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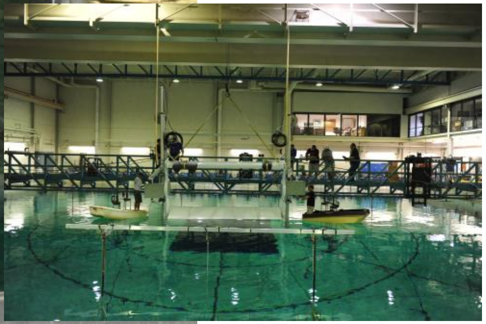

Cycloidal Wave Energy Converter TRL Advancement to Level 4

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Purpose, Objectives, & Integration

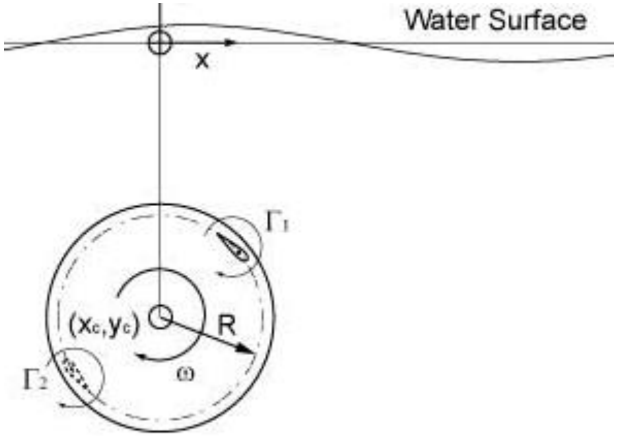
- Wave Energy extraction a difficult fluid dynamic problem:
  - Unsteady, fluctuating nature of wave energy
  - Slow velocities (O~1m/s) » large devices if buoyancy / drag based
  - Large energy density » huge forces
- Many existing devices inefficient by design:
  - Symmetric point absorbers limited to 25 – 50% of wave energy absorption based on first principles (Falnes, 2002)
  - While the energy is “free”, the device to extract it needs to be larger if it is less efficient » more costly to build and maintain
- Many existing devices unable to survive storms
  - Cannot be feathered like wind turbines
- Costly, inefficient power takeoff systems (pneumatics, hydraulics)
- High Cost of Electricity due to large converters, poor overall conversion efficiency

All of these shortcomings are addressed by the Cycloidal Wave Energy converter detailed on the next slide

Technical Approach

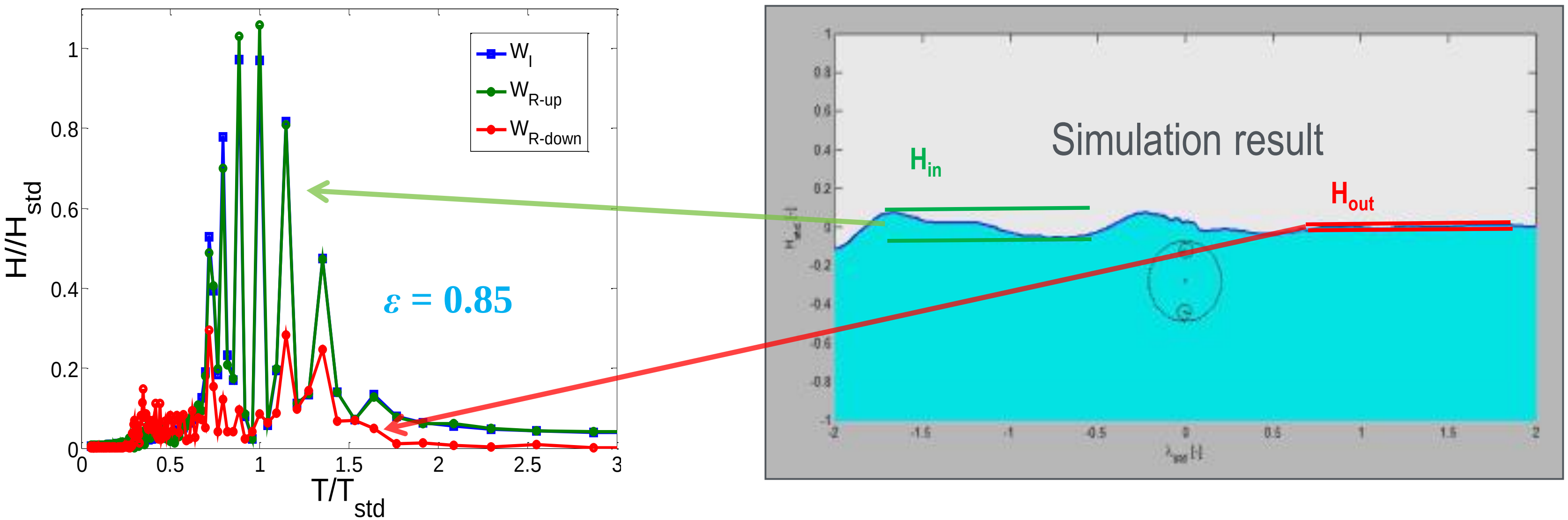
Unique features of a Cycloidal Wave Energy Converter:

- Consists of one or two hydrofoils rotating around a central shaft
- Use Lift instead of Drag/Buoyancy/Pressure
  - Decreases size, since lift force is more than an order of magnitude larger than drag for a typical hydrofoil
    - Improves efficiency
    - Reduces cost
  - Allows for feathering of device for storm survival
  - Technology improvement similar to wind turbines – very old designs are drag based, all current devices are lift based
- Use *flow sensors* and *feedback* for control
  - Non-resonant type of energy conversion
  - Adjust to wide range of wave climates
  - Storm survival – shut down converter
- Cluster converters on a float to cancel forces
  - Eliminates need for extensive mooring
    - Less environmental impact
    - Better storm survivability
    - Can be deployed in very deep water
- Produce shaft power directly - with constant torque and frequency
  - No inefficient, expensive power take off system required (mechanical or fluidic)
  - Only 2-3 rotating parts, no linear or oscillating motions



Technical approach: Simulations

- Based on potential flow theory
  - Equations published by J.V. Wehausen and E.V. Laitone (1960)
  - Idealized hydrofoils (vortices) moving under a free surface
  - Numerical integration of resulting integral equation
- Wave climate modeling using Bretschneider spectrum
- Real-time control of WEC determined by incoming wave phase and height
- Control volume analysis shows extraction efficiency >80% of ALL available wave energy for all wave climates



Plan, Schedule, & Budget

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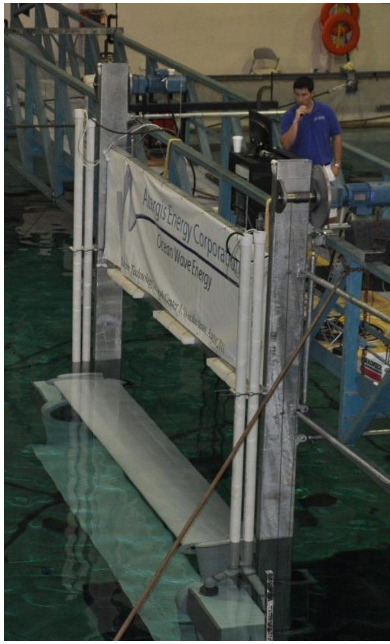
Schedule

- Initiation date: 9/1/2010
- Planned completion date: 6/30/2012
- Demonstrated irregular wave cancellation by numerical simulation (Spring 2011)
- Completed model construction of 1:10 scale model CycWEC (August 2011)
- Milestones: Two testing campaigns at Texas A&M OTRC wave basin:
  - Completed first campaign end of August 2011, data post processing ongoing
  - Second campaign scheduled for March 2012
- Modifications of model mounting system for second campaign being designed
  - Mods req'd due to structural inadequacies of the OTRC bridge to handle full CycWEC loads



Budget

- $413.3k (91.3%) of the FY 11 budget had been expended through 31 Aug 2011
- Expect 97.3% expenditure of FY11 budget by 30 Sep 2011
- $86.7k of the total $500k project budget remains to be spent (Sep 11 - Jun 12)
- OTRC costs will be higher than budgeted in FY12

Budget History

FY2010		FY2011 (new start)		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	$380.4k	$72.2k	$20k	$47.4k