MHK Reference Model: Relevance to Computer Simulation

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Reference Model Partners

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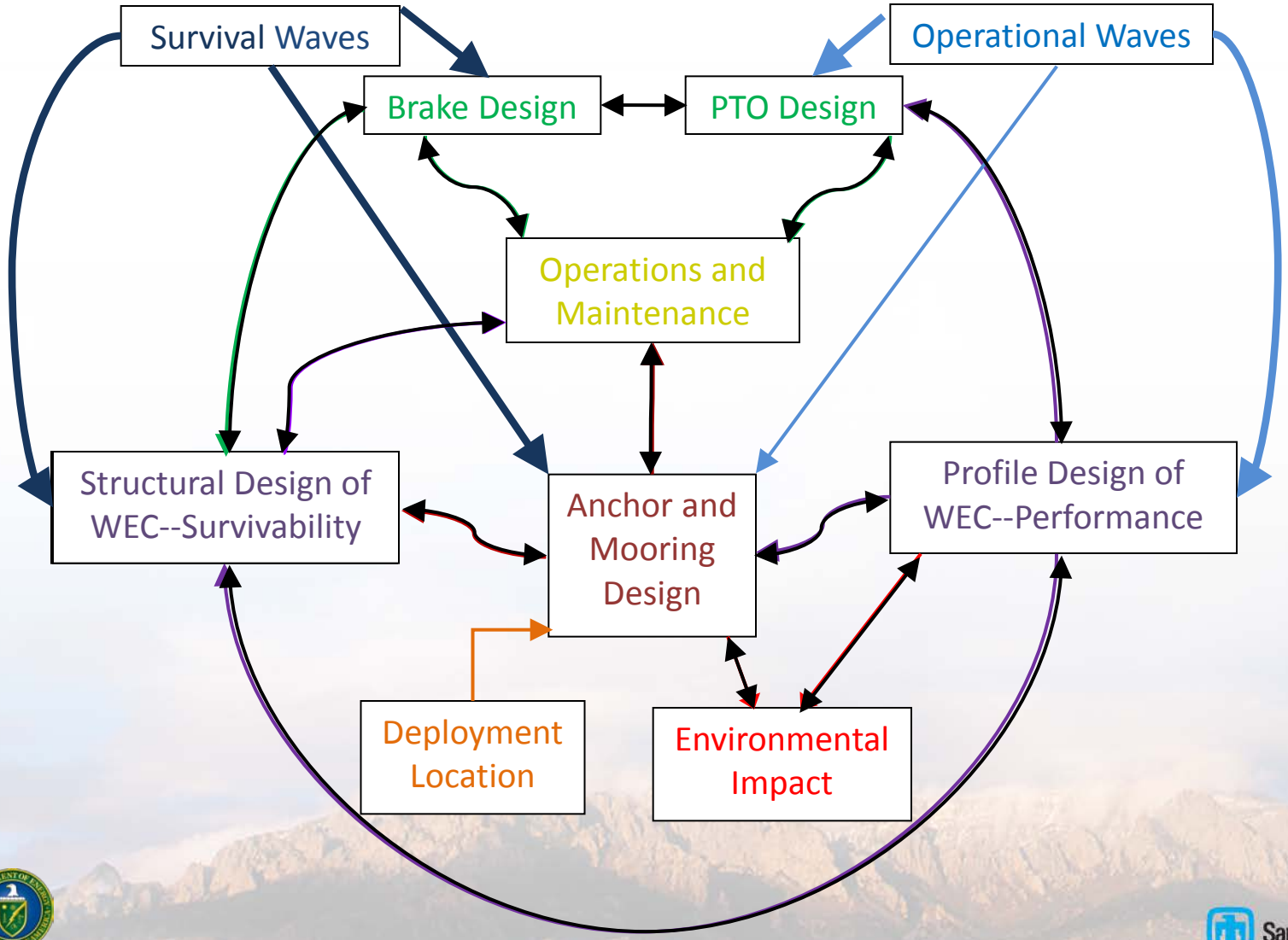
WEC Design


Survival Waves
Operational Waves
Brake Design
PTO Design
Operations and Maintenance
Structural Design of WEC--Survivability
Anchor and Mooring Design
Profile Design of WEC--Performance
Deployment Location
Environmental Impact

Reference Model: TRL 1-4

- **TRL 1/2: An academic study of the basic concept and current literature.**
  - Identify performance drivers: size, mooring, etc.
  - Identify major O&M and environmental design drivers.

- **TRL 3: Develop frequency domain performance model of WEC to "test" a set of concept designs.**
  - Full equations of motion must be developed for each device and slow tuning optimization used to evaluate a devices match (in terms of capture length) to the deployment climate.

- **TRL 4: Build component models.**
  - Time-domain performance
  - Structural Design
  - Anchor & Mooring
  - PTO Design
  - Wavetank/Flume Test

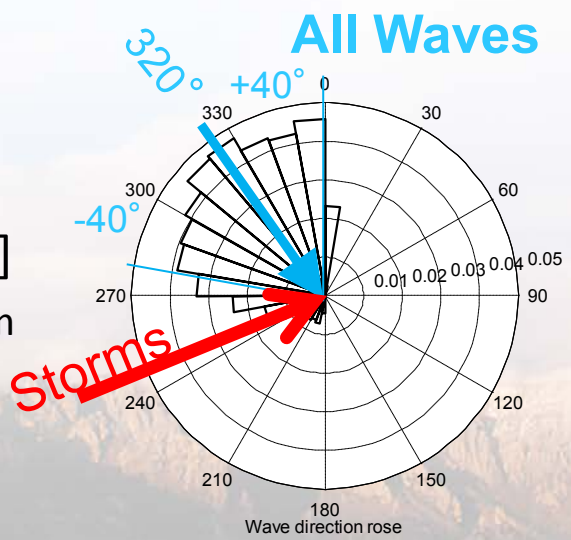
- **Do not treat: fatigue (on the mooring, structure, or PTO) or dynamic structural loading—those are the purview of TRL's 5-6.**
  - WEC availability is accounted for in O&M however not derived from a component model in the same way structural design is right now.

Wave Climate Modeling

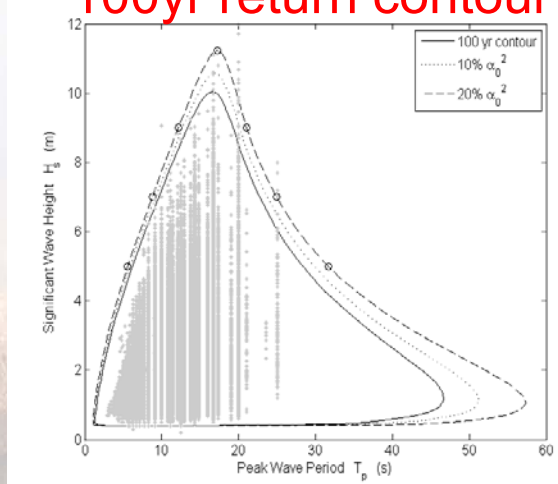
Operational Climate

Significant Wave Height, Hs [m]	Peak Period, Tp [sec]																	
	3.7	4.7	5.7	6.7	7.7	8.7	9.7	10.7	11.7	12.7	13.7	14.7	15.7	16.7	17.7	18.7	19.7	20.7
0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.75	0.0	0.0	0.002	0.007	0.006	0.010	0.004	0.004	0.0	0.004	0.0	0.007	0.0	0.004	0.0	0.0	0.0	0.0
1.25	0.0	0.002	0.008	0.022	0.015	**0.043**	0.017	0.013	0.003	0.011	0.002	0.012	0.002	0.007	0.0	0.0	0.0	0.0
1.75	0.0	0.0	0.005	0.028	0.017	0.039	0.025	0.023	0.007	0.019	0.002	0.013	0.0	0.005	0.0	0.0	0.0	0.0
2.25	0.0	0.0	0.0	0.014	0.017	0.036	0.020	0.026	0.009	0.025	0.003	0.016	0.0	0.006	0.0	0.0	0.002	0.0
2.75	0.0	0.0	0.0	0.006	0.009	0.036	0.012	0.019	0.008	0.026	0.003	0.018	0.0	0.007	0.0	0.0	0.003	0.0
3.25	0.0	0.0	0.0	0.002	0.004	0.024	0.009	0.012	0.005	0.021	0.003	0.017	0.0	0.006	0.0	0.0	0.002	0.0
3.75	0.0	0.0	0.0	0.0	0.0	0.010	0.007	0.007	0.003	0.014	0.002	0.015	0.0	0.005	0.0	0.0	0.0	0.0
4.25	0.0	0.0	0.0	0.0	0.0	0.004	0.003	0.003	0.002	0.009	0.0	0.012	0.0	0.004	0.0	0.0	0.0	0.0
4.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.004	0.0	0.008	0.0	0.004	0.0	0.0	0.0	0.0
5.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.005	0.0	0.003	0.0	0.0	0.0	0.0
5.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.002	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

- Humboldt—NDBC 46022
- Water Depth = 604[m]
- Incident Power = 37.4[kW/m]
  - Assumed Bretscheinder spectrum



Survival Events—
100yr return contour



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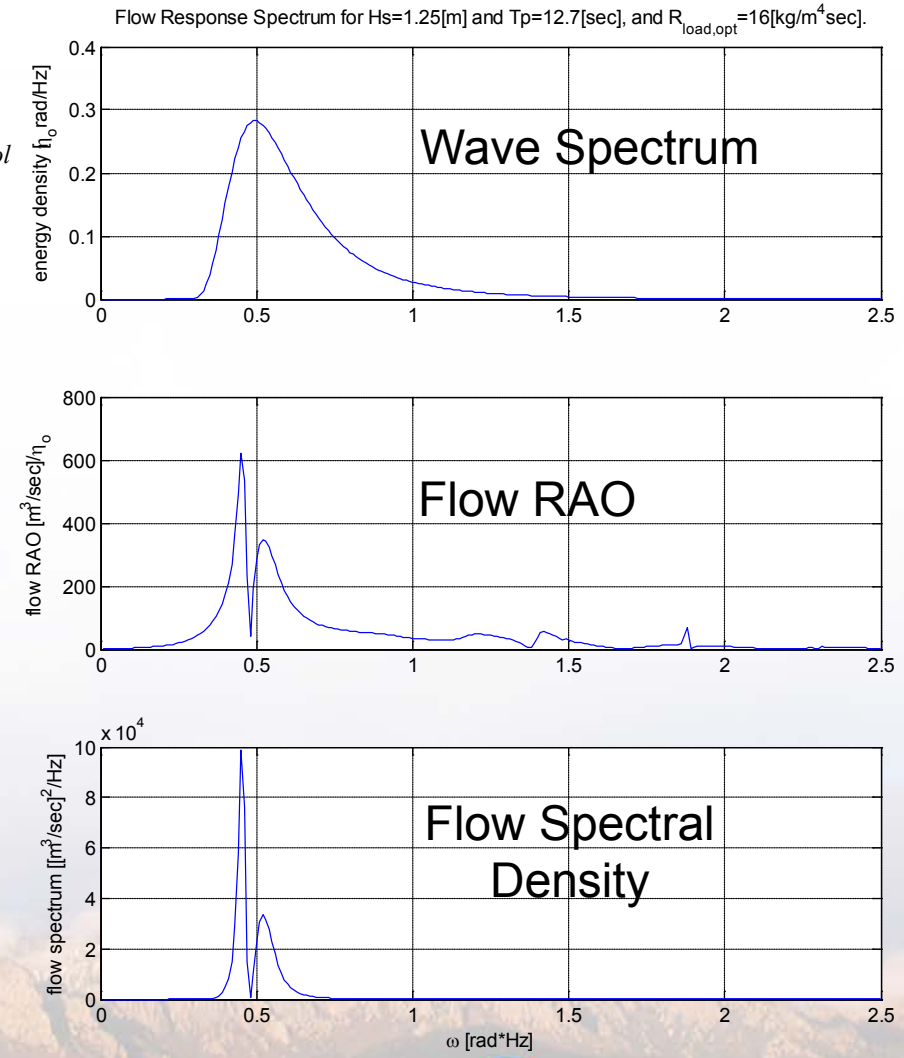
John Berg, SNL, has been instrumental in climate analyses.

Performance Modeling Frequency Domain

- **Equations of motion for a device are derived from governing equation:**

$$F_{total} = F_{hydrodynamic} + F_{hydrostatic} + F_{ViscousDamping} + F_{mooring} + F_{Control}$$

- $F_{hydrodynamic}$ **&** $F_{hydrostatic}$ **are found from a potential flow solver, like WAMIT**
- $F_{ViscousDamping}$ **found with aid of CFD, experiment, or targeted RAO response at resonance**
- $F_{Mooring}$ **are found through evaluation of design in OrcaFlex for operational conditions.**
- $F_{Control}$ **, the optimal "slow tuning" parameters are found for each sea state**
  - The control parameters are independent of the PTO type at this stage.



RM6: BBDB OWC

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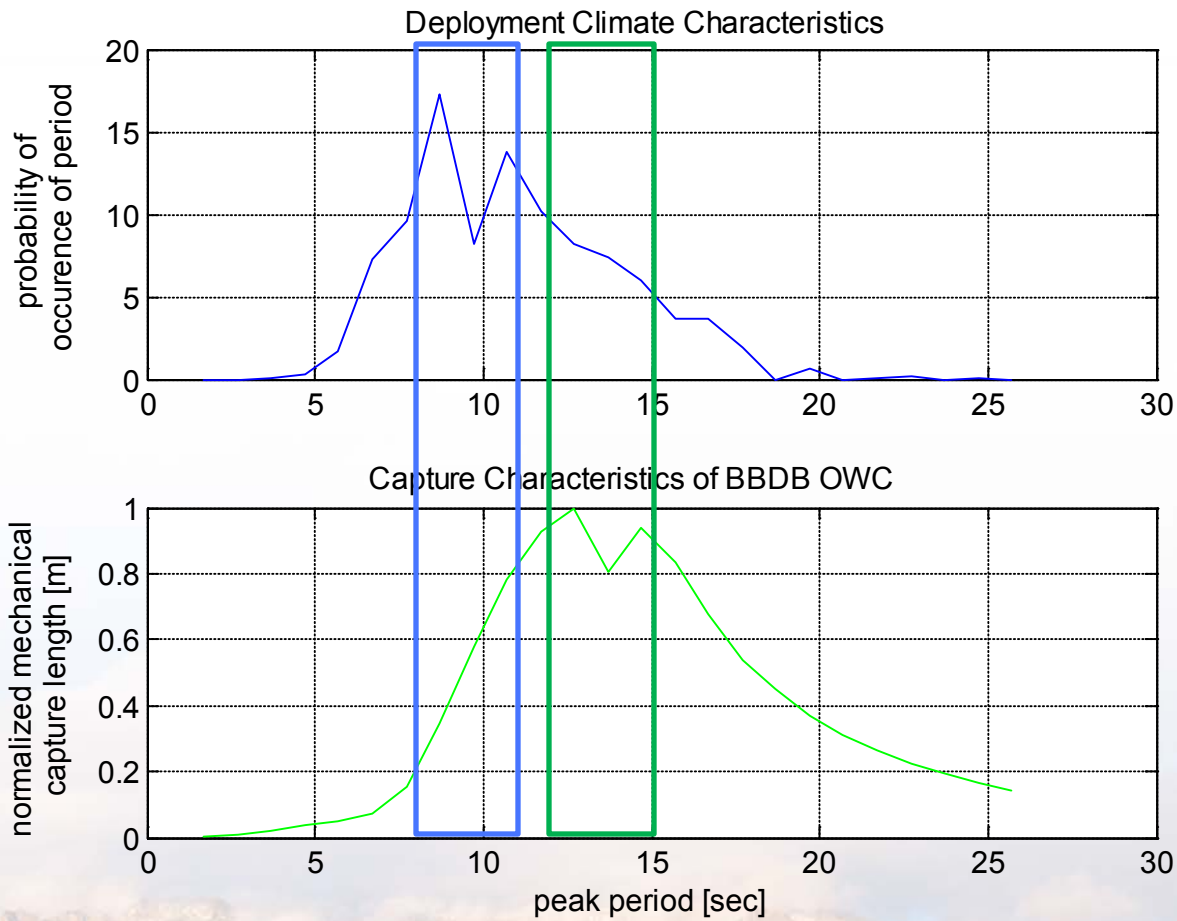
Performance Model Outcome

- The average power for each sea state is found through

$$\langle P \rangle = R_{control} \int_0^\infty |u|^2 S(\omega) d\omega$$

- Evaluating a design can be aided by comparing the deployment characteristics to the device capture characteristics.
- Goal is to match the device design to the deployment location.



Most Probable Periods in Climate

Largest Capture Length by Device

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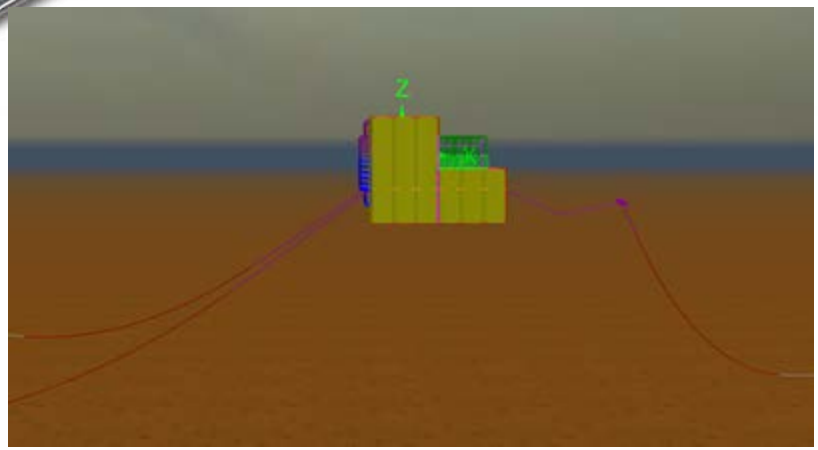
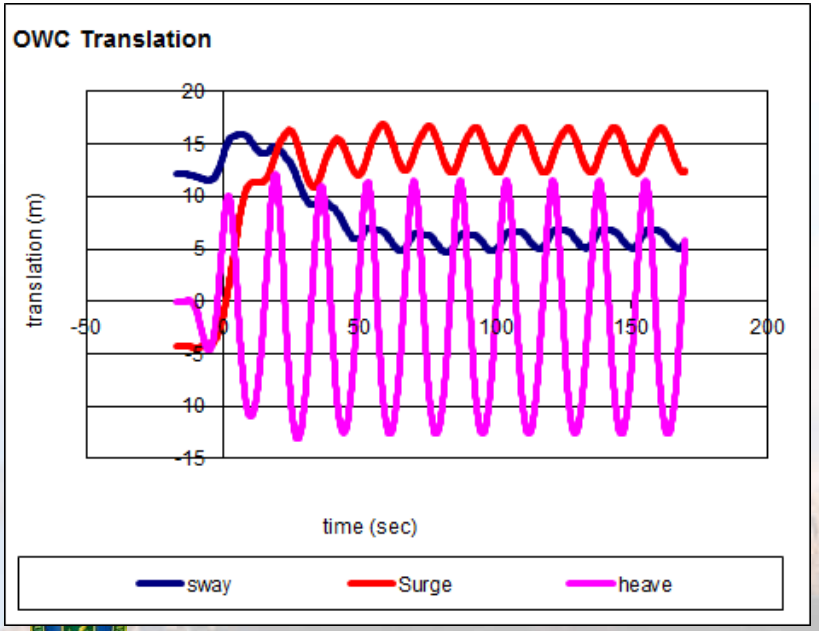
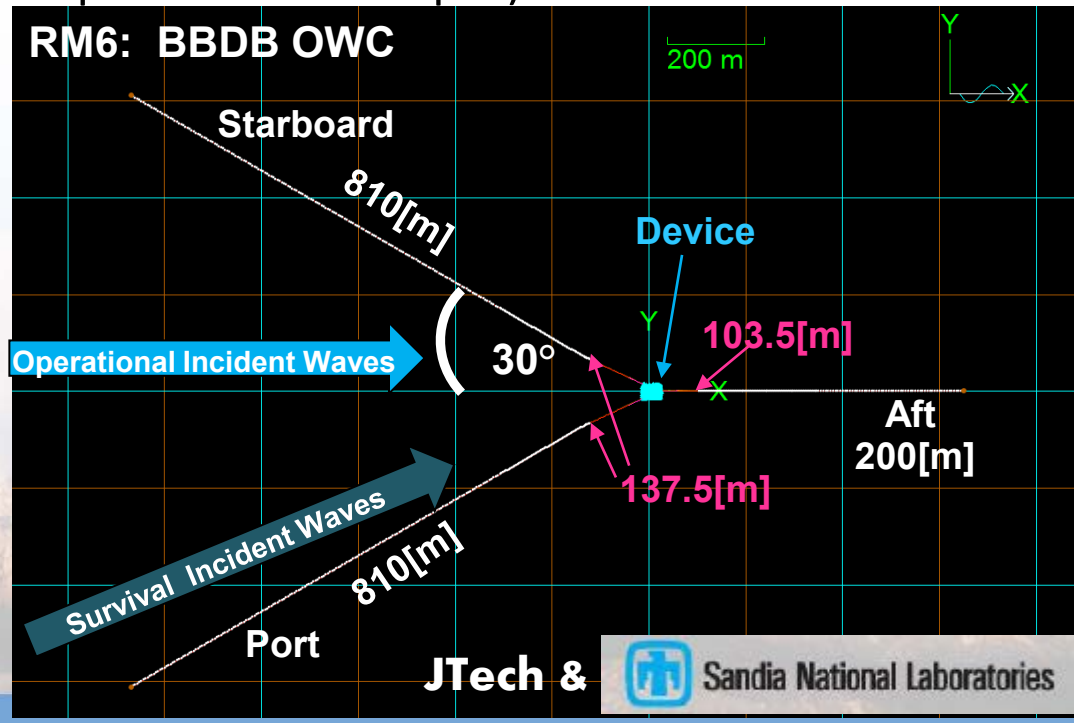
Anchor & Mooring Modeling

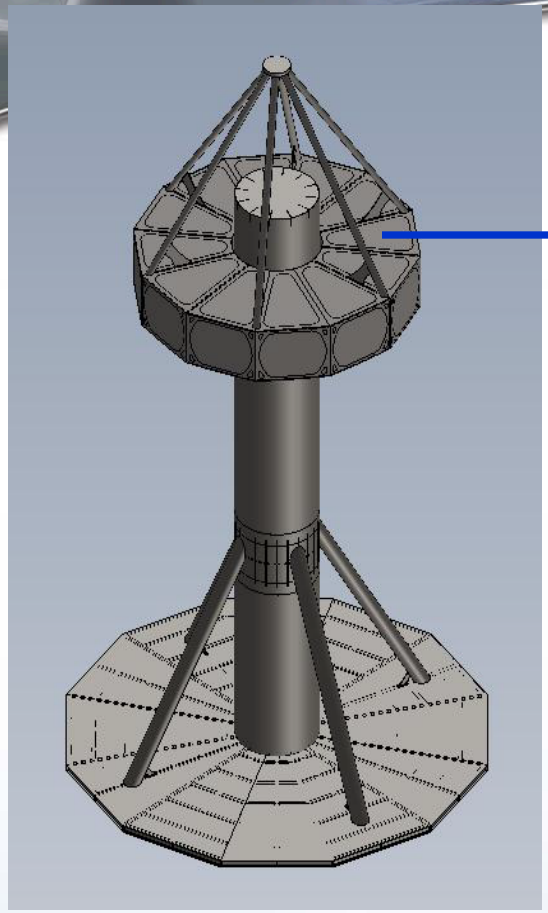


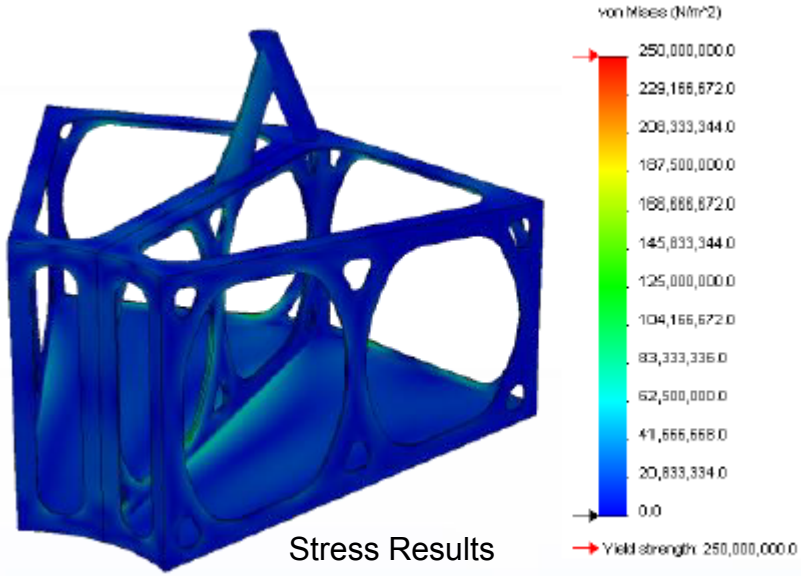
- Mooring design is driven by survival conditions
- Use DNV Standards to assess mooring: 100-yr return for waves & wind, 10-yr return for current
- Use OrcaFlex to build a device with motions determined purely through Morison Eq. (no potential flow input)



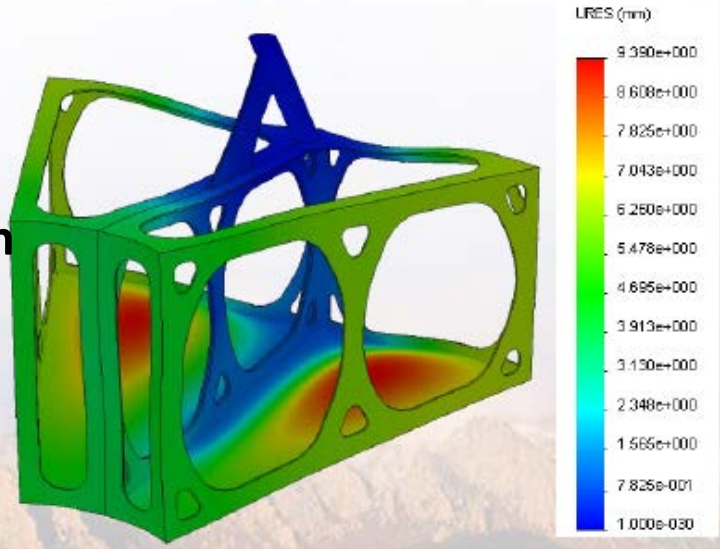


Structural Modeling





Stress Results



Displacement Results
(Deformation Scale: 95.81)

- **Initial Design: use standards to obtain conservative baseline structure**
  - Center of Gravity
  - Moments of Inertia
- **Structural Integrity: perform FEA to ensure FOS standards**

Blake Boren, SNL intern OSU PhD student (RM3: Pt. Abs)

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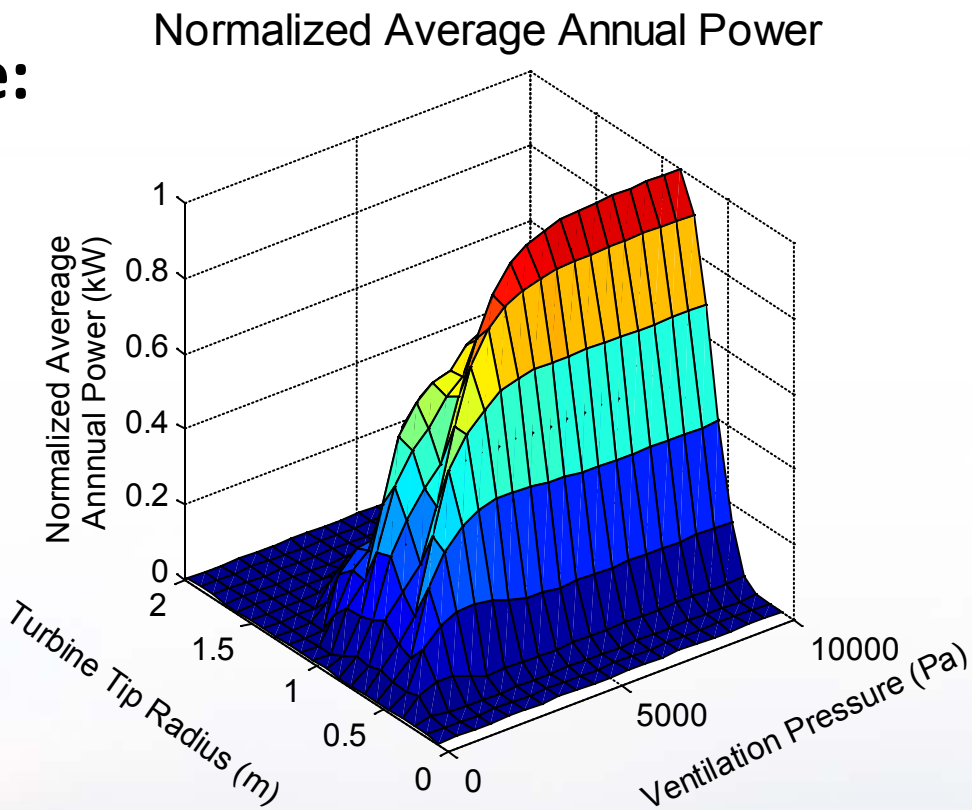
PTO Modeling

Designing PTO, must balance:

- **Large variability's:**
  - Across the entire deployment climate.
  - Within a particular sea state—average vs. peak values.
- **Single vs. Multiple PTO's**
  - Added redundancy can increase WEC availability but may adversely effect cost or efficiencies
- **PTO size**
  - Must be optimized for the climate variability
- **PTO efficiency**
- **PTO serviceability and reliability**
  - The PTO and its subcomponents are the most likely to break, need to really consider O&M for this component



ARL in collaboration with SNL has been developing an optimization code to optimize average annual electrical power for various Well's Turbines for RM6 (BBDB OWC)

Questions.

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