Agenda

9:00-9:30	Progress Overview
9:30-10:45	Numerical Analysis (Development and Validation)
10:45-12:30	Concept Analysis and Evaluations
12:30-1:30	Lunch
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Power Buoy Project Overview

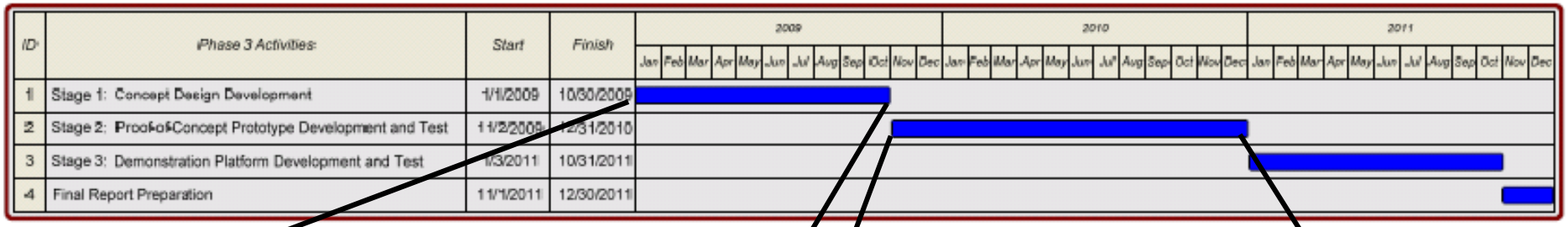
Stage 1 – Concept Development & Analysis
- Concept Exploration
- Development of Analysis Tools
- Model Testing
- Refinement of Concept Design

Stage 2 – Prototype Development
- Prototype Testing (at-sea)
- Autonomous Platform Development

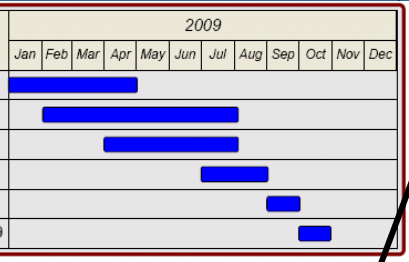
Stage 3 – Testing and Demonstration
- Demonstration Platform Development
- Extended Test Deployment (Autonomous Behaviors)

Project Stage I and II – As Proposed

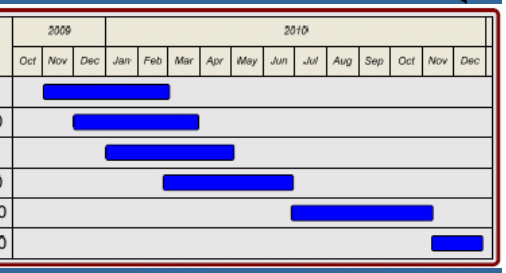
ID	Phase 3 Activities	Start	Finish
1	Stage 1: Concept Design Development	1/1/2009	10/30/2009
2	Stage 2: Proof-of-Concept Prototype Development and Test	11/2/2009	12/31/2010
3	Stage 3: Demonstration Platform Development and Test	1/3/2011	10/31/2011
4	Final Report Preparation	11/1/2011	12/30/2011



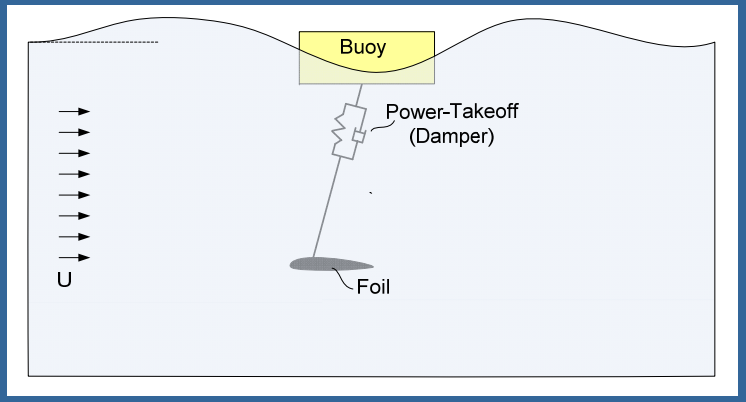
ID	Phase 1 Activities	Start	Finish
1	Design Space Study	1/1/2009	5/1/2009
2	Modeling of potential systems	2/2/2009	8/4/2009
3	Testing to verify model elements	4/1/2009	8/4/2009
4	Trade-off Study/Downselect	7/1/2009	9/1/2009
5	Functional Requirements Development	9/1/2009	10/1/2009
6	Concept Design Review	10/1/2009	10/30/2009

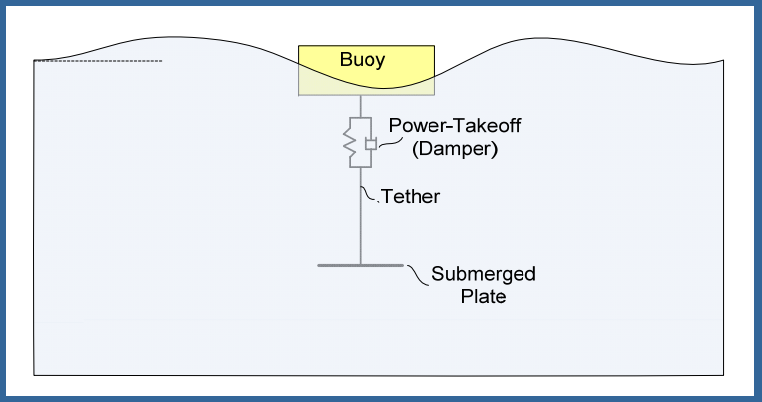


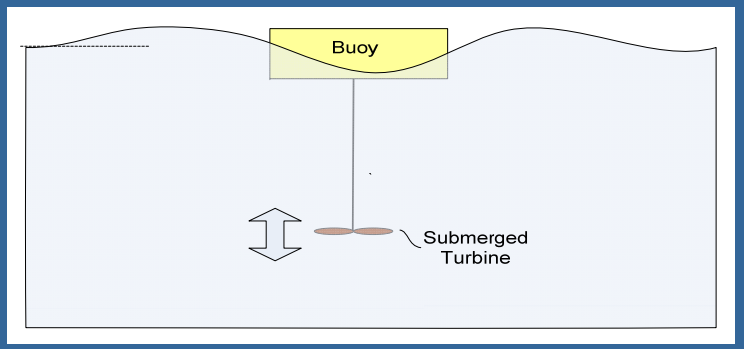
ID	Phase 2 Activities	Start	Finish
1	Detailed Development of Prototype from Concept	11/2/2009	3/2/2010
2	Design work prior to fabrication	12/1/2009	3/30/2010
3	Prototype Fabrication	1/1/2010	5/3/2010
4	Assembly, Integration and Test of prototype	2/25/2010	6/29/2010
5	Field testing of Prototype	6/28/2010	11/10/2010
6	Final performance assessment.	11/10/2010	12/28/2010

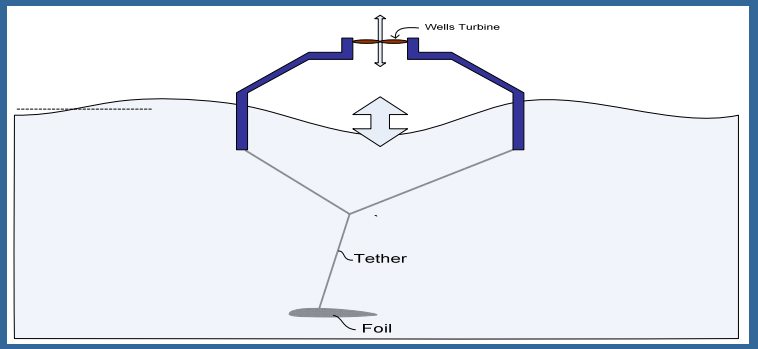


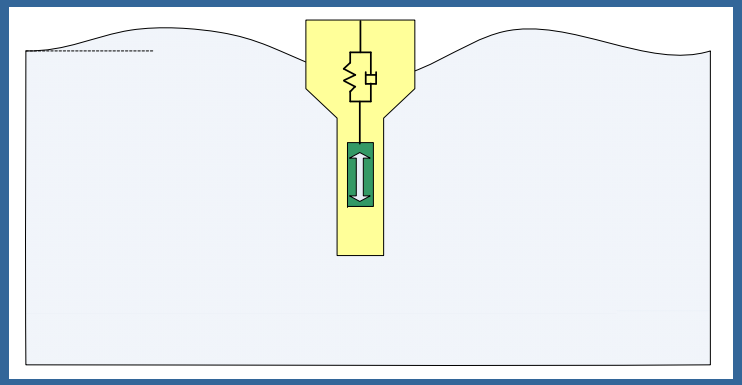
Concepts – Potential Designs

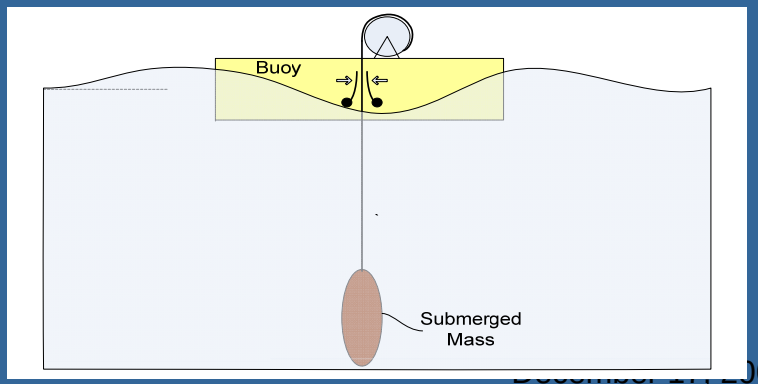








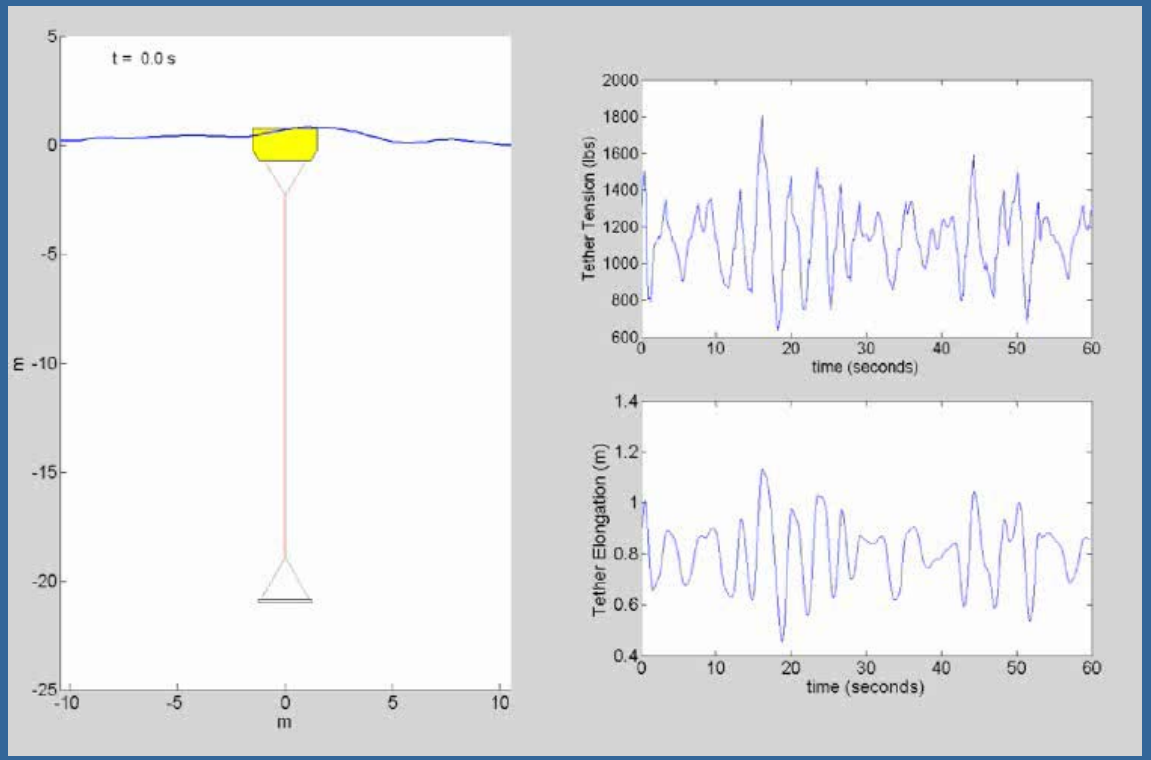




Analysis and Modeling

Time-Domain Numerical Modeling

- TD_xxx: Matlab tool for analyzing floating body concepts
- Numerical tools validated by at-sea tests
- Provides performance predictions of various concepts



Prototype development plans for 2010

Instrumented Proof of Concept Prototype:

- Buoy with Submerged Plate/Submerged Foil
- Power take-off and storage system
- GPS/Radios/Lights/etc
- Tests in Summer/Fall 2010

Expanded Team:

Jon Erickson – MBARI Mechanical Engineer
Wayne Radochonski – MBARI Software Engineer
Paul McGill – MBARI Electrical Engineer
Chad Kecy – MBARI Electrical Engineer
Brian Kieft – MBARI Software Engineer
MBARI Technician Staff

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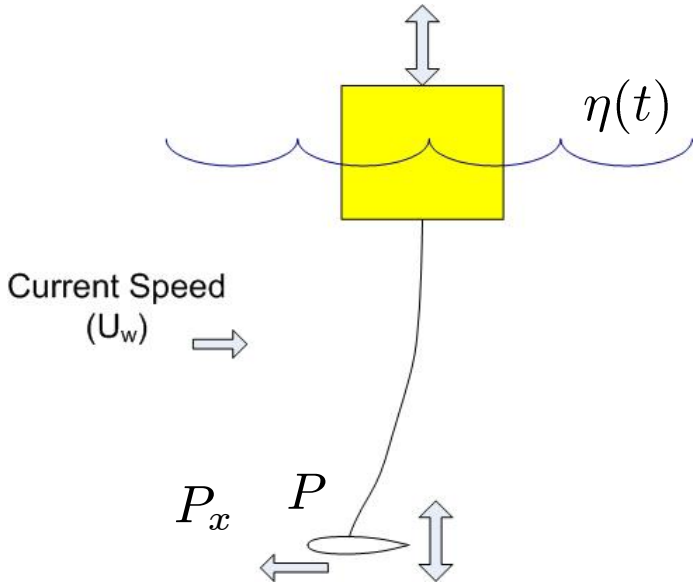
Time-Domain Numerical Analysis (Development and Validation)

Goal

- Input:
  - Wave Spectrum
  - Wind Speed
  - System Characteristics
    (Mass, Size, Shape, etc)

- Output:
  - Body Motions
  - Force Histories



Problem

Apply Newtons equations of motion to each body in system.

$$M_B \ddot{x}_B = \Sigma F_B$$
$$M_F \ddot{x}_F = \Sigma F_F$$

Solution

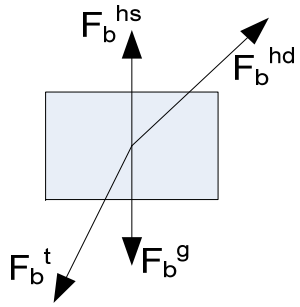
Two coupled problems:

- Wave-Hydrodynamics (TD_xxx)
- Reaction-Foil Forces

Time-Domain Modeling

Free-Body Diagrams and Equations of Motion

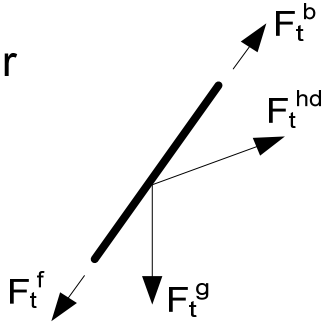
Buoy



F_b^{g} = Force on Buoy Due to Gravity
F_b^{t} = Force on Buoy Due to Tether
F_b^{hs} = Hydrostatic Force on Buoy
F_b^{hd} = Hydrodynamic Force on Buoy

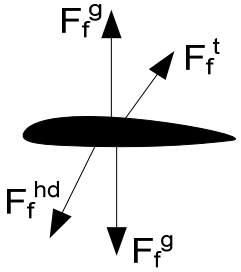
$$\Sigma F_b = F_b^{g}+F_b^{t}+F_b^{hs}+F_b^{hd}=M_b \ddot{X}_b \qquad (1)$$

Tether



$$\Sigma F_t = F_t^{b}+F_t^{f}+F_t^{g}+F_t^{hd}=M_t \ddot{X}_t \qquad (2)$$

Foil



$$\Sigma F_f = F_f^{g}+F_f^{t}+F_f^{hs}+F_f^{hd}=M_f \ddot{X}_f \qquad (3)$$

TD_xxx – Time-Domain Code

Purpose

- Compute forces and motions for floating bodies tethered together in waves subject to specified wave fields or other forcing (i.e. Wind)

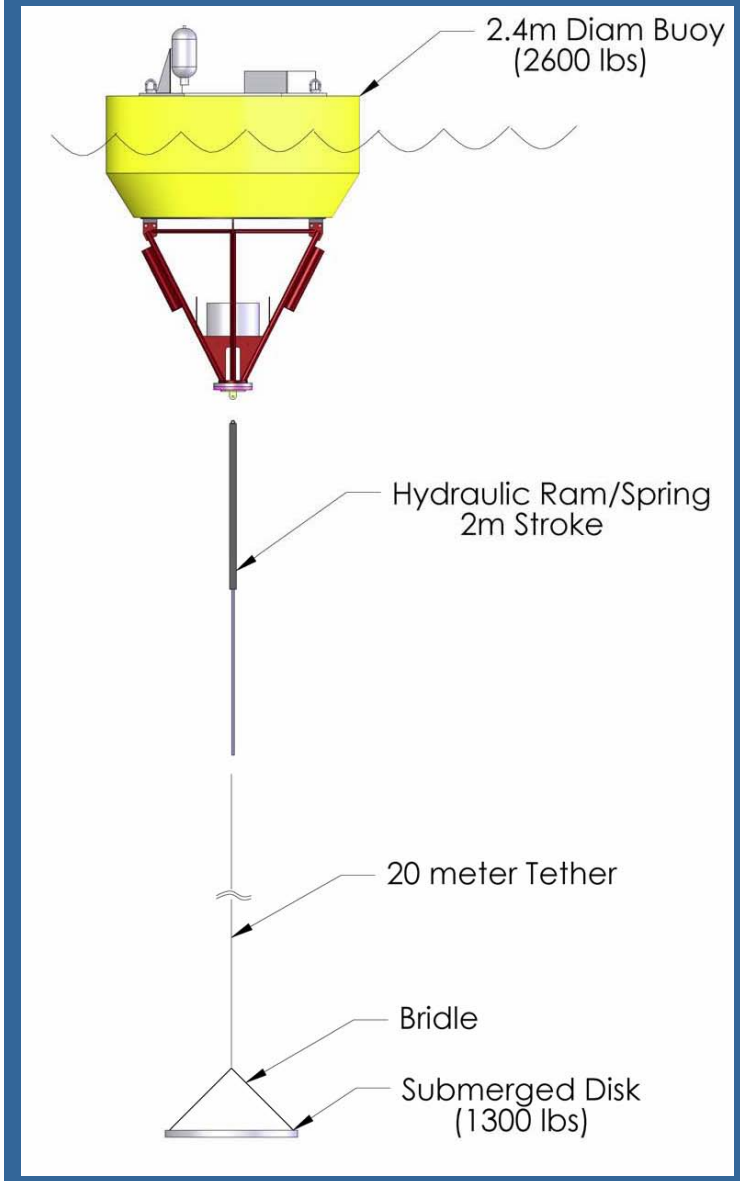
Techniques

- Solves Newton's equation of motion (F = ma) in the time-domain (4^{th} order RK solver)
- Linear wave theory for wave excitation and radiation. Impulse response functions computed from WAMIT frequency domain results.

Code

- Written in Matlab programming language
- Extensible to any number of bodies with arbitrary forcing that can be described as a function of body motion (position and velocity histories).
- Takes the role of the MI&T software in original proposal.

Code Application and Validation



Forces on Buoy

- Wave Exciting Forces
- Wave Radiation Forces
- Viscous Drag

Forces on Plate

- Drag from Drag Coefficient for Flat Plate

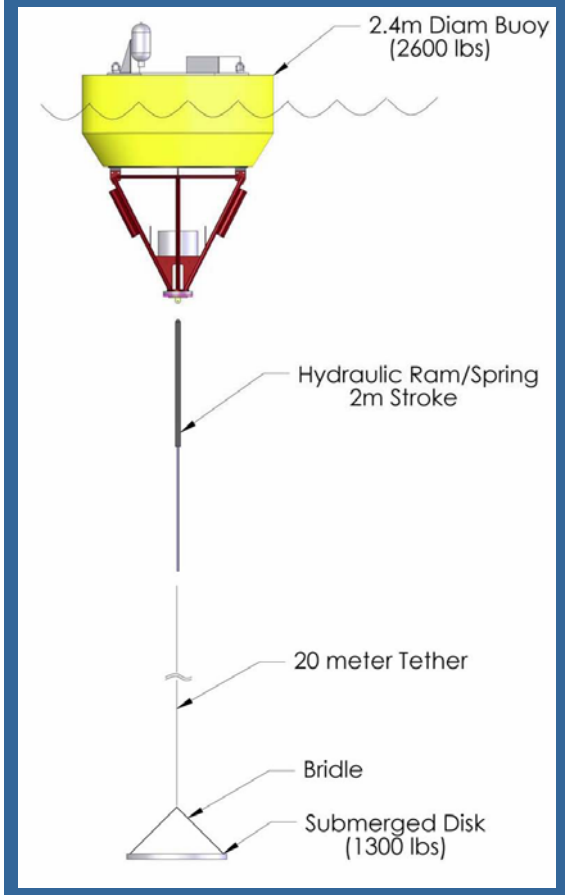
Tether Forces

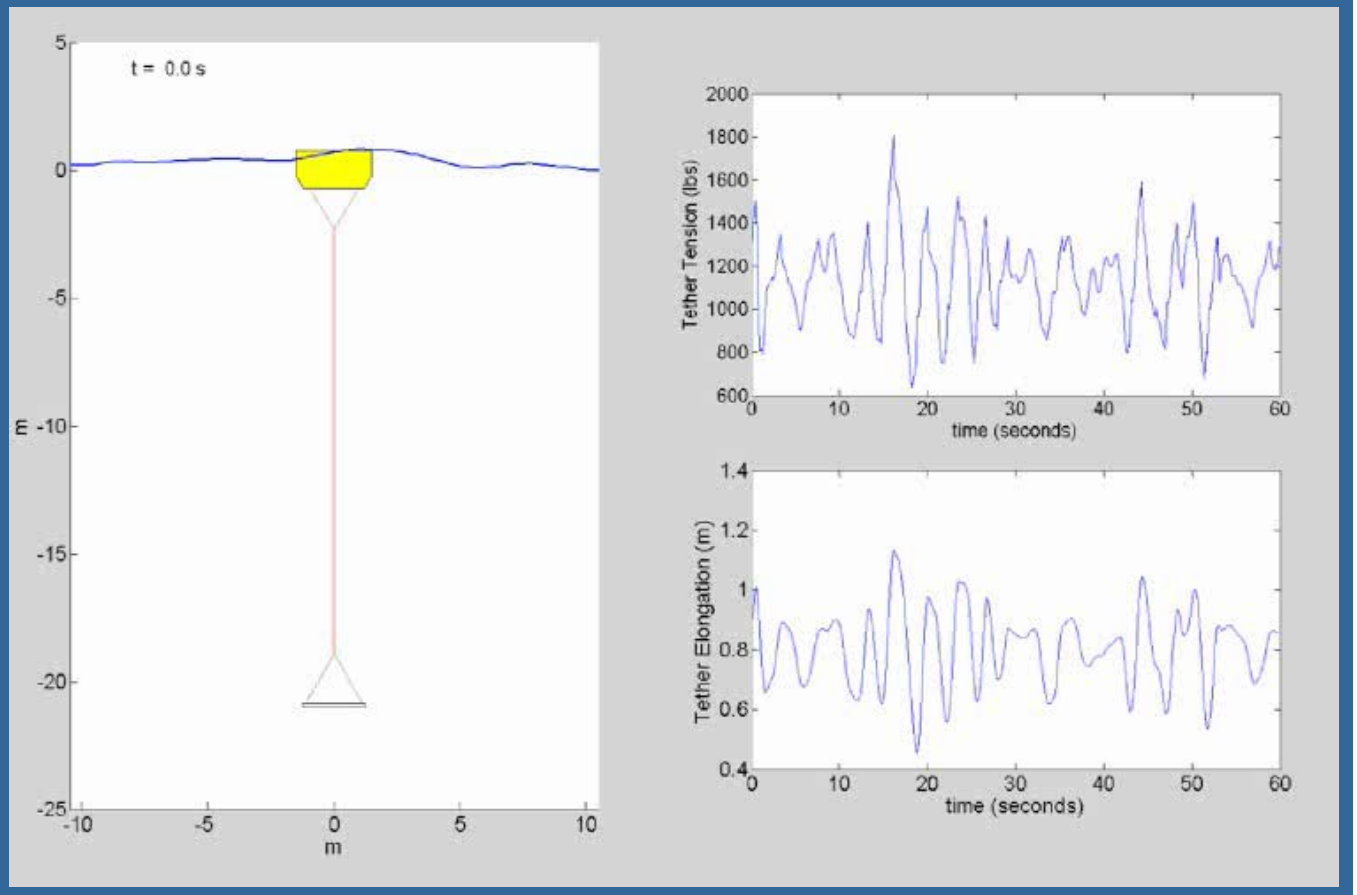
- Couples motion of buoy and plate
- Modeled as non-linear spring and non-linear damper.

Instrumentation

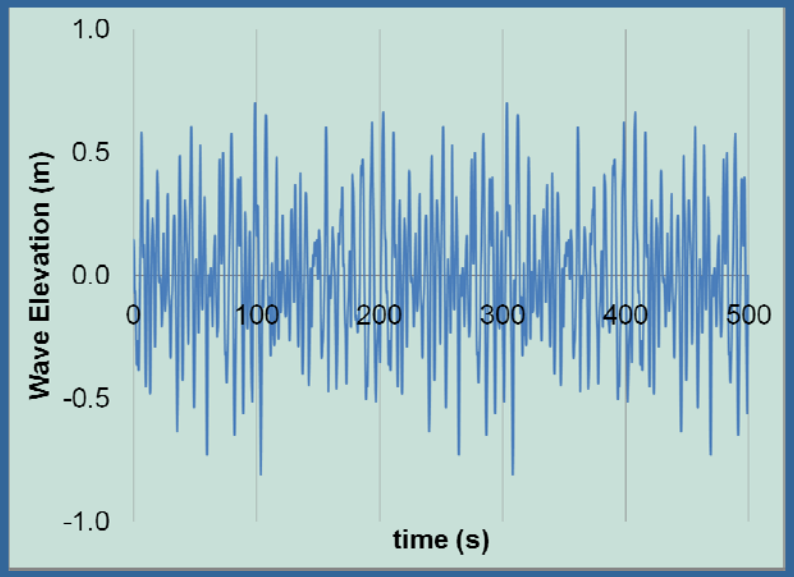
- Spring Elongation Measurement Vs Time (100 Hz)
- Tether Tension Vs Time (100 Hz)
- Independent wave-field measurement

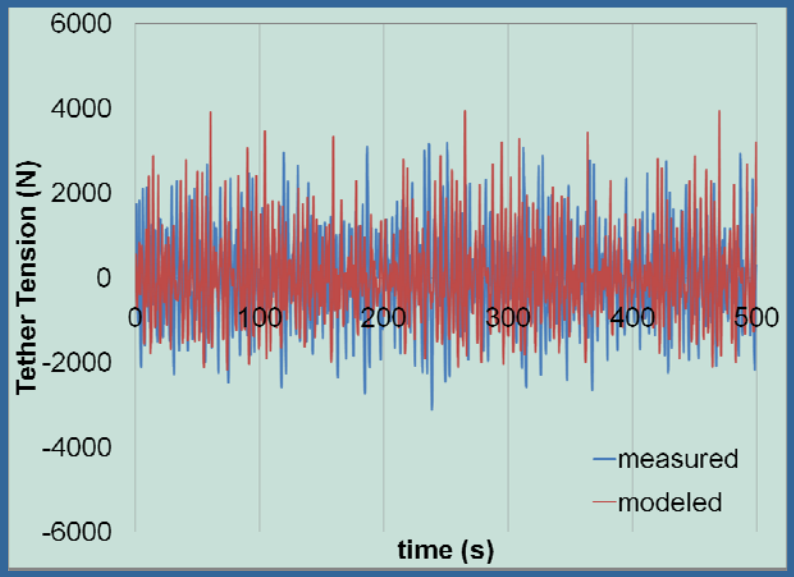
Validation Tests Model Results

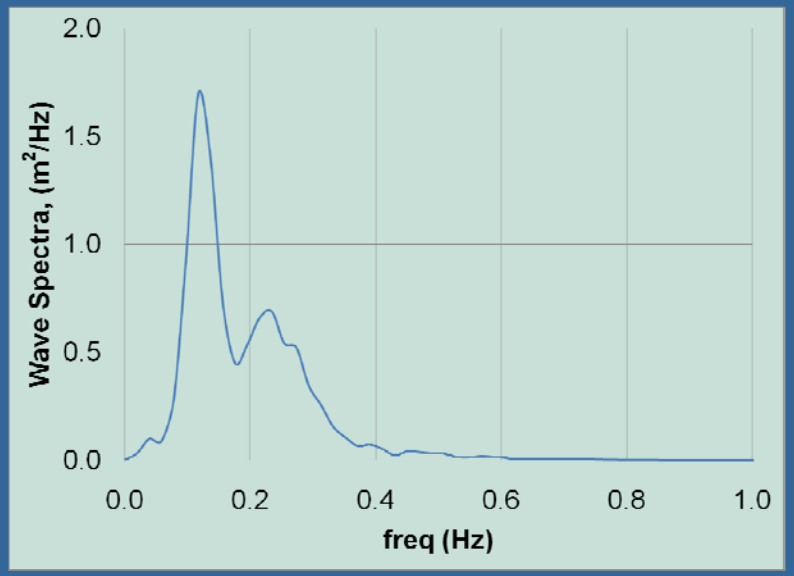


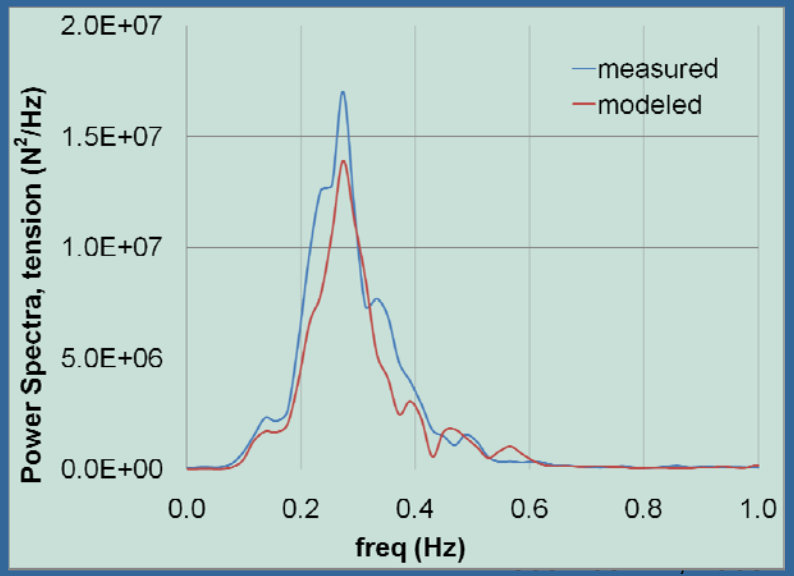


Validation Test At-Sea Results

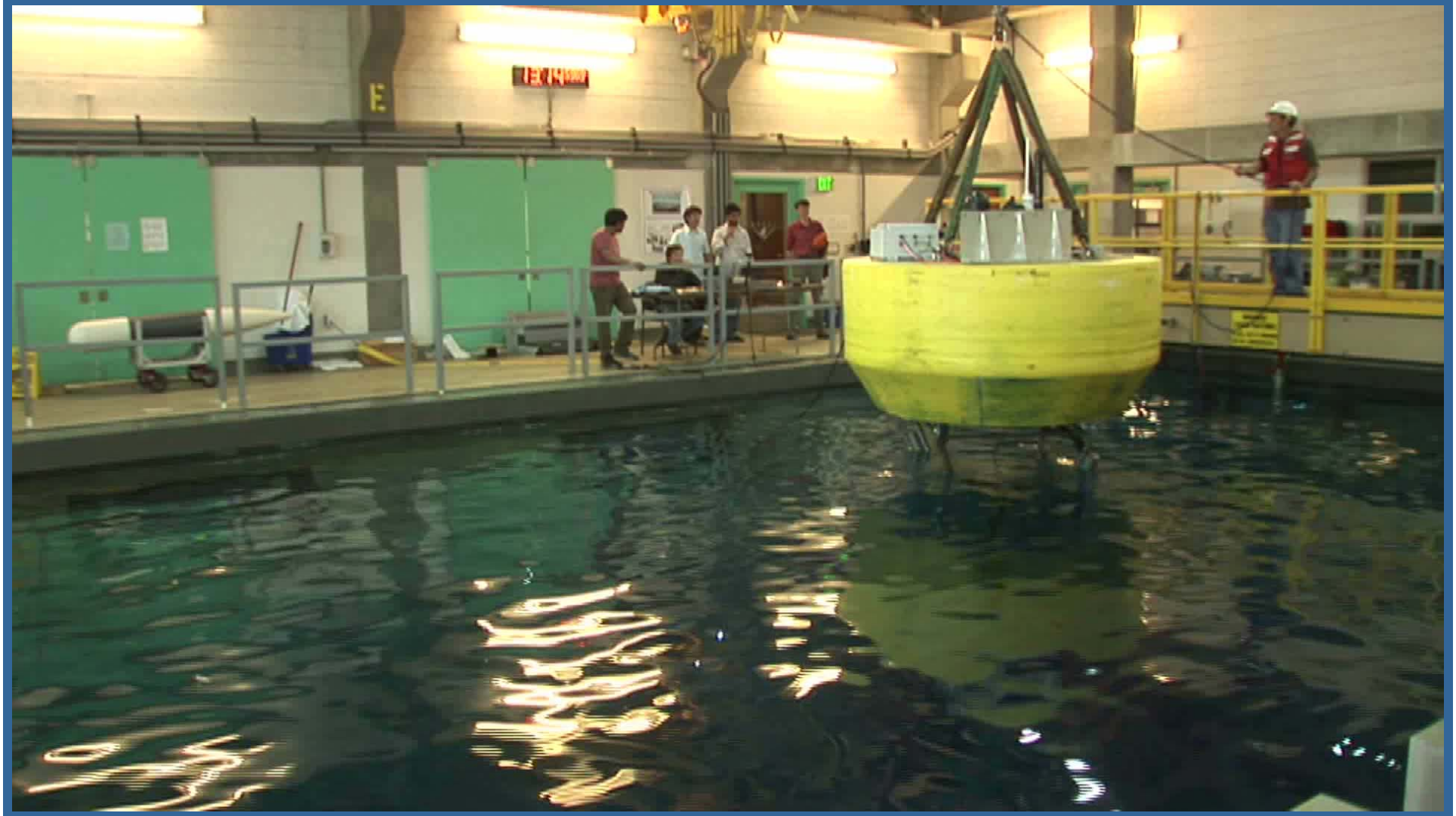








Validation Step-Response Test



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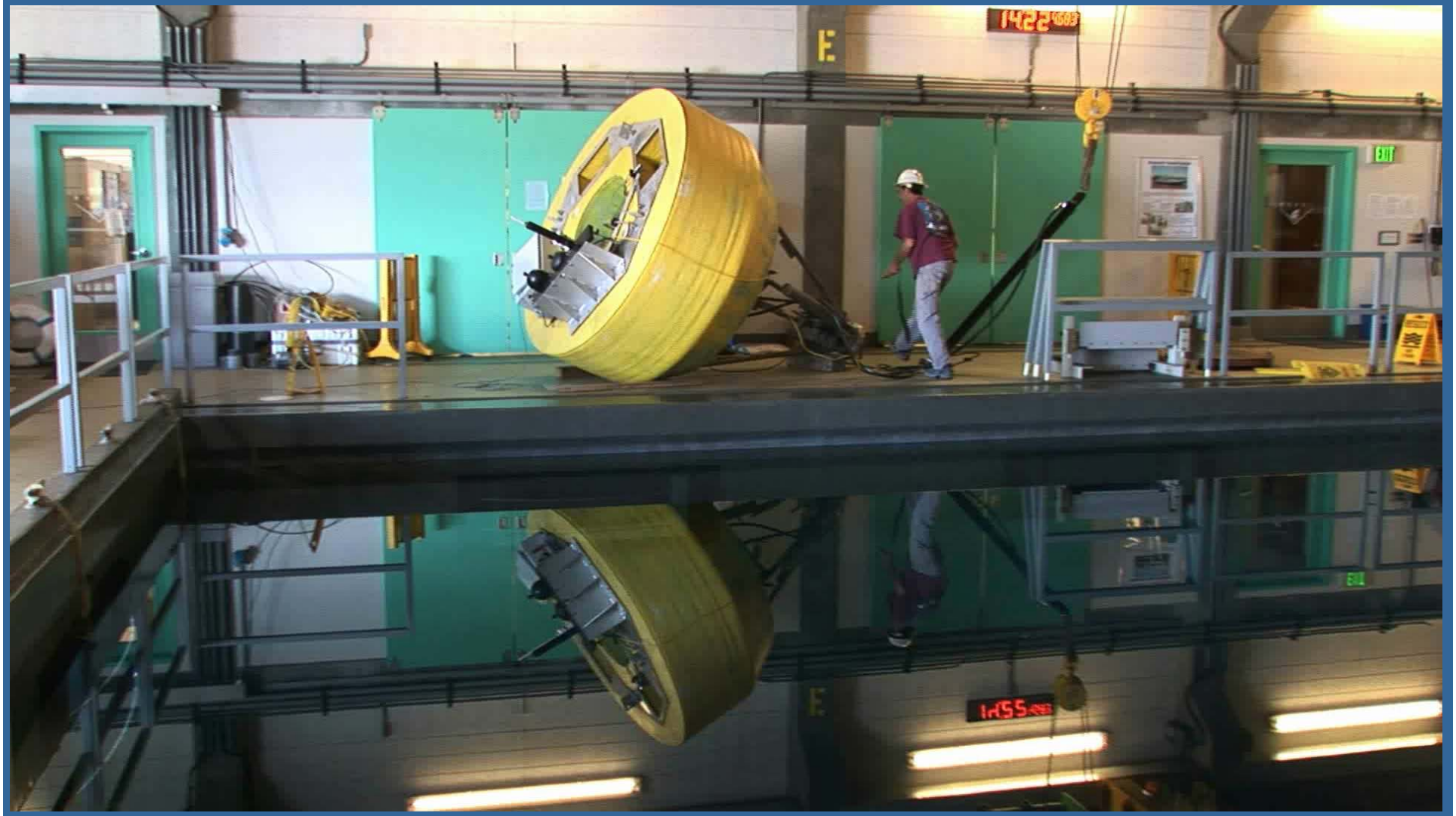

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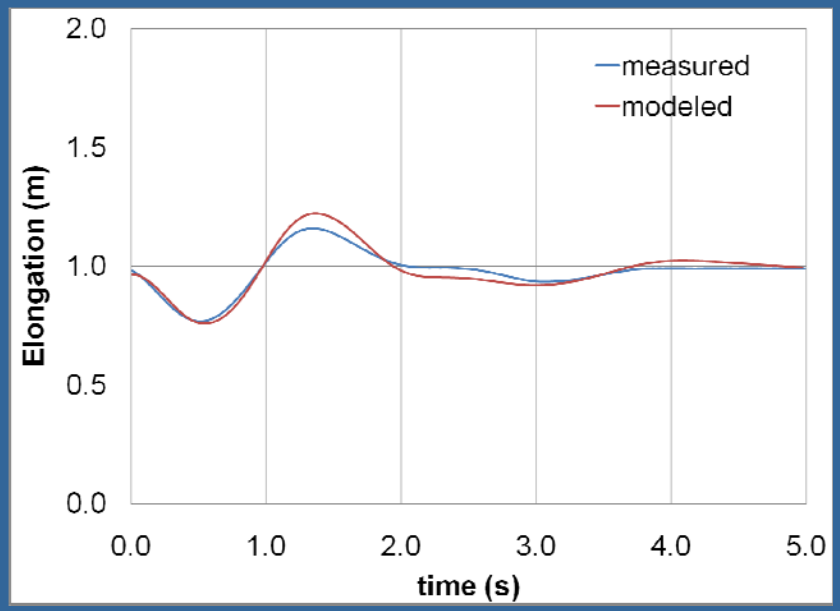
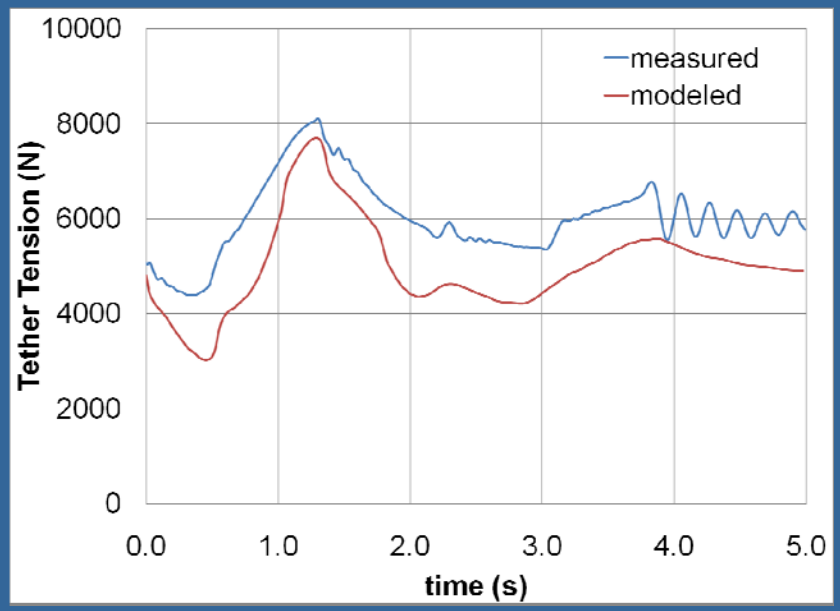
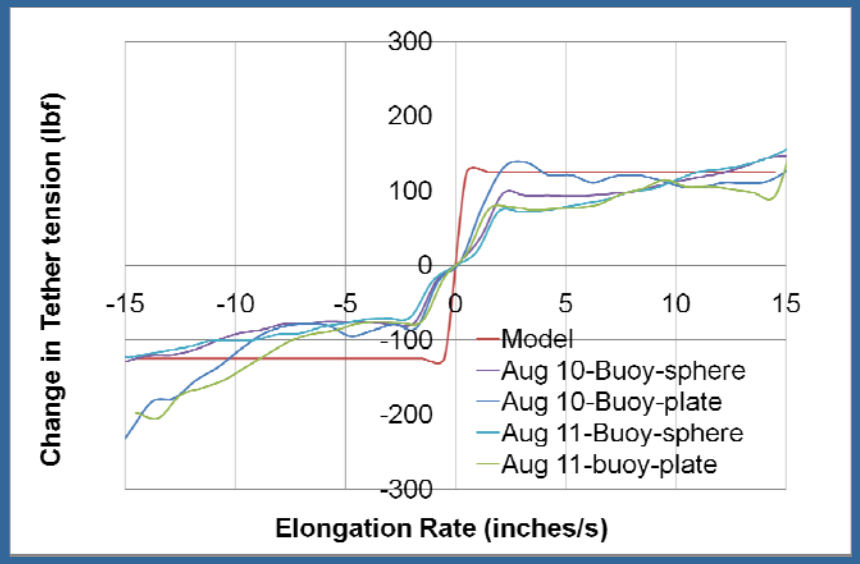
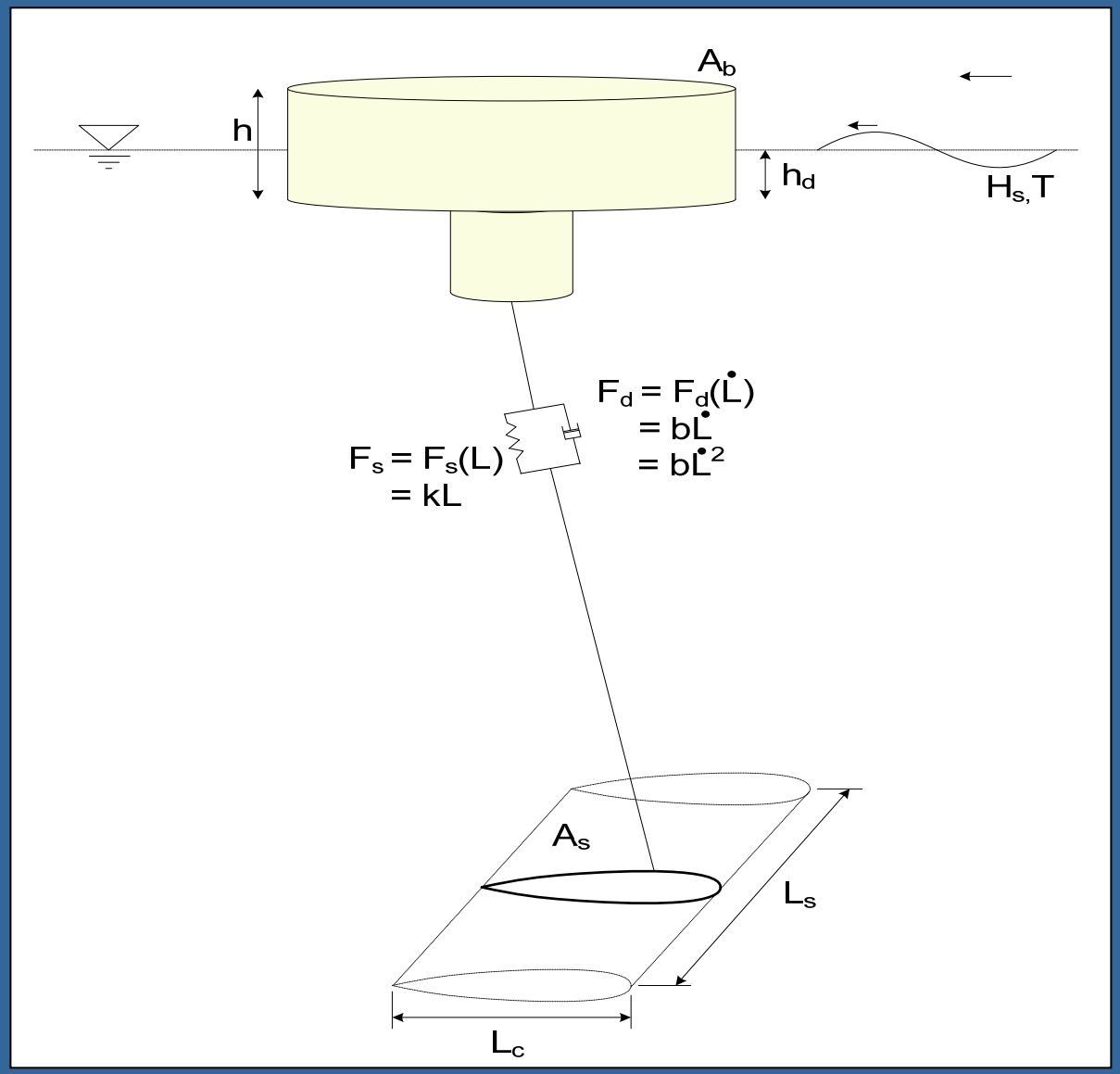






Flapping Foil Simulations



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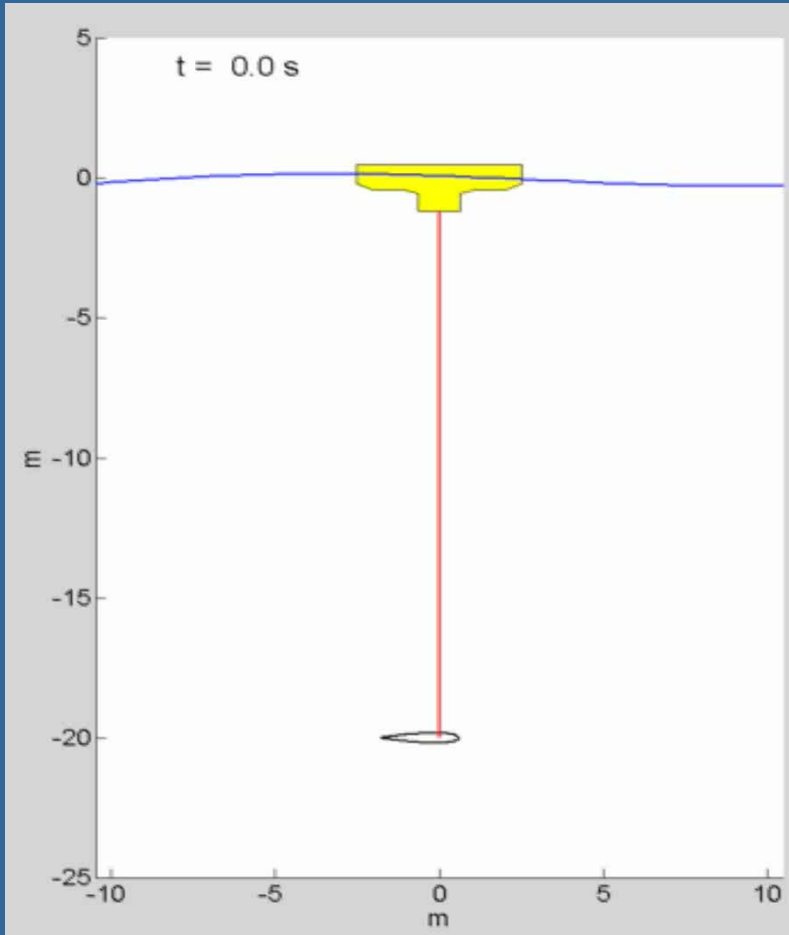

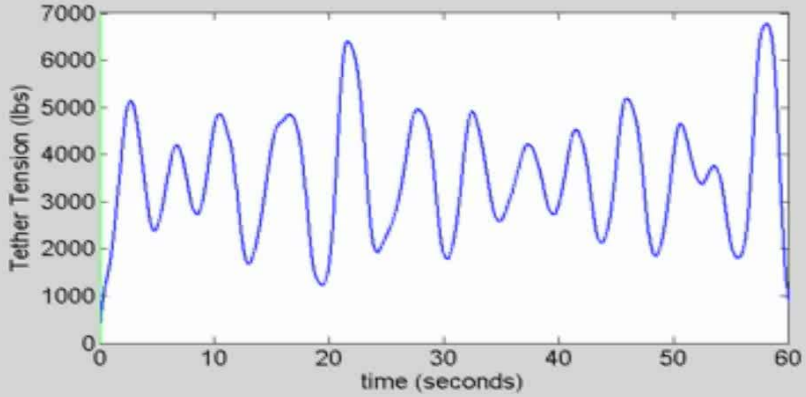

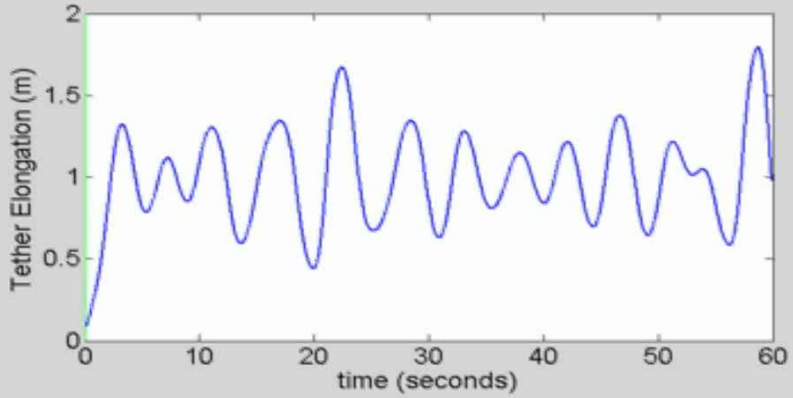

Flapping Foil Simulations