

**Distributed Acoustic Sensing for Ocean Acoustics**  
**September 23, 2026**  
**Webinar Q&A**

**1) Can DAS use existing cable infrastructure, or must dedicated cables be installed?**

No, dedicated cables are not required. DAS works on standard single-mode optical fiber by analyzing Rayleigh backscattered light, so existing telecommunication cables, research/observatory cables, and spare (dark) fibers in power or other cables can be interrogated, as long as one has access to a fiber end where the interrogator can be connected. Temporary cables, including towed cables, can also be used. Purpose-built cables can improve sensitivity and frequency response, but they are an option rather than a requirement.

**2) How do you manage to get the scattered signal back through a repeater in reverse?**

Long-haul submarine repeaters contain optical isolators, so ordinary Rayleigh backscatter cannot travel back through them on the same fiber. Instead, repeaters include a passive loopback path (a high-loss loopback coupler) that was designed so the cable operator can monitor the health of the system. It couples a small fraction of the light, including the Rayleigh backscatter generated in the span, from the outgoing fiber onto the return fiber of the pair, which carries it back to the interrogator.

Because only a small fraction of the light is coupled back, the signal drops after each repeater and the signal-to-noise ratio falls span by span. A highly coherent, stable (narrow-linewidth) laser and low-noise detection are therefore needed to recover the phase of the backscatter beyond the repeaters.

**3) What range would be considered high frequency within the DAS capabilities, and what are the upper frequency limitations?**

There is no single upper limit; it depends on the interrogator settings, the cable, and the fiber length.

First, sampling: the interrogator must wait for each pulse to travel to the end of the fiber and back before sending the next one, so the maximum pulse repetition rate is about  $c/(2nL)$ , where  $L$  is the fiber length and  $n$  is the refractive index (about 1.47).

Second, the transfer function of the system. DAS measures strain averaged over the gauge length, which acts as a spatial filter. The response has notches at frequencies where the apparent wavelength along the fiber is an integer fraction of the gauge length. By choosing the gauge length (and pulse width and recording parameters) you can push the notches to higher or lower frequencies depending on the application; a shorter gauge length extends the usable bandwidth but reduces sensitivity.

Third, the cable itself: its construction, coupling to the water and seafloor, and burial determine how an acoustic wave is converted into strain in the fiber. For standard telecom cables the useful acoustic band is generally up to a few hundred hertz. With custom cable designs, such as the loop and spiral configurations I showed, we were able to see signals up to 10 kHz.

**4) For FK the plane wave assumption breaks down for the long lengths you have. How do you address slice? Sliding spatial windows?**

You are right: a single plane wave is not a valid model over tens of kilometers, because the cable is not straight, the bathymetry and sound speed change along the route, and sources can be in the near field. The usual approach is to apply the FK analysis in sliding (overlapping, tapered) spatial windows over which the cable is approximately straight and the medium approximately homogeneous. The window must contain several channels per apparent wavelength and span at least a few wavelengths (for a 20 Hz whale call, with a wavelength of about 75 m, windows of a few hundred meters to a few kilometers work well) and should be much longer than the gauge length. Shorter windows give better spatial localization but poorer wavenumber resolution.

The local cable heading should also be accounted for, since DAS measures only the strain component along the fiber, so the apparent velocity depends on the angle between the wave and the cable. For longer apertures or nearby sources, curved-wavefront (near-field) beamforming or model-based methods, such as matched-field processing with the actual cable geometry and a propagation model, are more appropriate than a plane-wave assumption.

**5) From someone who contributed on the firsts OSW in US and Europe, can similar technologies be applied for US OSW transmission lines to increase defense?**

Yes, in principle. Offshore wind export and inter-array cables typically contain optical fibers (used for communications and temperature monitoring), and spare fibers can be interrogated with DAS. This can detect and track vessels, anchor dragging, dredging, and other activity near the cable and the wind farm, which is useful for cable protection and for security and maritime domain awareness.

Practical considerations include access to a spare fiber and a place to install the interrogator (onshore or at the substation), the fact that burial reduces sensitivity to sound from the water column, strong narrowband noise lines from the power transmission, and data security and ownership issues. In general, DAS can be conducted on any fiber-optic cable to which one has access.

**6) Any data of cargo or ship recorded by hydrophone array posed on the seafloor? What are dominant factors affecting performance?**

Yes. Ship noise is routinely recorded by seafloor and cabled hydrophones and seismometers. Large cargo ships are among the loudest sources in the ocean, with most energy between about 10 Hz and 1 kHz (strongest at tens to a few hundred hertz) and broadband source levels of roughly 170-190 dB re 1  $\mu$ Pa at 1 m, mainly from propeller cavitation, with tonal components at the blade rate and machinery frequencies. Ship signals typically show a characteristic interference pattern in spectrograms, caused by reflection from the sea surface (Lloyd's mirror).

The dominant factors affecting detection performance are the source level (ship type, speed, load), sound propagation (water depth, sound speed profile, bottom type, and range, which determine transmission loss), the ambient noise (wind, rain, other ships, biological and seismic sources), the receiver depth and location in the water column, and the array design (number of elements, aperture, geometry, and array gain), as well as the receiver self-noise and flow noise. For DAS, a single channel is

generally less sensitive than a good hydrophone, but the very large number of channels and the long aperture allow beamforming, localization, and tracking of ships.

**7) For repurposed cables and/or Purpose-Built DAS Cables, can I ask about what the estimated costs for building these have been in your experience?**

Costs vary widely with the project, so these are only rough, order-of-magnitude figures and should be confirmed with quotes. For a repurposed cable, the fiber already exists, so the main costs are the interrogator (typically on the order of hundreds of thousands of US dollars or less, depending on the model), access and landing-station arrangements with the cable owner, and data storage, processing, and personnel.

For a purpose-built cable, the main cost is not the fiber itself but the cable manufacturing, the installation vessel (ship time is often tens of thousands of dollars or more per day), possible burial or protection, and connectors and termination. Subsea cable systems are commonly priced per kilometer, and costs depend strongly on water depth, route length, and the level of protection required.

**8) Would it be possible to trail a FX cable from a UAV and thus record acoustic signatures over a wider area? Would this work better than a hydrophone from the perspective of what it was capable of picking up in the ocean if the line was say 100M long? Thinking of detecting whale calls in particular or would there be no noticeable difference.**

In principle yes: a fiber can be trailed from an underwater vehicle, with a compact interrogator inside the vehicle (the same power, heat, and data-storage constraints as for portable DAS, see Q13). This would let one record over a wider area than a fixed cable. However, I would not expect it to work better than a hydrophone for a 100 m line.

A 100 m fiber with a gauge length of around 10 m gives only about 10 independent channels. A 20 Hz fin whale call has a wavelength of about 75 m, so the aperture is only about one wavelength, which limits directivity at low frequency. A straight fiber is also much less sensitive to waves arriving broadside to the cable, and the per-channel sensitivity of DAS is generally lower than that of a good hydrophone. In addition, a trailed line picks up flow noise, cable strumming, and the self-noise of the vehicle (thrusters, propeller, electronics), which affect hydrophones as well.

For detecting whale calls from a moving vehicle, a hydrophone or a small towed hydrophone array is generally more sensitive and simpler. The advantage of DAS comes from the very large number of channels over kilometers of cable, which a 100 m line does not provide.

**9) What is the sensitivity of DAS- how far it can hear let's say Cargo ships? in quiet ocean.**

There is no single number, because the detection range depends on many factors that are still being studied: the source level and speed of the ship, the sound propagation (water depth, sound speed profile, and seafloor properties), the ambient noise level, how the cable is coupled to the seafloor (buried or unburied, sediment properties), the angle between the cable and the direction to the ship (a

straight fiber is least sensitive to broadside arrivals), and the interrogator parameters (gauge length, noise floor). More research is required.

As a general guide, large cargo ships radiate strongly at low frequencies (tens to hundreds of hertz), and published DAS studies on seafloor telecom cables have detected and tracked them at ranges from several kilometers to a few tens of kilometers. In a quiet ocean the limit is set by the instrument noise floor rather than by ambient noise, which is generally worse for DAS than for a hydrophone.

**10) Is there any concern for damage to the cables, and what would cause it? Has there been any impact of trawlers or other anthropogenic machinery on cables?**

Yes. Submarine cables are damaged mostly by human activity: roughly two-thirds or more of all cable faults are caused by fishing (especially bottom trawling) and by ship anchors, particularly in shallow water on the continental shelf. Natural causes include earthquakes, submarine landslides and turbidity currents, strong currents or storms that abrade or suspend the cable, and, much more rarely, animal interactions. Dredging, construction, and deliberate damage are other causes.

Cables are protected by armoring, by burial in shallow water (typically 1-2 m deep out to water depths where fishing occurs), by route planning, and by marking on nautical charts. DAS itself can also be used to detect trawling and anchor dragging near a cable. The interrogation does not damage the cable, because the optical power used is low and the cable is passive.

**11) Have you dealt with scenarios where there is a sudden large change in the bathymetry because of a shipping lane, for example. I guess this will challenge the "linear array of sensors" assumption when computing cross correlation / TDoA. How would you recommend to deal with this?**

There are two issues. The first is spatial resolution. There are two factors in the data recording: how often we sample along the fiber, which sets the distance between channels (every few meters or every few kilometers, depending on the data volume we can record), and the gauge length and pulse width, since DAS is not a point measurement but an average over a section of the cable. If the scale of the change in the bathymetry (for example, a mud patch) is smaller than the gauge length (typically a few to tens of meters), we cannot resolve it in the data. We can change the recording parameters to adapt to the scale of the feature of interest.

The second is the geometry. TDOA and cross-correlation methods do not strictly need a linear array: they need the correct positions of the channels, so I would recommend using the actual 3-D cable geometry (position, depth, and heading), calibrated with known sources such as ship passages, instead of assuming a straight line. Also use local or sliding windows, and a propagation model that includes the bathymetry and the sound speed (for example ray tracing or parabolic equation) for localization, such as matched-field processing. Finally, the response of the cable may change where the bathymetry or the seafloor type changes, so channel-by-channel calibration is useful.

**12) Is the entire cable (fiber + armor) configured in a spiral? Or is the fiber wound in a spiral within the cable core (spiral fiber + straight armor)? Is this cable construction or cable deployment configuration? Is a spiral core possible with bend radius limits?**

Either is possible. In the pipeline monitoring application, for example, the cable was wrapped around the pipe along its whole length. In my experiment, only sections of the cable were arranged in loops or a spiral configuration, while the rest was straight, because we wanted to compare the straight sections with the loop and spiral sections. We can be creative and use different configurations.

To answer your questions directly: both exist. Helically wound fiber inside the cable core is a cable construction choice, while arranging sections of the whole cable (fiber and armor) in loops or spirals is a deployment configuration. Both make the fiber sensitive to a wider range of arrival directions than a straight fiber, which is mostly sensitive to strain along its axis. Bend radius limits apply: the loop or spiral radius must be larger than the minimum bend radius specified by the cable manufacturer (typically many times the cable diameter), which is why the loops are usually meters in size; a helical winding within the core has a large effective radius and is compatible with these limits.

### **13) Are you familiar with what the main challenges are in moving towards portable DAS systems?**

There are limited studies with portable DAS, but some manufacturers are able to make a compact interrogator that can fit in a pressure housing. To deploy it in the ocean and record autonomously, we need to think about the power (battery), the data storage (hard drives, because DAS produces very large data volumes, often terabytes per day), and the heat transfer. In order to have a stable, narrow-linewidth laser, the system must be kept cool and thermally stable, which is a challenge in a sealed housing. The processing and time synchronization are other limitations. But there has been a successful experiment showing that portable DAS is possible.

### **14) Can you share more about what research has been done for on-site computing solutions and limitations?**

This is an active research area, and the number of field studies is still limited. DAS produces very large data volumes (terabytes per day), so processing near the interrogator (edge computing) is used to reduce the data: decimation, filtering, FK filtering or beamforming, and detection or classification with machine learning models, often running on GPUs, FPGAs, or embedded processors. Only detections, features, or compressed data are then stored or transmitted.

The main limitations are the available power and heat dissipation (especially in a subsea pressure housing), limited storage and communication bandwidth (acoustic modems or satellite links carry very little data), the risk of discarding data that may be useful later if lossy compression or event-only recording is used, and the generalization of trained models to new cables, sites, and noise conditions.

### **15) What is the smallest change in length you can measure?**

DAS does not measure absolute length: it measures changes in the phase of the backscattered light, which are converted to strain (change in length divided by length) or strain rate over the gauge length. The smallest detectable change depends on the gauge length, the laser, the frequency, and the noise level. Typical interrogators reach noise levels of roughly picostrain to nanostrain per square root of hertz. For a 10 m gauge length, a strain of 10 picostrain corresponds to a length change of about 0.1

nanometer, so DAS can detect sub-nanometer length changes of a gauge section at favorable frequencies.

**16) What is the strategy for selecting the optimal locations for loops and/or spirals along the line?**

We chose the locations at specific depths and positions based on historical data, which included 20 years of whale observations, to tell us where whales had been observed most of the time. So we designed the loops to be in those locations.

The other consideration is the size of the loop. The mathematical analysis shows that it should be larger than the gauge length. The gauge length is the length of cable over which the strain is averaged, so we want the loop to be larger than the gauge length, so that the individual gauge segments around the loop have different orientations, and the loop as a whole is sensitive to waves from all directions (360 degrees).

**17) I was wondering is it possible to discriminate among invertebrate species and classify anthropogenic noise from biotic sources?**

Distinguishing biological sounds from anthropogenic noise is feasible, because they differ in frequency content, duration, and behavior: for example, baleen whale calls are typically narrowband, repeated, and frequency-modulated, while ship noise is broadband with tonal components and shows a smoothly changing (Doppler) signature as the ship moves.

Discriminating invertebrate species is much harder. Most invertebrate sounds (for example, snapping shrimp, which produce broadband impulsive clicks mostly above 2 kHz, or sounds from lobsters and urchins) are weak and high-frequency, where standard cables have low sensitivity, and I am not aware of a demonstration of species-level classification with DAS. It might become possible with custom cables, close deployment, and ground-truthed classification, but at the moment it is not established.

**18) Do the cables require regular maintenance and if so, what has been the process for that?**

The cable itself is passive and, if it is properly buried or protected, does not require regular maintenance. Telecom systems are designed for a lifetime of about 25 years and are monitored continuously by the owner (with OTDR and repeater monitoring). When a fault occurs, it is located from shore, and a repair ship recovers the cable, replaces the damaged section, and re-lays and re-buries it.

The maintenance for DAS is mostly on the interrogator on land (power, cooling, data storage, calibration, laser aging) and the data processing. For research cables in shallow water, periodic inspection of burial and cable condition (by ROV or survey) may be needed.

**19) Is there a defense concern with multiplex uses? I understand that pulses are sent at difference wavelengths, but seems DoD would be concerned sharing a fiber with a commercial comms.**

That is a legitimate concern, and I cannot speak for DoD policy. DAS interrogation uses low-power laser pulses, and the DAS wavelength can be separated from the communication channels by using a different wavelength or a dedicated dark fiber, so technically the two can share a cable. However, the high peak power of the pulses can cause nonlinear effects (such as stimulated Raman scattering) that can degrade co-propagating channels unless the power and wavelength are managed.

There are also security issues: any fiber on which an interrogator is connected acts as a sensor, which exposes information about activity near the cable, and the interrogator is a further point of access at the landing station. For sensitive applications, the usual approach is a dedicated fiber (not shared with commercial traffic), physical and logical isolation, control of the interrogator and data by the cable owner, and control of data distribution.

**20) Could DAS be used inversely, not only to detect sources but to continuously estimate environmental parameters such as sound-speed structure, sediment properties, or changing seabed conditions? That could make the cable part of a continuously updated ocean digital twin.**

Yes, this is an active research area and an exciting direction. DAS on seafloor cables has been used for ambient-noise interferometry (cross-correlating noise between channels) to estimate the seismic velocity structure of the shallow sediments and seafloor (including from Scholte waves), for monitoring ocean surface waves, tides, and microseisms through their pressure loading on the seafloor, and for detecting earthquakes and faults. Slow (quasi-static) strain and temperature changes can also be monitored.

For sound speed in the water column, in principle ship noise or whale calls recorded along the cable could constrain the sound speed structure (for example from modal dispersion or matched-field inversion), but this is much less mature. Challenges include the cable coupling and transfer function, which need calibration, the noise, the non-uniqueness of the inversions, and the limited bandwidth. A continuously updated, cable-based digital twin is therefore a plausible goal, but it requires further development.

**21) What factors affect the speed of acoustic waves travelling in water (temperature/salinity or are there others?) Or can the source be a factor?**

The speed of sound in seawater is about 1500 m/s and depends mainly on temperature, salinity, and pressure (depth). Temperature has the strongest effect (roughly +3 to +4 m/s per degree Celsius near typical temperatures), salinity increases the speed by about 1.3 m/s per practical salinity unit, and pressure increases it by about 1.7 m/s per 100 m of depth. Gas bubbles in the water can strongly reduce the effective sound speed, particularly near the surface and in shallow water; suspended sediment has a small effect.

The source does not affect the sound speed (for the small-amplitude waves considered in ocean acoustics): the speed is a property of the medium. The motion of the source causes a Doppler shift in frequency, not a change in the sound speed, and currents advect the sound, changing the speed relative to the ground.

**22) Can you please explain a bit more in detail how multi-repeater setting works for high frequencies?**

In the multi-repeater setting, the loopback path at each repeater returns the backscatter from each span to the interrogator on the return fiber. The signal from the later spans arrives later in time, and the pulses are sent at a rate limited by the round-trip time over the whole fiber, so the maximum pulse repetition rate is  $c/(2nL)$ , where  $L$  is the total length of the fiber that is being interrogated. For a link with many repeaters that is hundreds of kilometers long, this limits the bandwidth to tens or a few hundred hertz (Nyquist frequency).

Therefore, for high frequencies, the interrogation is limited to the nearer spans (so that a higher pulse repetition rate can be used), or the sampling must be designed for the signal of interest. The higher-frequency signals are also limited by the decreasing signal-to-noise ratio after each repeater, since only a small portion of the light is returned.

**23) For the Portable DAS, what kind of deployment time does that require, approximately? and Part 2 for this, is there a somewhat quick fiber that mates to that fast deploy method ?**

The deployment time depends strongly on the platform and the location. The interrogator itself can typically be connected and tested in minutes to hours (including the laser warm-up and checks of the recording parameters), and the main time is needed for the cable deployment, which for a kilometer-scale cable laid from a vessel can take hours to days, depending on the water depth and the burial.

For quick deployment, ruggedized, pre-terminated cables on reels (such as tactical or expeditionary fiber cables, and the thin fibers used on tethers and ROV umbilicals) and wet-mate connectors are used. Their sensitivity and coupling may differ from those of purpose-built sensing cables, so the choice of cable is a trade-off between speed of deployment and acoustic performance.

**24) From the already deployed cables, are their cable positions also published along with the received DAS data?**

Not always. It depends on the data set and the cable owner. Research cables and public data sets usually come with the channel locations or the cable route, but for commercial telecom cables the exact route is often not published, because it is considered sensitive (and cable route lists are sometimes only approximate). Also, the DAS channel positions are given along the fiber (optical distance), and the fiber length is not the same as the cable length because of slack, excess fiber length, and helical winding, so the channels must be mapped to geographic coordinates. This is usually done with calibration, such as tap tests or tracking of ships or known sources. So the channel location should always be checked against the metadata of the data set.

**25) From your experience, if the cable is slightly buried in the ocean floor, could that be compensated by detecting the acoustic signals in other sections of the cable?**

Only partly. Burial changes the coupling between the cable and the water and the seafloor, so it changes the transfer function of the cable (usually it reduces the sensitivity to the acoustic wave in the water, especially at high frequencies, but it can also reduce flow noise and improve the coupling to seismic

waves in the seafloor). The information that is lost in the buried section cannot be recovered from the other sections.

However, if the same source is recorded on both the buried and the unburied sections, the relative amplitude and phase response can be calibrated channel by channel, using, for example, ships or whale calls. Also, the unburied parts of the cable can be used for the detection, and the array processing (beamforming) can use the better-coupled channels.

**26) Have you tried to plug AI layer to your system for anomaly detection. Any data to share if you had the experiment (performance vs how hard to train the models)?**

Machine learning has been applied to DAS data for the detection and classification of vessels, whale calls, and earthquakes, using, for example, convolutional neural networks and other deep-learning models, and also with unsupervised methods (such as autoencoders) for anomaly detection. The trade-off between performance and training effort depends on the amount and quality of the labeled data: supervised models need a large amount of labeled examples, and the performance usually improves with more data but then saturates.

The labeling effort and the poor generalization to new cables, sites, and noise conditions are the main problems. Transfer learning, synthetic data, pretraining without labels, and ground truth from AIS or hydrophones can reduce the effort. Rigorous quantitative comparisons are still scarce, so the results should be assessed for each application.

**27) Can you use the data to tell precisely where loops are along the cable?**

Yes, in general. The loops can be identified in the data because within a loop the fiber length is longer than the distance along the route, and the arrival times and amplitudes along the channels show different patterns (for example, a changing apparent velocity and the response to the direction of arrival). Tap tests or the passage of a ship or another known source can be used to locate them. The precision is limited by the channel spacing and the gauge length, typically meters to tens of meters.

**28) What is the lower frequency limit of signal detection of the DAS system?**

DAS is based on the phase of the backscattered light, so it can measure very slow strain changes, down to millihertz frequencies or even lower (for example, tides, temperature changes, and slow seafloor deformation), but the practical lower limit is determined by the noise: laser frequency drift, temperature drift, and other noise sources increase at low frequencies. Also, because many interrogators record the strain rate, the response of the system decreases toward the lower frequencies.

**29) Has there been determined an optimal number of loops for your biological target signal?**

No universal optimal number has been determined. It depends on the frequency of the target calls (and thus the wavelength), the expected detection range, the cable length, and the goal (detection only, or

bearing and localization). The number of loops is limited by the available cable length, the cost, and the difficulty of the deployment.

**30) You mentioned correlating DAS information with hydrophone data. what are other multimodal sensing possibilities that complement DAS e.g, magnetic anomaly detection or electrical sensor etc. Have you encountered such examples?**

Yes. Complementary sensors include hydrophones and seismometers (ocean-bottom seismometers), accelerometers, bottom pressure gauges, and also distributed temperature sensing (DTS) and distributed strain sensing on the same cable. Environmental sensors such as CTDs, current profilers, and wave buoys, together with ground truth from AIS (ship positions), radar, and satellite imagery, are also very useful. Cabled observatories often combine several of them.

Magnetic and electric field sensors can also be added, but the DAS itself does not measure them. They would need to be separate sensors on the same cable or node. The SMART cable initiative proposes to add temperature, pressure, and acceleration sensors to the repeaters of the telecom cables.

**31) In terms of ground truthing, are there any datasets in this area so that people can know what types of DAS data can be referred.**

There are some public data sets, but they are still limited. Ground truth for DAS is usually provided by AIS records for ships, by co-located hydrophones or seismometers, and by visual or acoustic observations of animals. Public repositories include data from some cabled observatories, such as the OOI Regional Cabled Array off Oregon.

**32) What is the best source to find DAS cables already in existence that could be used for this type of research? I'm interested in baleen whale (low frequency < 1kHz) detection in the Gulf of Mexico.**

A good starting point is the Submarine Cable Map and the NOAA nautical charts (which show the charted cable areas), along with the FCC cable landing licenses for the cables that land in the US. Contact the cable owners, as the access to the fibers requires their agreement.