# Mapping the Ocean Floor

Qitong Gao
qitong.gao@duke.edu

William Willis
william.a.willis@duke.edu

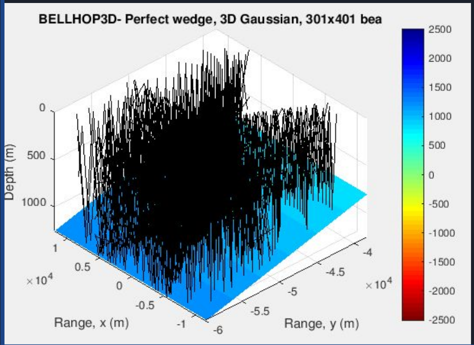
## Introduction

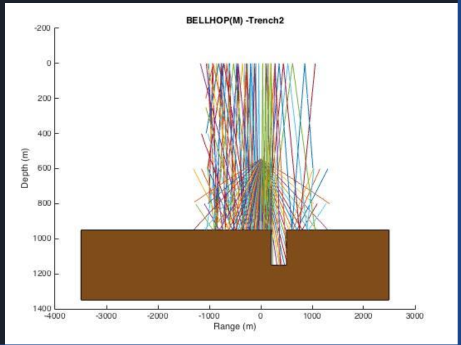
- Competing in the Shell Ocean Discovery XPRIZE. Goal to map 500 km$^2$ of the ocean floor autonomously with high efficiency and high resolution (5 meters in horizontal resolution and 0.5 meters vertically).

- Autonomous drone and pod will be deployed into the mapping area.
- Drone with hybrid gas-electric engine ensures the long flight time.
- Pod with self-designed sonar system will gather ocean data.

## Simulation Software

- Simulation software built from Bellhop, an open-source program distributed by HLS Research
- 2D/3D ray traces and arrival calculation for various simulated ocean bathymetries
    - Specification of source and receiver positions
    - Gaussian and geometric beam simulation
    - Arrival data - amplitude and time delay



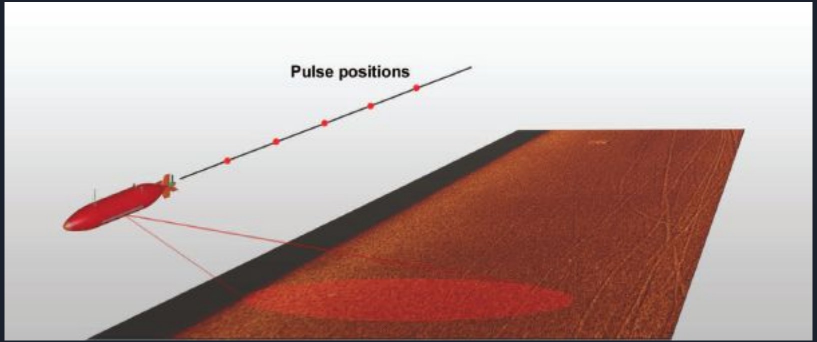
# Approach A - Synthetic Aperture Sonar (SAS)

## Overview of SAS

- Creates a synthetic aperture, equivalent to an extremely long receiver antenna
- Sonar source and receiver array move along a near linear path, emitting pulses at selected intervals. Typically horizontal path and 2D images.
- SAS was first developed based on existing methods for Synthetic Aperture Radar (SAR)
- Generally uses a horizontal path to produce a two-dimensional image of the sea floor
- With precise enough location information, can produce extremely high-resolution images

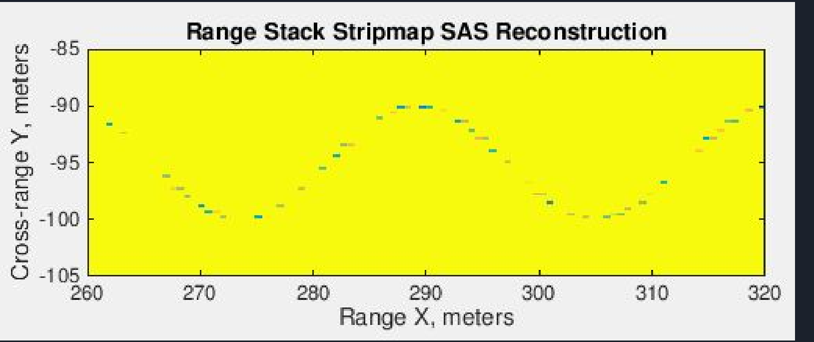
## Methods and Goals

- Relies on Fourier transform of reflected signal $s(t,u)$, where t is time and u is synthetic aperture position, to frequency domain $S(\omega,k)$. Currently based on SAR code by Mehrdad Soumekh.
- Pod design uses a vertical SAS path, imaging ocean floor points as 2D, vertical slices.
- Requires directional information for sonar echos. Can be obtained using spatial frequency information or image coregistration between two receivers. Plans to limit source directionality also.



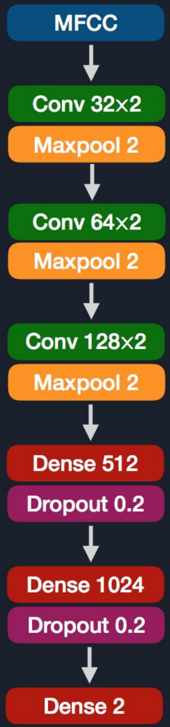

< Typical SAS Imaging Path

Sine Wave Bathymetry Reconstructed By Simulation >



# Approach B - Neural Nets and Error Reduction

## Sonar data classification




- Convolutional Neural Networks (CNN) have been used for classifying different bathymetry types.


- Mel Frequency Cepstrum Coefficient (MFCC) was used at the beginning of the project to extract useful features from the sonar sound files (input).
- Obtained overall accuracy of 96.7%.

## Error reduction method

- In this approach, we add random coherent noise to a low-resolution map to form several high-resolution maps. The map that is most consistent with the underwater sonar data is chosen as the final map.
- Low resolution maps of the ocean floor are available online.
- The detailed processes are: