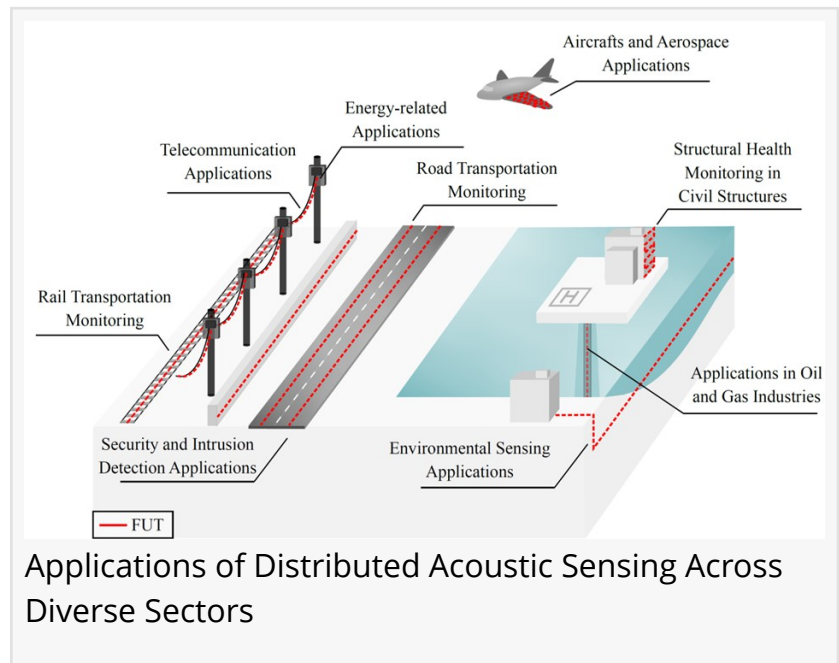


Comprehensive Review of Distributed Acoustic Sensing

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-- Distributed Acoustic Sensing (DAS) transforms optical fiber cables into dense networks of virtual sensors for long-range monitoring. A comprehensive review examines DAS technologies, signal processing methods, challenges, and applications spanning geophysics, infrastructure, transportation, energy, environmental monitoring, security, and aerospace. Advances in photonics, artificial intelligence, and data standardization could improve sensing range, resolution, affordability, and portability, expanding DAS into emerging civilian applications such as healthcare wearables and smart cities.



This paper provides a comprehensive review of Distributed Acoustic Sensing (DAS), a technology that enables standard optical fiber cables to function as dense arrays of virtual sensors distributed along their length. By continuously monitoring vibrations, acoustic waves, and dynamic strain, DAS systems generate spatiotemporal data that can detect, locate, and characterize events over distances ranging from tens to hundreds of kilometers across diverse applications.

The authors examine the main DAS technologies currently in use, including their operating principles, system configurations, signal processing methods, market trends, commercial solutions, recent research developments, challenges, and future directions. The review highlights the rapid growth of the optical fiber sensing market and the increasing importance of DAS, with the global market expected to reach USD 7.8 billion by 2030. The review was published in [Opto-Electronic Advances](#) on July 09, 2026.

The paper focuses on two major sensing approaches: Optical Frequency Domain Reflectometry (OFDR) and Optical Time Domain Reflectometry (OTDR), along with DAS architectures derived from them. OFDR provides extremely high spatial resolution, often at the millimeter or centimeter level, making it suitable for detailed structural monitoring. However, it has a shorter sensing range and lower dynamic bandwidth. In contrast, phase-sensitive OTDR (φ -OTDR), which forms the basis of most commercial DAS systems, supports long-range monitoring over tens of kilometers while maintaining high sensitivity to vibrations and acoustic events.

DAS systems use various signal processing techniques to extract meaningful information from measured signals. These include the Hilbert transform and IQ demodulation for phase retrieval, as well as phase differentiation and phase unwrapping algorithms. However, current DAS systems face several challenges, including difficulty separating strain and temperature effects, signal fading caused by Rayleigh backscattering interference, laser phase noise, and hardware limitations. Proposed solutions include frequency-, polarization-, and space-division multiplexing, dual-pulse interrogation, pulse compression, and improved noise-compensation methods.

DAS has applications across numerous fields. In geophysics, it supports earthquake detection, subsurface imaging, volcanic monitoring, and observation of extreme environments such as glaciers and avalanches. In civil engineering, DAS enables structural health monitoring by detecting small deformations, stress concentrations, and material fatigue in bridges, tunnels, buried infrastructure, and wind turbines. In transportation, it can monitor train movements and rail integrity while also supporting traffic-flow analysis, vehicle classification, and passenger-occupancy monitoring.

The oil and gas industry uses DAS for well-integrity diagnostics, vertical seismic profiling, multiphase-flow monitoring, and detecting leaks or sand ingress in pipelines. Environmental applications include monitoring groundwater fluctuations, landslides, subseafloor conditions, and marine ecosystems. DAS can passively track whale vocalizations across large ocean areas without disturbing marine life. The technology also supports perimeter security by detecting and locating activities such as footsteps and digging. In aerospace, DAS can monitor airport ground traffic, detect low-flying drones, assess aircraft structural flutter in real time, and capture sonic booms from spacecraft re-entering the atmosphere.

DAS can contribute to public safety and quality of life by enabling early detection of infrastructure damage, natural hazards, and pipeline leaks. Continuous monitoring of bridges, tunnels, and other structures can support preventive maintenance and reduce accident risks, while earthquake, landslide, and avalanche monitoring can improve disaster preparedness. In marine environments, DAS can support wildlife conservation, and its ability to detect unauthorized activities can strengthen the protection of sensitive facilities and critical infrastructure.

Future advances in integrated photonics, optical hardware, signal processing, and artificial intelligence are expected to improve DAS portability, spatial resolution, affordability, and data

interpretation. Silicon photonics could enable smaller and more cost-effective interrogators, while improved optical configurations and processing methods may extend sensing range and enhance signal quality. Standardized data formats, performance metrics, and publicly available datasets could also improve the reliability of machine learning models and facilitate comparisons between DAS systems.

As DAS becomes more compact, affordable, and accessible, its applications could expand beyond large-scale industrial and infrastructure monitoring. Emerging civilian uses may include healthcare wearables for remote patient monitoring, smart flooring for movement and fall detection, portable security systems, and smart-city applications. Together, these developments could establish DAS as a versatile and cost-effective sensing technology capable of replacing or complementing conventional electronic sensors across an increasingly broad range of applications.

Reference

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Prof. Arnaldo Leal-Junior is a researcher at the Federal University of Espírito Santo (UFES), Brazil, where he leads a multidisciplinary research group based at the LabSensores laboratory. His research focuses on optical sensing, fiber-optic technologies, distributed sensing, and advanced interrogation techniques, with applications in healthcare, biomechanics, infrastructure, and industry. His work incorporates machine learning, signal processing, and innovative optical sensor designs for motion analysis, rehabilitation, and patient monitoring. Prof. Leal-Junior also maintains international collaborations and industry partnerships, supporting the development of practical sensing technologies and providing opportunities for interdisciplinary research, student training, and large-scale collaborative projects.

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