A Framework for Wave-to-Wire Simulation of Wave Energy Converter for Autonomous Underwater Vehicle Recharging

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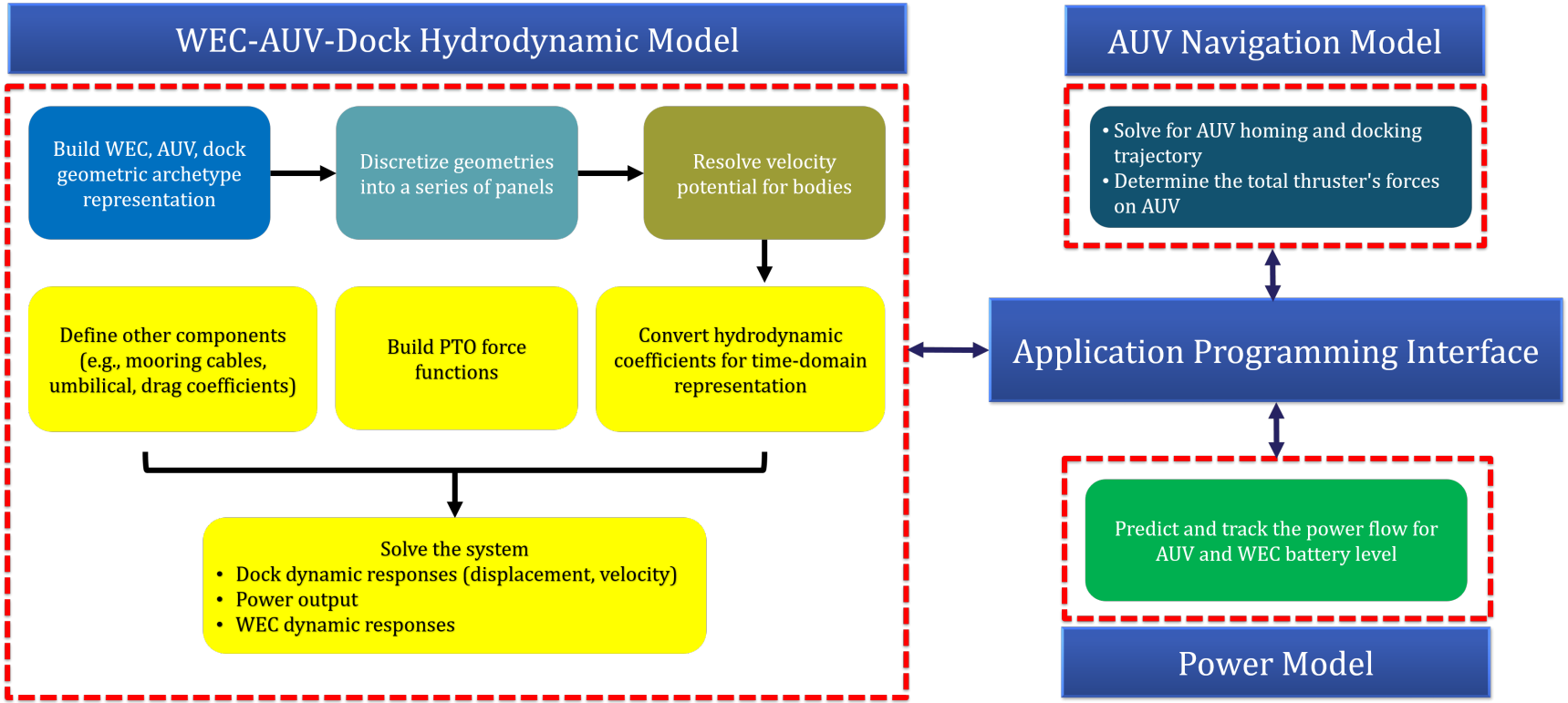
Objective

Develop a coupled wave energy converter (WEC), dock and AUV hydrodynamics, AUV navigation, and power tracking modeling framework to simulate and analyze AUV recharging using marine energy. Specifically:

1) A coupled WEC-AUV dock hydrodynamic model will be solved for analyzing the dynamic responses of the system and estimating the power output.
2) Total AUV thrusters' force can be obtained from an AUV navigation algorithm using the resulting dock dynamic responses from the hydrodynamic model.
3) The WEC and AUV battery levels will be predicted using a power model based on WEC power output estimation and AUV motion.

Modeling Framework



Hydrodynamic Modeling Methodology

Time-domain hydrodynamic formulation:

$$\boldsymbol{m}\ddot{\mathbf{X}} = \boldsymbol{F}_{exc}(t) + \boldsymbol{F}_{rad}(t) + \boldsymbol{F}_{B}(t) + \boldsymbol{F}_{PTO}(t) + \boldsymbol{F}_{m}(t) + \boldsymbol{F}_{v}(t)$$

$\boldsymbol{m}$: mass matrix

$\ddot{\mathbf{X}}$: acceleration vector of the device

$\boldsymbol{F}_{exc}(t)$: wave excitation force

$\boldsymbol{F}_{rad}(t)$: wave radiation force

$\boldsymbol{F}_{B}(t)$: net buoyancy restoring force

$\boldsymbol{F}_{PTO}(t)$: power-take-off (PTO) force

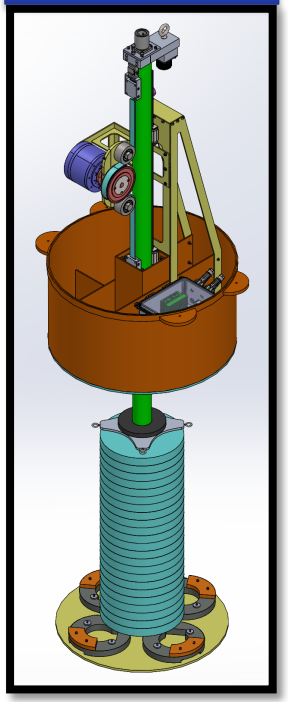
$\boldsymbol{F}_{m}(t)$: mooring force

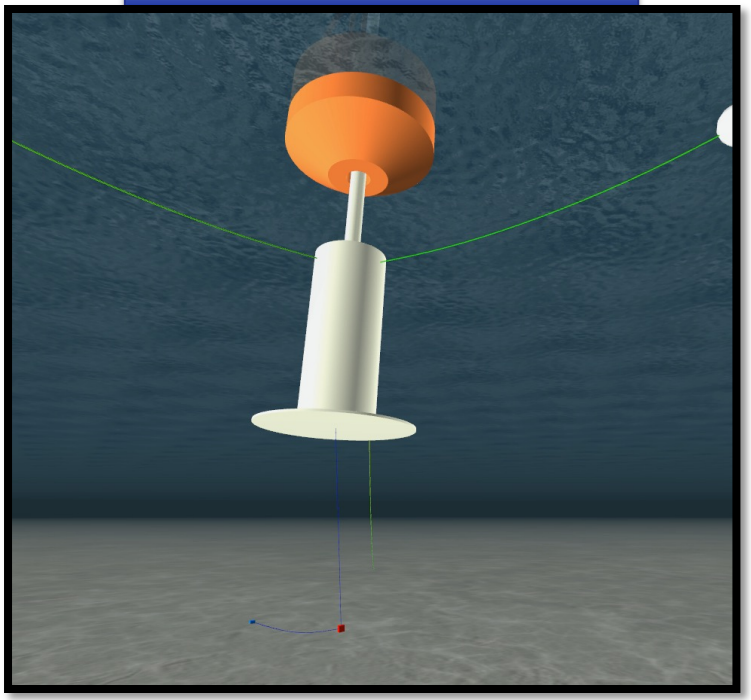
$\boldsymbol{F}_{v}(t)$: linear and/or quadratic viscous force

Note: $\boldsymbol{F}_{exc}(t)$, $\boldsymbol{F}_{rad}(t)$, and $\boldsymbol{F}_{B}(t)$ are calculated using hydrodynamic coefficients obtained from the frequency domain boundary-element solver.

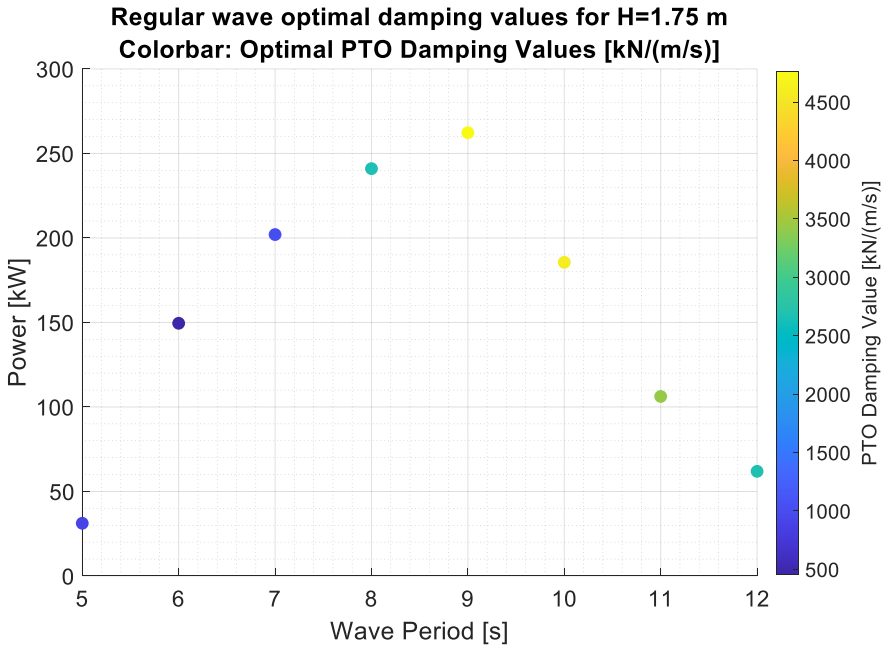
WEC, AUV, and Dock Hydrodynamic Modeling

LUPA Physical Model → **Validation** → LUPA Lab-Scale PDS Model → **Scale to Practical** → 20 Times to The Lab-Scale PDS Model





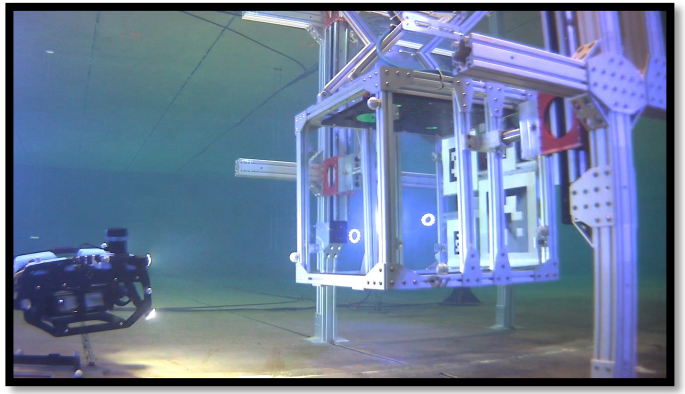
WEC Hydrodynamic Analysis

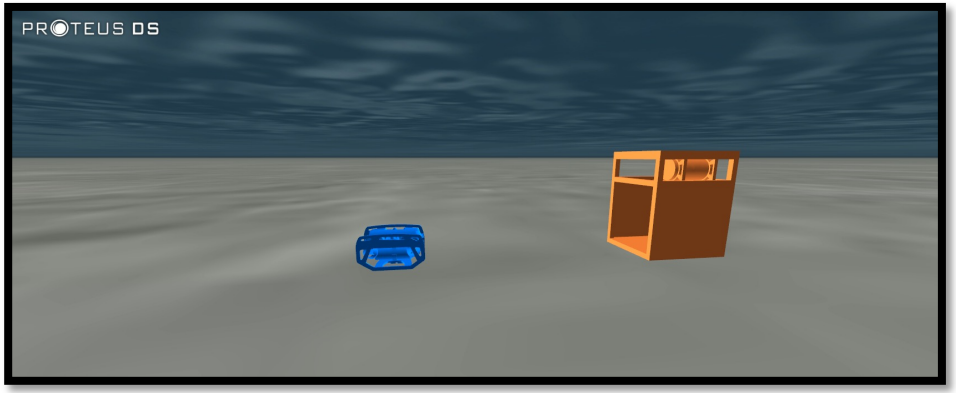


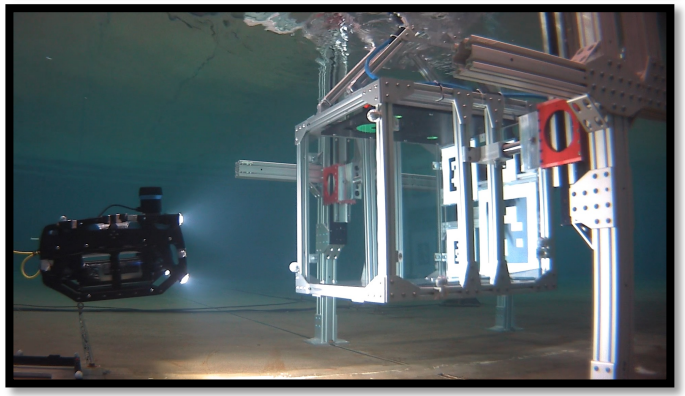
Power Matrix (kW)

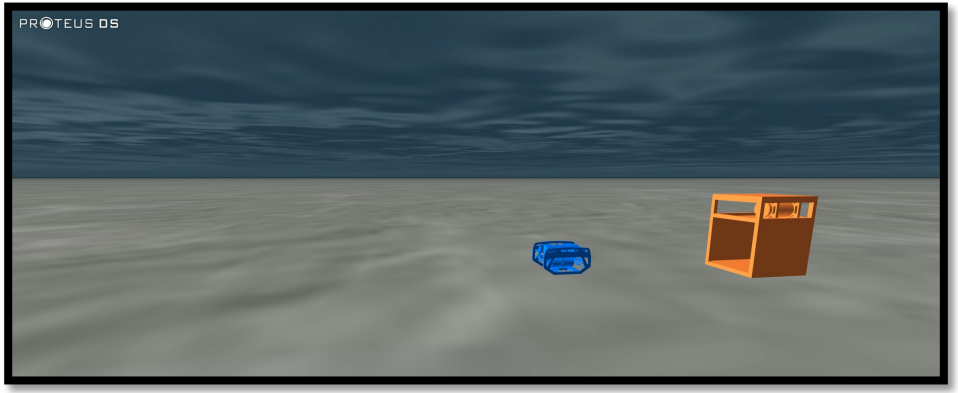
Significant Wave Height (m) \ Peak Period (s)	5	6	7	8	9	10	11	12
5	N/A	N/A	N/A	N/A	538.36	443.62	463.44	413.30
4.5	N/A	N/A	N/A	591.52	325.46	344.70	398.82	359.13
4	N/A	N/A	214.05	322.90	287.53	330.27	303.58	273.14
3.5	N/A	N/A	199.57	302.55	222.10	242.44	249.62	192.65
3	N/A	87.09	116.80	180.88	186.15	189.94	200.75	170.06
2.5	N/A	88.33	108.93	144.08	150.40	149.36	146.78	123.78
2	46.72	58.06	77.08	86.24	93.34	87.96	102.57	76.28
1.5	15.11	27.25	52.60	58.62	53.16	52.34	49.68	51.57
1	7.38	10.03	15.94	17.72	27.20	24.89	25.24	20.40

AUV Docking Hydrodynamic Model

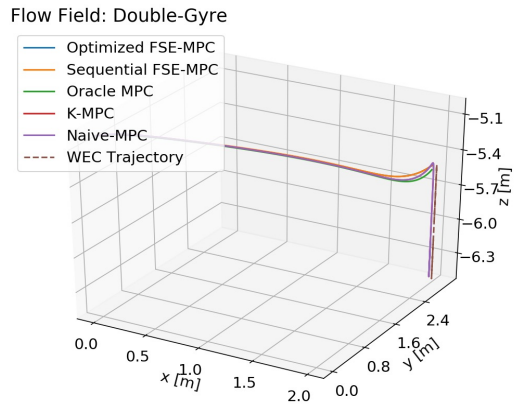


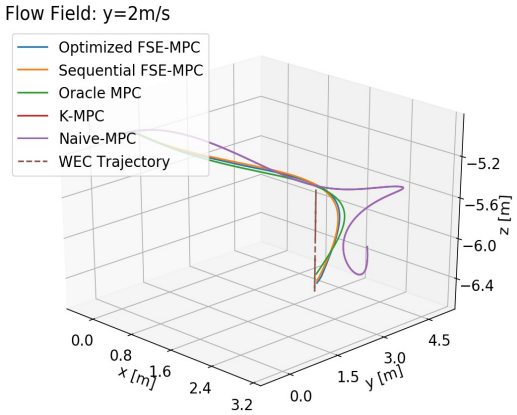


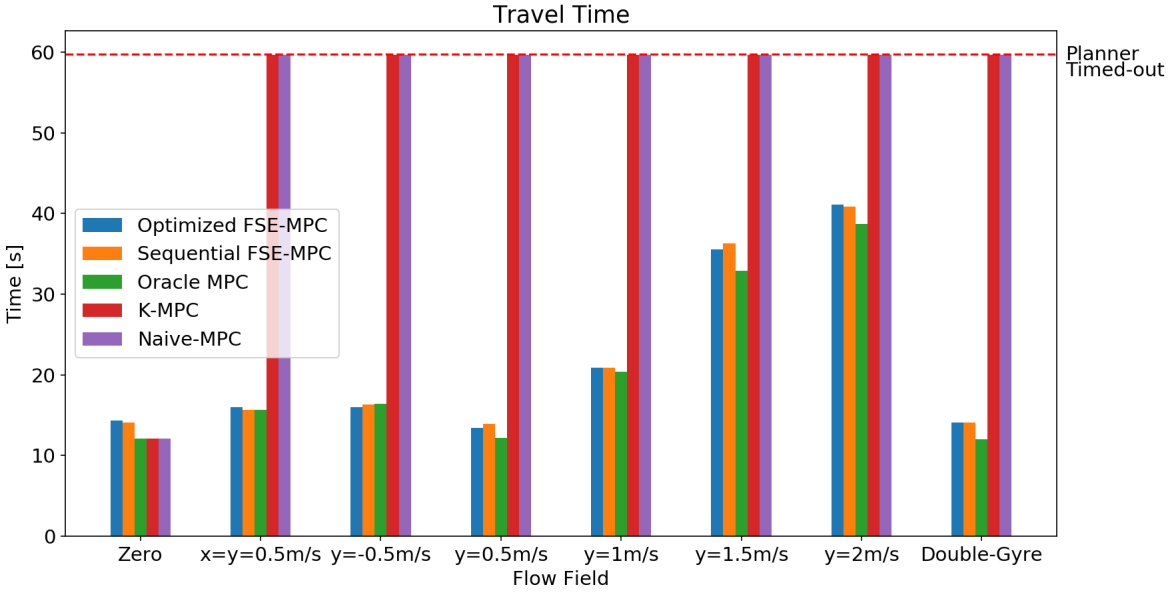




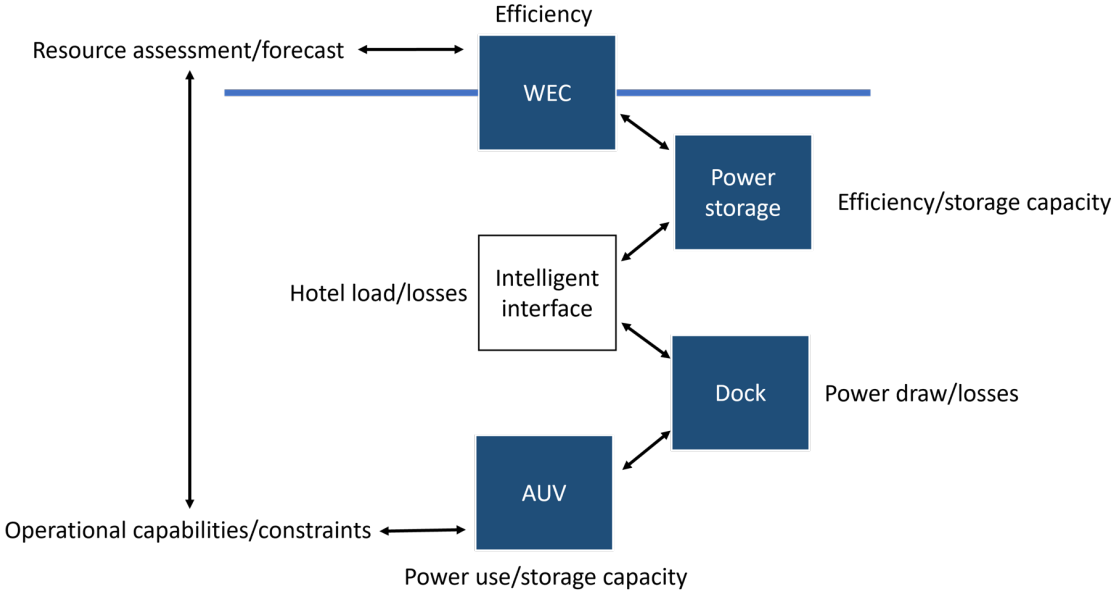
AUV Navigation Model

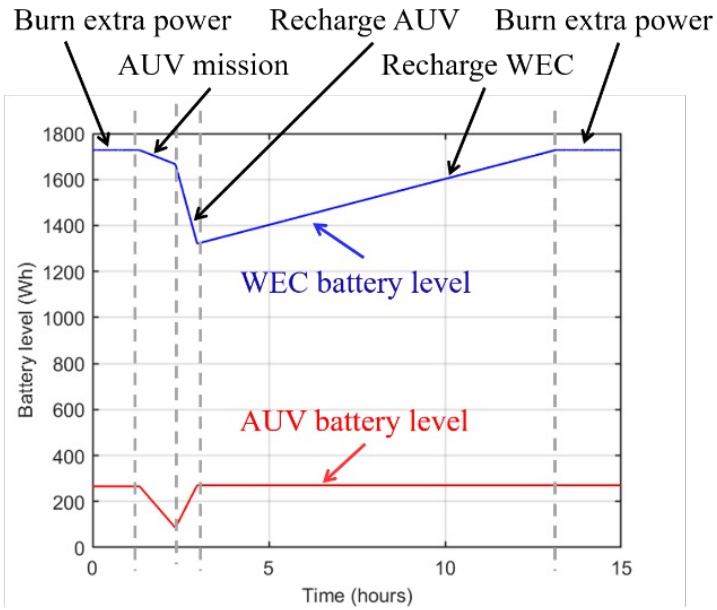






Power Model


Efficiency
Resource assessment/forecast
WEC
Power storage
Efficiency/storage capacity
Hotel load/losses
Intelligent interface
Dock
Power draw/losses
AUV
Operational capabilities/constraints
Power use/storage capacity


Burn extra power
Recharge AUV
Burn extra power
AUV mission
Recharge WEC
WEC battery level
AUV battery level
Battery level (Wh)
Time (hours)
0
200
400
600
800
1000
1200
1400
1600
1800
0
5
10
15

Thank you for listening

Questions …