Utilizing Distributed Fiber Optic Sensing to Provide Cost-Effective Operational Advantage Along the Northern and Southern U.S. Borders

This paper contains four sections outlining how distributed fiber optic sensing (DFOS) can be used to achieve operational advantage of the northern and southern borders of the United States. The first section explains the technology behind DFOS; the second section explains challenges facing the United States along the northern and southern borders; the third section explains how DFOS can provide solutions to 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 international borders, critical infrastructure, power stations, telecom networks, railways, roads, bridges, terrestrial and subsea power cables and pipelines. DFOS systems connect opto-electronic interrogator units (IUs) to an optical fiber (or cable containing optical fiber), converting the optical fiber into an array of distributed sensors. The fiber becomes the sensor when the IUs 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 thousands of times per second down the fiber optic cable. Some of this light is scattered by the glass back towards the interrogator. Changes in vibrations/acoustics, temperature, or strain in the vicinity of the fiber optic cable modulate this backscattered light. These changes can be identified and classified in real time by intelligent monitoring software, which then alerts the operator of the system to the nature of the disturbance and precisely where it is located (better than 10m location accuracy over hundreds of miles).

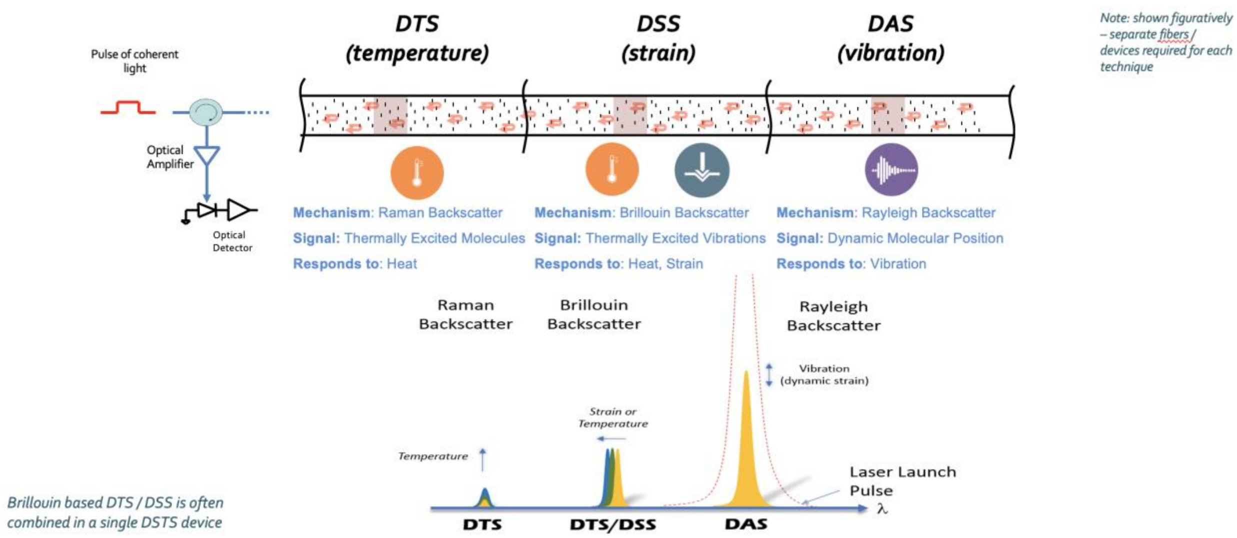
There are three basic types of DFOS systems:

1. Distributed Acoustic/Vibration Sensing (DAS/DVS)
   DAS systems turn fiber optic cable into a series of thousands of sensitive microphones or vibration sensing devices. 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. It can also be used for asset condition monitoring by detecting events such as cable faults, pipeline liquid and gas leaks or broken rails, damaged rolling stock, 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 fire detection in fuel storage

facilities, tunnels and buildings, power cable and overhead line temperature monitoring, 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.

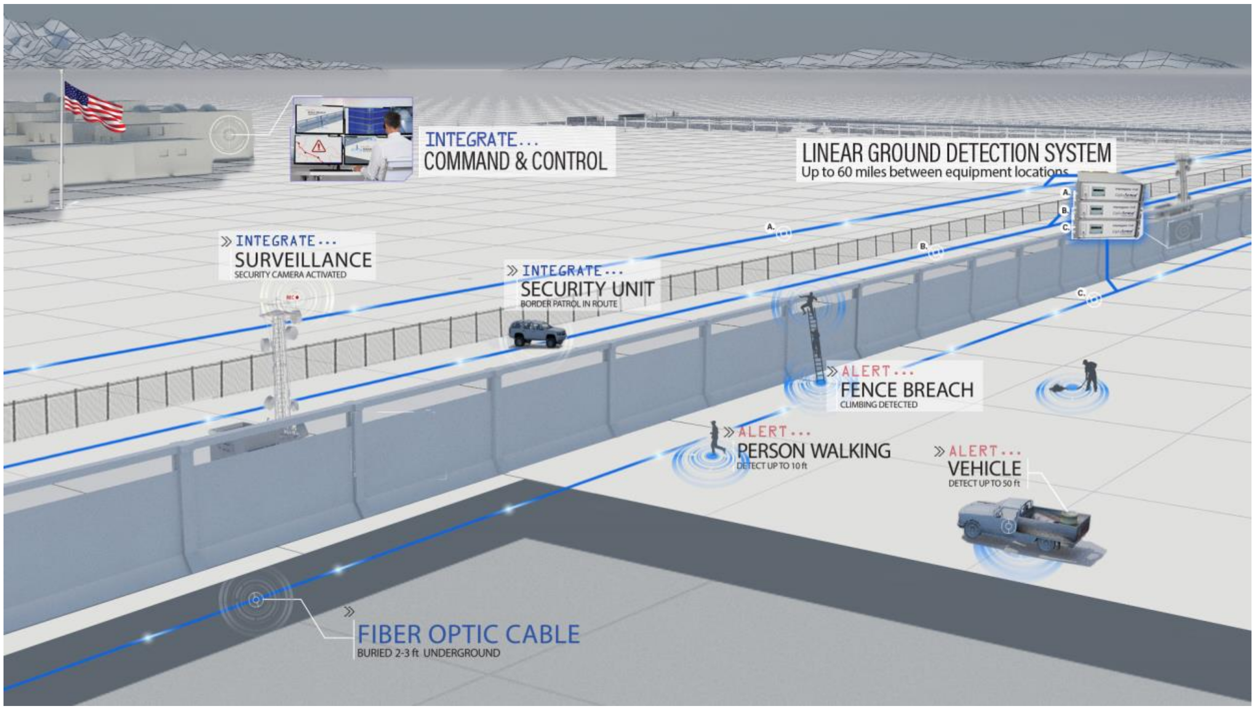
3. Distributed Strain Sensing (DSS)
   DSS is a fiber optic sensing technology that measures changes in strain at any point along the length of a fiber optic cable. DSS is commonly used for monitoring large structures, where changes in strain may be indicative of an impending failure. Aging and modern infrastructure like pipelines, dams, levees, bridges, tunnels, roadways, and power cables 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.



For the purpose of this brief, we focus on DAS systems, which provide detection of surface crossings and tunnel activity in a reliable, low-cost way. The first step is to attach fiber optic cable to a border barrier or to bury cable along a stretch of the border. IUs then are connected to the cable. Each IU can monitor the cable up to 30 miles laterally in both directions, for a total span of 60 miles. Adding an IU every 60 miles can extend the monitored distance hundreds, even thousands, of miles. The entire length of the cable is a fully distributed sensor with spatial resolution as small as 3 feet for continuous monitoring of the border on a 24/7 basis. Power and communications services are needed only every 60 miles. A DAS system reliably detects a variety of border threats with very few nuisance alarms. It can work in concert with existing border surveillance technologies (e.g. by cueing cameras) to provide security personnel a new benefit in fighting trans-border crime.

DAS systems are resilient. With an IU connected to each end of the cable, in the event that a fiber optic cable is inadvertently cut, the remaining spans will continue to function.

In the case of deliberate cable tampering, such as cutting, these systems immediately pinpoint where the cut is occurring so that intervention and repair can occur without time-consuming, costly searches.



DFOS technology is not constrained by line of sight, allowing monitoring capacity in locations or conditions where cameras are constrained. Electricity is only required to power the interrogator equipment while the fiber optic cable installed along the border is completely passive, requiring no electricity and is immune to the effects of radio frequency and electromagnetic interference. The technology can easily operate on unused (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. Northern and Southern Border Security Challenges in the United States

Southern Border

The southwest border is approximately 1,933 miles. The Secretary of Homeland Security is mandated to achieve and maintain operational advantage over this entire land border as well as the maritime borders of the United States. Securing this border against illegal immigration, human trafficking, smuggling of drugs and other contraband, and terrorist activities is a key part of the Department of Homeland Security's (DHS) mission.

U.S. Customs and Border Protection (CBP) has relied on the construction of physical barriers along the southern border to achieve operational advantage. The **border wall system** consists of 18’-30’ tall steel bollard walls, all-weather roads, enforcement zone gates, three-phase power distribution systems, lighting and all necessary supports, enforcement cameras, closed-circuit TV, **fiber optic cables and linear ground detection systems (LGDS),** and electronic equipment and fiber optic shelters.

There are many daunting challenges for building a physical barrier along much of the southwest border including private-property rights, Native American reservations, floodplains, topography, and the terrain and geography, including the Rio Grande River and its changing course, sand dunes, mountains, canyons, and deserts with extremely harsh conditions.

Northern Border

The U.S.-Canadian border is 5,525 miles (3,987 miles excluding Alaska) and is the longest common non-militarized border between two countries. Approximately 2,400 miles of the northern border consist of waterways, the Great Lakes system, and the Strait of Juan de Fuca.

Safeguarding and securing the Northern Border presents its own unique challenges. The most common threat to U.S. public safety along the Northern Border continues to be the bi-directional flow of illicit drugs. Transnational criminal organizations (TCOs) are active along the border and they continually adapt their drug production, smuggling methods, and routes to avoid detection by U.S. and Canadian law enforcement.

Since CBP’s priority has been to secure the U.S.-Mexico border, staffing and resource challenges limit its enforcement activities along the U.S.-Canada border. Topography, terrain, weather, distance, high-density recreational boating traffic, and the large volume of legitimate travel between the U.S. and Canada present additional detection and interdiction challenges along the northern border.

DHS last issued a “Northern Border Strategy” in 2018. FOSA believes, given the challenges stated above, that an updated strategy document including the viability of DFOS and LGDS solutions is necessary to understand current and future northern border security vulnerabilities.

III. How Can DFOS Solve These Challenges?

Technologies like DAS reduce the strains on Border Patrol manpower while vastly improving situational awareness along the northern and southern borders as well as in littoral zones near the borders. A stand-alone DAS system is able to monitor large physical areas with timely, tight spatial resolution under variable and extreme environmental conditions. These systems can detect, classify, and localize multiple targets simultaneously and covertly. They are capable of detecting tunnel, surface, and airborne activity in real-time with high accuracy and low false positives at a fraction of the cost of a physical barrier. They can also be made interoperable with other CBP systems, providing Border Patrol with increased situational awareness along the borders. With only the fiber optic cable in the field as the sensor, this technology is renowned for reliability with systems continuing to operate with little maintenance for decades.

DAS systems are well-suited for varying terrains and vegetation densities was well as environmental operating conditions (e.g. freezing or hot temperatures, heavy snowfall). They can be used in areas where the terrain is flat, rolling, or rugged, with no detection or reliance on line-of-sight. They are capable of monitoring remote deserts, areas with dense vegetation, marshlands, and along natural barriers like the Rio Grande river. Since the system consists of a buried fiber optic cable and an IU, they could be a minimally invasive solution to monitor privately-owned land along the border without resorting to eminent domain. Such systems are easily integrated with existing infrastructure such as walls and fences or where significant infrastructure is not desired or practical, a buried system can provide invisible persistent sensing of human presence and movement.

DAS technology lends itself to two main concepts of operation that can provide significant value and efficiency to Border Patrol's overall approach to securing the border:

1. Immediate threat identification and rapid reaction to activity in urban areas and fast response interdiction or investigation (particularly in the case of tunneling).
2. Situational awareness in remote areas, understanding pattern of life activity, and cost-effectively understanding where hot spots or lone or small group activity may be developing, queuing other technologies or patrols to specific locations with immediacy.

No single technology "does it all," but fiber optic sensing lends itself to easy integration for a holistic approach to technology and personnel management as a continuous sensor providing early warning and situational awareness over long distances and in varying terrains.

IV. FOSA Recommendations

FOSA supports CBP's goal of achieving and maintaining operational advantage of the U.S. northern and southern borders and believes that the following actions can help CBP reach that goal:

- Require DHS to develop and regularly update a technology strategy for achieving and maintaining operational advantage of the southern border, as well as a plan for bridging the gaps. Require DHS to solicit input from industry for the technology strategy.
- Require DHS to develop and implement a northern border strategy implementation plan that identifies actions to address gaps in capabilities to secure the northern border between ports of entry including the use of sensor

technology in locations where full-time deployment of enforcement personnel is not practical.

- Funding and language in the FY2024 Homeland Security Appropriations bill to deploy DAS technologies in areas on the northern and southern borders, including pilot programs to test the use of:
    - DAS as a stand-alone solution on the southern border in an environment not suitable for physical barriers or on privately-owned land in lieu of eminent domain.
    - DAS on the northern border as a solution that can operate during adverse weather conditions such as freezing temperatures and heavy snowfall.
    - DAS along a littoral environment on the northern border as a solution for detecting illegal smuggling across lakes, straits, and rivers.
- Provide best value for the federal government by requiring DHS to employ full and open competitions for acquiring border security technology.

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.