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Beach Preservation Technology
February 6-8, 2019

FLORIDA SHORE & BEACH
PRESERVATION ASSOCIATION
A League of Cities and Counties on Beach and Coastal Issues

MOBILITY OF UNEXPLODED ORDNANCE

USING SPHERICAL SURROGATES IN THE SWASH ZONE

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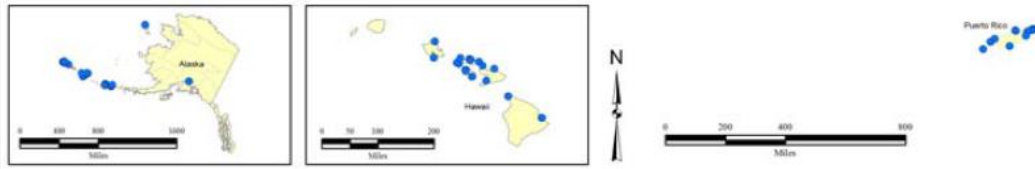
1743

MOTIVATION

- Formerly Used Defense Sites
  - Unexploded Ordinance (UXO)
  - Littered coasts from military training and testing



- BLU-61 cluster bomb
  - Steel, spin-armed submution
  - Spherical (with fins)
  - D = 80 mm, S.G. = 5.1

GOALS/INTENT

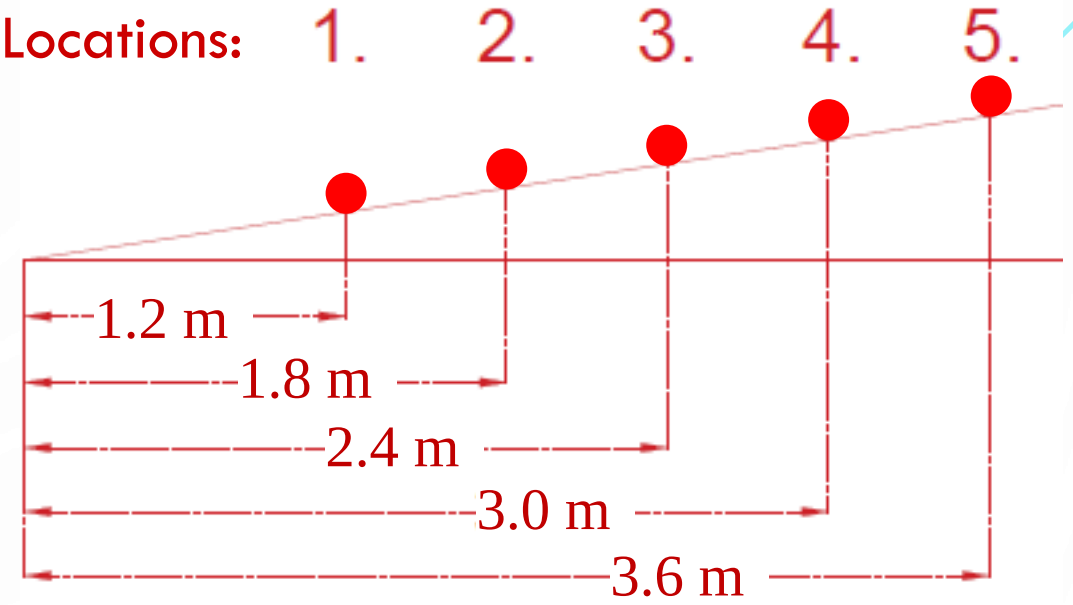
- Create and test spherical surrogates
- Produce repeatable wave forcing
- Relate wave forcing to object response
  - Determine threshold to initiate motion
- Probabilistic prediction of migration
  - since each response varies

TESTING PROCEDURE / MATRIX

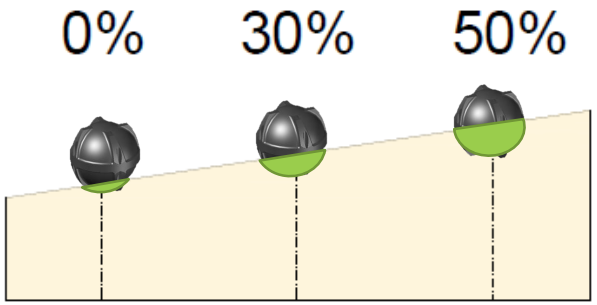
- 4 Spheres:

Material	Specific Gravity (SG)
Stainless Steel	7.7
Lead Core	4.2
Aluminum	2.7
Concrete	1.8

- 5 Locations:



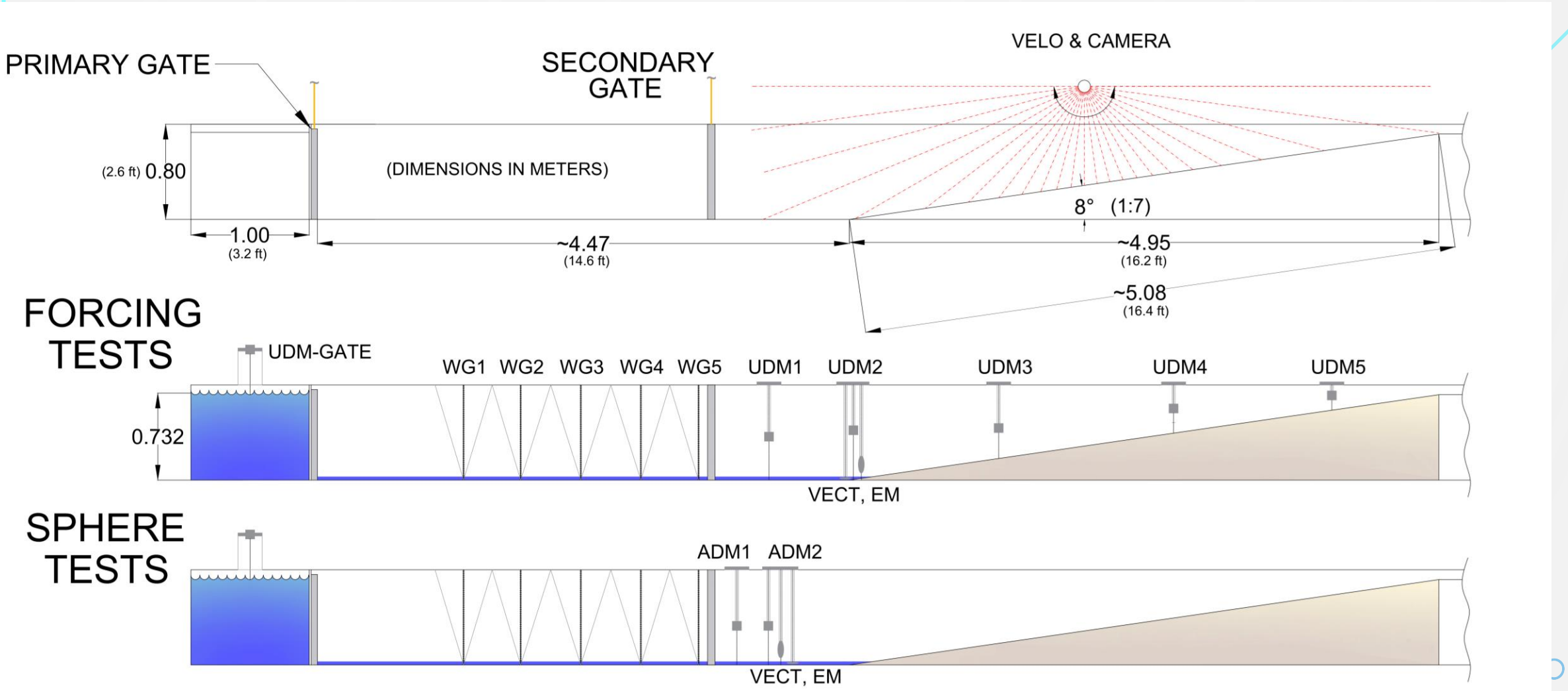
- 3 Burial depths:



- Repeated (at least) 5 times

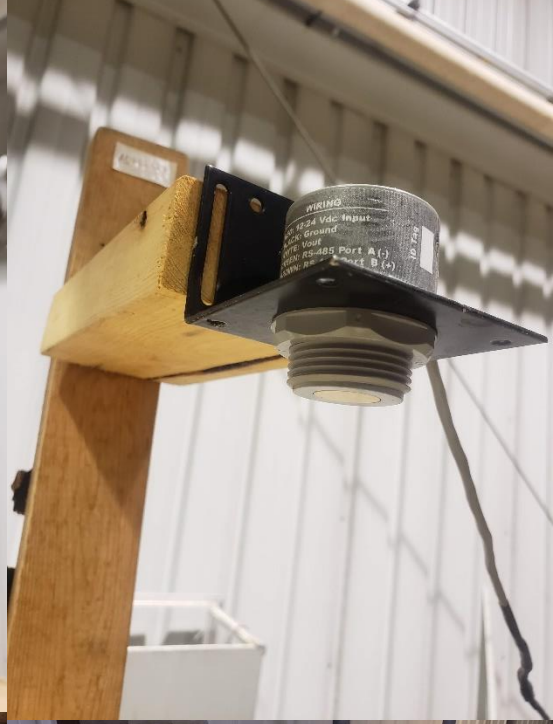
→ 300 total test, tested 2 spheres at a time

EXPERIMENTAL SETUP

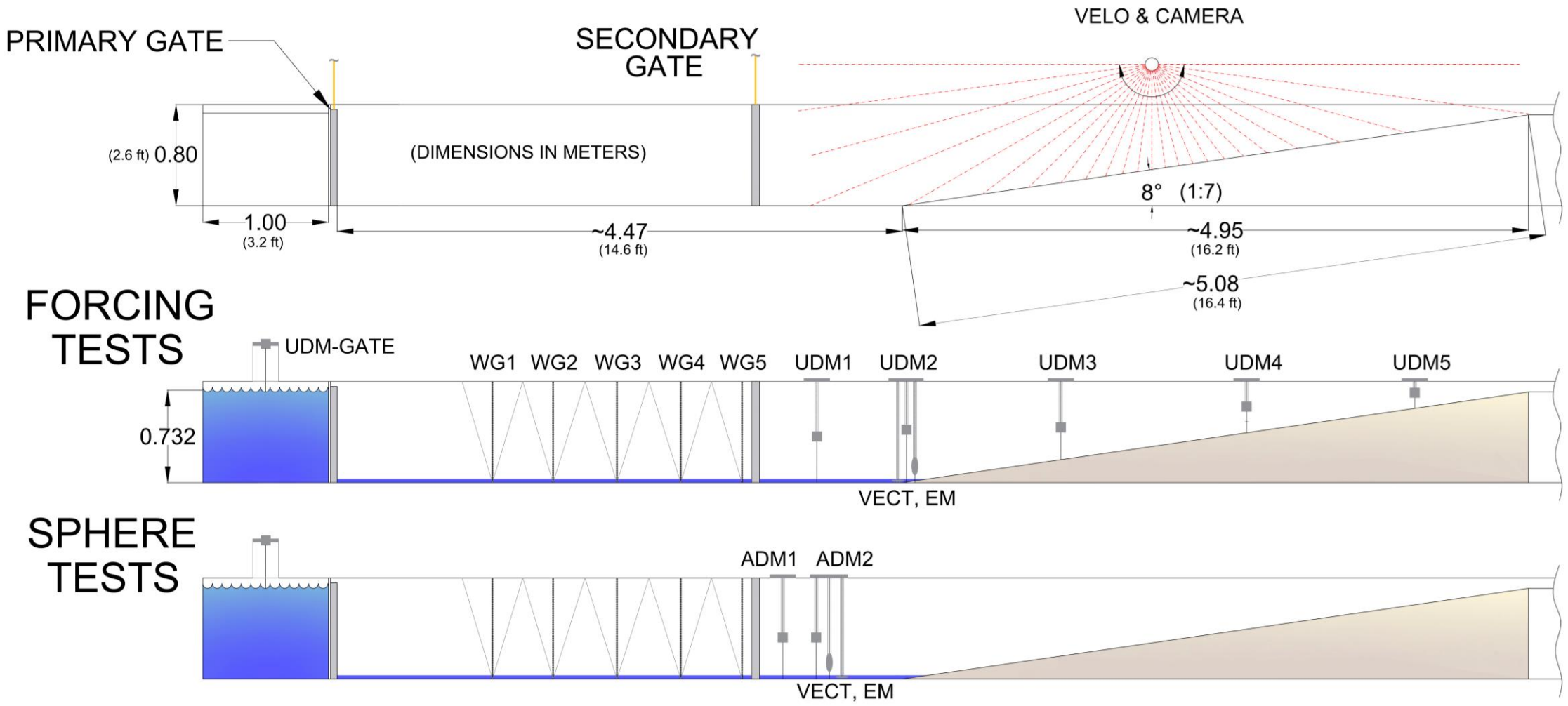


EQUIPMENT

- Ultrasonic Distance Meters (6)
- Resistance Wave Gauges (5)
- Electromagnetic Current Meter (1)
- Vectrino (1)
- Velodyne VLP-16 laser (1)
- Wide-angle lens Camera (1)

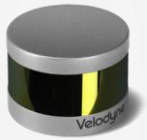


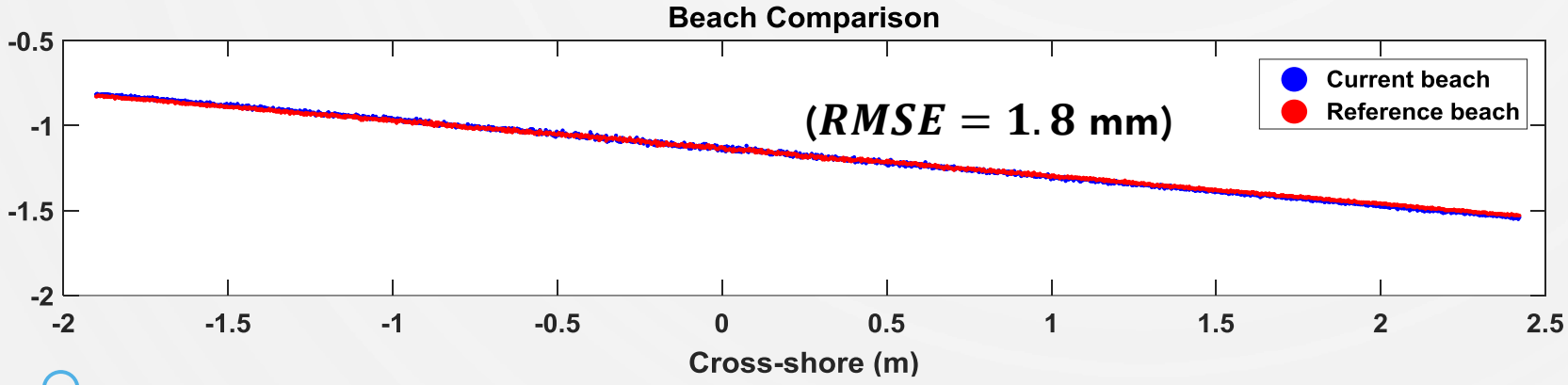
EXPERIMENTAL SETUP

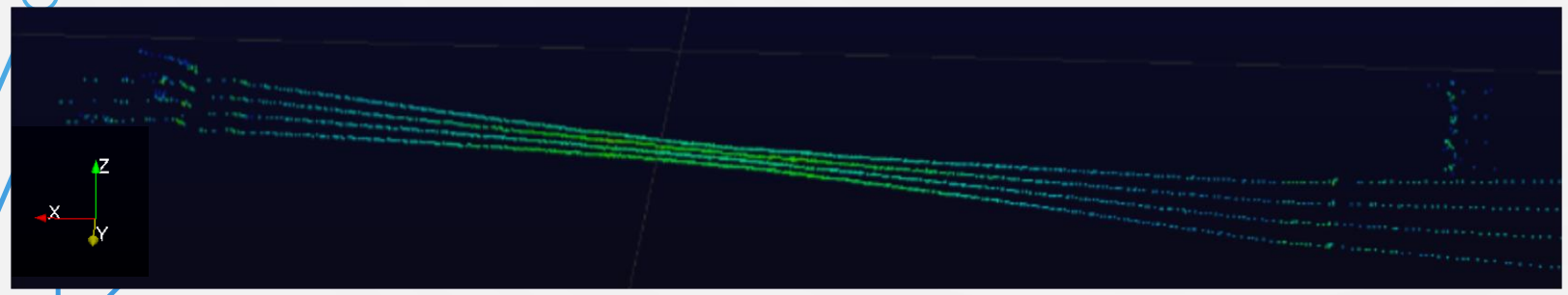


EXPERIMENT VERIFICATION

- Laser scan of beach profile
  - Compare to ‘reference’ beach
  - $RMSE = sqrt(\Sigma(z_{ideal} - z_{test})^2) \ < 3\text{mm}$

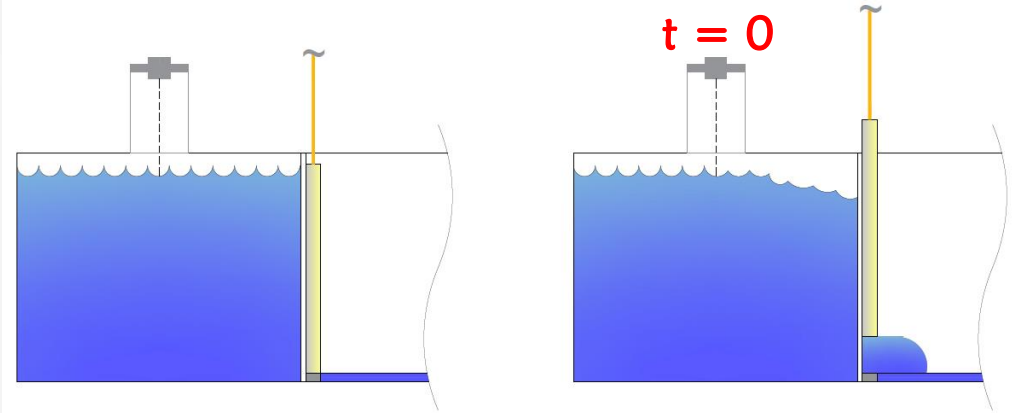






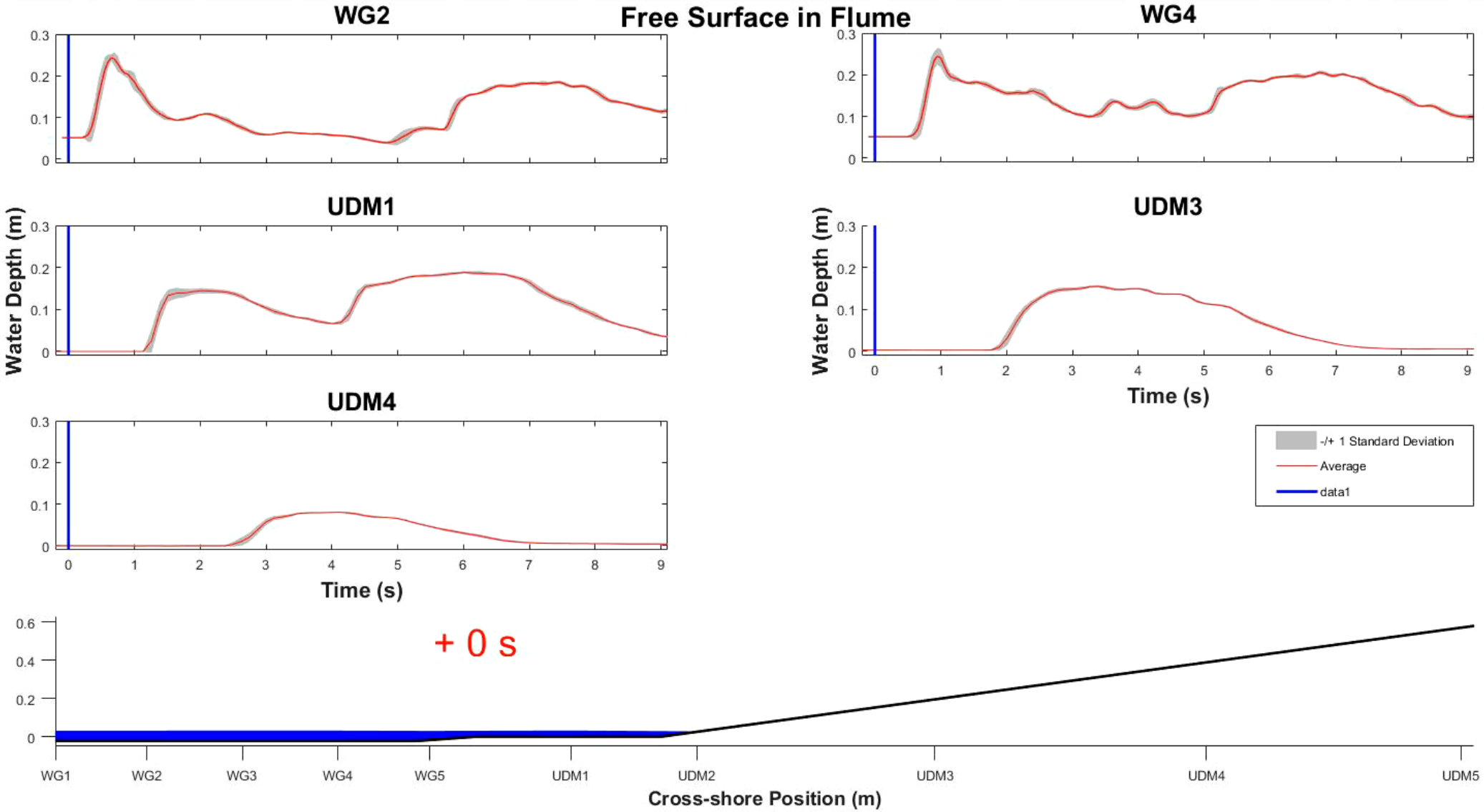
TESTING

WAVE FORCING



- Experiment validation:
  - Wave is launched when UDM above reservoir reads +/- 2mm of experimental setup
    - Wave launch 'start time' initiates from change in UDM reading above reservoir
  - Repeatable forcing determined from averaged free surface elevations

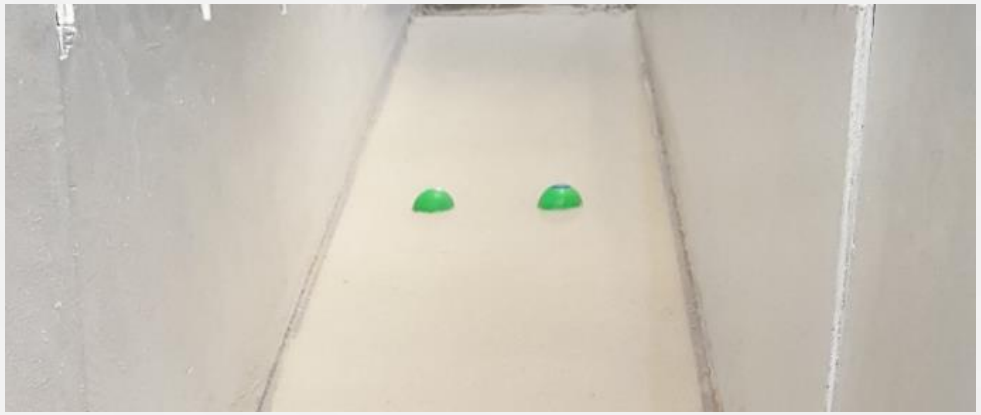
- Critical forcing parameters:
  - Water velocity ➔ obtained from direct velocity measurements at locations of interest
  - Sphere velocity ➔ obtained from tracked trajectory over time


Free Surface in Flume
WG2
WG4
UDM1
UDM3
UDM4
Water Depth (m)
Time (s)
-/+ 1 Standard Deviation
Average
data1
+ 0 s
WG1
WG2
WG3
WG4
WG5
UDM1
UDM2
UDM3
UDM4
UDM5
Cross-shore Position (m)

SPHERE MOTION / TRACKING

- Target contrasting pixels by applying mask
  - Green most pixels (Aluminum & Concrete)
  - Darkest pixels (Lead & Stainless Steel)

- Identify and follow track of these ‘blobs’ over time



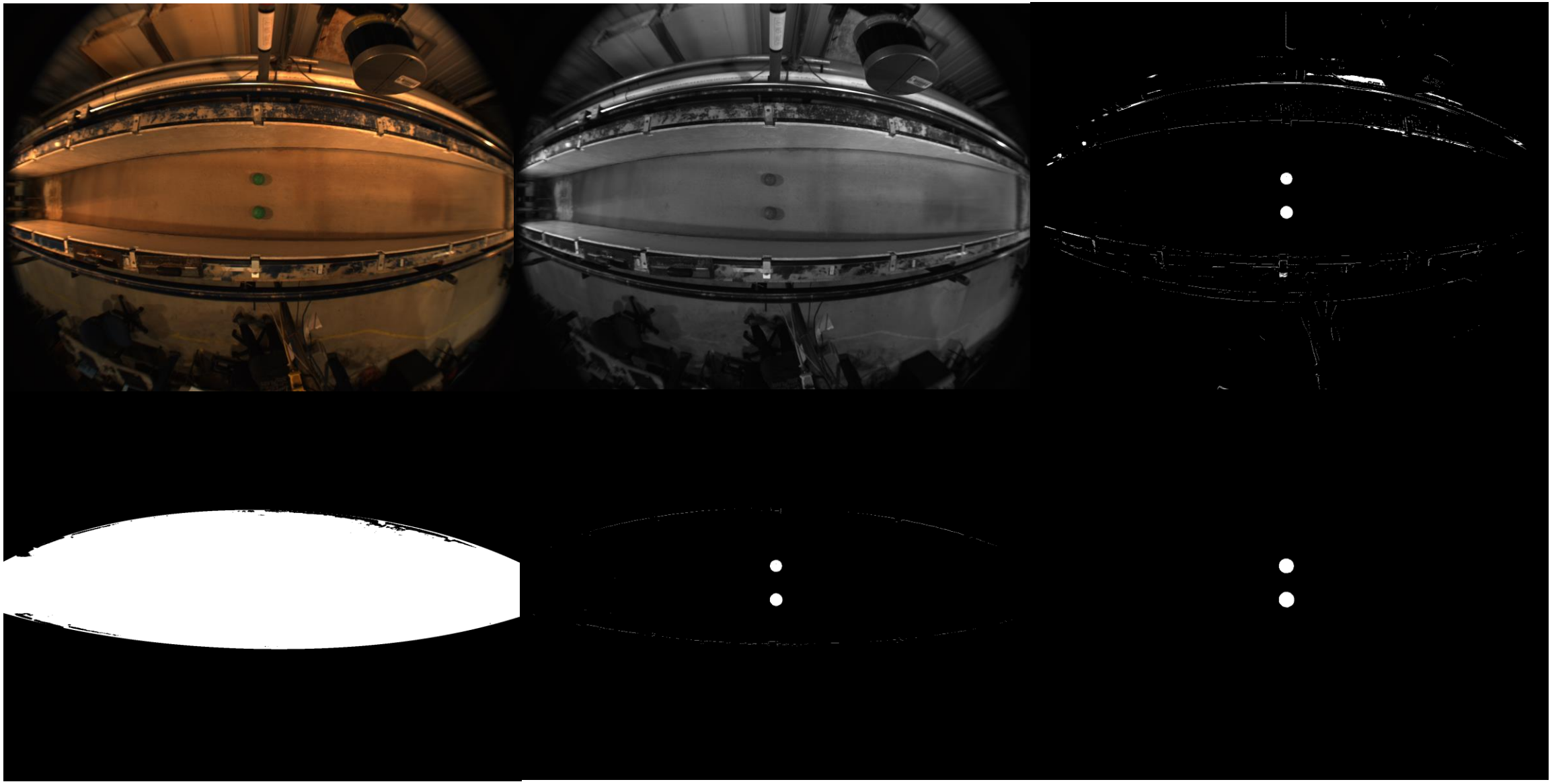
OBJECT TRACKING

Computer Vision System Toolbox– MATLAB

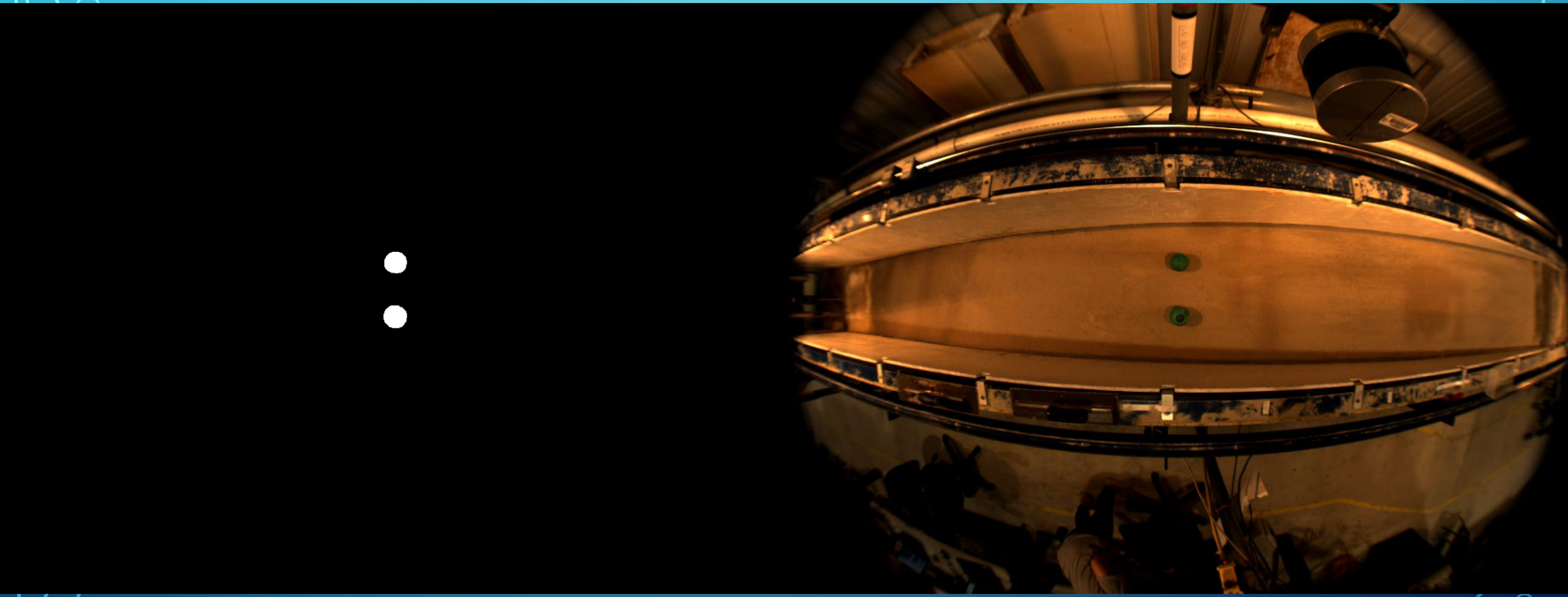
Detection → Mask

Prediction → Kalman filter

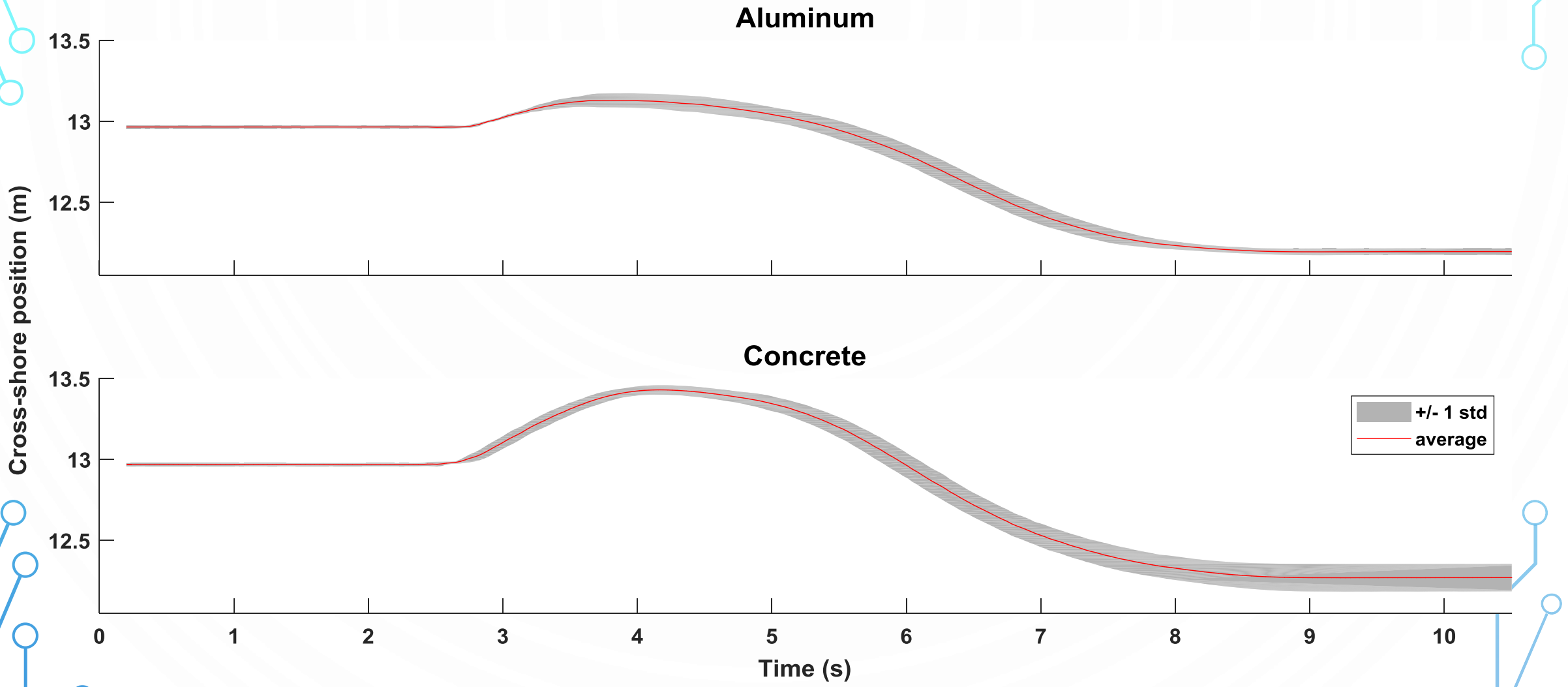
Data association → Cost assignment algorithm



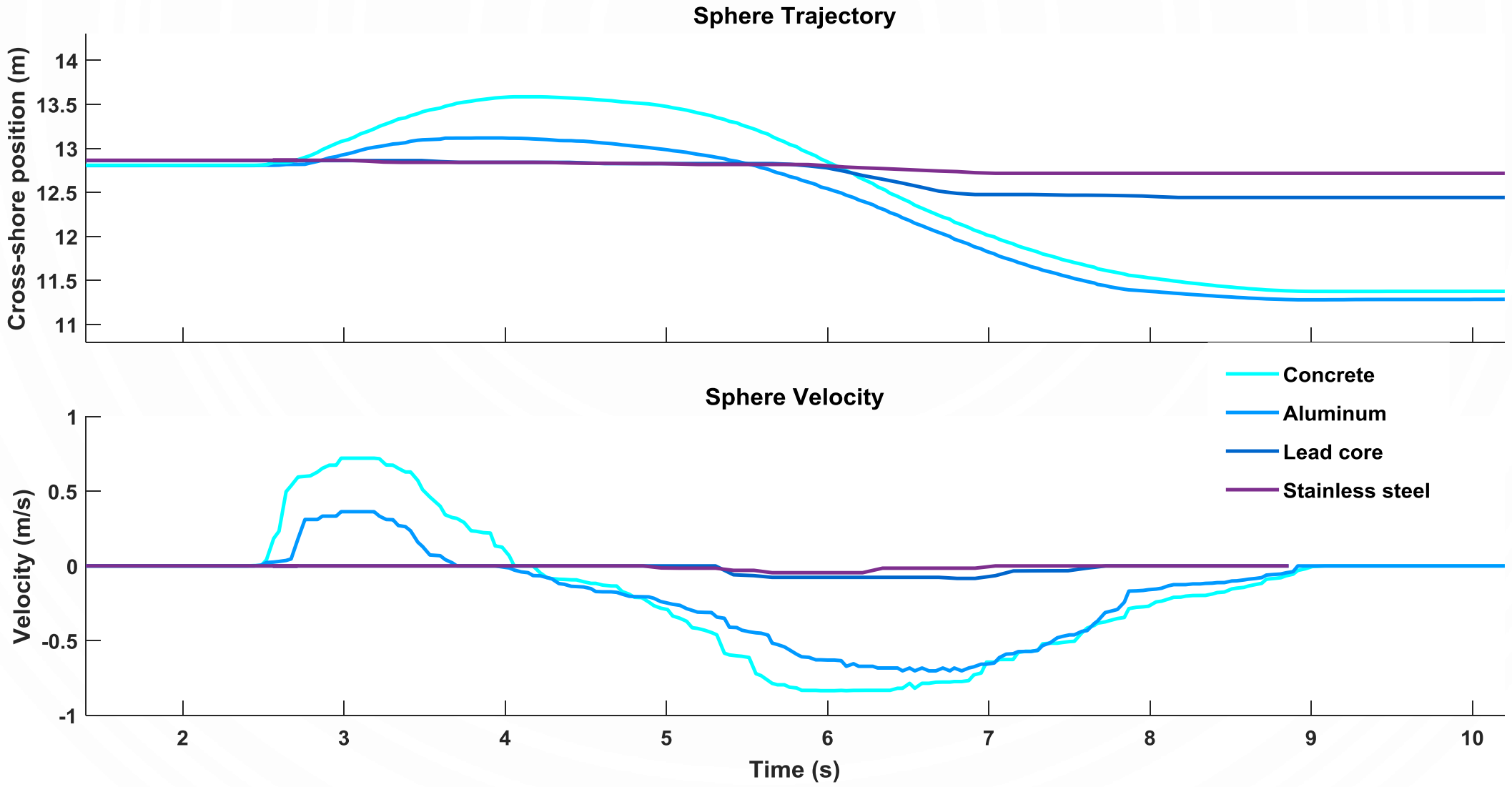
SUCCESSFUL TRACKING

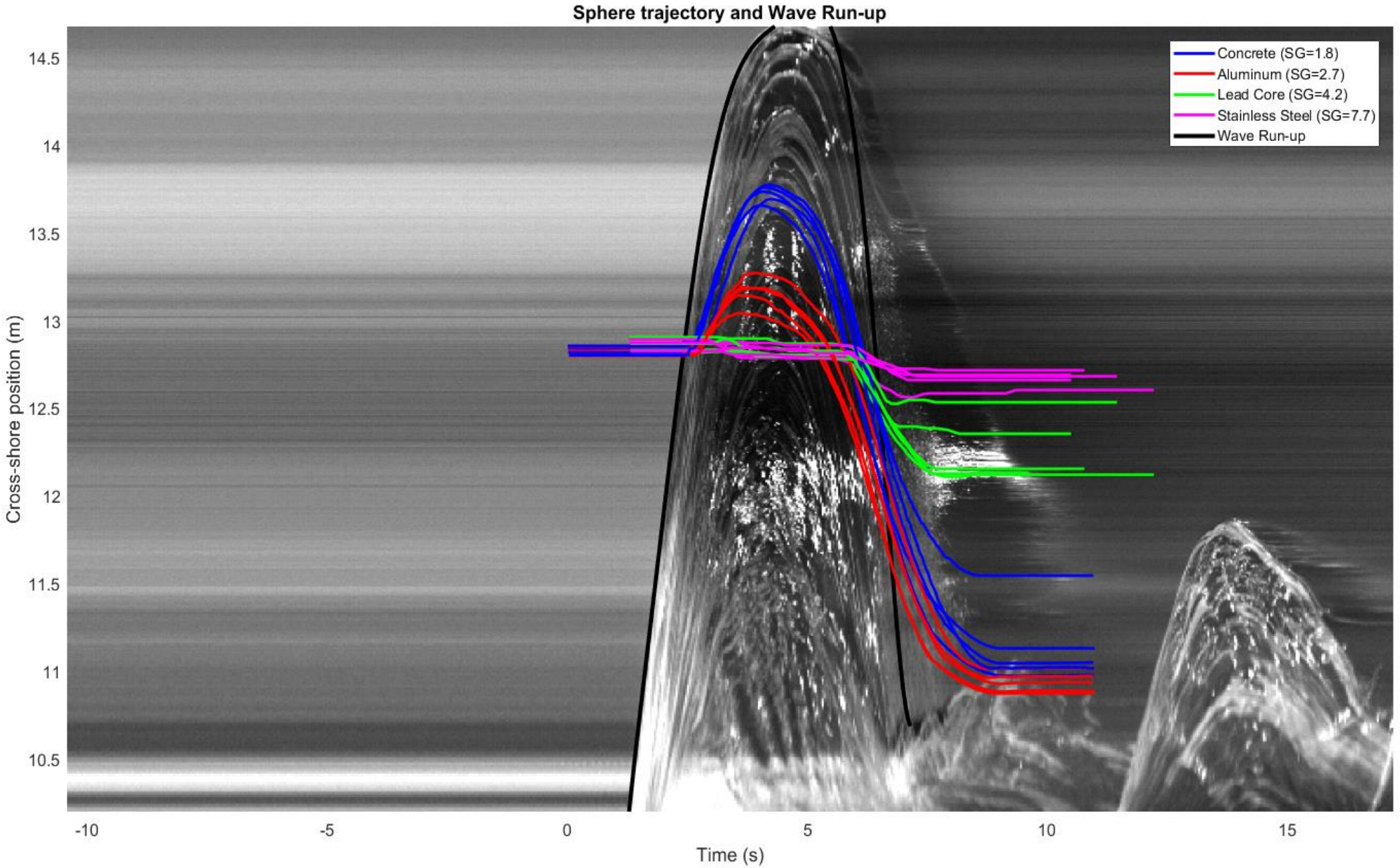


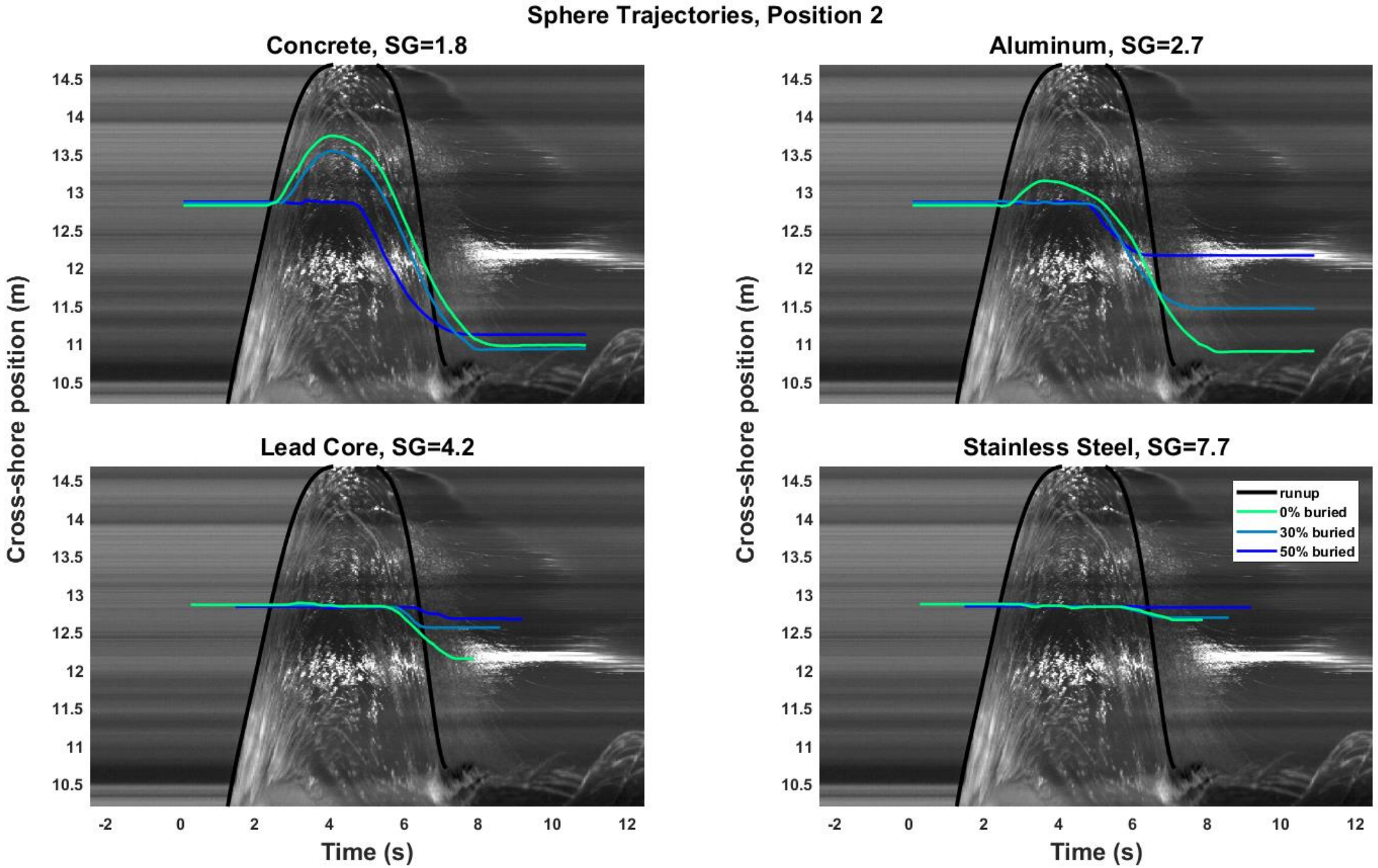
AVERAGED TRAJECTORIES



SPHERE MOTION CHARACTERISTICS




Sphere trajectory and Wave Run-up
Concrete (SG=1.8)
Aluminum (SG=2.7)
Lead Core (SG=4.2)
Stainless Steel (SG=7.7)
Wave Run-up
Cross-shore position (m)
14.5
14
13.5
13
12.5
12
11.5
11
10.5
-10
-5
0
5
10
15
Time (s)


Sphere Trajectories, Position 2
Concrete, SG=1.8
Aluminum, SG=2.7
Lead Core, SG=4.2
Stainless Steel, SG=7.7
Cross-shore position (m)
Time (s)
14.5
14
13.5
13
12.5
12
11.5
11
10.5
-2
0
2
4
6
8
10
12
runup
0% buried
30% buried
50% buried

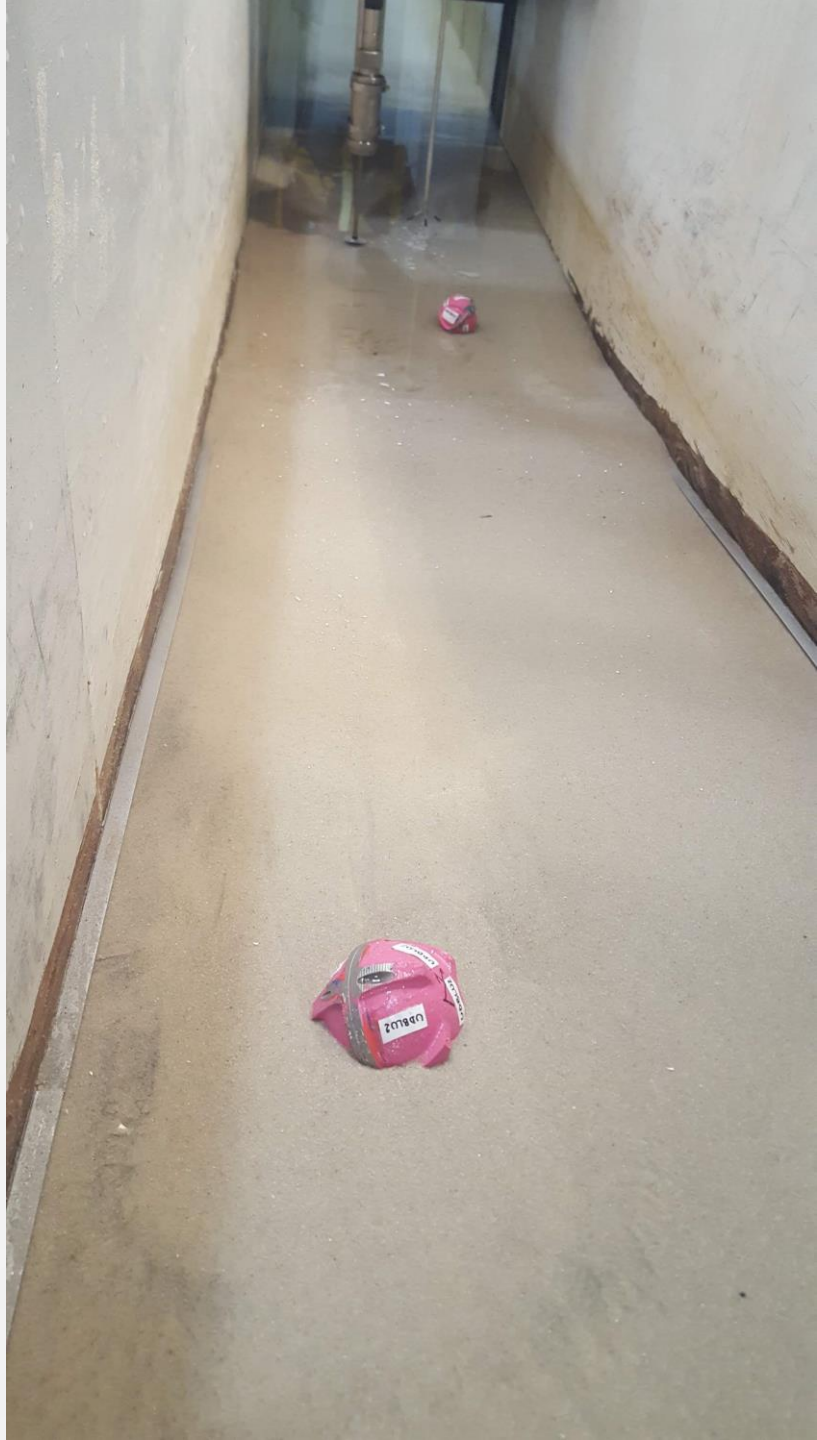
ONGOING ANALYSIS

- Prediction matrix/equation given initial conditions and wave forcing
- Compare to **KEULEGAN-CARPENTER NUMBER** (*Friedrichs, 2016*)

$$KC = \frac{UT}{D}$$

- T: duration of the swash event
- D: munition diameter
- U: flow velocity

- Testing non-spherical objects in a flume
- Long-term migration (multiple waves)



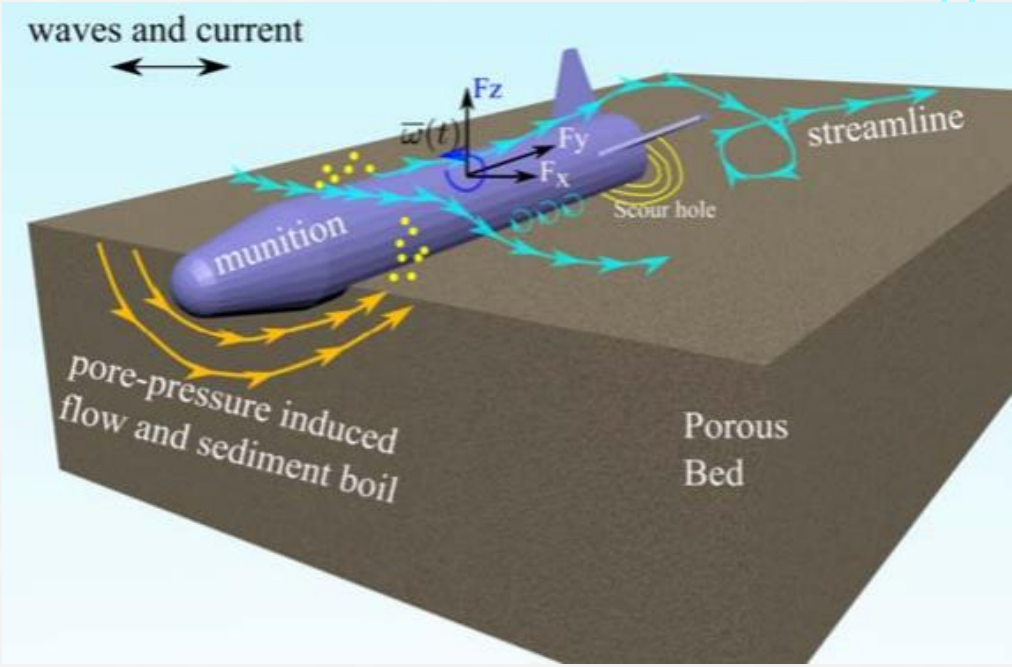
OTHER EFFORTS

- Xiaofeng Liu, Pennsylvania State University,

"Modeling of Munition Dynamics due to Turbulent Flow and Scour"

- Demetra Cristaudo, University of Delaware,

"Mobility and Burial of Munitions in the Swash Zone"



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