# Adversarial Machine Learning Training for Signal-to-Noise Generalization in Passive Undersea Acoustics

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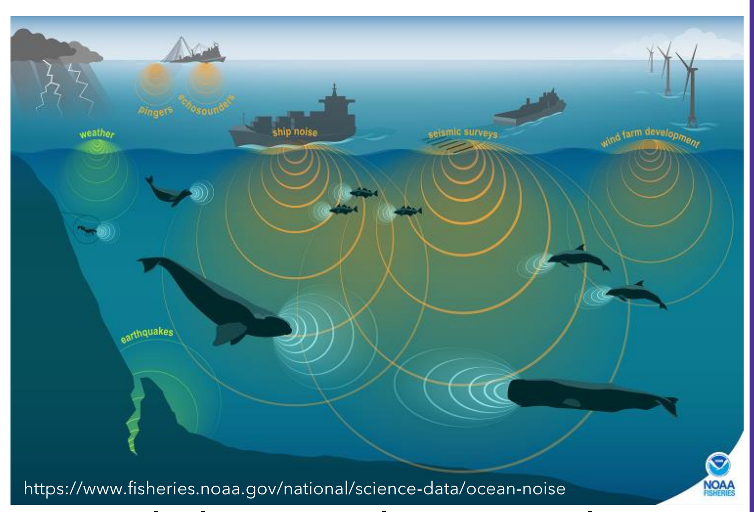
## Summary

We present a framework for embedding undersea acoustic simulation capabilities directly into neural networks as trainable layers. These layers provide critical data augmentations that are optimized through sets of interpretable, tunable parameters to enhance neural network performance and generalization.

Our poster illustrates examples of two trainable (differentiable) data augmentation layers: (1) an ambient undersea noise model and (2) a tunable signal-to-noise (SNR) ratio. The addition of these augmentation layers reduces simulation cost, data volume and training time by optimally sampling, and thus reducing, the combinatorial complexity of the noise model parameter space.




Our approach is inspired by [1] and adds flexibility that differs from other work in adversarial data augmentation techniques [2] and adversarial training for generative adversarial network (GANs). We illustrate the interpretability of our augmentation layers and show that they enhance generalization as compared toa baseline using traditional, non-adversarial training methods.

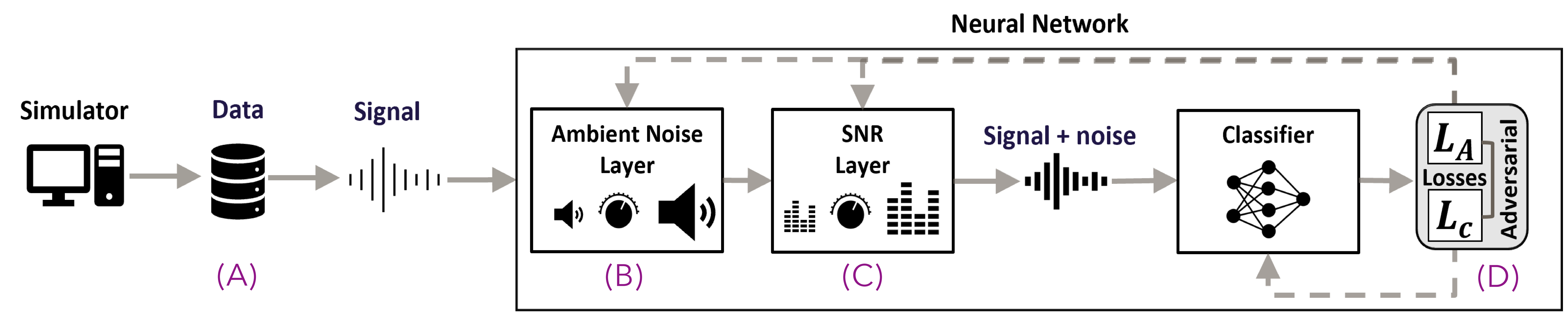
## Our Group

The Leidos Hydrodynamic Machine Learning Group develops edge-focused, data-driven technologies for remote sensing. We specialize in interpretable neural network architectures that process raw sensor data on low size, weight and power hardware.

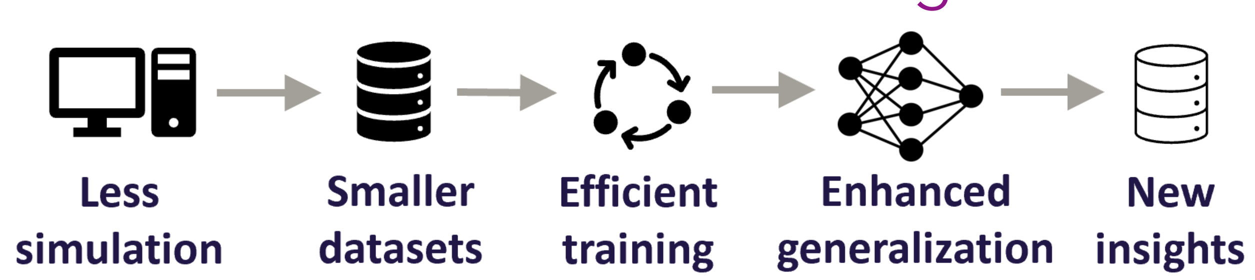
## References

1. D. Schwalbe-Koda, Differentiable sampling of molecular geometries with uncertainty-based adversarial attacks. *Nat Comm* **12**, 5104 (2021).
2. M. Shu, et al., Adversarial Differentiable Data Augmentation for Autonomous Systems, *IEEE ICRA*, (2021).
3. S. Zhau, et al, Differentiable Augmentation for Data-Efficient GAN Training, *Neural Information Processing Systems* (NeurIPS), (2020).
4. G. M. Wenz,*J. Acoustic. Society of America*, **34**,12 (1963).
5. Ocean Noise and Marine Mammals. Nat. Acad. Press, (2003).
6. C. Tollefsen & S. Pecknold, A simple yet practical noise model. Defense Research and Development Canada, (2022).

## Training Pipeline and Neural Network Architecture



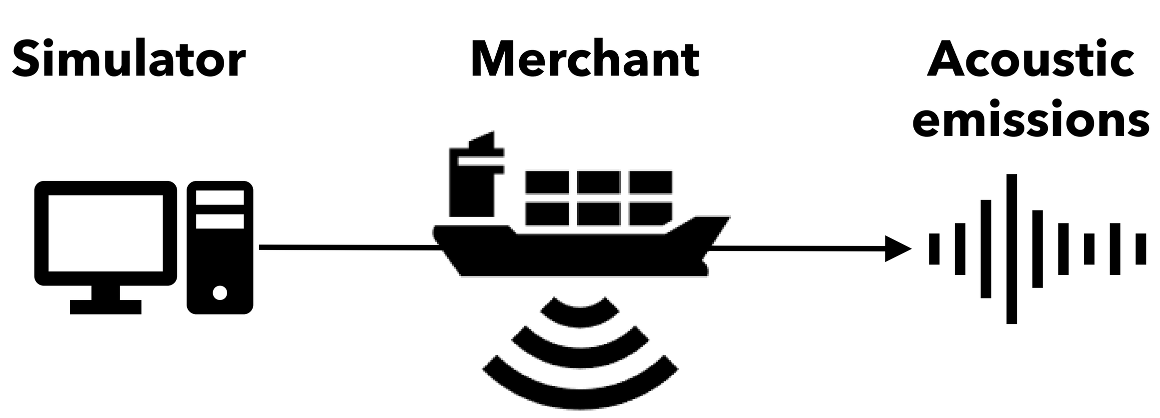

### Benefits of Differential Data Augmentation




### (D) Loss Functions


Loss functions are adversarially coupled and target specific layers in the neural network

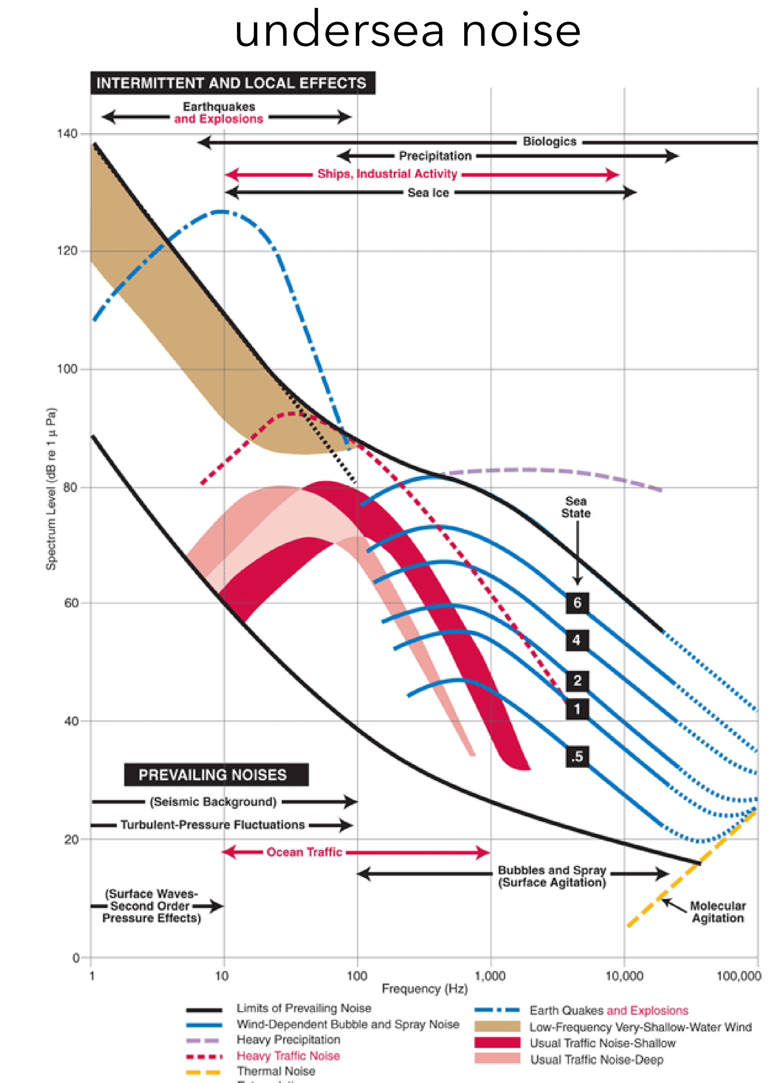
### (A) Data



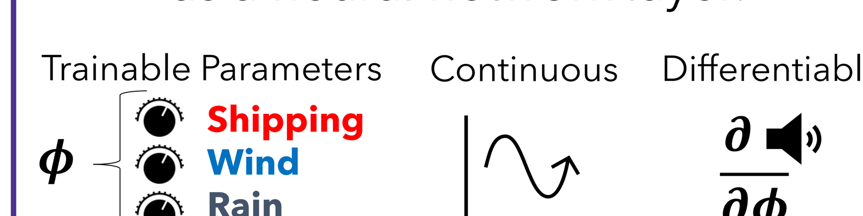

### (B) Ambient Noise Layer

Wenz Curves [4,5, 6]

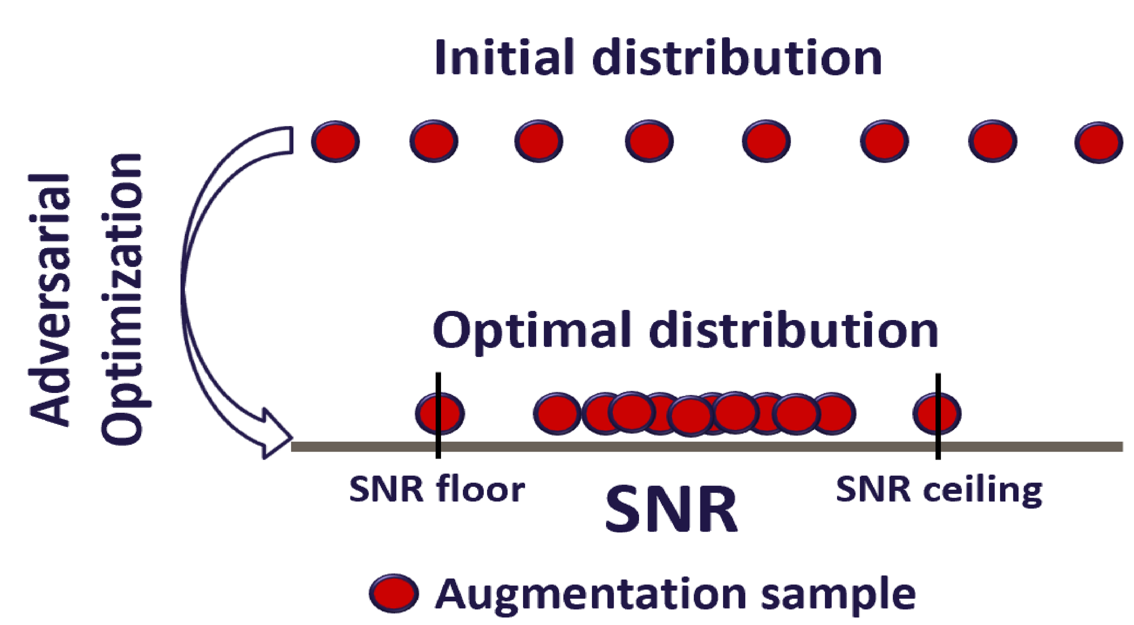
A spectral model for ambient undersea noise




as a neural network layer.

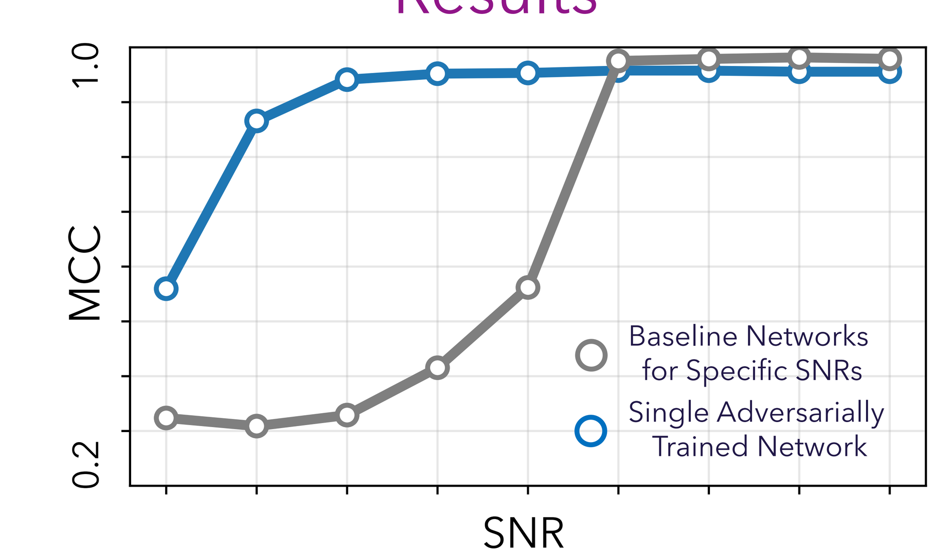



### (C) SNR Layer

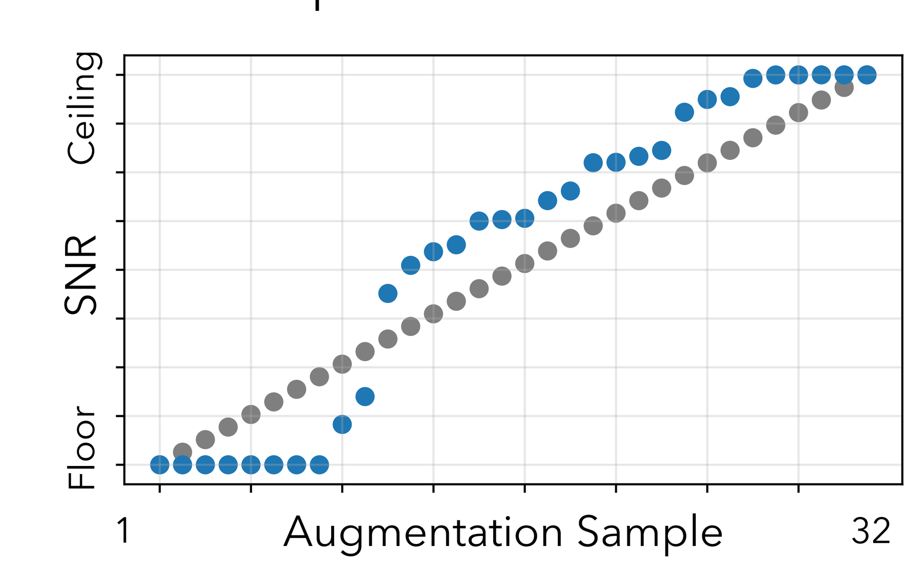



This trainable layers identifies the most useful distribution of training SNRs within a set floor and ceiling. The SNR is used to combine the original signal with the generated noise.

### Results




A single adversarial network generalizes across SNRs and performs better than SNR and condition-specific networks




The initial (gray) and final (blue) distributions of SNR augmentations show a preference for low and high SNR values

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