Fiber Optic Sensing Association
Connect and Protect

Utilizing Distributed Fiber Optic Sensing to Improve Safety, Reduce Delays, and Cut Costs on Railroads

This paper contains four sections outlining how distributed fiber optic sensing (DFOS) can be used to improve safety and reliability, increase capacity, reduce delays, and cut costs on railroads in the United States. The first section explains the technology behind DFOS; the second section explains the challenges facing the passenger and freight railroad industries in the United States; the third section explains how DFOS can provide solutions to address these challenges; and the fourth section outlines recommendations for Congress and the Executive Branch.

I. What is Distributed Fiber Optic Sensing (DFOS)?

Distributed fiber optic sensing (DFOS) systems are sensor technologies used around the world to constantly and consistently monitor railways, roads, bridges, pipelines, power stations, terrestrial and subsea power cables, international borders, critical infrastructure, and telecom networks. DFOS systems connect laser interrogator units (IUs) to a fiber optic cable converting the optical fiber to an array of distributed sensors. The fiber becomes the sensor when the interrogator units inject laser light into the fiber to detect events along the fiber over very long distances.

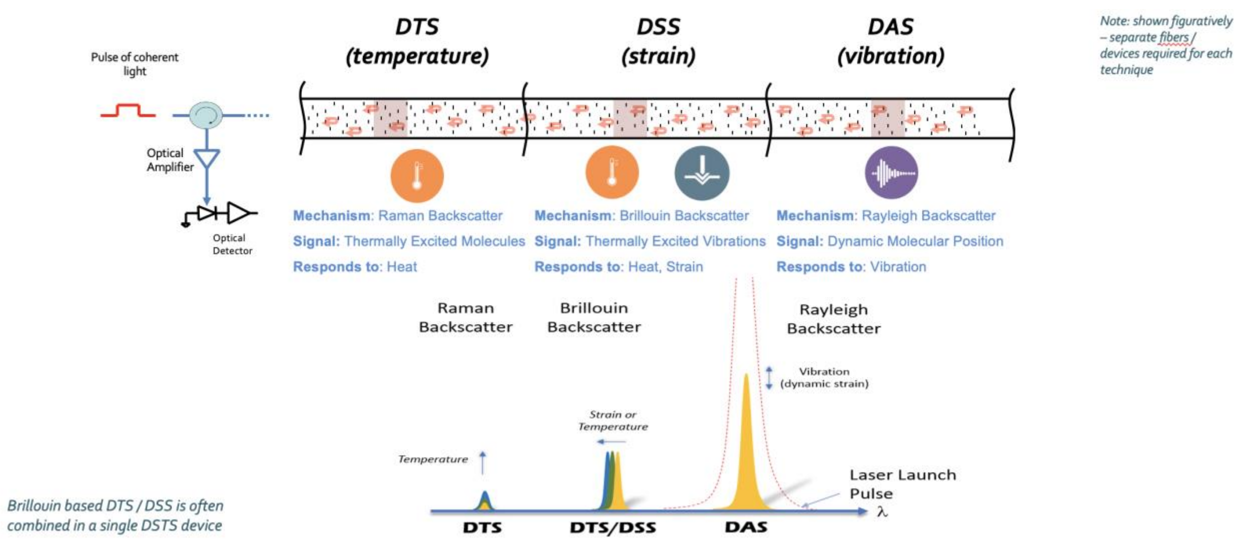
More specifically, DFOS systems consist of a fiber optic cable, IUs, and intelligent monitoring software. The IU pulses light up to 10,000 times/second down the fiber optic cable. Changes in vibrations/acoustics, temperature, or strain at or near the fiber optic cable are identified and classified in real time by intelligent monitoring software, which then alerts the operator of the system with what the disturbance is and precisely where it is located. These technologies can span hundreds of miles and provide real-time readings at up to three-foot (one meter) intervals along the entire span. Tighter spatial resolution of less than one meter (~ three feet) is also possible but often viewed as unnecessary.

There are three basic types of DFOS systems:

1. **Distributed Acoustic Sensing (DAS)**
   DAS systems convert fiber optic cable into a series of thousands of sensitive microphones or vibration sensing locations. Using specially developed algorithms it is possible to listen to, track, detect, and pinpoint various activities and events along assets, including vehicle and foot traffic, digging, excavation, tunneling, seismic activity, rock falls, anchoring of ships, and landslides. DAS can also be used for asset condition monitoring by detecting events such as cable faults, broken rails, damaged rolling stock, pipeline liquid and gas leaks, and much more.
2. **Distributed Temperature Sensing (DTS)**
   DTS is a fiber-optic sensing technology for measuring temperature profiles along fiber-optic sensor cables installed near linear assets as well as on two- or three-

dimensional objects. Major applications of DTS are power cable and overhead line temperature monitoring; fire detection in fuel storage facilities, tunnels and buildings; monitoring of industrial equipment such as ovens and reactors and oil and gas in-well production, as well as leak detection at pipelines and storage tanks.

3. **Distributed Strain Sensing (DSS)**
   DSS is a fiber optic sensing technology that measures changes in strain at any point along the length of a fiber optic cable. DSS is commonly used for monitoring large structures, where changes in strain may be indicative of an impending failure. Aging and modern infrastructure like power cables, pipelines, dams, levees, bridges, tunnels, and roadways are all assets that can benefit from DSS monitoring. Similarly, industrial process monitoring, as well as pipeline deformations, tunneling, subsidence, and landslides can be detected by DSS measurements.



DFOS technology is not constrained by line of sight or remote power access, and can be deployed in continuous lengths over hundreds of miles with detection at every point along its path. Electricity is only required to power the interrogator equipment at one end of the system while the fiber optic cable installed along the assets to be monitored is completely passive, requiring no electricity and is immune to the effects of radio frequency and electromagnetic interference. The technology commonly uses existing, underutilized (dark) telecommunication fibers. Oftentimes and preferably, the fiber cable used is located within conduit pathways which enable rapid and easy repairs to the fiber cable if required, in addition to possibly desired future fiber cable additions or replacement.

II. Rail Safety and Capacity Challenges in the United States

The U.S. freight rail network is comprised of nearly 140,000 miles of track and over 100,000 bridges and is responsible for moving more than 40% of U.S. freight every year (nearly 2 billion tons of goods). Passenger rail (Amtrak) operates a 21,356-mile network in over 500 communities and carried 12.2 million passengers in 2021 (record 32.5 million passengers in 2019).

While the U.S. rail network is widely considered the largest, safest, and most cost-efficient freight system in the world, in 2021 there were 9,251 passenger and freight rail accidents, 2,145 highway-rail grade crossing collisions, and 1,121 pedestrian rail trespass casualties (fatalities + injuries).

These accidents and casualties are attributed to the more than 211,000 at-grade crossings in the United States, numerous trespassers on railroad rights-of-way, aging infrastructure and equipment (average age of North American freight rail cars was 19.8 years in 2021), longer freight trains (some of which are nearly 3 miles long), and rail defect and catastrophic rail failure in Class II track.

III. How Can DFOS Help Solve These Challenges?

A DAS system can enhance safety and support predictive maintenance needs in the railroad industry by continuously monitoring the condition of rail, track, and rolling stock. The system can also detect and accurately locate unauthorized persons and falling objects on the tracks, alerting operators of intrusions, vandalism, and cable thefts. A DTS system offers continuous temperature monitoring for heat/fire detection and location within cable ducts and cable trays, and inside train stations.

A 2018 study into the potential benefits of DFOS, performed by the Transportation Technology Center entitled *Fiber Optic Availability and Opportunity Analysis for North American Railroads* identified multiple "priority applications" for the deployment of fiber optic sensing technology – broken rail detection, train tracking, monitoring equipment health and track integrity, fire detection in cable ducts, and security and detection of people or other objects on the tracks.

A DAS rail monitoring system also provides intelligent automated traffic management enabling actively controlled and automated train operation that minimizes delays and increases capacity of the rail system - more trains can be run safely at a higher density with minimized train separation. Costs are reduced by utilizing energy more efficiently through minimized brake/acceleration cycles, and a potential future benefit of decreasing signaling infrastructure. In addition, a range of real-time travel information is possible.

And the data from a DAS system provides information on the condition of vehicles and routes, as well as wear and tear over time. This provides the ability to conduct preventative and predictive maintenance, minimizing unscheduled service disruptions.

IV. FOSA Recommendations

The United States currently trails Europe and China in deployment of fiber optic sensors to monitor railroad infrastructure. To encourage the increased implementation of DFOS systems to monitor U.S. railroad infrastructure, FOSA supports the following initiatives:

- Prioritization of multi-use for broadband deployment so that fiber can also be used for sensing at railway-highway grade crossings to reduce pedestrian fatalities and injuries, detecting third-party intrusions at grade crossings and along railroad rights-of-way, and continuously monitoring railway track infrastructure to identify track defects.
- Encourage eligible FRA Consolidated Rail Infrastructure and Safety Improvements (CRISI) grant recipients to incorporate real-time sensing technology to detect third-party intrusions and track defects.
- Future development and testing activity by ENSCO at the Transportation Technology Center (TTC) to address:
  - Optimization of track side security
  - Improving worker safety
  - Reducing the number and severity of derailments
  - Development of optimal DFOS installation techniques
  - Leveraging of existing fiber networks near railways (including addressing barriers to using non-railroad owned fiber optic cable along rail rights-a-way)
  - Cost benefit analysis to evaluate alternative safety technologies

About the Fiber Optic Sensing Association (FOSA)

The Fiber Optic Sensing Association (FOSA) is a non-profit organization composed of organizations that manufacture, install, test, evaluate, support or use fiber optic sensing systems and equipment. FOSA's mission is to educate industry, government, and the public on the benefits of fiber optic sensing and how it can be used to secure critical facilities, enhance public safety, and protect the environment.