

Wave Energy Converter Model Development at Sandia

Presented By: Kelley Ruehl

Wind & Water Power Technologies

Sandia National Laboratories

SAND Number: 2012-6432C

Marine and Hydrokinetic Instrumentation, Measurement &
Computer Modeling Workshop – Broomfield, CO

July 9th, 2012

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.



Sandia National Laboratories



Outline

■ Overview of SNL's WEC Modeling Activities

- Wave Energy Development Roadmap
- MHK Reference Models – Diana Bull
- WEC Model Tool Development – Kelley Ruehl

**Reference Models and SNL Array Modeling
presented in next session**



Wave Energy Development Roadmap



Overall Goal and Motivation

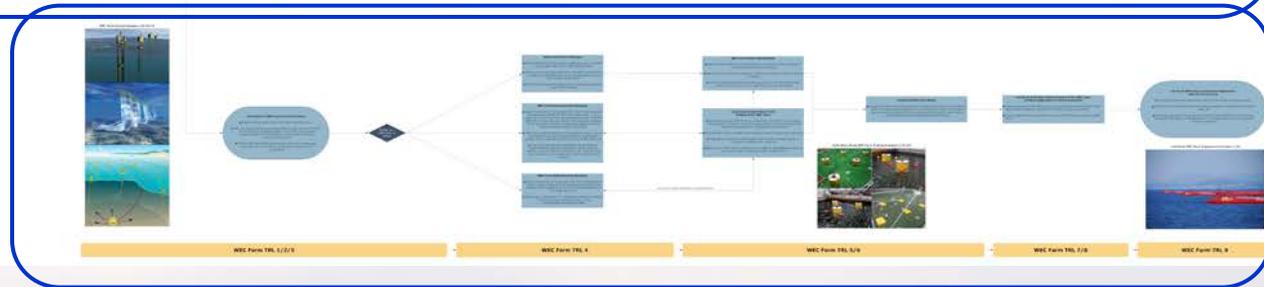
- **Goal:** Develop a suggested path for WEC development from design to commercialization.
- **Motivation:** Guide industry towards successful design optimizations, prototype deployments, and **utility scale commercialization** by providing a roadmap incorporating numerical modeling and experimentation.
 - Suggests path towards commercialization, referring to deployment of large arrays of WECs (WEC Farms)
 - Relates development stages to Technical Readiness Levels (TRLs)
 - Clarifies need for different types of numerical modeling and experimentation
 - Guides future research areas

Roadmap developed to clarify and identify gaps to promote industry success



Wave Energy Development Roadmap: Design to Commercialization

WEC Single Device TRLs 1 – 8



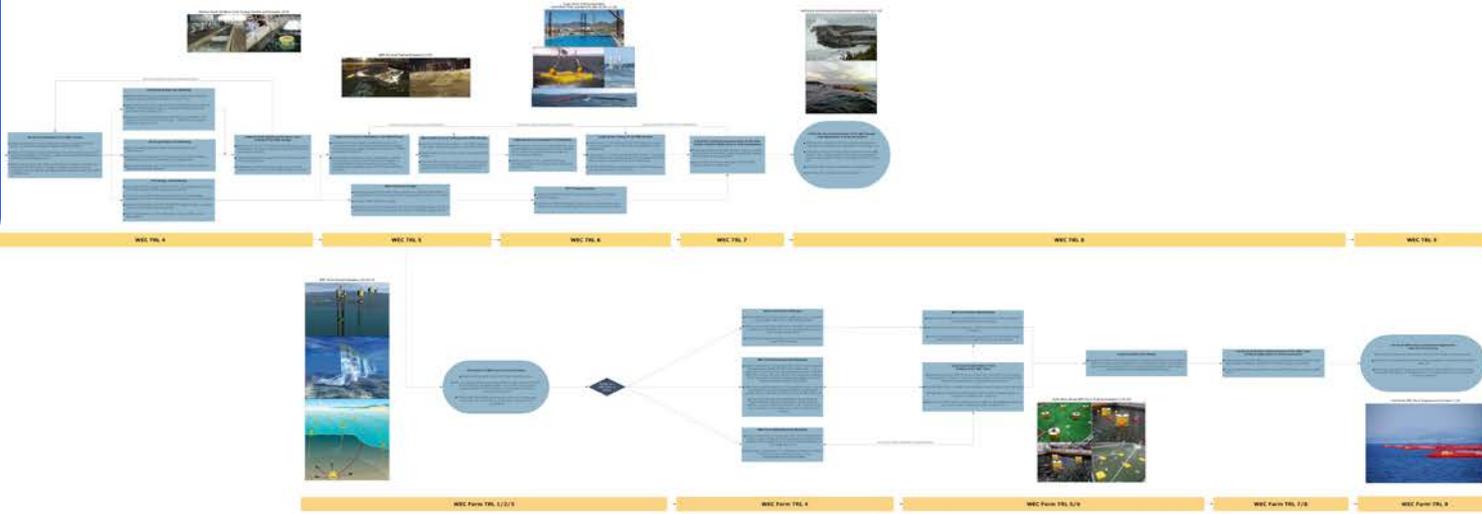
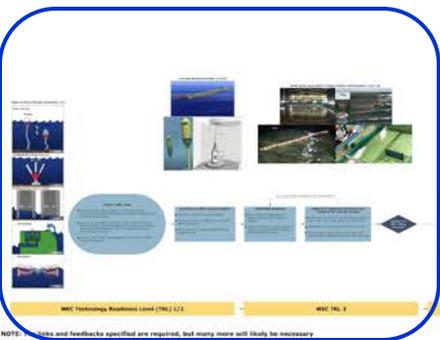
WEC TRLs 5 – 9

Note: All specified flows are required, but many more will likely be necessary
Looking for feedback on the roadmap



Wave Energy Development Roadmap: WEC TRL 1/2 & 3

WEC TRL 1/2 & 3



NOTE: Tasks and feedbacks specified are required, but many more will likely be necessary

Note: All specified flows are required, but many more will likely be necessary



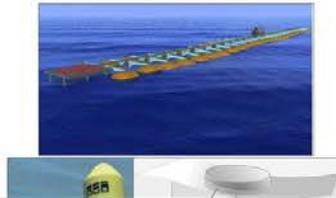
Wave Energy Development Roadmap:

WEC TRL 1/2 & 3

Types of Wave Energy Converters: [1]



Concept Design Examples: [2,3,4]



Small Scale Wave Basin Testing Facility and Examples: [5,6,7,8]



Choose a WEC
Type

Generate WEC
Concept
Designs

Modeling of
Concept
Designs

Small Scale
Testing
(1:100-1:25)

Wave Energy Development Roadmap: WEC TRL 4 & 5

WEC TRL 4 & 5



Note: All specified flows are required, but many more will likely be necessary



Wave Energy Development Roadmap: WEC TRL 4 & 5



WEC Survival Testing Examples: [7,9]

Structural Design and Modeling

Numerical Modeling of WEC Design

Mooring Design and Modeling

Medium Scale Testing (1:25-1:10)

Rigorous Numerical Modeling of WEC Design

Survival Testing

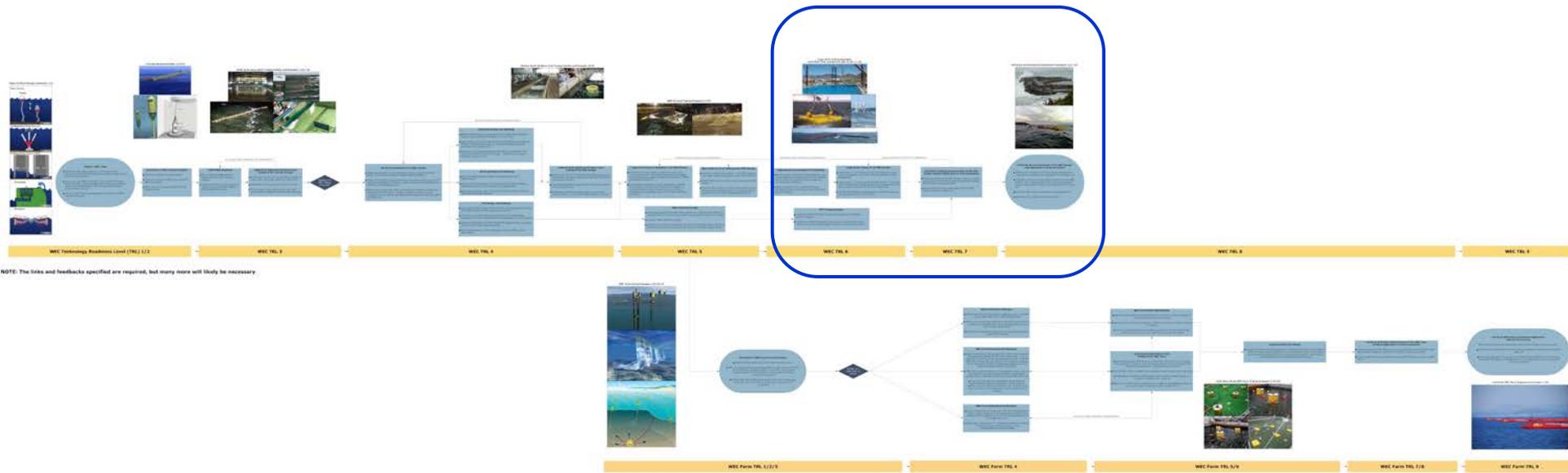
PTO Design and Modeling

WEC Telemetry Design



Wave Energy Development Roadmap: WEC TRL 6, 7 & 8

WEC TRL 6, 7 & 8



Note: All specified flows are required, but many more will likely be necessary



Wave Energy Development Roadmap:

WEC TRL 6, 7 & 8

Large Scale Testing Examples:
Controlled Tank and Nursery Site [6,10, 11,12]



Full Scale Grid Connected Deployment Examples: [13, 14]



Rigorous
Structural Design
and Modeling

Large Scale Testing
(1:3-1:10)

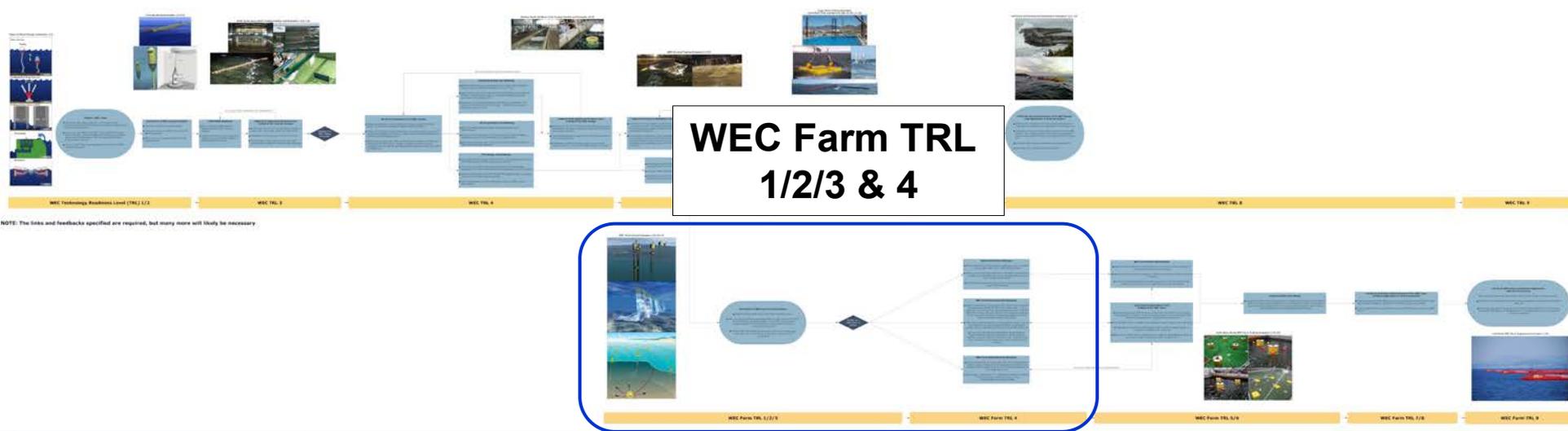
Full Scale Prototype
Demo

Full Scale Ocean
Deployment with
Application

PTO Characterization

Wave Energy Development Roadmap:

WEC Farm TRL 1/2/3 & 4



Note: All specified flows are required, but many more will likely be necessary



Wave Energy Development Roadmap: ***WEC Farm TRL 1/2/3 & 4***

Generate WEC
Farm (Array)
Designs

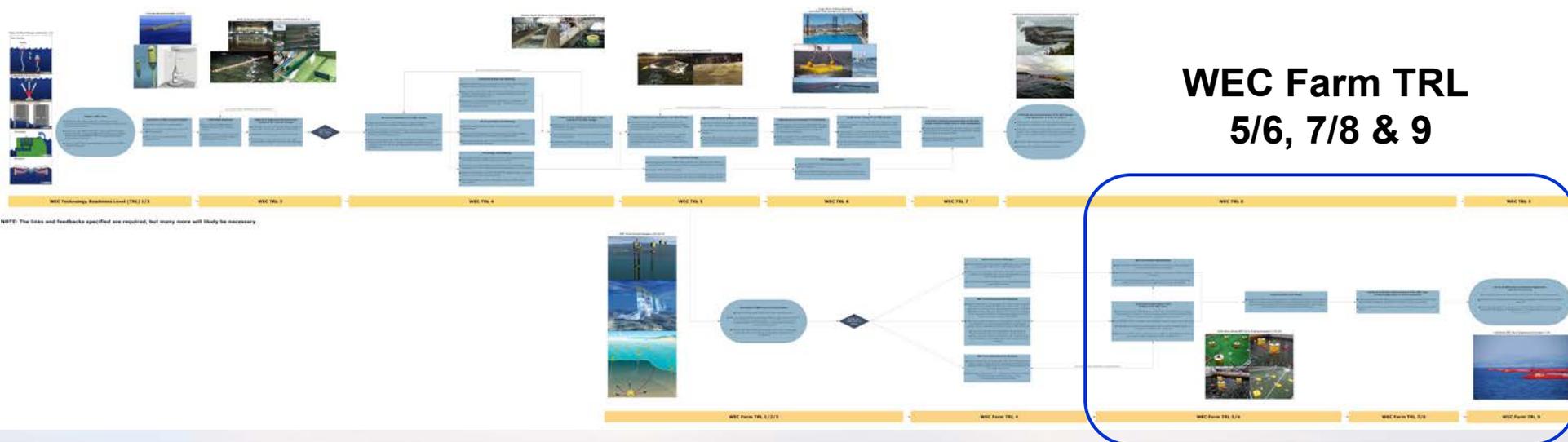
WEC Farm Power
Modeling

WEC Farm
Environmental
Modeling

WEC Farm
Hydrodynamic
Modeling

Wave Energy Development Roadmap:

WEC Farm TRL 5/6, 7/8 & 9



Note: All specified flows are required, but many more will likely be necessary



Wave Energy Development Roadmap: ***WEC Farm TRL 5/6, 7/8 & 9***

WEC Farm Power
Optimization

WEC Farm Testing

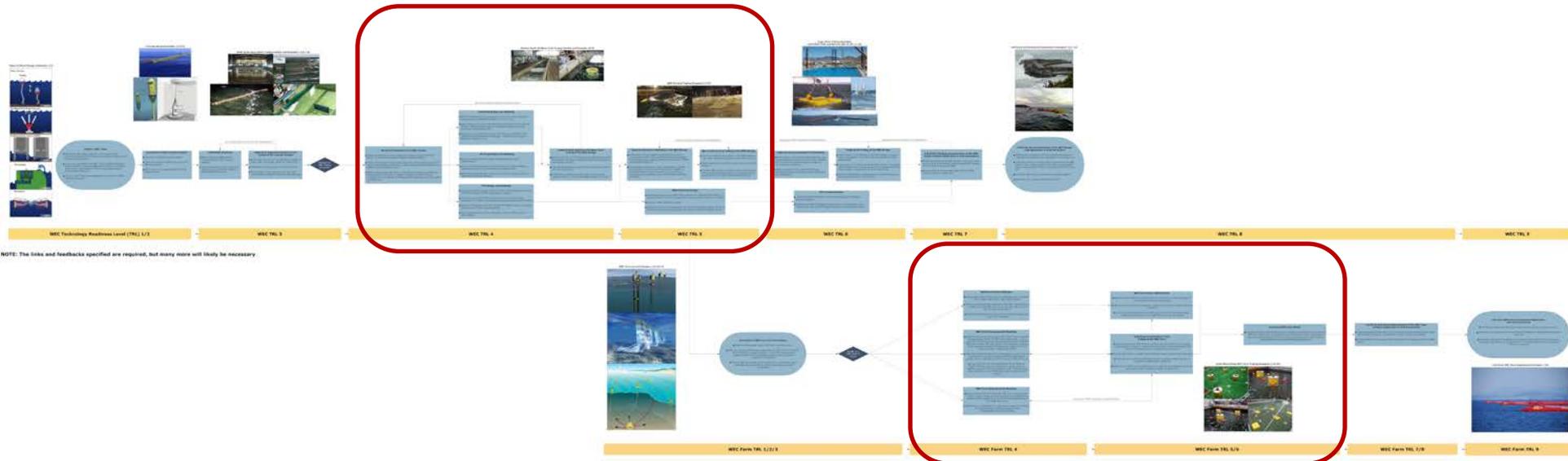
Combined WEC Farm
Model

Full Scale Prototype
of WEC Farm

Full Scale
Commercial
Deployment of
WEC Farm

Wave Energy Development Roadmap: Research Areas

WEC TRL 4 & 5



WEC Farm TRL 4 & 5/6

■ Single Device

- WEC Hydrodynamic and Survivability Modeling

■ Multiple Devices

- WEC Farm Power, Environmental and Hydrodynamic Modeling
- WEC Farm Power Optimization and Control



MHK Reference Models



MHK Reference Models: Overall Goal and Motivation

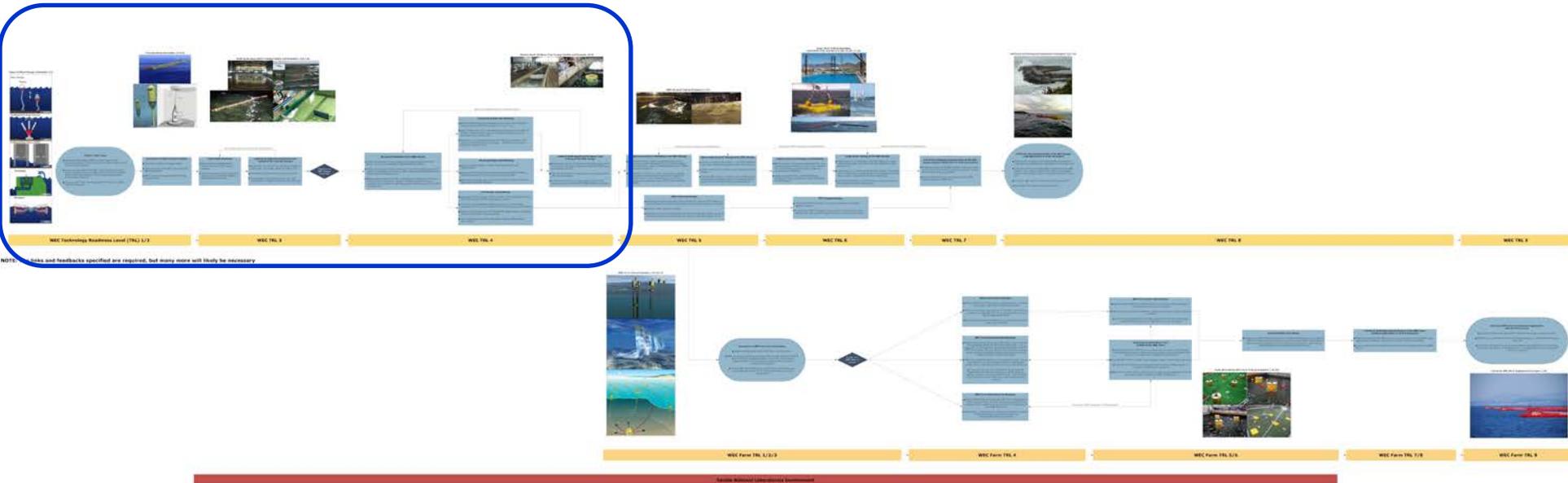
- **Goal:** Develop a representative set of Reference Models (RM) for the MHK industry to develop baseline **Cost of Energy (COE)** and evaluate key cost component/system reduction pathways.
- **Motivation:** Industry needs for COE targets with regard to technology type, and identify future innovation opportunities to prioritize research and cost reduction pathways
 - Promote and assist a vibrant and cost effective MHK industry
 - Develop and disseminate system design tools and/or MHK models for the development of advanced MHK designs (*DOE Goal – 10 platforms*)

**MHK Reference Models developed to determine
baseline COE**



MHK Reference Models: RM on the Roadmap

WEC TRL 1/2, 3 & 4



MHK Reference Models: Integrate Program



WEC Model Tool Development



WEC Model Tool Development:

Overall Goal and Motivation

- **Goal:** Develop the computational framework for near- and far-field WEC and WEC Farm models.
- **Motivation:** Promote development of the wave energy industry by bridging the gap between existing WEC modeling capabilities and WEC modeling needs.
 - Uses roadmap to pinpoint research areas in need of development
 - Currently focused on improved modeling of WEC Farms
 - Future work will also be focused on single devices

**Develop computational framework for modeling
WECs in the near- and far-field**



WEC Model Tool Development: SNL on the Roadmap

WEC TRL 4 & 5



WEC Farm TRL 4 & 5/6

■ Single Device

- Research primarily falls into RM activities

■ Multiple Devices

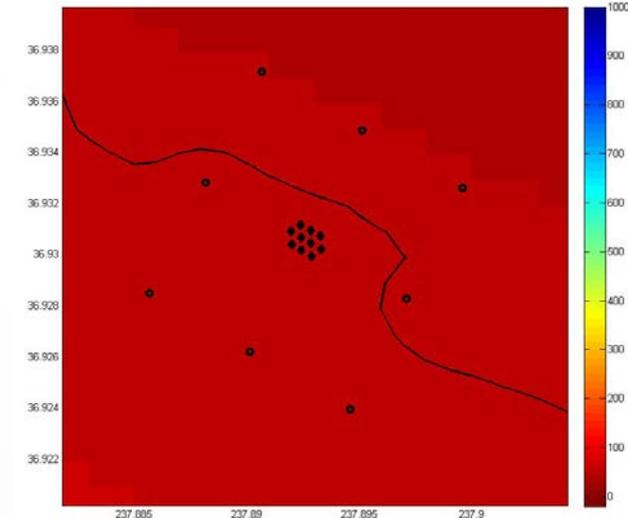
- Currently focused on improving large scale wave models for environmental assessments



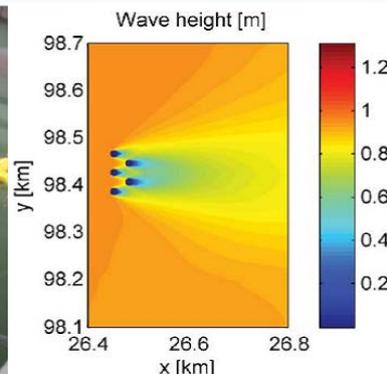
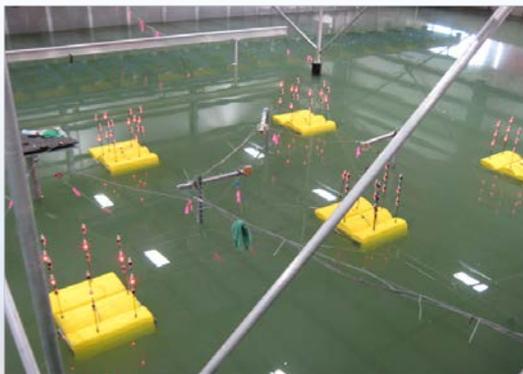
WEC Modeling

■ SNL uses several WEC modeling tools

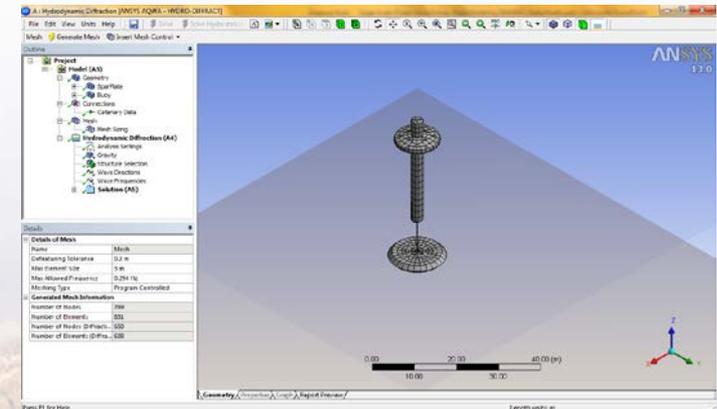
- ANSYS-AQWA: Device Scale BEM solver
- WAMIT: Device Scale BEM solver
- OrcaFlex: Device Scale Morison EQ solver
- SWAN: Large Scale spectral wave solver
- SNL-EFDC: Resource Scale Hydrodynamics



SWAN WEC Array Model (SNL model)



Columbia Power WEC array testing at OSU Tsunami Basin (left) and SWAN model for a similar array configuration(right).



ANSYS-AQWA 2-Body Point Absorber WEC Model (SNL model).



WEC Model Tool Development:

Preview

■ **WEC Farm Modeling**

- SWAN (Simulating WAVes Nearshore) is a spectral solver often used to model WEC Farms
- Currently WEC Farms are modeled as obstacles that remove a percentage of the incident wave energy across all frequencies
- WECs are designed to extract most energy at dominant wave periods
- SNL plans to develop energy sinks that can extract wave energy as a function of frequency and direction



Recap

■ Overview of SNL's WEC Modeling Activities

- Wave Energy Development Roadmap
- MHK Reference Models – Diana Bull
- SNL Model Tool Development Activities – Kelley Ruehl

**Reference Models and SNL Array Modeling
presented in next session**

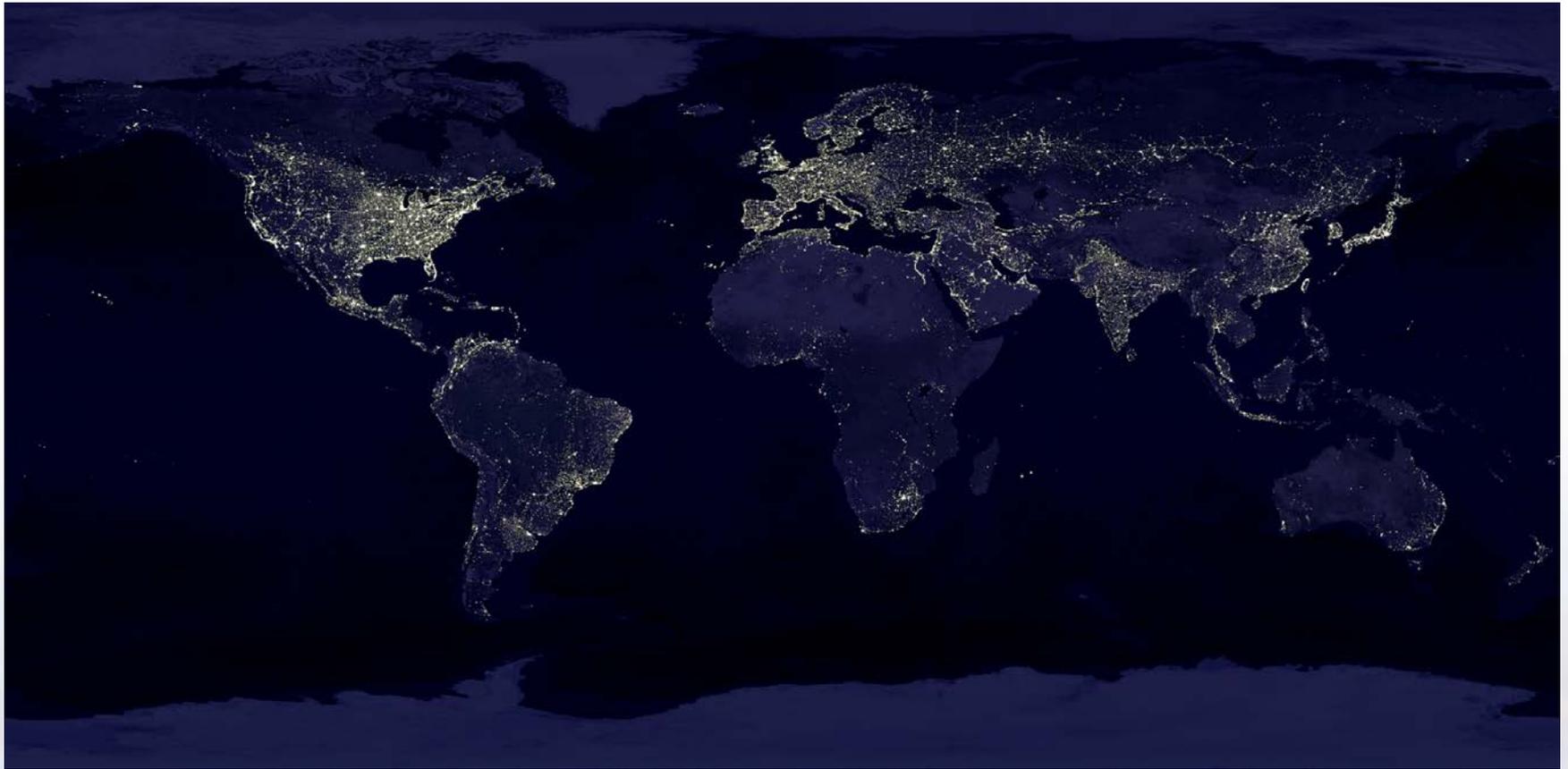
**SNL-EFDC and CACTUS presented by Erick
Johnson on Tuesday**



Questions???

Thanks for your time!

kmruehl@sandia.gov



<http://visibleearth.nasa.gov/>