Instrumentation for WEC Testing at NNMREC-OSU Facilities

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Northwest National Marine Renewable Energy Center

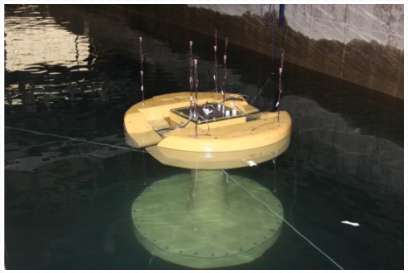
MHK Instrumentation Workshop, NREL, July 2012

The Northwest National Marine Renewable Energy Center

- A partnership between Oregon State University, the University of Washington, & the National Renewable Energy Lab.
- Develop a full range of capabilities to support wave and tidal energy development, from small-scale lab and tank systems to full-scale ocean facilities.
- Center activities are structured to:
  - facilitate device commercialization,
  - inform regulatory and policy decisions,
  - close key gaps in understanding.

Funding for NNMREC is provided by DOE, OSU, UW and multiple partners

NNMREC Scaling, Development and Evaluation Resources



Model Validation at OSU Facilities

- 20kW Wave Energy Linear Test Bed (WESRF), 2m stroke
- Tank Testing in Regular and Irregular Waves (HWRL)

Scale (λ); 1:35-100

Small-scale Device Testing at OSU Facilities

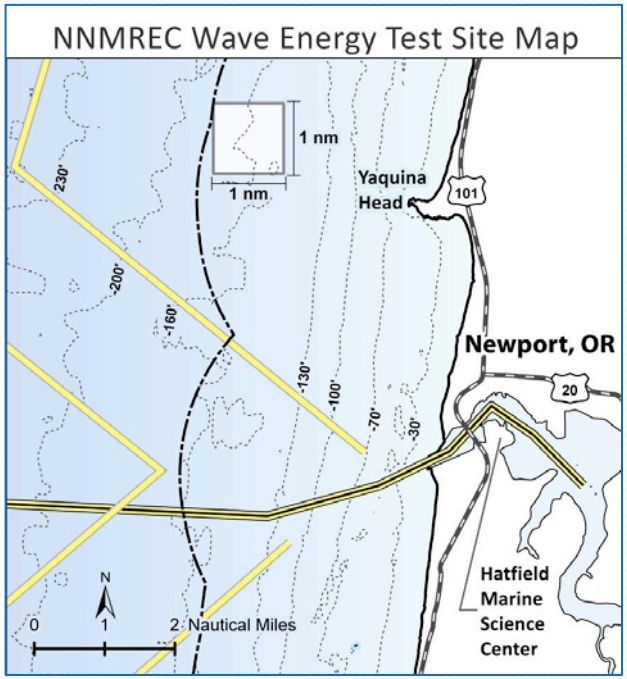
- 2-D flume with regular waves: 0-1m in 3m water depth
- 3-D tank with irregular waves: 0-0.5m in 1.5m water depth

Scale (λ); 1:15-50

NNMREC Scaling, Development and Evaluation Resources

Field Testing (Intermediate Scale)

- Yaquina Bay, OR: Wind Waves: 0-0.2m in 7.6m water depth
- Puget Sound, WA: Wind Waves: 0-1m in 16m water depth



Open Ocean Device Testing & Demonstration

- Newport, Oregon: Water depth 45-55m, sandy bottom
- Summer average wave heights and periods (1.5m, 6-8s)
- Winter average wave heights and periods (3.5m, 8-12s)

Wallace Energy Systems and Renewables Facility

- 750 KVA Adjustable Power Supply
  - Variable Voltage input(0-600Vac), 600A
  - 3-phase adjustable (while loaded) for balanced and unbalanced testing
- Highest Power University Lab in the Nation
  - Enables Multi-Scale energy research
- Four Quadrant Dynamometer
  - Programmable torque/speed
  - Dynamic Vector Controls 0-4000 rpm
- Bidirectional Grid Interface
  - Regeneration back to the utility grid
- Flexible, 300 hp, Motor/Generator test-bed
- 120KVA programmable source
  - Transient VLrms=680V
  - Steady State VLrms= 530V
  - Frequency range: 45Hz to 2KHz

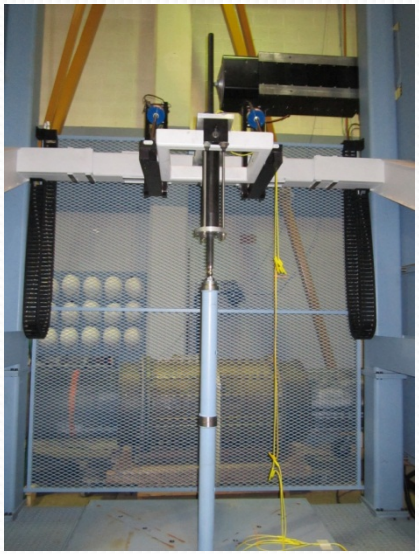
WESRF
Wallace Energy Systems & Renewables Facility

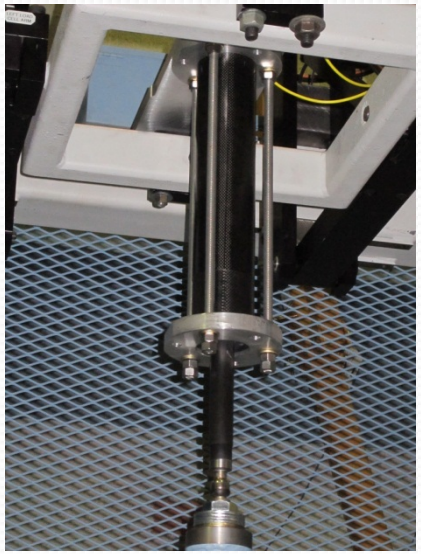
Wave Energy Linear Test Bed

- 20kW, shown with L-10.
- Creates the relative linear motion between a center “spar” and a surrounding “float” (active components).
- Enables dynamic testing, using captured or generated wave profiles.
- Specifications:
  - 2m relative motion/stroke (6.5 feet)
  - 1m/sec @ 20,000 N Thrust (4500 lbf)
  - 2m/sec @ 10,000 N Thrust (2250 lbf)
  - 14ft tall x 10.5ft wide x 8.5ft deep

Shift Power Solutions Testing on LTB

- Low power linear generator design.
- LTB used to characterize the machine.
- LTB Velocity Profiles:
  - Trapezoidal (fixed velocity)
  - Sinusoidal
  - Real wave profiles
- Force, Pos, Vel, Acc, Voltage, Current.





O.H. Hinsdale Wave Research Laboratory
Tsunami Wave Basin

Wave Basin Dimensions

• Length:	48.8 m	160 ft
• Width:	26.5 m	87 ft
• Max depth:	1.37 m	4.5 ft
• Freeboard:	0.6 m	2.0 ft

Wavemaker

• Type:	Piston-type, Electric motor
• Waveboards:	29 boards, 2.0 m (6.6 ft) high
• Wave types:	Regular, Irregular, Tsunami, Multidirectional, User defined
• Period range:	0.5 to 10 seconds
• Max. Wave:	0.8 m (2.6 ft) in 1 m (3.3 ft) depth
• Max. Stroke:	2.1 m (6.9 ft)
• Max. Velocity:	2.0 m/s (6.6 ft/s)

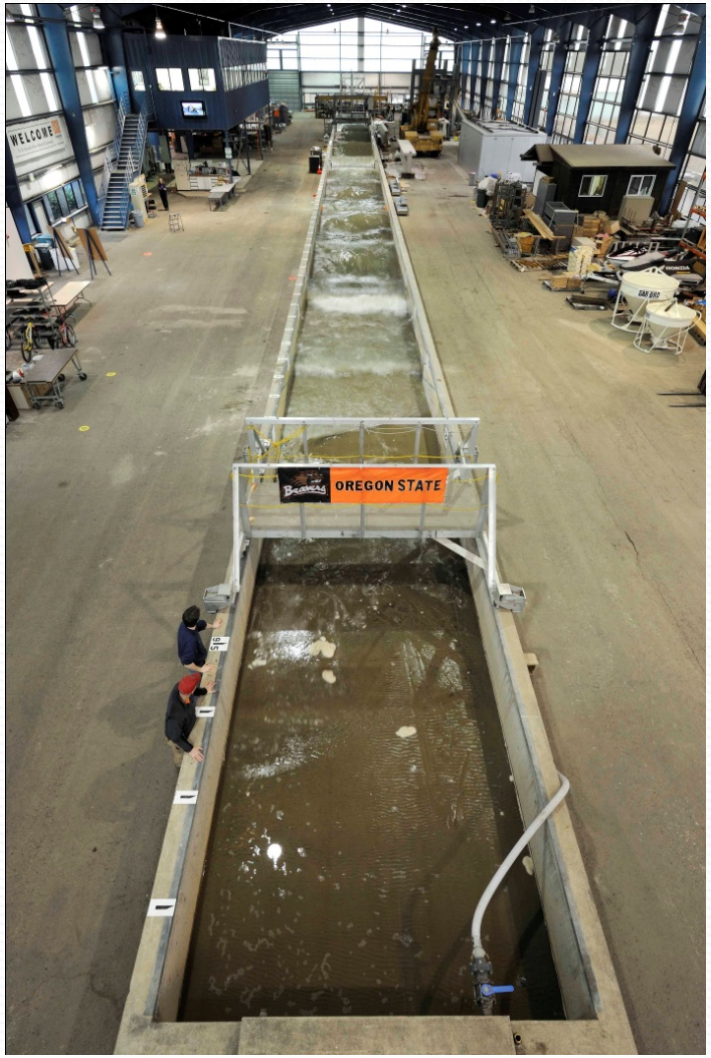
O.H. Hinsdale Wave Research Laboratory Large Wave Flume

Wave Basin Dimensions

• Length:	104 m	342 ft
• Width:	3.7 m	12 ft
• Depth:	4.6 m	15 ft

Wavemaker

• Type:	Piston-type, Hydraulic Actuator Assembly
• Wave Types:	Regular, Irregular, Tsunami, User Defined
• Period Range:	0.5 to 10 seconds
• Max Wave:	1.7 m (5.6 ft) @ 5 sec in 2.7 m water
	1.2 m (3.9 ft) tsunami in 3.0 m water
• Max Stroke:	4 m (13.1 ft) at 4 m/s (13.1 ft/s)



High-Precision Wave Tank Testing

Three Data Acquisition Systems

1. HWRL wave height data acquisition system
2. dSPACE data acquisition system (WESRF)
3. PhaseSpace optical motion tracking system

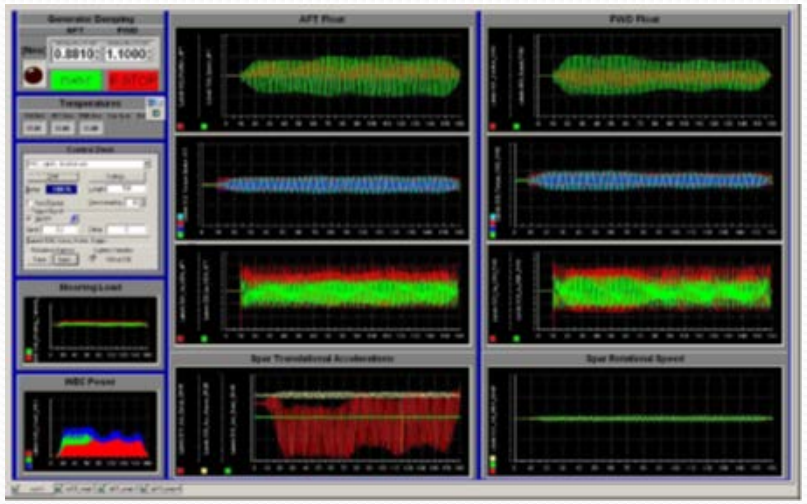
All synchronized with the wavemaker TTL trigger

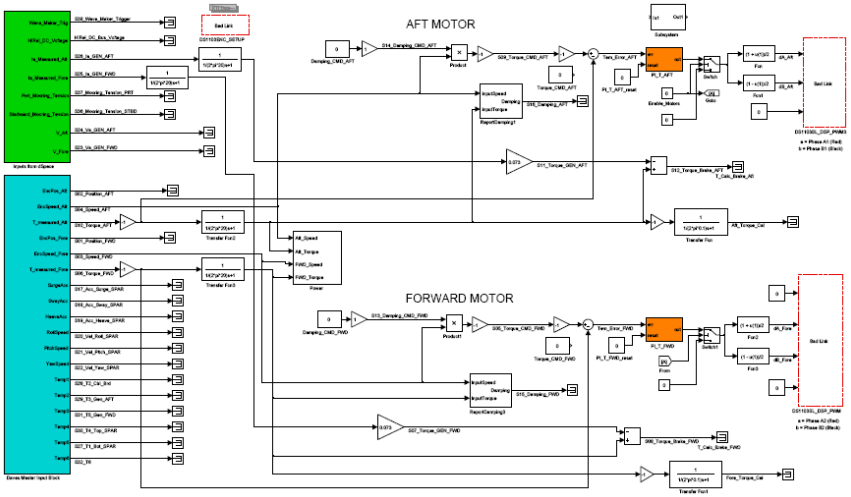
HWRL Instrumentation:

1. resistance-type wire wave gages
2. acoustic depth gauges
3. acoustic-Doppler velocimeters
4. various pressure transducers
5. PXI architecture DAQ systems
6. array of dry and submersible cameras

dSPACE Control and Data Acquisition

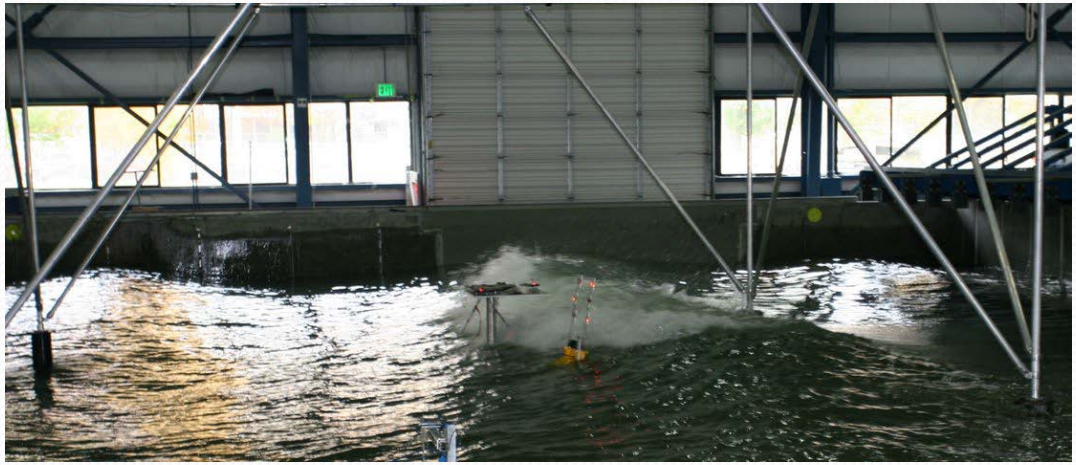
- dSPACE DS1103 single board rapid prototyping system in a standard desktop PC.
- Allowed data collection of internal parameters and controls optimization.
- Communicated to the WEC via RS-422 to a custom embedded controller inside the WEC nacelle.



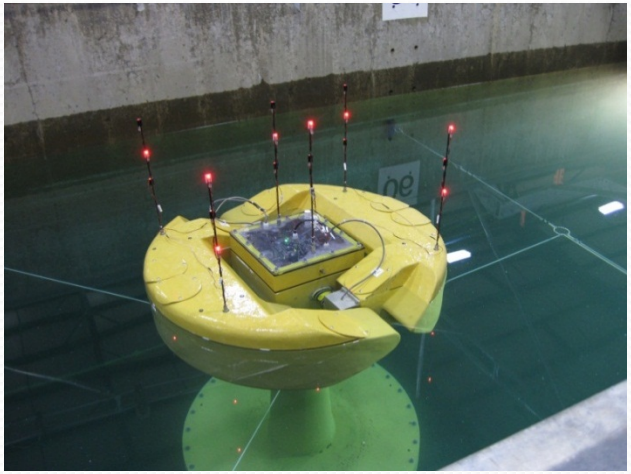


PhaseSpace Optical Motion Tracking System

- Third party product developed for the entertainment industry.
- Track the buoy's motions, 6 DOF.
- Uses flashing LEDs at different frequencies and cameras for tracking at 480 Hz sample rate.
- Multiple LEDs on each rigid body allows the motion to be tracked and recorded with sub-millimeter resolution.

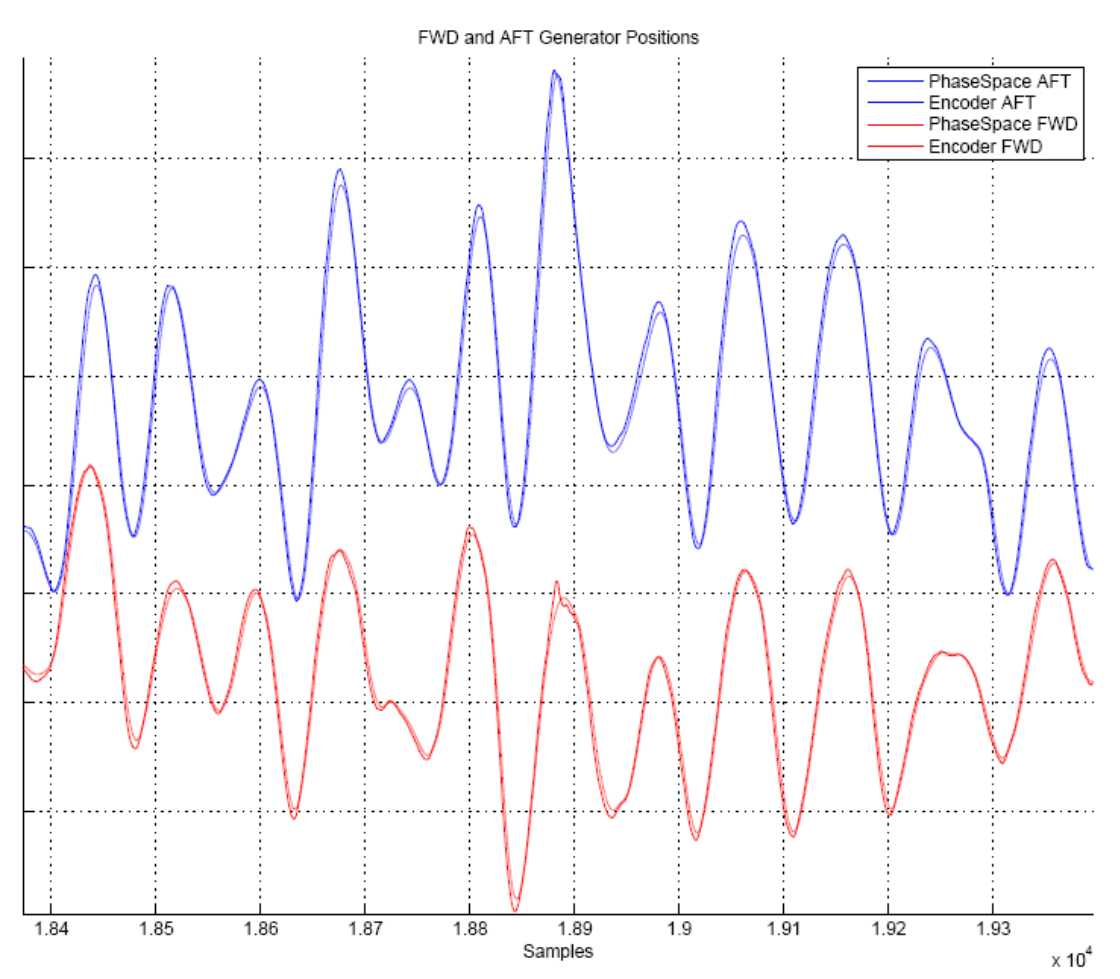


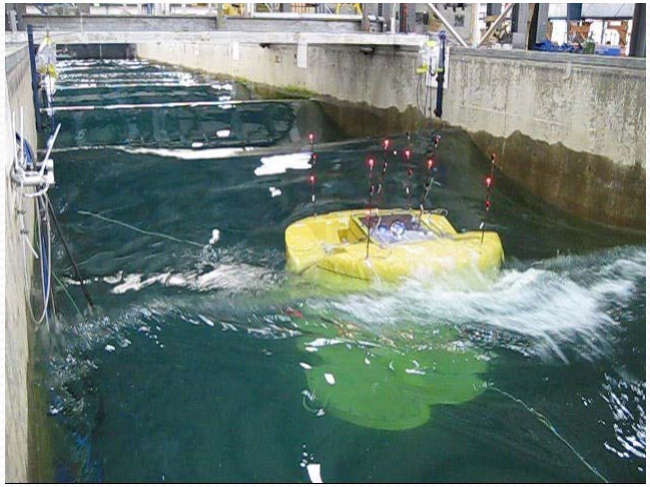
NWEI WET-NZ Testing in Tsunami Wave Basin



CPT's 1/15th Scale Testing in Long Wave Flume

PhaseSpace Verification





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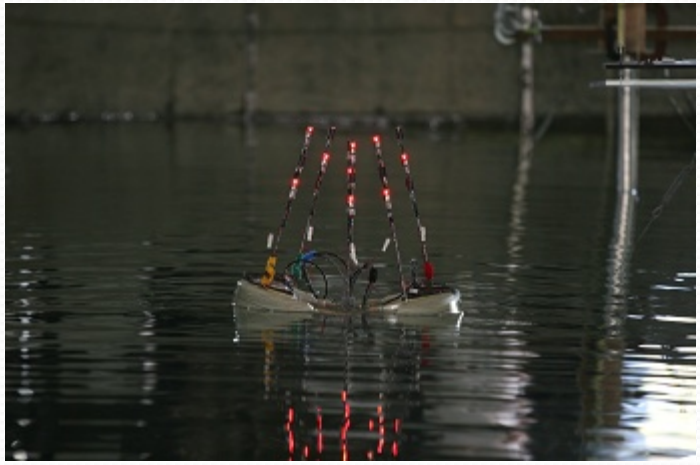
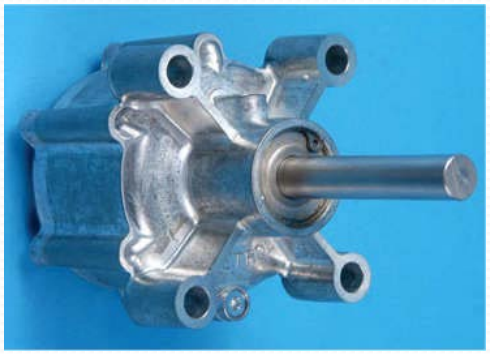
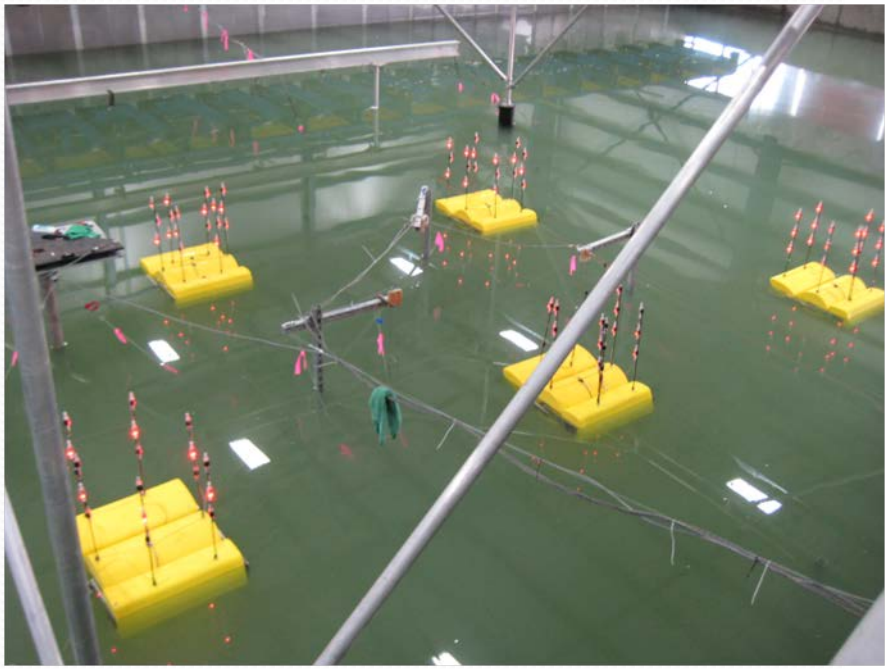


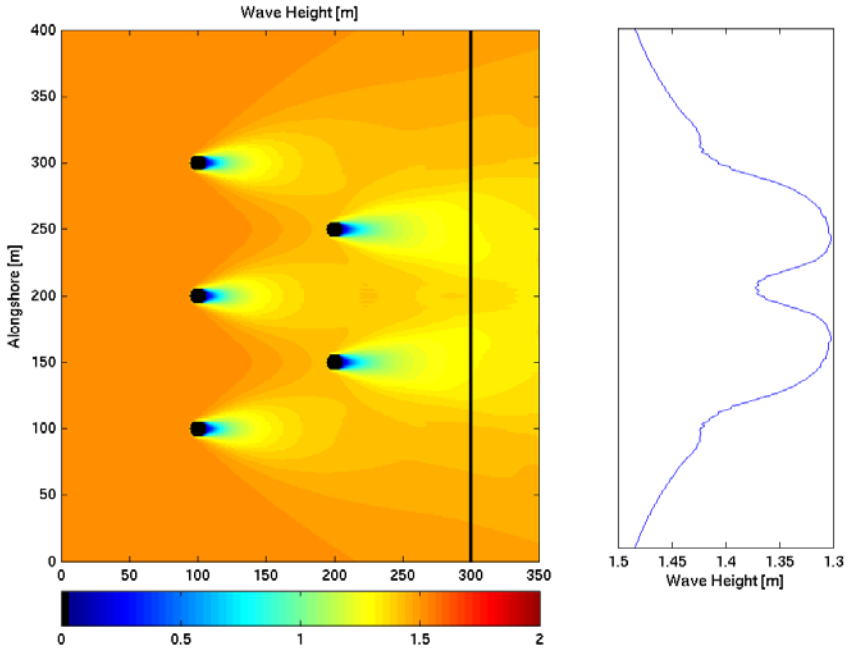
CPT's 1/33rd Scale Testing in 3D Tsunami Wave Basin

PhaseSpace in Array Testing

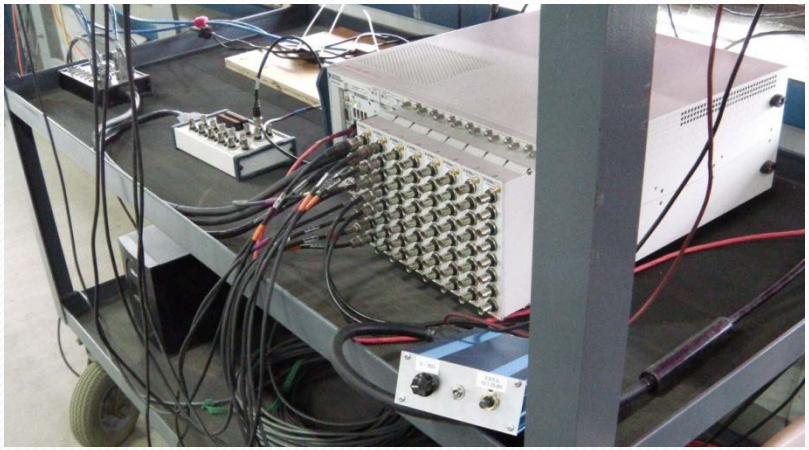
- PhaseSpace shown to accurately track PTO motion
- Paired with characterized rotational dampers
- Mechanical power extraction estimated by using motion capture and known damping constants

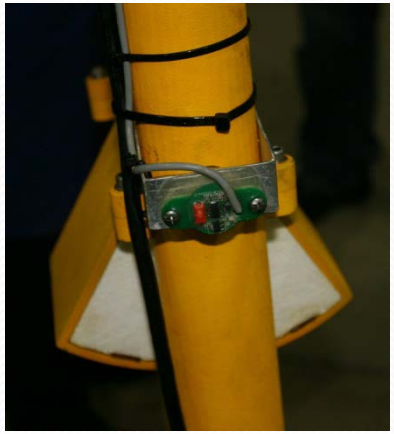






NWEI WET-NZ Testing in Tsunami Wave Basin





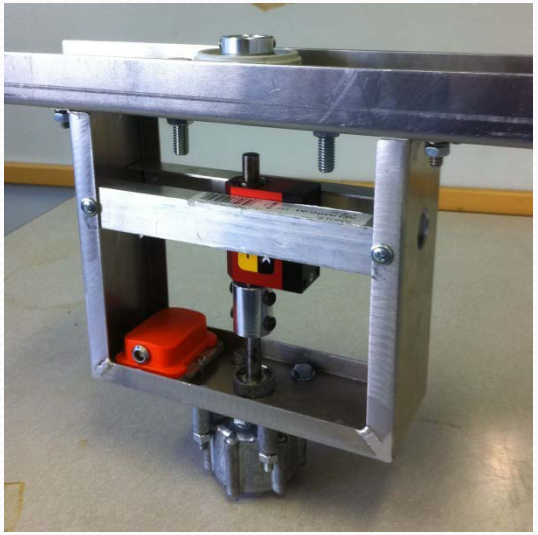
Onboard Instruments:

- PhaseSpace, Float Angle Sensor, electric PTO generator

Lessons Learned:

- PTO Cable dynamics
  - dominant with compliant mooring
- Angle sensor potting
  - use waterproof sensors if possible
- Electrical PTO
  - not optimal for model verification

Neptune Wave Power Testing in TWB



Onboard Instruments:

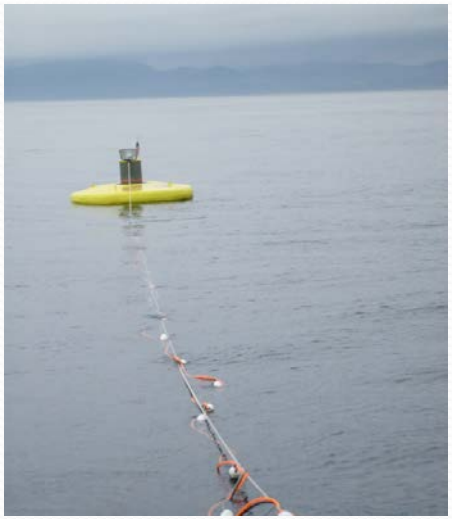
- Rotary Dashpot, Torque Transducer w/Encoder, MRU.

Lessons Learned:

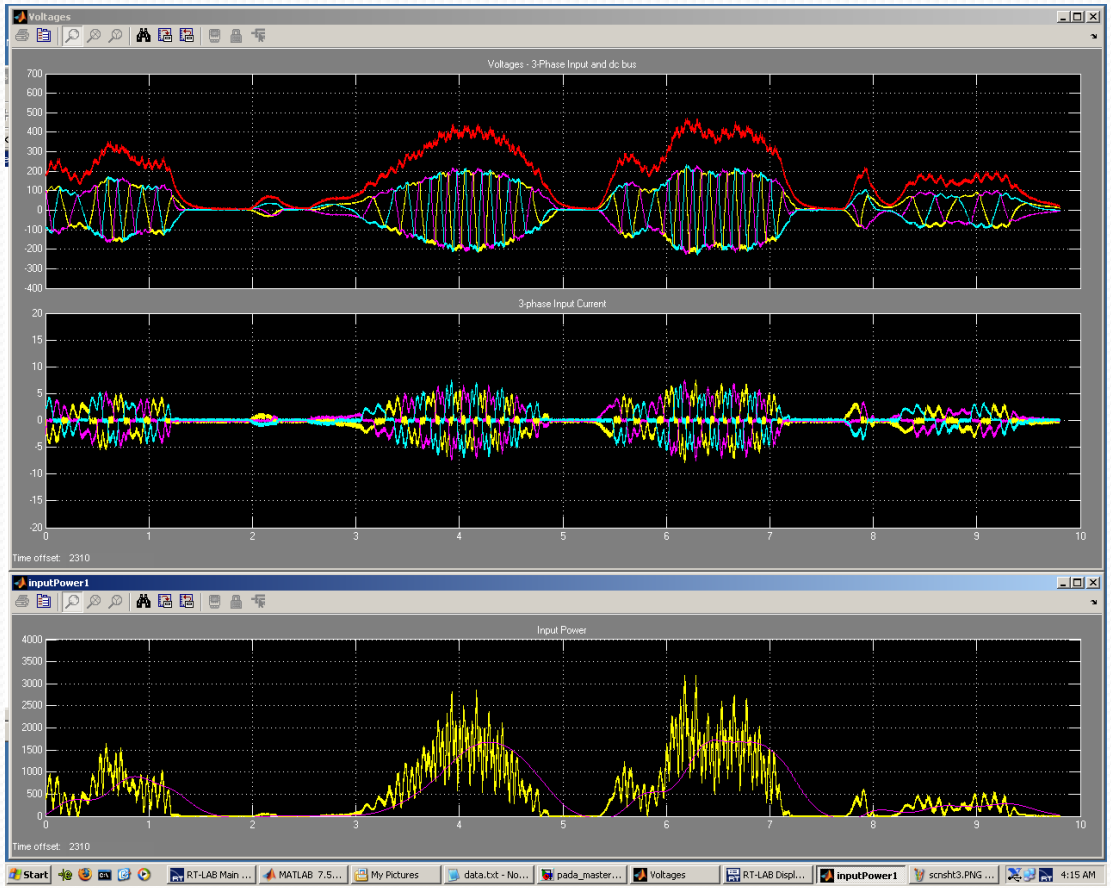
- Mechanical PTO provided reliable damping, adjustable.
  - However, adjustment required model disassembly.
- Waterproof connectors proved troublesome.

30 kW Prototype Power Analysis and Data Acquisition System

L10 WEC:

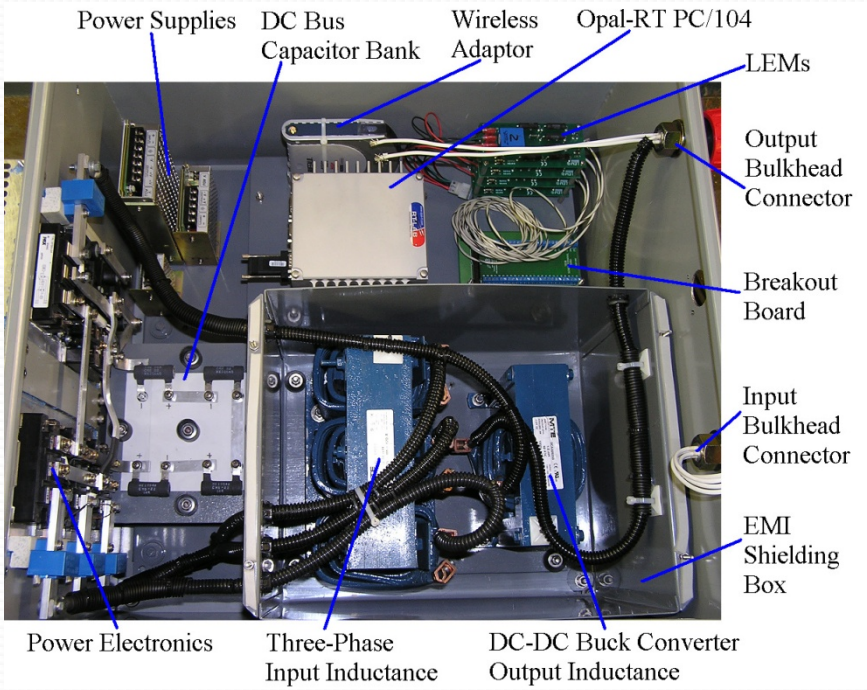


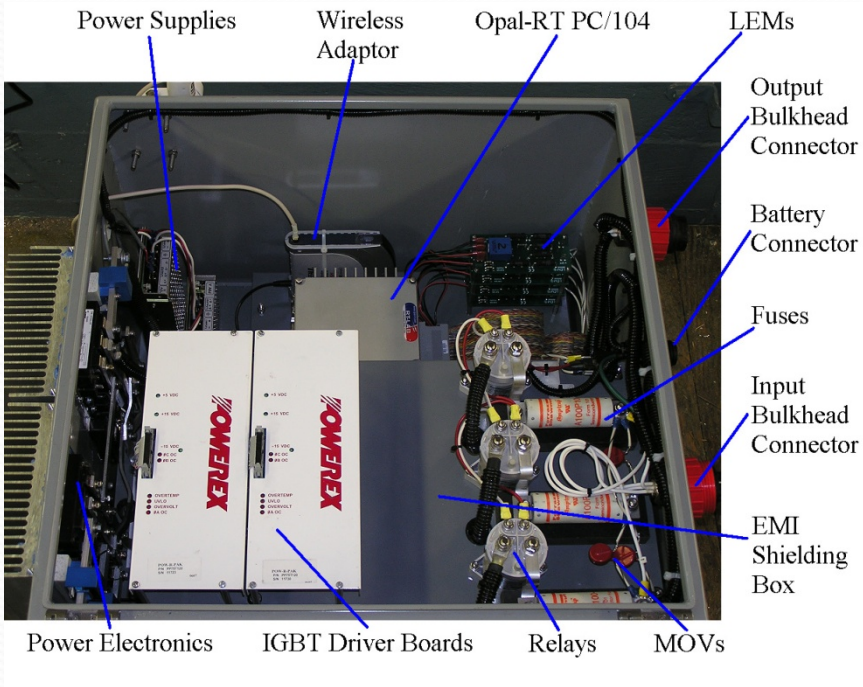
Screenshot from Host Computer:



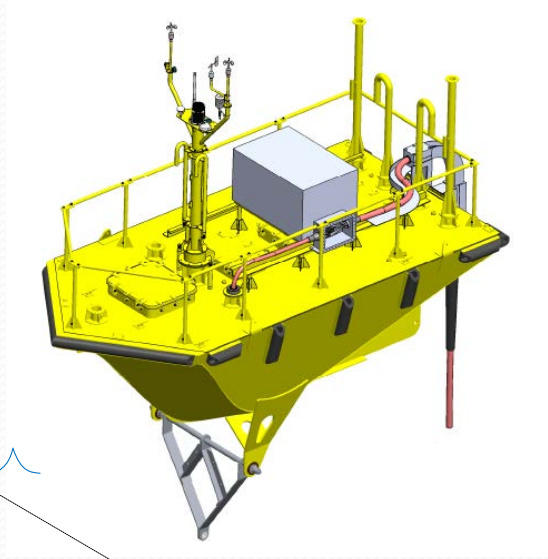
PADA with resistive load bank:

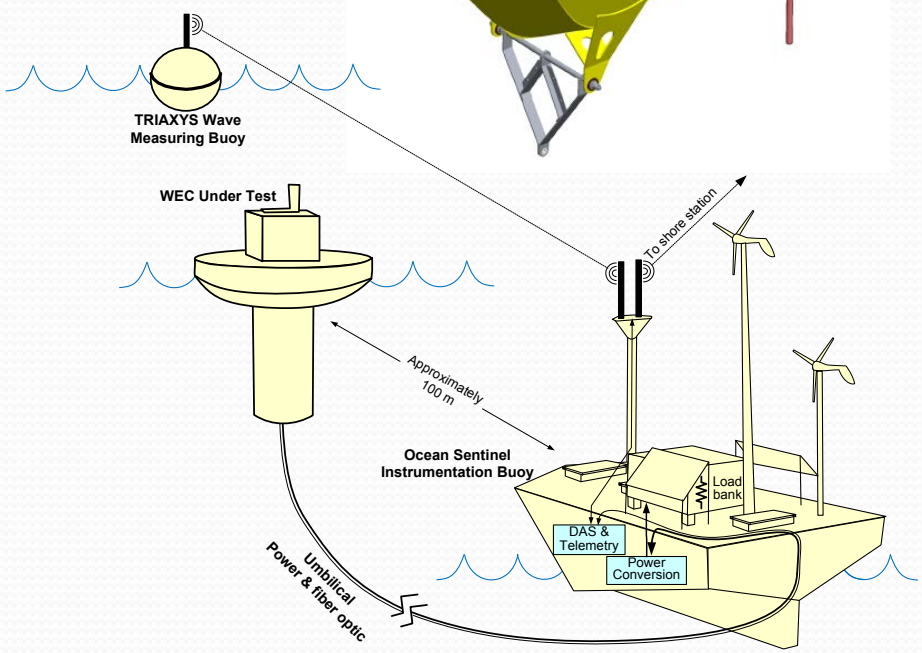
30 kW Prototype Power Analysis and Data Acquisition System

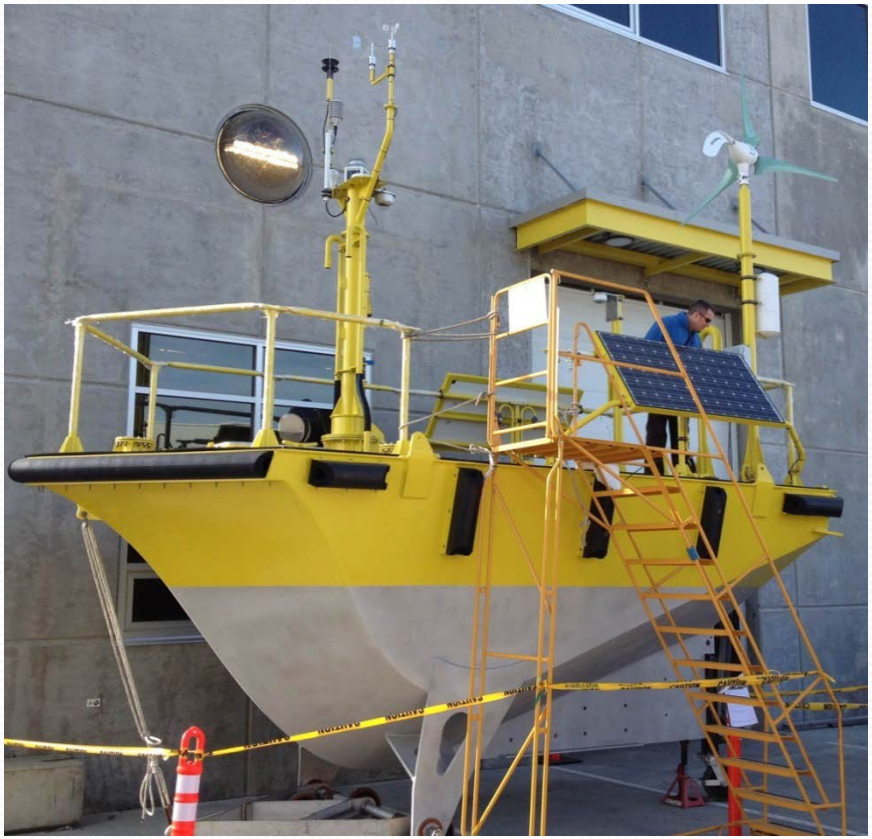




Ocean Sentinel Instrumentation Buoy







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