# Bay Area Geophysical Society Seminar Series

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## *Forensic seismic analysis and source modeling of the 2022 Nord Stream gas pipeline sabotage*


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**May 2nd, 2024, 5:00 PM PST – Mitchell Earth Sciences, 350/372, Stanford University Campus and on Zoom**

## Abstract:


On 26 September 2022, three of the four Nord Stream pipelines carrying natural gas along the seafloor of the Baltic Sea from Russia to Germany were sabotaged. Seismic data from Sweden, Denmark, and Germany reveal two sets of events, with waveforms indicating shallow, explosive sources close to the location of gas plumes observed on the sea surface. Empirical relations between yield and waveform amplitude developed for underwater explosions suggest 100-400 kg TNT equivalent for the events. However, we show that gas discharge from the pipelines also contributes to seismic radiation, reducing the estimated yield to less than 50 kg. We present a source model that combines explosion processes and pipeline gas discharge into an expanding and oscillating gas bubble, which radiates like the gas bubble produced by marine seismic sources (airguns). The pipeline model uses an expansion wave solution to the quasi-1D Euler gasdynamics equations to quantify mass and energy discharge into the bubble. The model also predicts seismic radiation using a regional wave propagation model. Radiation is

dominated by the initial outward expansion of the bubble, which is controlled by the combined effects of the outward blast wave from the explosion and gas discharge into the explosion bubble. The blast wave contribution provides the main constraint on yield. For typical underwater explosions, the yield can also be constrained from the gas bubble oscillation frequency, which is reflected in spectral peaks. However, we show that pipeline gas discharge into the bubble suppresses oscillations and the associated radiation. Finally, we use the model and seismic data to constrain the sequence and location of at least four distinct explosions on the different pipeline strands. This is joint work with Björn Lund (Uppsala University, Sweden), Andreas Steinberg (BGR, Germany), and others.

## Author:

Prof. Dunham's research focuses on the development and use of physics-based computational simulations to characterize and understand earthquakes, tsunamis, and volcanoes, and similar phenomena. His approach is to identify the fundamental mechanical processes governing a system of interest, develop numerical models incorporating these processes, validate them using geophysical observations, and then use the models to predict system behavior. Specific research areas include earthquake rupture dynamics and earthquake source processes, tsunami generation, volcano seismology and infrasound, ice stream stick-slip events and flexural-gravity waves in ice shelves, and numerical methods for wave propagation. Prof. Dunham received numerous awards that recognized his excellence as researcher and as teacher.

## Zoom meeting information:

Zoom ID: 890 2203 6378
Password: BAGS4ever