Computer Modeling of Wave Energy Devices

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Point Absorber Systems

- Waves lift the kayak
- In this process, waves do work on kayak
- Why not harness this energy?

$P = m \cdot g \cdot h / t$

$P = (120\ kg)(9.8\ m/s^2)(0.5\ m)/(0.5\ s)$

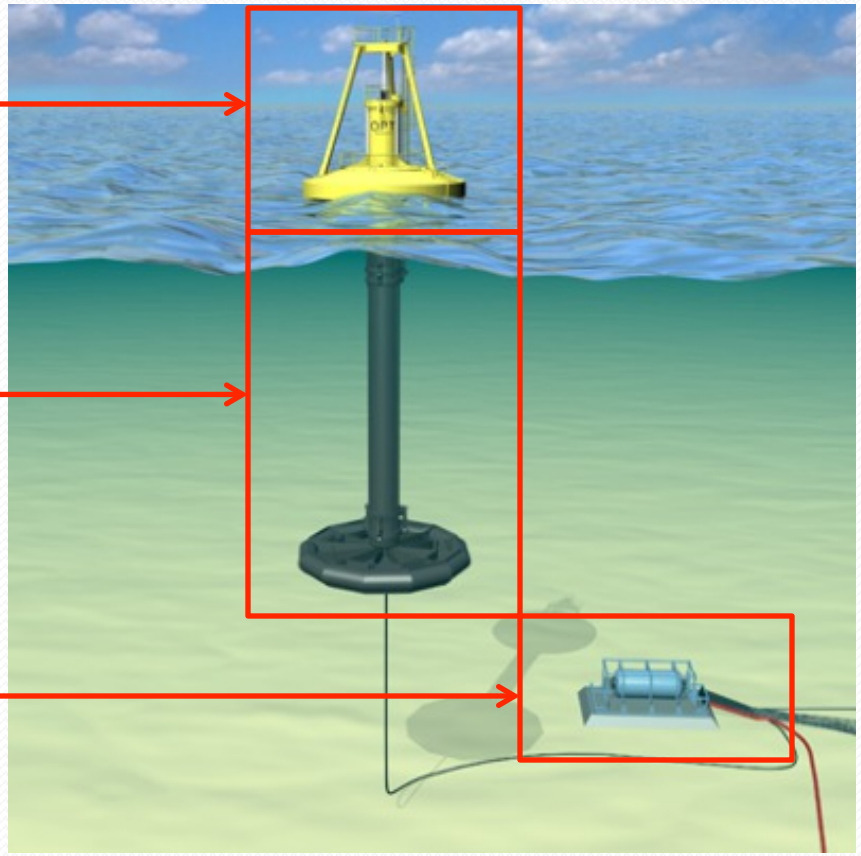
$P = 1.176\ kW$

Point Absorber Systems (cont.)

Floating Structure
(very buoyant)

Submerged Structure
(slightly buoyant)

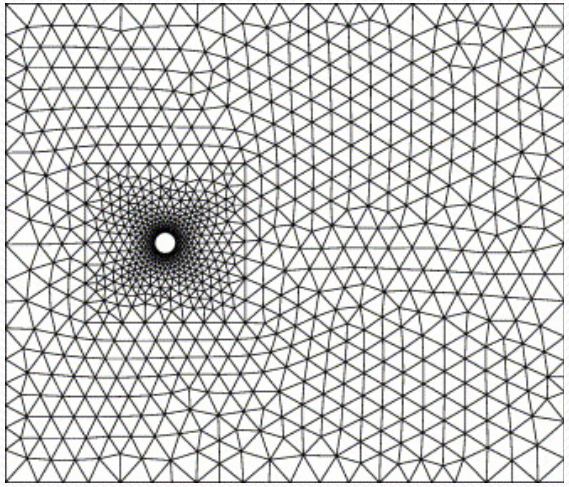
Power Conversion/Storage



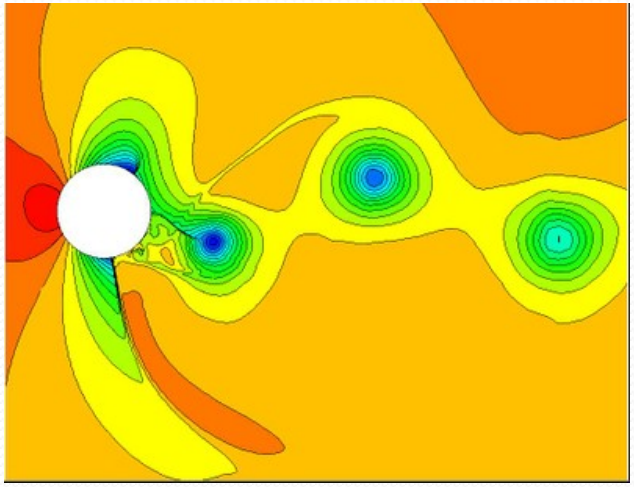
Wave Energy Resource

- Worldwide
  - Total Power: 3.0 TW
  - Electricity Production: 13,000 TWh/year
  - Enough to power: ~1 billion U.S. homes
- United States
  - Total Power: 0.3 TW
  - Electricity Production: 1,300 TWh/year
  - Enough to power: ~100 million U.S. homes

Computational Fluid Dynamics



Step 1: Meshing



Step 3: Post-processing

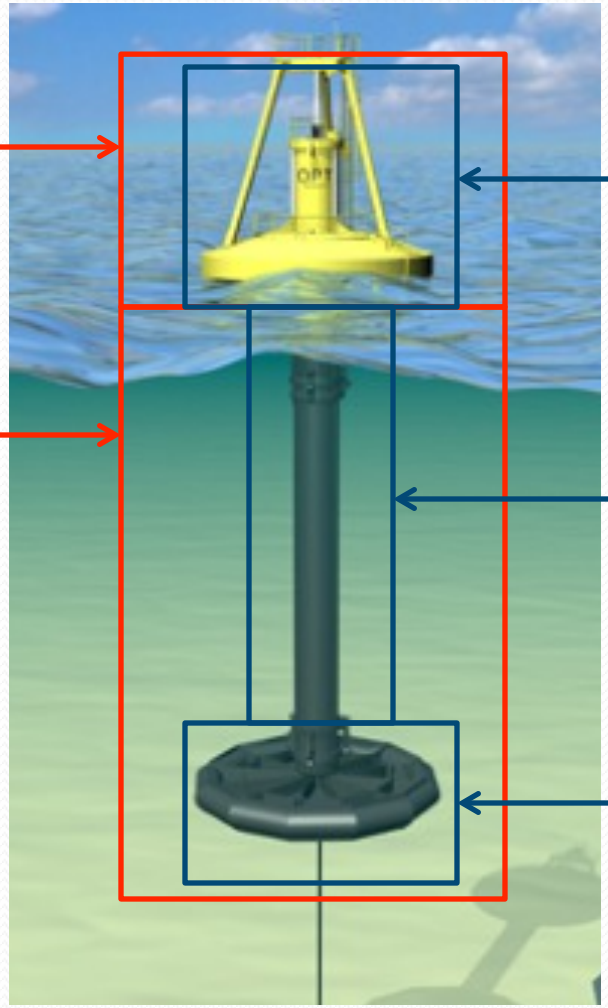
$$\frac{\partial \rho}{dt} + \nabla \cdot (\rho u_i) = 0$$

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(v\frac{\partial u_i}{\partial x_j} + \tau_{ij}\right)$$

$$\frac{\partial \gamma}{\partial t} + \nabla \cdot (\gamma u_i) = 0$$

Step 2: Computations

System Idealization



Floating Structure
(very buoyant)

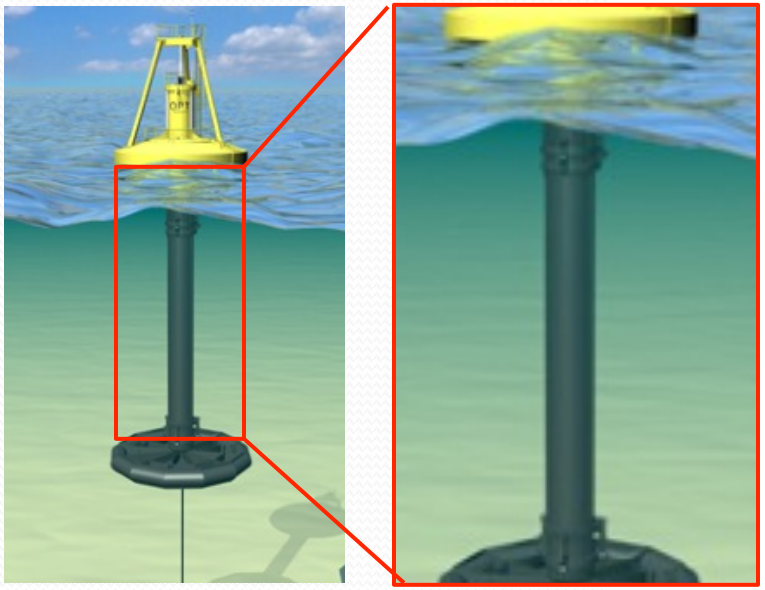
Submerged Structure
(slightly buoyant)

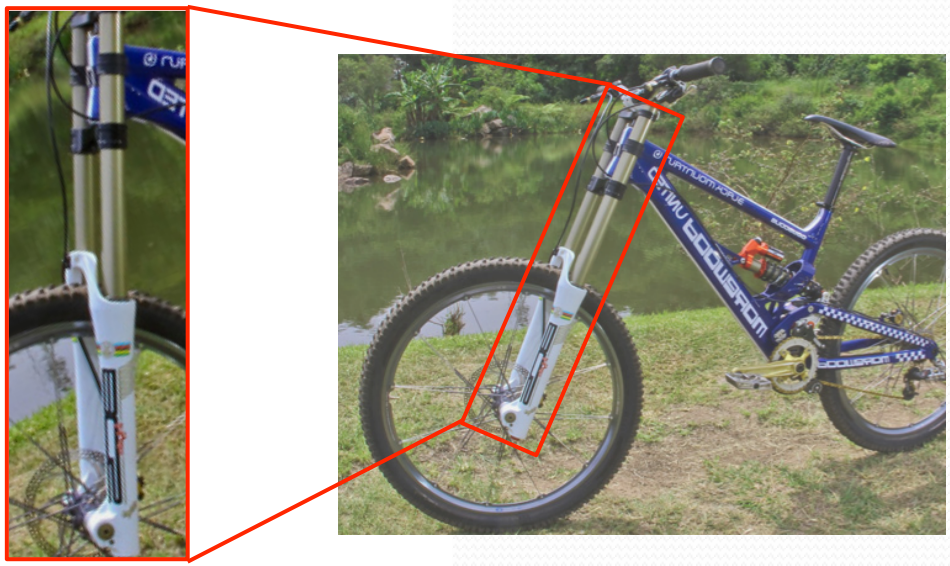
Float
(very buoyant)

Power Take Off System
(no mass, modeled as a spring)

Reaction Plate
(neutrally buoyant)

Idealizing the PTO System

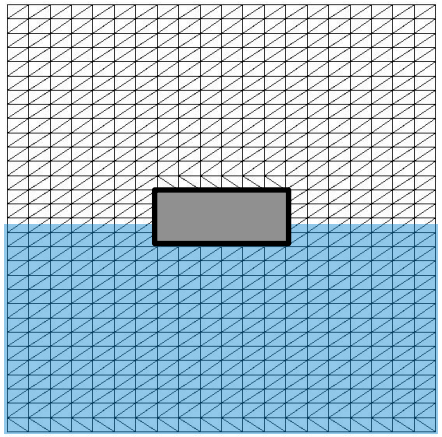


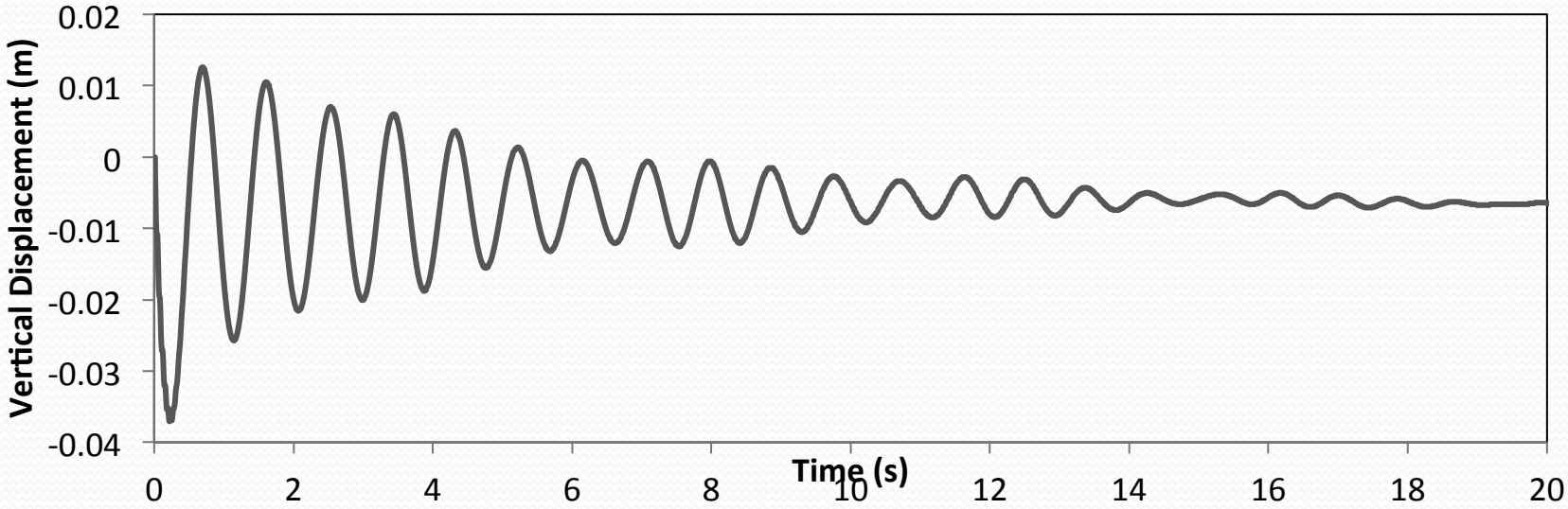


$$F_{PTO} = k(r_1 - r_2) + c(v_1 - v_2)$$

Simulation #1: Diagnostics

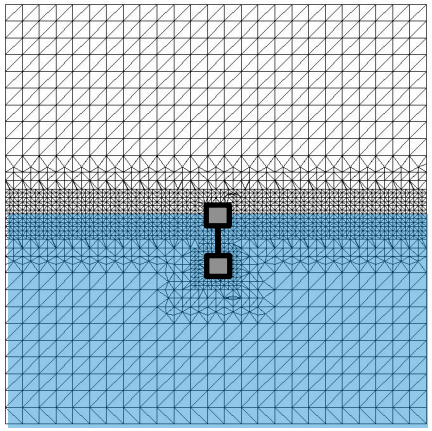
- Verification of VOF & 6DOF
- Free decay test conducted in heave

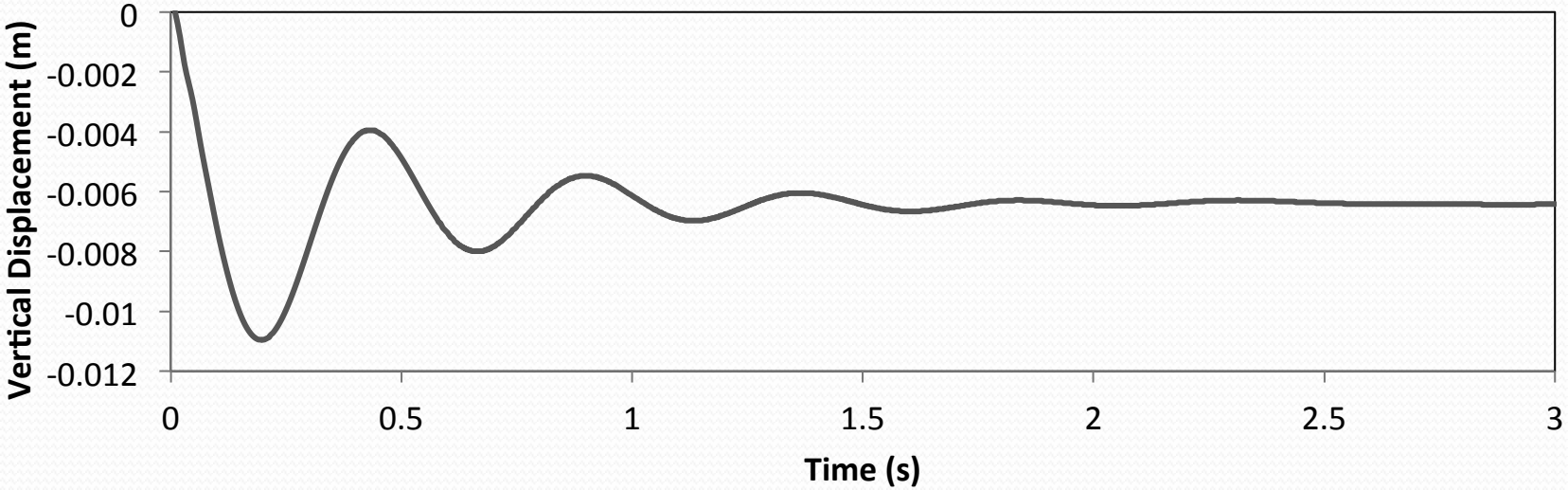




Simulation #2: PTO, Quiscent

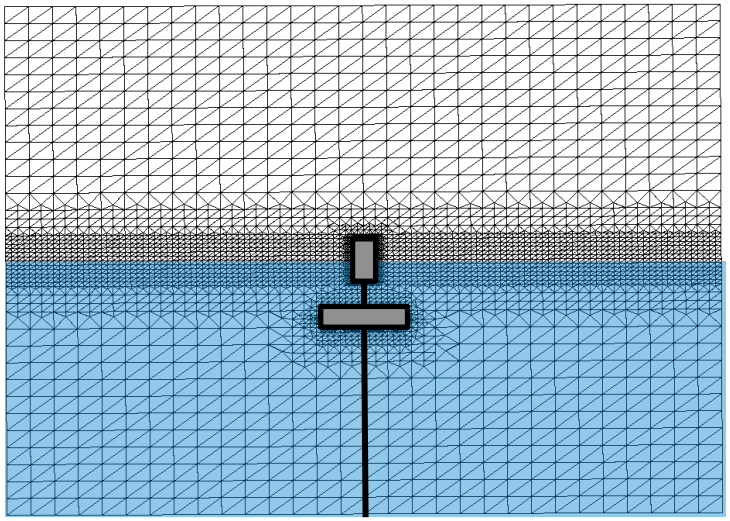
- Verification of VOF & 6DOF
- Free decay test conducted in heave

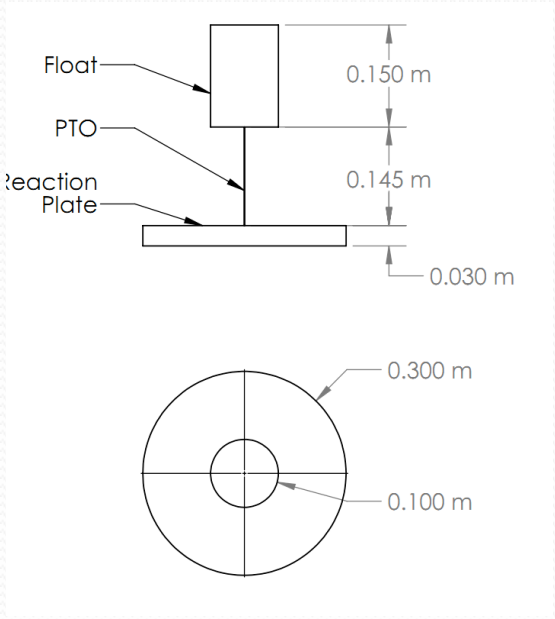




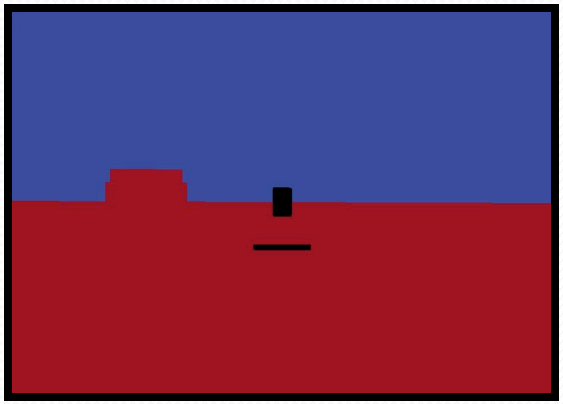
Simulation #3: PTO, Dynamic

- More realistic geometry
- Mooring line simulated with a spring element

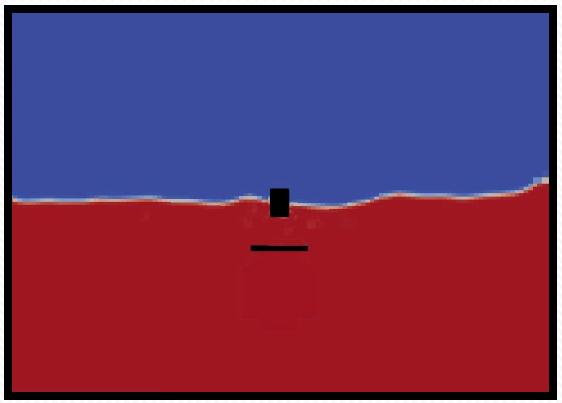




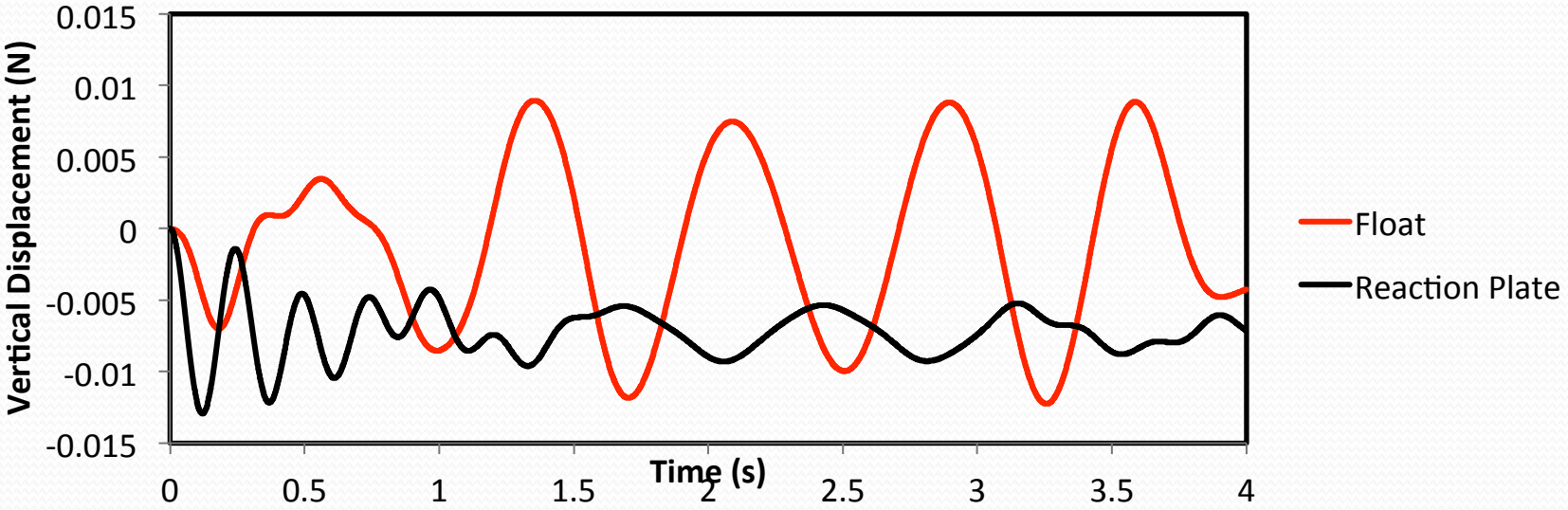
Simulation #3 (cont'd)



t = 0.0 sec



t = 4.0 sec



Conclusions and Future Work

- Conclusions
  - A robust linear PTO utility was developed within OpenFOAM
- Future Work
  - Develop an angular PTO utility
  - Develop an interface that will allow control systems to interact with the simulation

Questions?

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