin, Tien Khee Ng, & Boon S. Ooi. (2022). A Review of Distributed Fiber–Optic Sensing in the Oil and Gas Industry. *J. Lightwave Technol.* 40, 1407-1431. https://opg.optica.org/jlt/abstract.cfm?uri=jlt-40-5-1407.

[10] Hines, M. (2019). *Fiber Optic Sensing for Pipeline Leak and Damage Prevention*. North Dakota Public Service Commission. https://psc.nd.gov/jurisdiction/pipelines/docs/2019%20Pipeline%20Safety%20Seminar/FOSA-NDSD-Pipeline-Safety-04032019.pdf.

[11] Common Ground Alliance. (2024, October). *2023 DIRT Report*. Common Ground Alliance. https://dirt.commongroundalliance.com/.

[12] Texas 811. (2025). *How Fiber Optic Sensing Works*. Texas 811. https://texas811.org/how-fiber-optic-sensing-works.

[13] Common Ground Alliance. (2024, October). *2023 DIRT Report*. Common Ground Alliance. https://dirt.commongroundalliance.com/.

[14] Venketeswaran, A., Lalam, N., Wuenschell, J., Ohodnicki, P. R., Badar, M., Chen, K. P., Lu, P., Duan, Y., Chorpening, B., & Buric, M. (2021). Recent advances in machine learning for fiber optic sensor applications. *Advanced Intelligent Systems*, *4*(1). https://doi.org/10.1002/aisy.202100067.

Author

Benjamin Dierker, JD, MPA
Executive Director, Alliance for Innovation and Infrastructure
Owen Rogers
Public Policy Associate, Alliance for Innovation and Infrastructure

For more information or inquiries on this report, please contact the Aii Media Coordinator at info@aii.org

Recommended Citation for this report

Dierker, B. & Rogers, O. (March, 2025). *Improving Damage Prevention and Infrastructure Resilience: Utilizing Existing Infrastructure and Technology for Proactive Real-Time Monitoring*. Alliance for Innovation and Infrastructure. Aii.org.

About Aii

The Alliance for Innovation and Infrastructure (Aii) is an independent, national research and educational organization working to advance innovation across industry and public policy. The only nationwide public policy think tank dedicated to infrastructure, Aii explores the intersection of economics, law, and public policy in the areas of climate, damage prevention, eminent domain, energy, infrastructure, innovation, technology, and transportation.

Aii 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 Aii's own volunteer Advisory Council.

Board of Directors