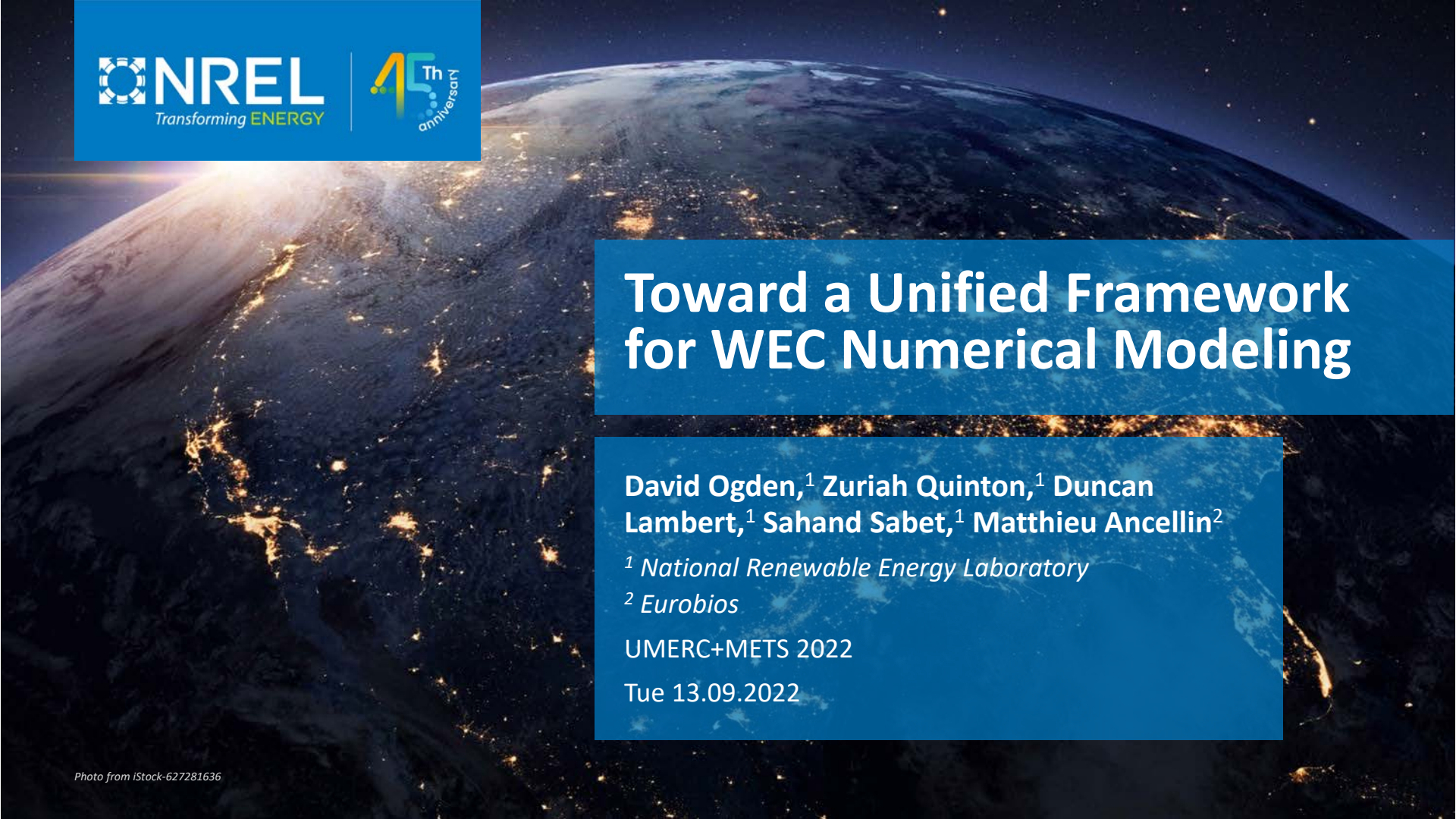

Toward a Unified Framework for WEC Numerical Modeling

David Ogden,[1] Zuriah Quinton,[1] Duncan Lambert,[1] Sahand Sabet,[1] Matthieu Ancellin[2]

[1] National Renewable Energy Laboratory

[2] Eurobios

UMERC+METS 2022

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Contents

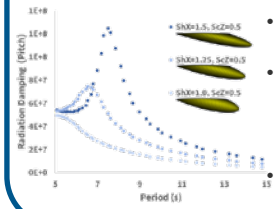
The Main WEC Numerical Modeling Domains

and Motivation for a Unified Framework

Computational Expense

Optimization

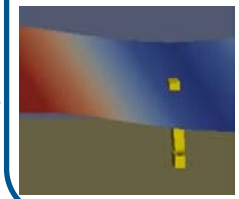
Low Fidelity



- Potential flow theory (i.e., inviscid fluid)
- Frequency domain hydrodynamic analysis of floating bodies
- e.g., Capytaine, WAMIT, HAMS

MIND THE GAP

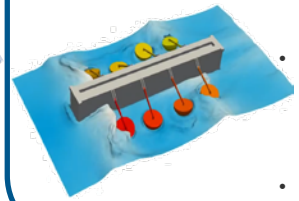
Mid Fidelity



- Potential flow theory in the time domain
- Enables simulation of nonlinear subsystems (e.g., joints, PTO, control, mooring)
- e.g., WEC-Sim, AQWA

MIND THE GAP

High Fidelity



- Solving the complete Navier-Stokes equations – either grid-based (Eulerian) or particle-based (Lagrangian)
- Enables simulation of shallow water, nonlinear waves, breaking waves, complex FSI (e.g., slamming), more accurate load profiles
- e.g., OpenFOAM, DualSPHysics, Star-CCM+

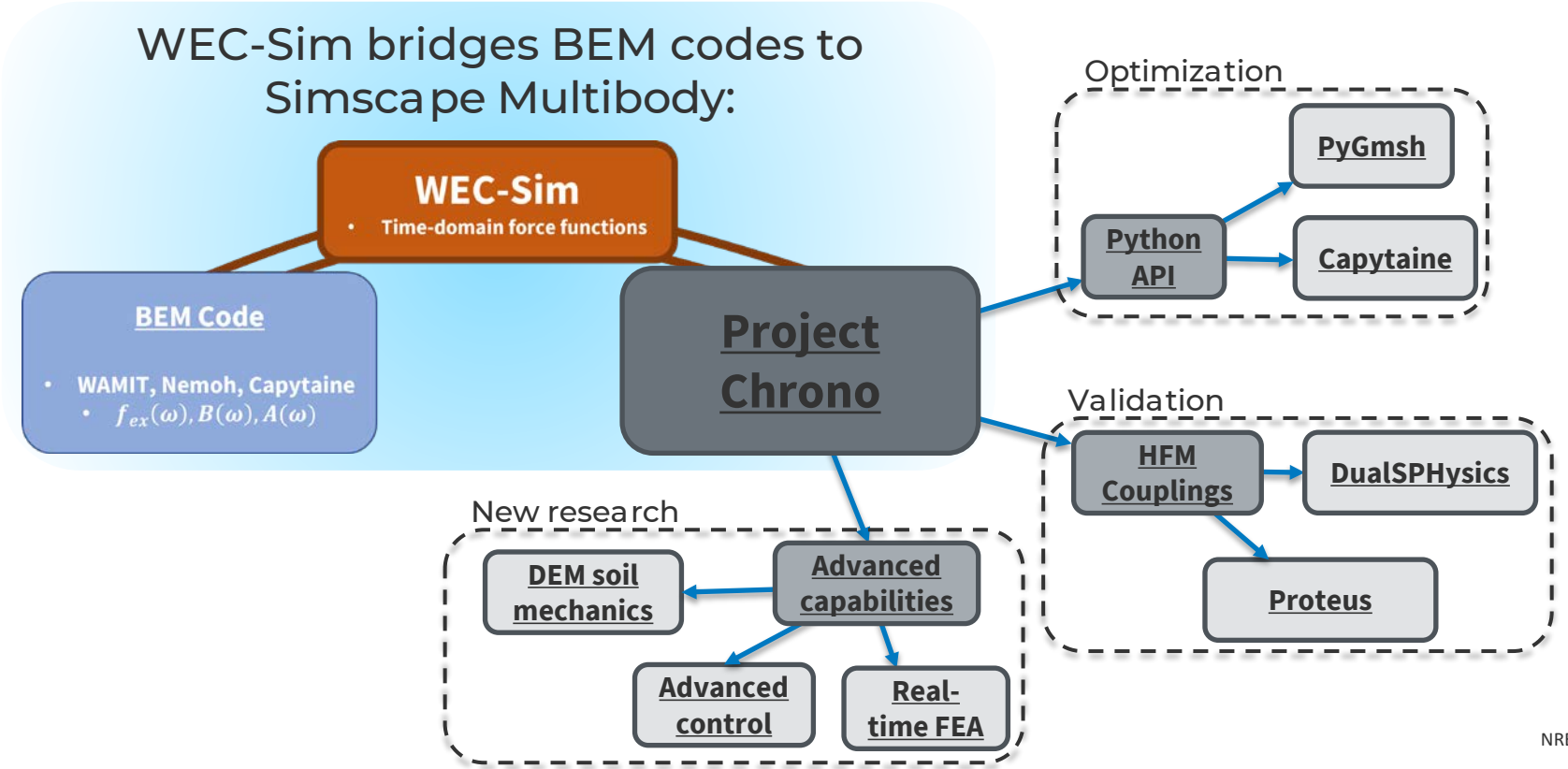
Validation

Accuracy

Design exploration (geometry, topology, PTO, control, mooring) – performance estimates

Validation, more accurate performance/load estimates

Replacing Simscape Multibody With Project Chrono



Rewriting WEC-Sim in C++ for Project Chrono

Architecture:

linker

Project Chrono

Multibody dynamics
Finite elements
Collision detection
Soil-structure interaction
Fluid-structure interaction

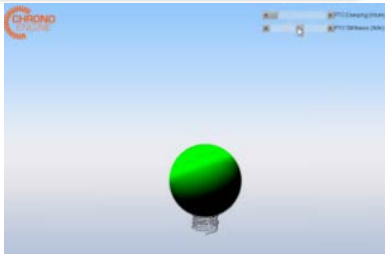
Hydrodynamics

.h5 i/o
Hydrostatics
Added mass
Radiation damping
Excitation force

WEC Model

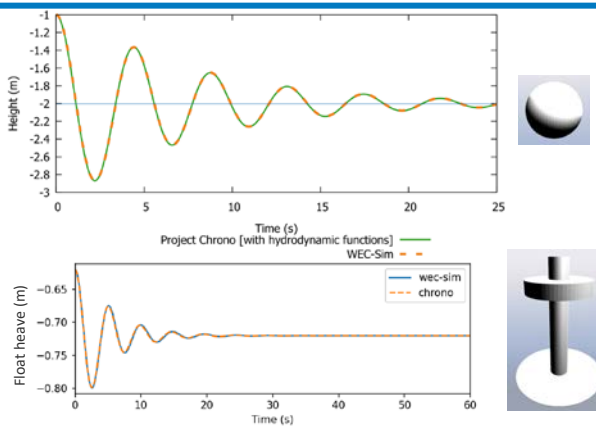
Complete access to Project Chrono
Append hydrodynamic forces to selected rigid bodies
Direct addition of dense [ndof x ndof] added mass matrix
Currently only available in C++

Real-time model control:

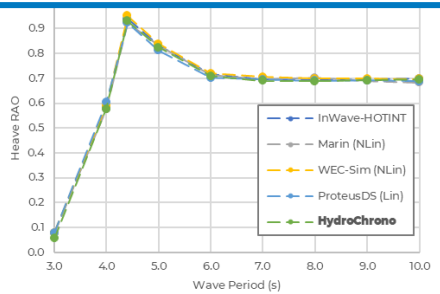


Zuriah Quinton, Sal Husain, Sahand Sabet

Verification: Sphere & RM3 decay



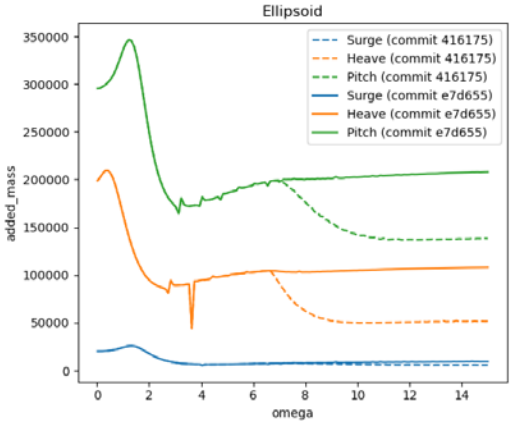
Verification: Sphere RAO

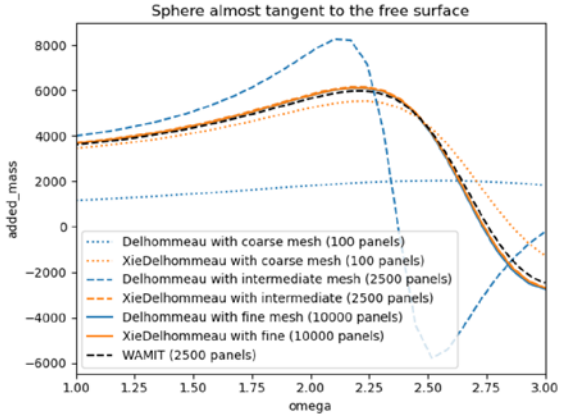


Open-Source BEM Code Development (Capytaine)

- In FY22, we began supporting the development of Capytaine
- Recent work has focused on supporting the community, improving the code's accuracy and speed

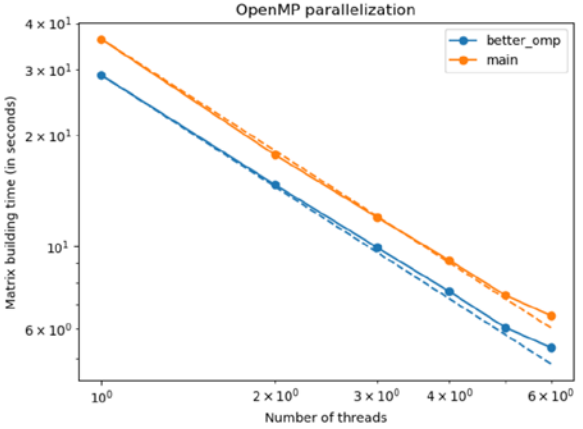
Better accuracy via Green function improvements





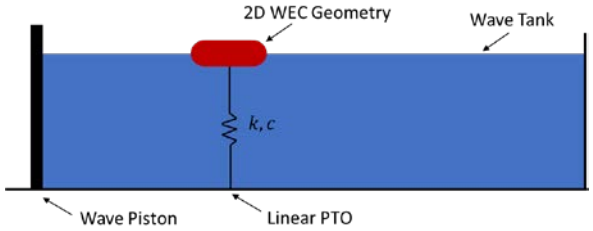
Matthieu Ancellin

Speed-ups via parallelization

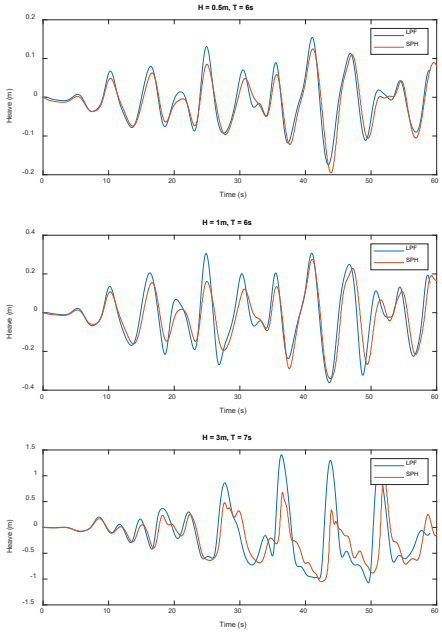


Chrono+DualSPHysics

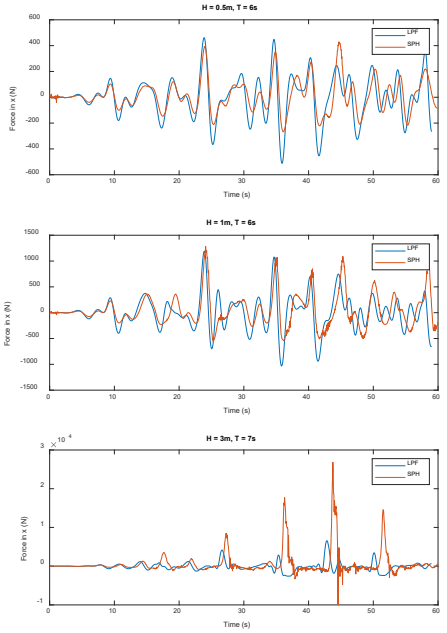
Point absorber in shallow water



Heave responses



Surge forces

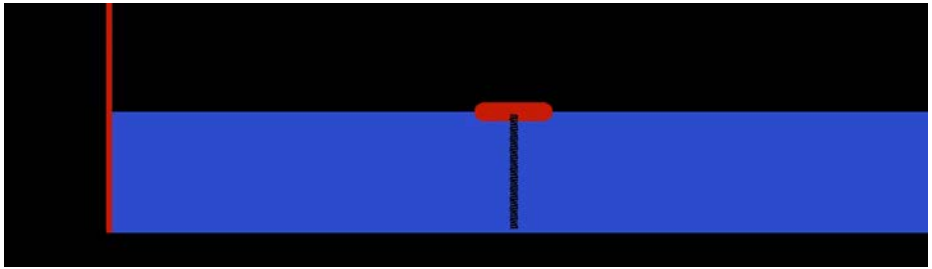


increasing wave height

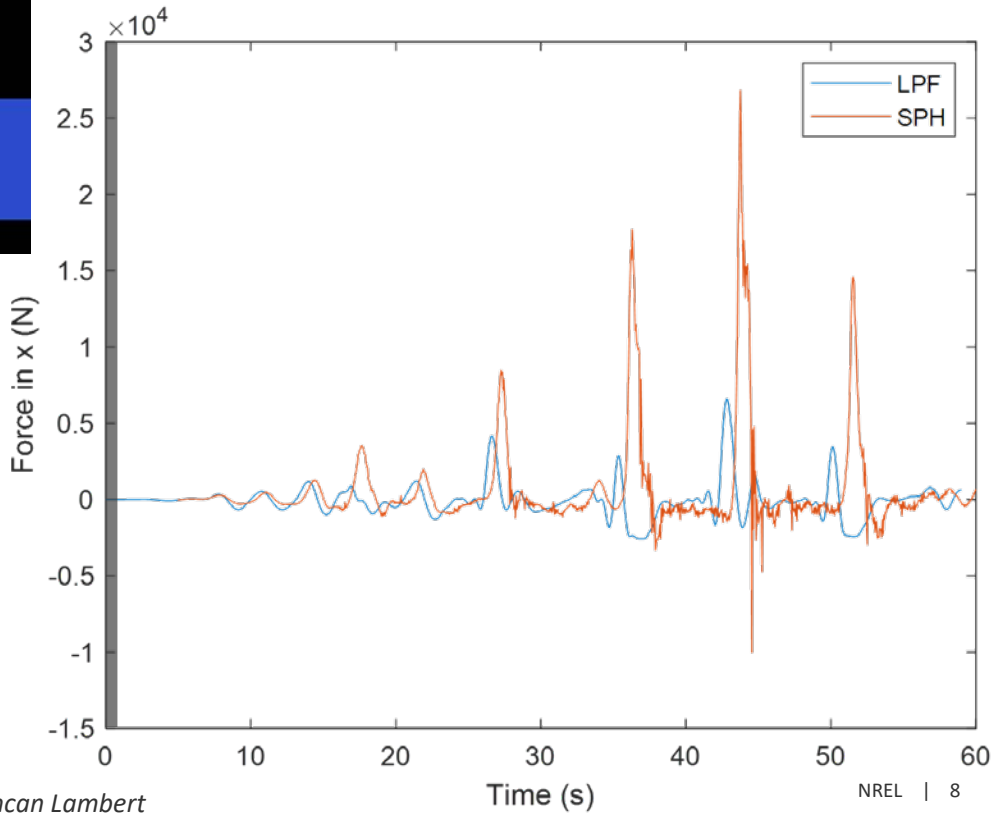
- **Chrono+DualSPHysics enables a wide range of WEC systems to be modeled with SPH**
- **This can help us to:**
  - **Validate potential flow results**
  - **Model devices in shallow water**
  - **Identify limits of potential flow models**

Duncan Lambert

Integration With Existing Chrono+DualSPHysics Coupling



- **DualSPHysics can us help identify impulsive loading events**
- **Chrono+DualSPHysics coupling will be augmented under recent NSF award (NJIT, U Vigo, UW-Madison, U Parma)**
- **TO DO: automatic .xml input file generation**



Future Work

- **FY23 publications:**
  1. Verification of the Project Chrono multibody hydrodynamics implementation (with dense added mass matrix addition) and speed comparison
  2. Using Chrono+DualSPHysics to identify impulsive loading events
  3. Improved accuracy and speed in Capytaine
- **Python API development**
  - Disseminate example case coupling PyGmsh, Capytaine and Chrono
- **Automatic .xml generation**
  - To use a single Chrono model with potential flow and SPH
- **Rigid-flexible body modeling**
  - Using FEM; relevant to variable geometry WECs, deformable WECs and moorings
- **Reinforcement learning**
  - Leveraging existing couplings to OpenAI, TensorFlow, and Stable Baselines

Conclusions

- A unified framework for WEC numerical modeling could help device developers on 3 fronts:
  - Optimization
  - More accurate load estimates
  - Validation
- Work is ongoing to couple meshing, frequency-domain and time-domain tools together for optimization
- By using Project Chrono, we can leverage existing couplings with SPH and CFD codes

Q&A

www.nrel.gov

NREL/PR-5700-83973

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