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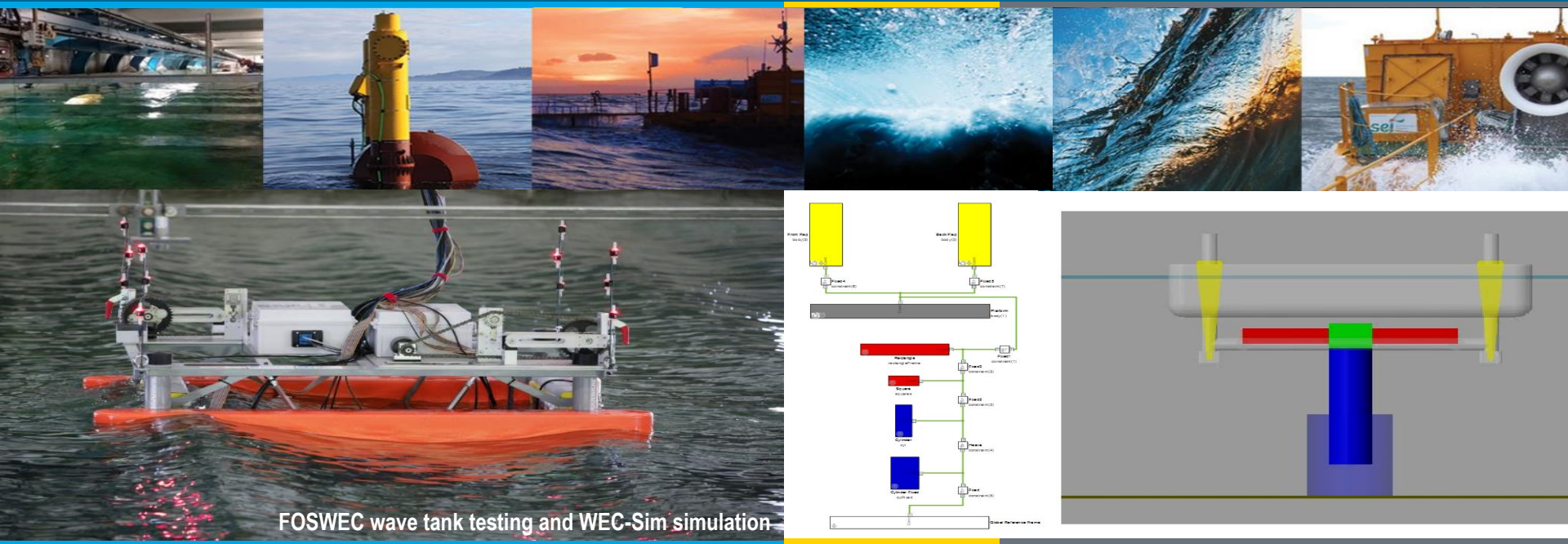


FOSWEC wave tank testing and WEC-Sim simulation

WEC-Sim Training Course

for users and developers

February 15, 2020

Yi-Hsiang Yu (NREL)
Kelley Ruehl (Sandia)

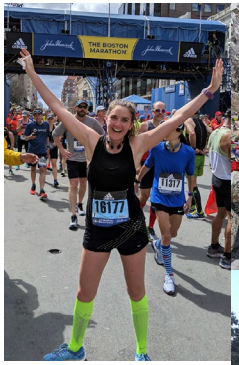
SAND2021-1634 PE

B.S. & M.S. Marine Environment and Engineering (1998 & 2000)

Ph.D. Civil, Architectural, & Environmental Engineering, majored in ocean engineering (2008)

ROSE-HULMAN FIGHTIN' ENGINEERS

Oregon State University



B.S. Mechanical Engineering, minor in German (2009)

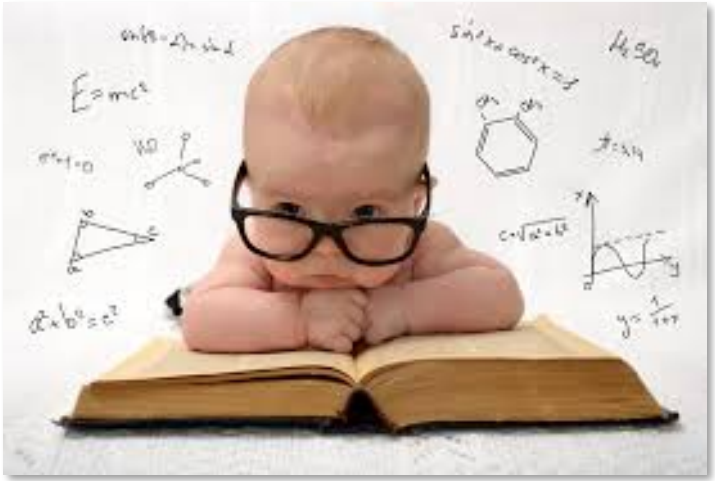
M.S. Mechanical Engineering, minor in Ocean Engineering (2011)

Course Agenda

Session	Duration	Topic	Description
Lecture 1: WEC-Sim Theory and Workflow	0:20	**WEC-Sim Overview**	Overview of course topics and WEC-Sim code
	0:20	**Theory & Workflow**	Cummins' equation and WEC-Sim workflow (BEM->BEMIO->WEC-Sim) Description of what happens when you execute WEC-Sim (wecSim.m)
	0:50	**Code Structure Overview**	Overview of WEC-Sim's input file (wecSimInputFile.m), classes (*.m) and library blocks (*.slx)
Lecture 2: WEC-Sim Classes and Debugging	0:30	**Wave Class**	Describe how waves are modeled in WEC-Sim using waveClass.m and variant subsystems
	0:30	**Body Class**	Describe how bodies are modeled in WEC-Sim using bodyClass.m and variant subsystems
	0:30	**Debugging/Homework Q&A**	Discuss common errors with WEC-Sim: incorrect setup, path, and BEM data, coordinate systems and data at cg.
Lecture 3: WEC-Sim Features	0:15	**Multiple Conditions Run**	Show how to use wecSimMCR for RM3
	0:15	**Mooring**	demonstrate the WEC-Sim Applications for Mooring, https://github.com/WEC-Sim/WEC-Sim_Applications/tree/master/Mooring
	0:15	**Boundary Element Method Input/Output (BEMIO)**	Run BEMIO using statespace, and changing other flags for RM3
	0:15	**GitHub**	Overview of how to use GitHub for version control and collaborative development.
	0:15	**WEC-Sim Applications**	Review of relevant WEC-Sim applications cases
	0:15	**Homework Q&A**	

What can I learn?

- Basic WEC-Sim theory and workflow
- How to modify the code if needed
  - Detailed code structure
  - Deep dive into different classes
- How to debug the code
- How to use WEC-Sim for different applications



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WEC-Sim Training Course

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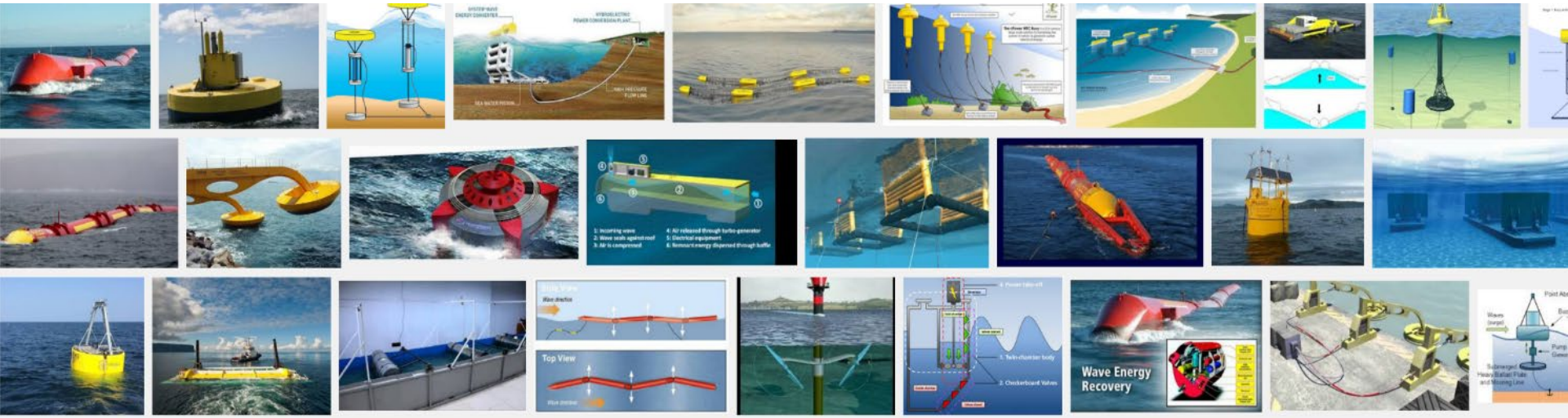

WEC-Sim Overview

Yi-Hsiang Yu (NREL)

What is WEC-Sim?

WEC-Sim (Wave Energy Converter Simulator)

- Simulates wave energy converter dynamics
- Time-domain equation of motion solver based on Cummins' formulation
- Open source code developed in MATLAB/SIMULINK
- Joint NREL/Sandia project funded by the US Department of Energy
- First Release: v1.0 in June 2014
- Current Release: v4.2 in Dec 2020

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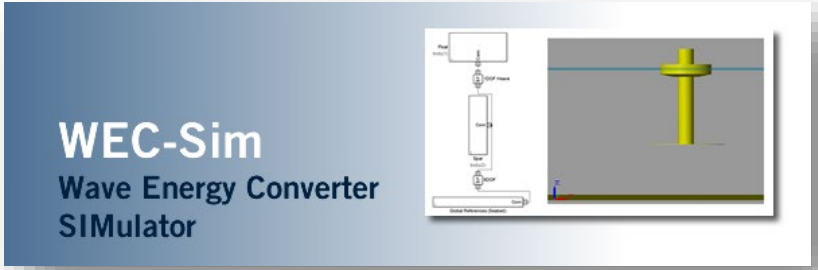
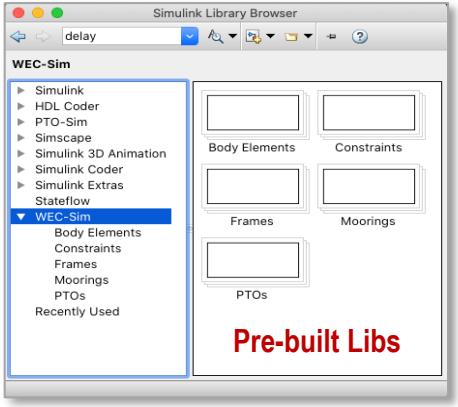


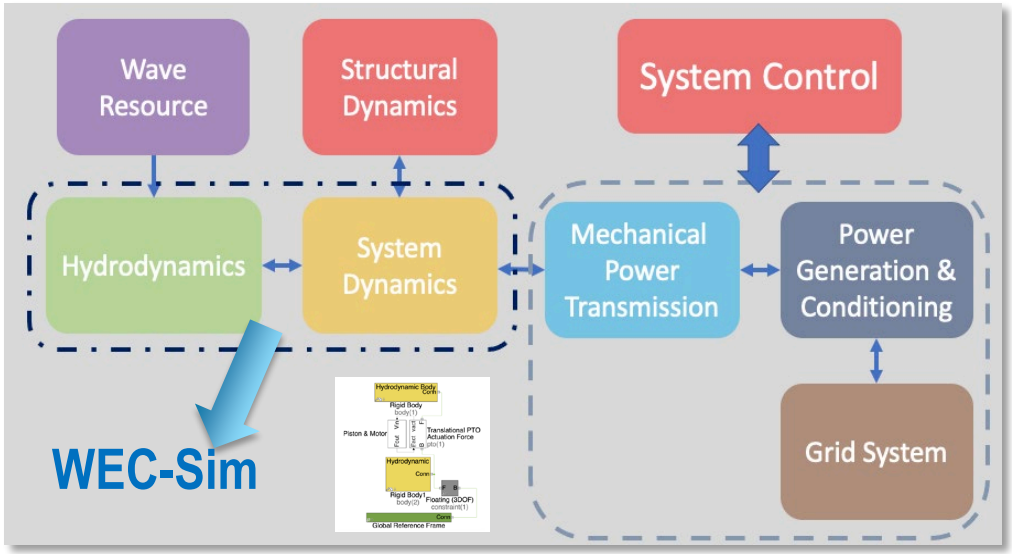
Apache 2.0

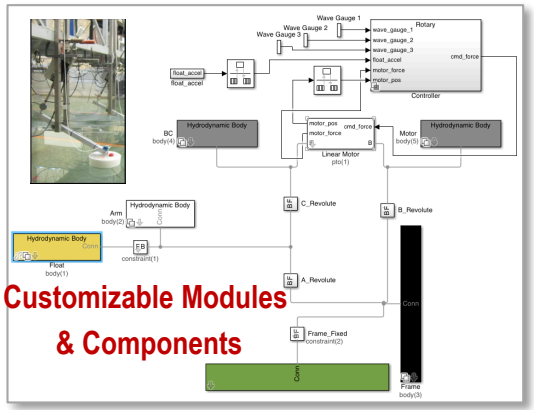
License:

Why use WEC-Sim?

- Provide hydrodynamic representation of the WEC that consists of multiple bodies (pre-built libs)
- Allows user specific modules for system control and other applications





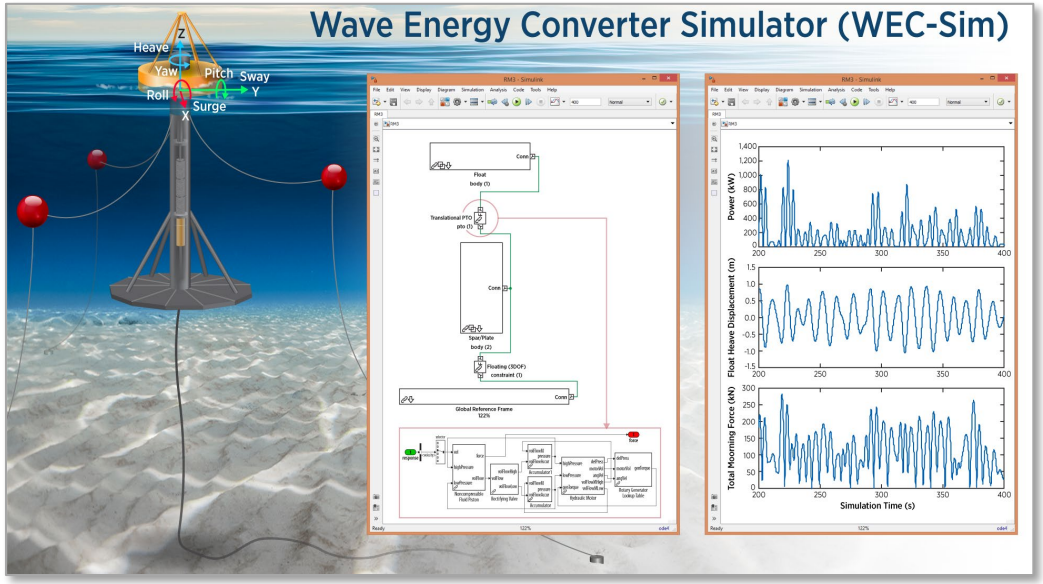


Why use WEC-Sim?

- WEC-Sim has the ability to model the dynamics of devices that are comprised of rigid/flexible bodies, power-take-off (PTO) systems, and mooring systems.

- WEC-Sim uses hydrodynamic coefficients derived from frequency-domain boundary element (BEM) simulations to model the relevant hydrodynamics.

- Time-domain simulations are performed by solving the governing WEC equations of motion in 6 degrees-of-freedom.



WEC-Sim Theory

- Dynamics simulated by solving time-domain equation of motion (Cummins, 1962)

$$m\ddot{x}(t) = f_{hs}(t) + f_{ex}(t) + f_{rad}(t) + f_{v}(t) + f_{pto}(t) + f_{m}(t)$$

- $f_{hs}(t)$: Hydrostatic restoring force
- $f_{ex}(t)$: Wave excitation & diffraction force (from BEM simulations)
- $f_{rad}(t)$: Radiation force: added mass and radiation damping (from BEM simulations)
- $f_{v}(t)$: Viscous force
- $f_{pto}(t)$: Power take-off force
- $f_{m}(t)$: Mooring force

- Use radiation and diffraction method and calculate the hydrodynamic forces from frequency-domain Boundary Element Method (BEM)

$$f_{rad}(t) = -A_{\infty}\ddot{X} - \int_0^t K(t-\tau)\dot{X}(\tau)d\tau$$

(A_{∞}: BEM; $K(t-\tau)$: BEM)

$$f_{ex}(t) = \Re\left[R_f F_X(\omega_\tau) e^{i(\omega_\tau t+\phi)} \int_0^{\infty} \sqrt{2S(\omega_\tau)d\omega_\tau}\right]$$

($F_X(\omega_\tau)$: BEM)

$$= \int_{-\infty}^{\infty} \eta(\tau) f_e(t-\tau)d\tau$$

($f_e(t-\tau)$: BEM)

WEC-Sim Software Requirements

- CAD (Computer-aided design), e.g., Rhinoceros, SolidWorks, ANSYS, etc.
- BEM (Boundary Element Method), e.g., WAMIT, NEMOH, AQWA
- WEC-Sim (Wave Energy Converter Simulator)
  - http://wec-sim.github.io/WEC-Sim/
  - Requires MATLAB, Simulink, Simscape, and Simscape Multibody
  - Full functionality has been verified on 2019b through 2020a.

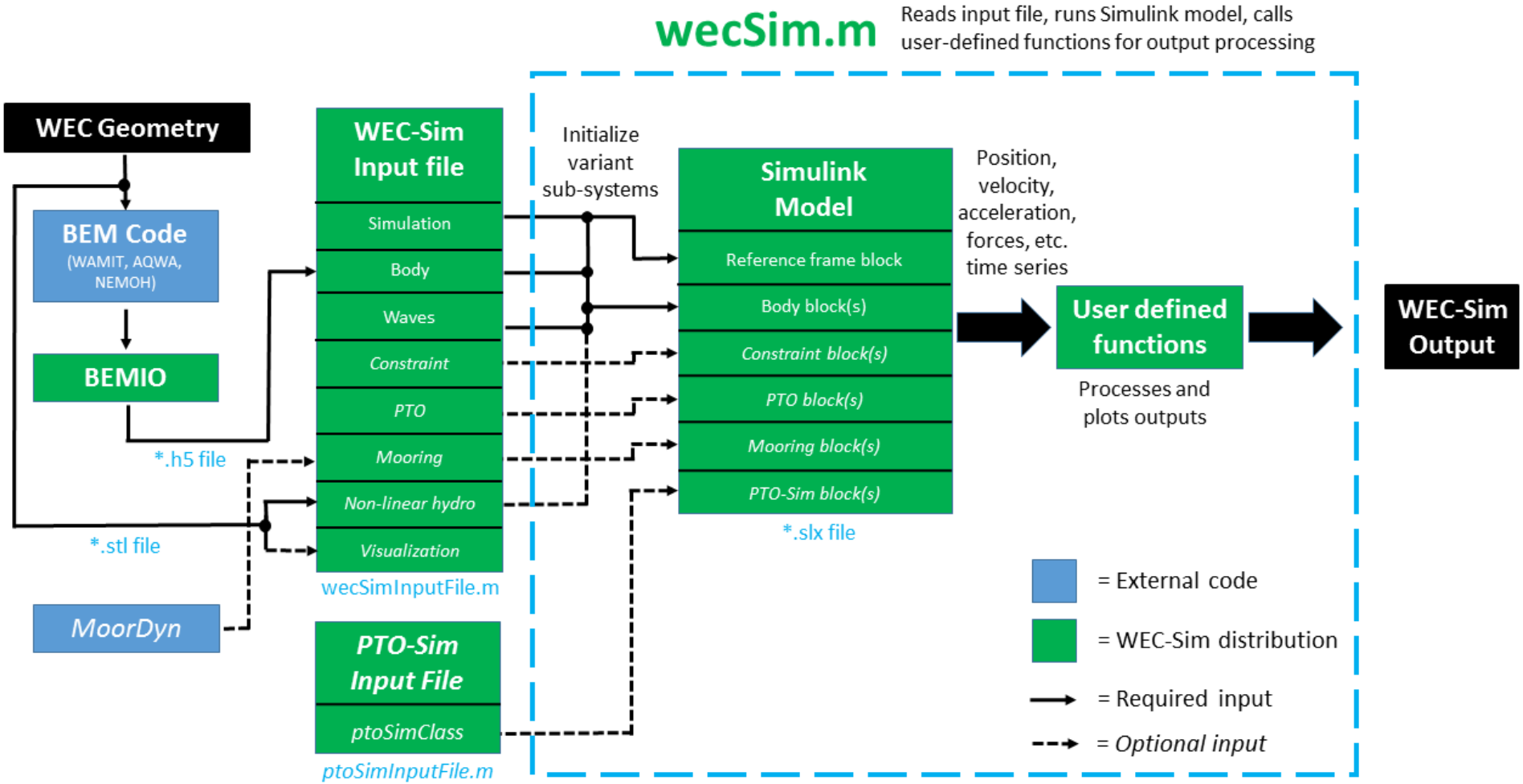
Required Toolbox	Oldest Compatible Version
MATLAB	Version 9.7 (R2019b)
Simulink	Version 10.0 (R2019b)
Simscape	Version 4.7 (R2019b)
Simscape Multibody	Version 7.0 (R2019b)

Optional Software

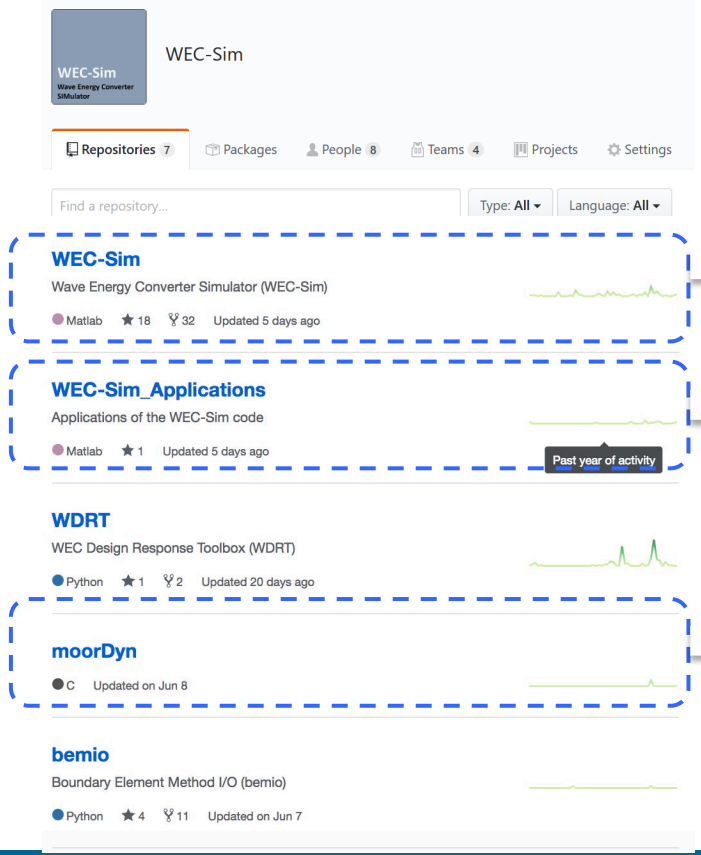
- ParaView (Optional)
  - http://www.paraview.org/
  - Optional, for additional visualization and analysis capabilities
  - BSD License, https://www.paraview.org/paraview-license/

- MoorDyn (Optional)
  - https://github.com/WEC-Sim/moorDyn
  - Optional, for additional mooring simulation features
  - GNU General Public License v3.0

MOORDYN


wecSim.m
Reads input file, runs Simulink model, calls user-defined functions for output processing
WEC Geometry
BEM Code
(WAMIT, AQWA, NEMOH)
BEMIO
*.h5 file
*.stl file
MoorDyn
WEC-Sim Input file
Simulation
Body
Waves
Constraint
PTO
Mooring
Non-linear hydro
Visualization
wecSimInputFile.m
PTO-Sim Input File
ptoSimClass
ptoSimInputFile.m
Initialize variant sub-systems
Simulink Model
Reference frame block
Body block(s)
Constraint block(s)
PTO block(s)
Mooring block(s)
PTO-Sim block(s)
*.slx file
Position, velocity, acceleration, forces, etc. time series
User defined functions
Processes and plots outputs
WEC-Sim Output
= External code
= WEC-Sim distribution
= Required input
= Optional input

GitHub Repositories



https://github.com/WEC-Sim

WEC-Sim Source Code

Additional Applications

Complied MoorDyn Library

To use MoorDyn in WEC-Sim,

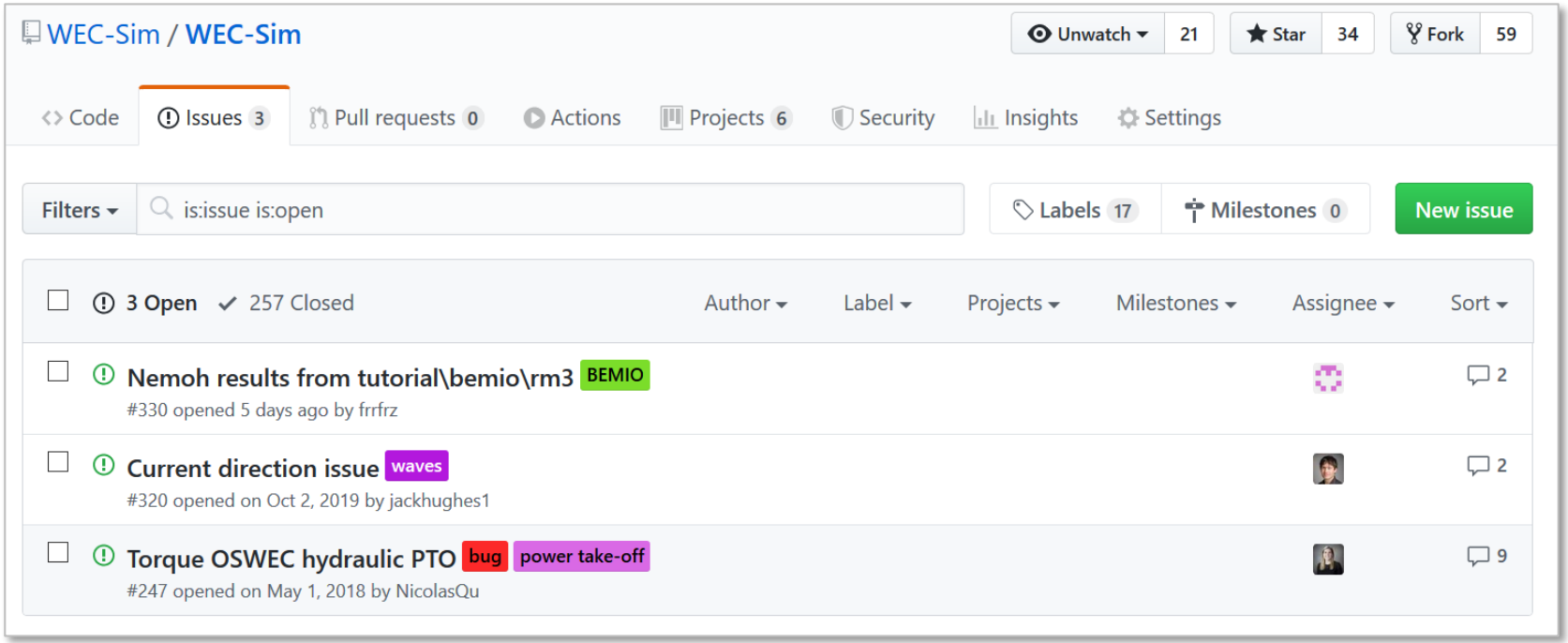
1. Please Download MoorDyn from the repo https://github.com/WEC-Sim/moorDyn
2. Place all the files and folders under WEC-Sim/source/functions/moorDyn folder

Documentation

http://wec-sim.github.io/WEC-Sim/

Online Forum

https://github.com/WEC-Sim/WEC-Sim/issues



Thank you!

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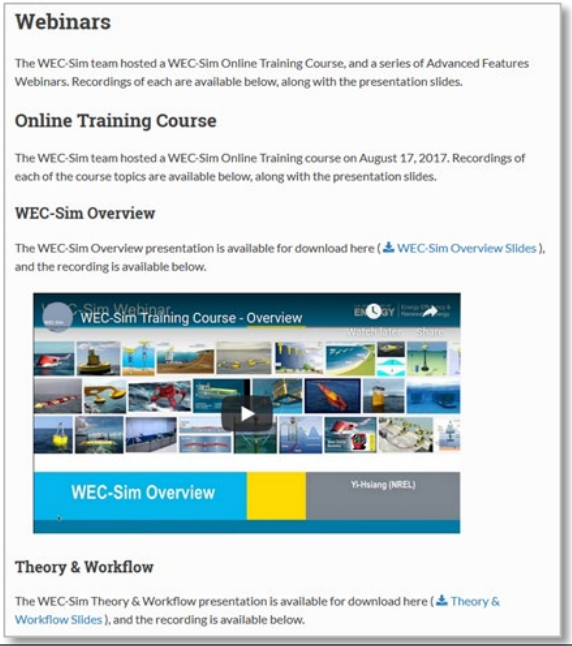
Webinar slides and recordings available online:
http://wec-sim.github.io/WEC-Sim/master/man/webinars.html



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