Resolving the Role of the Dynamic Pressure in the Burial, Exposure, Scour, and Mobility of Underwater Munitions

Stephanie Gilooly[A] and Dr. Diane Foster[B]

Motivation

In the United States, there are more than 400 active and former military installations with munitions in underwater environments. Property potentially containing munitions in underwater environments exceeds 10 million acres. These munitions can be dangerous to the public and marine life and are difficult to locate, as they can move and be buried or unburied rapidly under certain flow conditions.

Munitions Brought Onshore by a Winter Storm in California [1]

The inner surf zone is a very active place, as it experiences a combination of oscillatory, steady, and turbulent flows on a bed of heterogeneous sediment. This project hopes to allow for a prediction of munition movements in the inner surf zone.

Background

Sediment transport and incipient motion is difficult to characterize due to the effects of combined (oscillatory, steady, and turbulent) nature of the flow interacting with heterogeneous sediment. Quasi-steady environments are parameterized with the Shields parameter, which characterizes the ratio of disruptive shear stress to the resistive forces of the bed. As the Shields parameter increases, shear stresses dominate and motion occurs.

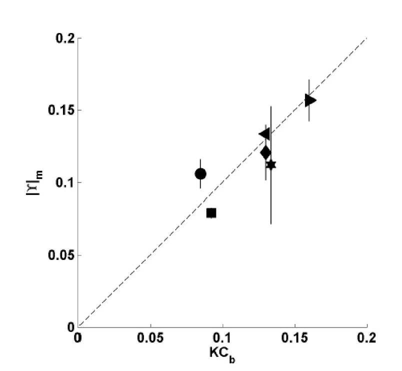
$$\theta = \frac{\partial\tau/_{\partial z}}{\rho(s-1)g} = \frac{{u_*}^2}{(s-1)gd_{50}} \text{ [2]}$$

Sleath (1999) then established a Sleath parameter that is a ratio between the disruptive pressure gradient and the restoring bed forces. At Sleath parameters as low as 0.1, sediment can be moved together as a "plug."

$$S = \frac{-\partial P/_{\partial x}}{(\rho_s-\rho)g} \text{ [3]}$$

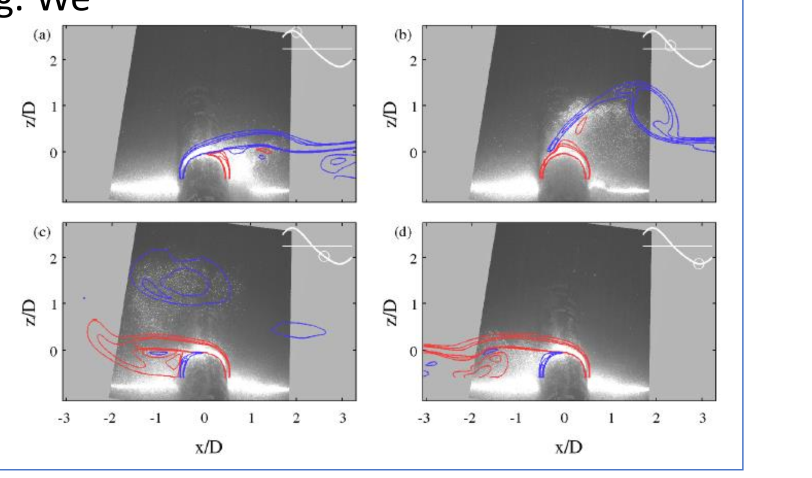
Foster *et-al* (2006) created a parameter that combines the effects of these two mechanisms and shows that incipient motion begins as a function of bed state parameters. [4] Frank (2015) performed experiments with gravel, acetate beads, and plastic spheres, finding agreement. [5]

$$|\Upsilon| = \left|-\theta\frac{d_{50}}{h} - S\right| \geq KC_b$$



Frank et-al (2015): Incipient Motion for acetate beads (circles), gravel (squares), and smart grains (other symbols)

Studying incipient motion for large cylinders on a sediment bed implies further complexities such as shielding, armoring, and overpassing as a result of the very heterogeneous sediments. Fluid passing around a cylinder also results in vortex shedding. We propose these vortices result in an additional pressure gradient component and should play a role in the incipient motion of the cylinder.



Smith (2008): Cylinder exposed to oscillatory flow in the Oregon State University O. H. Hinsdale Large Wave Flume results in positive (red) and negative (blue) vortices as the phase of the wave progresses

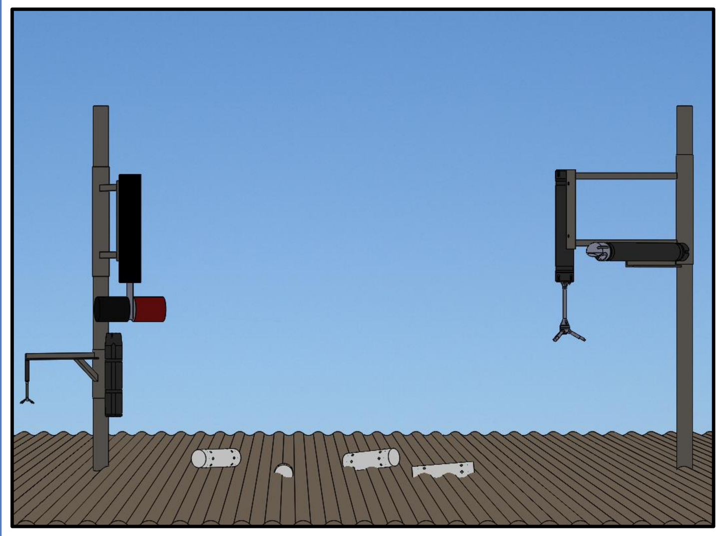
Research Objectives

The main objective of this research is to resolve the role of dynamic pressure on underwater munitions during their burial, exposure, scour, and mobility. The pressure gradient will need to be evaluated in two components to introduce the dynamic pressure gradients resulting from vortices shedding off the cylinder.

$$\partial P/_{dx\ total} = \partial P/_{dx\ wave} + \partial P/_{dx\ vortex}$$

Then the munition's mobility will be related to current incipient motion criteria used in sediment transport. To achieve these goals, a pressure-mapped munition (PMM) will be created to obtain Lagrangian measurements of position, orientation, and surface pressure.

The PMMs will be deployed at sites along the New England coast with varying bed states and tidal and current influences. Acoustic Doppler Velocimeters (ADVs), a profiling ADV, a laser grid and camera, a 2-axis profiling IMAGENEX sonar, and pore water pressure sensors will also be deployed. These additional instruments will be used to obtain Eulerian measurements of the velocity profile, bedform geometry, scour, and pore water pressure.



Schematic of Field Deployment of PMM Bases and Accompanying Instruments

Pressure Sensors

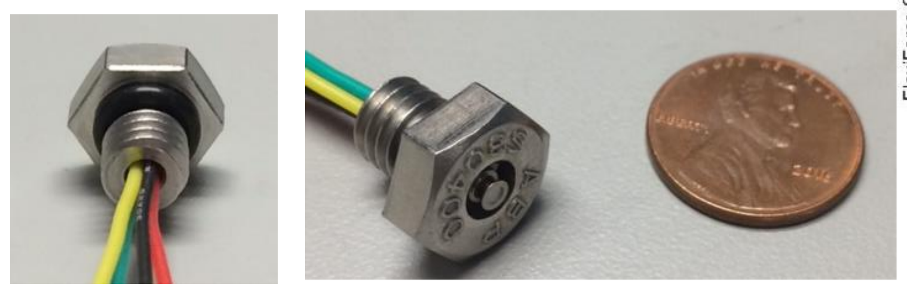
This project will evaluate two types of surface mounted pressure sensors. FlexiForce sensors are thin and flexible enough to wrap around the PMM. A diaphragm pressure sensor can be added to the PMM such that the sensing area is flush to the outer surface of the munition.

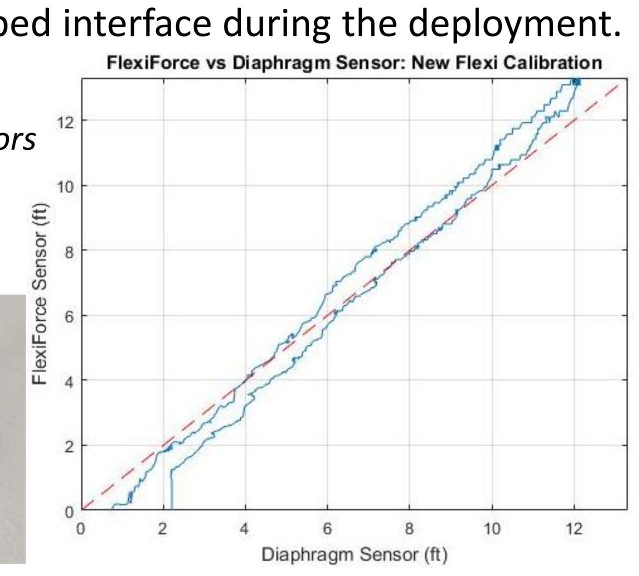
Pressure Sensors Chosen for PMM - FlexiForce (left) and MS5837-30BA (right) [6,7]

Initial experiments have shown hysteresis, drift, and other calibration issues with the FlexiForce sensors. As a result, only diaphragm sensors will be used on the first phase of the PMM while further research will incorporate a combination of both sensors. The sensors are potted into a hollow screw, which an includes an O-ring to create a waterproof piston seal with the PMM base. These sensors will also be included in a vertical "pressure stick" that will concentrate the sensors at the fluid-bed interface during the deployment.

LEFT: Experimental Results of FlexiForce vs Diaphragm Sensors

BELOW: Embedded Diaphragm Sensor

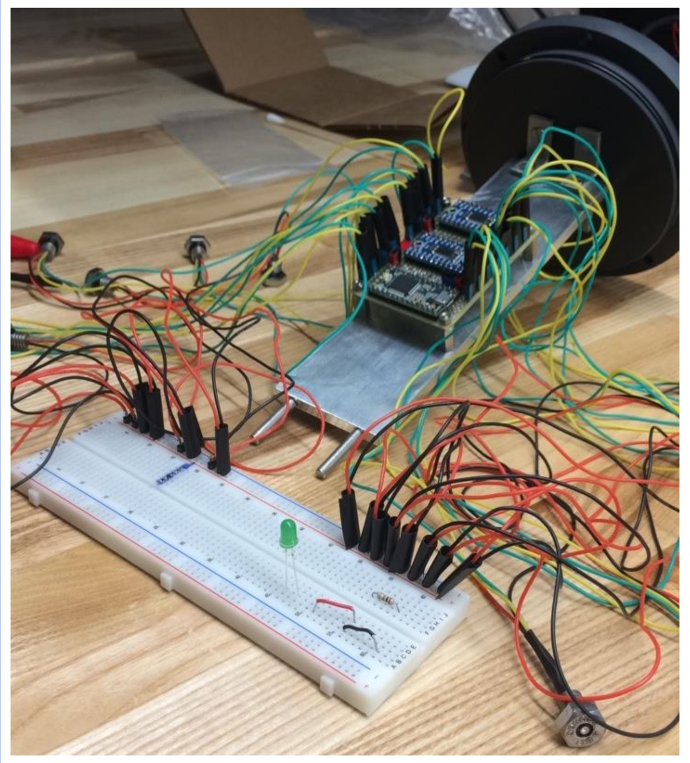




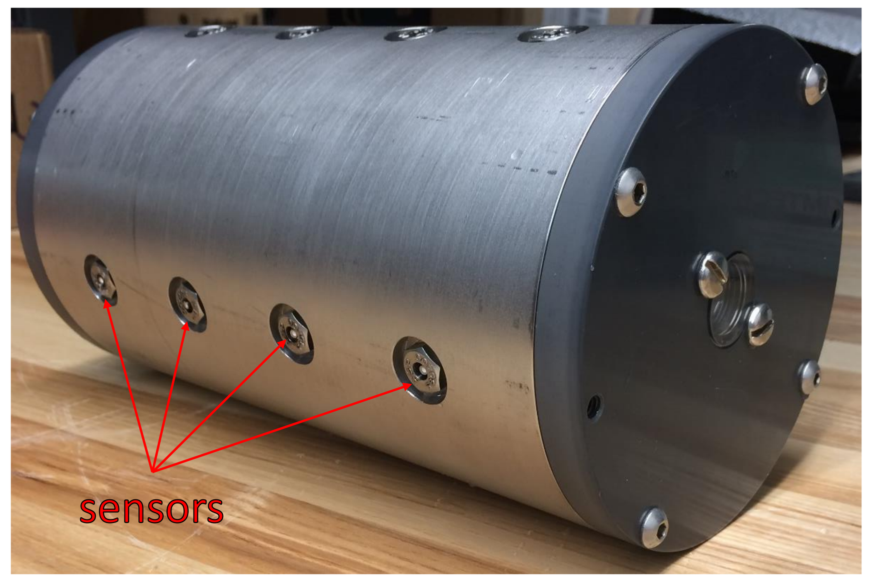
PMM Development

Along with 16 diaphragm pressure sensors, the PMM incorporates an Inertial Measurement Unit (IMU), which combines an accelerometer, gyroscope, and magnetometer to allow for orientation and position tracking. The NGIMU has been chosen as the IMU for this project. The NGIMU also includes a microSD card reader and writer such that the data can be stored and collected after deployment. The PMM will include an acoustic tracker and green LED to facilitate visual tracking and PMM collection after the deployment. All electronics will run on lithium batteries that will power the PMMs for at least 12 hours at a time. The housing is made of steel.

The base of the PMM has been built and this will house all the electronics. It has been left under 20 feet of water overnight and is therefore considered waterproof. In later phases of the project, various fins and cones can be added to the base to simulate different munitions. Currently, validation work is being done on the PMM base.



Internal and External Views of Pressure-Mapped Munition Base



Future Work

- Test and calibrate PMM in wave tank and short-scale deployment (CURRENT)
- Develop theoretical incipient motion response to dynamic pressure gradients and add to a new combined parameter
- Deploy PMMs and other instruments at Fort Foster, ME (JANUARY 2018)
- Apply data collected at Fort Foster to theoretical formulations

References

[1] "Munitions on Beach." US Fish & Wildlife Service, 8 Jan. 2013. Web.
[2] A. Shields. Anwendung der Anhlichkeitsmechanik und Turbulenzforschung auf die Geschiebebewegung. *M itt Preuss Versuchsanstalt fur Wassebau und Schijfbau.*, 26, 1936.
[3] J. F. A. Sleath. Conditions for plug formation in oscillatory flow. *Cont. Shelf Res.*, 19(13):1,643-1,664, October 1999.
[4] D. L. Foster, A. J. Bowen, and R. A. Holman. Field evidence of pressure gradient induced incipient motion. *J. Geophys. Res.*, 111(C5, C05004):l-8,2006.
[5] Frank, D., D. Foster, I. M. Sou, and J. Calantoni (2015), Incipient motion of surf zone sediments, J. Geophys. Res. Oceans, 120, 5710–5734, doi:10.1002/ 2014JC010424.
[6] "FlexiForce A201 Sensor." Tekscan. N.p., 2017. Web.
[7] "0-30 BAR DIGITAL PRESSURE SENSOR." 0-30 Bar Digital Pressure Sensor | TE Connectivity. TE Connectivity, 2017. Web.

Contact Information

[A] Stephanie Gilooly, *University of New Hampshire:* sem748@wildcats.unh.edu
[B] Dr. Diane Foster, *University of New Hampshire:* diane.foster@unh.edu