DOCKETED	
Docket Number:	23-ERDD-01
Project Title:	Electric Program Investment Charge (EPIC)
TN #:	259959
Document Title:	Powerpoint Floating Offshore Wind Research and Development Portfolio Showcase Webinar
Description:	N/A
Filer:	Archal Naidu
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	11/8/2024 2:18:11 PM
Docketed Date:	11/8/2024

Floating Offshore Wind Research and Development Portfolio Showcase Webinar

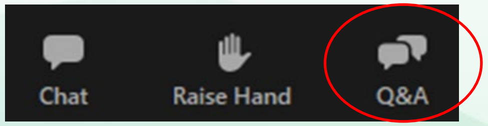
November 5, 2024

Agenda

Time	Item
9:30 am	• Welcome and Introduction, Katherine Greenwald-CEC • EPIC Offshore Wind R&D Overview, Daphne Molin-CEC
9:45 am	Project Presentations 1. Grace Chang, Integral Consulting Inc. 2. Yuxin Wu, Lawrence Berkeley National Laboratory 3. Jason Cotrell, Sperra 4. Spencer Hallowell, University of Maine 5. Greyson Adams, Schatz Energy Center and Erica Escajeda, H.T. Harvey & Associates 6. Zachary Miller, Triton Anchor 7. Matthew Hall, National Renewable Energy Laboratory
11:05 am	Break
11:15 am	Panelist Discussion Q&A
12:00 pm	Adjourn

Housekeeping

- This webinar is being recorded will be posted along with the presentation slide decks to the CEC event page website : https://www.energy.ca.gov/event/webinar/2024-11/floating-offshore-wind-research-and-development-portfolio-showcase-webinar
- Attendees will be muted during the presentation. Please chat your question using the Q&A window. We will leave time between speakers for any technical/clarifying questions that come in, discussion-oriented questions will be held until the end.



EPIC R&D Objectives

- Electric Program Investment Charge (EPIC) funds technology development to advance market adoption of clean energy solutions:
  - Improve technology performance, reliability, and safety
  - Reduce technology costs
  - Address environmental and equity issues

- EPIC floating offshore wind objectives:
  - Lower levelized cost
  - Reduce technical and financial risk
  - Inform environmental mitigation, deployment planning, permitting

Research Prioritization

Stakeholders

- Industry
- State agency partners
- Federal Partners
- Communities, fishers, Tribal members

Research

- Publications
- Reports
- Conferences
- Webinars

State policies & Planning

- Clean energy goals
- CA Strategic Plan
- Development timeline

EPIC Offshore Wind R&D Investments

~$30M Awarded

- Remote Environmental Monitoring
- Anchor and Mooring Line Designs
- Innovative Manufacturability of Components
- Environmental Evaluations

[Search | CEC (energizeinnovation.fund)](energizeinnovation.fund)

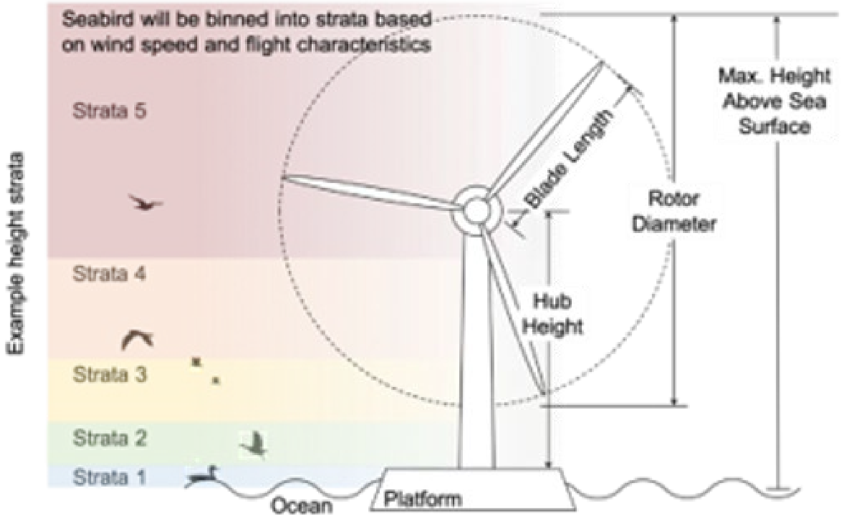


Photo credit: Sperra

Investments in Progress

GFO-22-401 - Environmental Monitoring Technologies Solicitation

Award Amount: $8,900,868

Purpose: Advance technologies to support detecting marine life or ecosystem processes to assess risks and impacts to California's Wind Energy Areas.

Investments in Progress

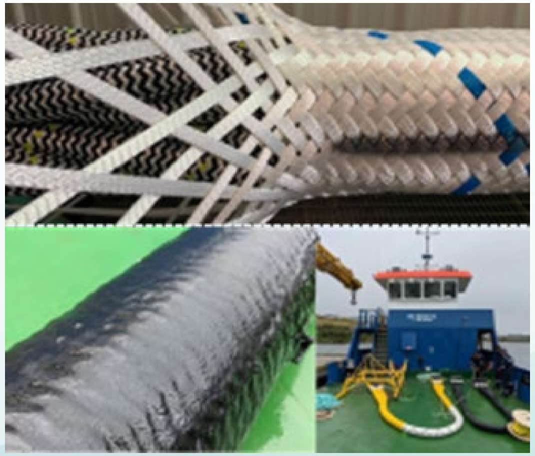
GFO-22-402 – Advancing Designs for Floating Offshore Wind Mooring Lines and Anchors

(Award Amount: $11,869,231)

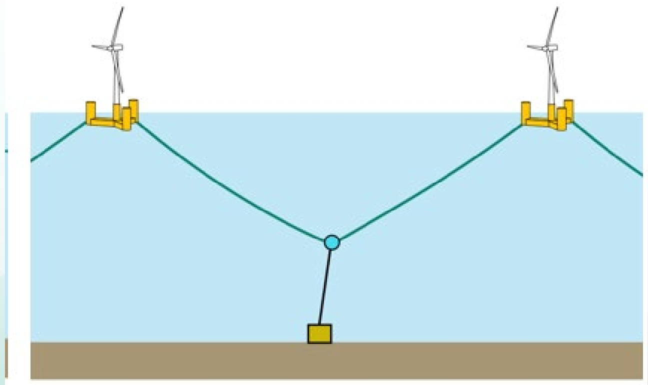
- **Purpose**: Design and test mooring line materials, anchor designs, and/or shared mooring lines and anchors for California conditions

Torpedo Anchor

Mooring Line



Shared Mooring Configurations



FOSW R&D under Consideration

1. Optimizing Designs for Cost and Operational Efficiency
2. Cost-Effective Installation and Operations & Maintenance Developments
3. Grid Integration Innovations and Port Infrastructure Readiness Strategies
   a. Request for Information: Deep water HVDC substations
4. Environmental Impact Assessment and Minimization
   a. Request for Information: Entangled Debris Monitoring

~$17M EPIC Funding for Offshore Wind and Solar Through 2025

Thank You!

Please let us know if you have additional questions:

Daphne.Molin@energy.ca.gov (Supervisor, R&D Division)

Integrated, Real-Time, Multi-Scale System for Monitoring Seabird Interactions with Floating Offshore Wind Technologies

Grace Chang

CEC Floating Offshore Wind Research and Development Portfolio Showcase

November 5, 2024

Problem Statement

California's wind energy areas are rich with seabirds under protection by the Migratory Bird Treaty Act and the Endangered Species Act.

Black-footed albatross

Marbled murrelet

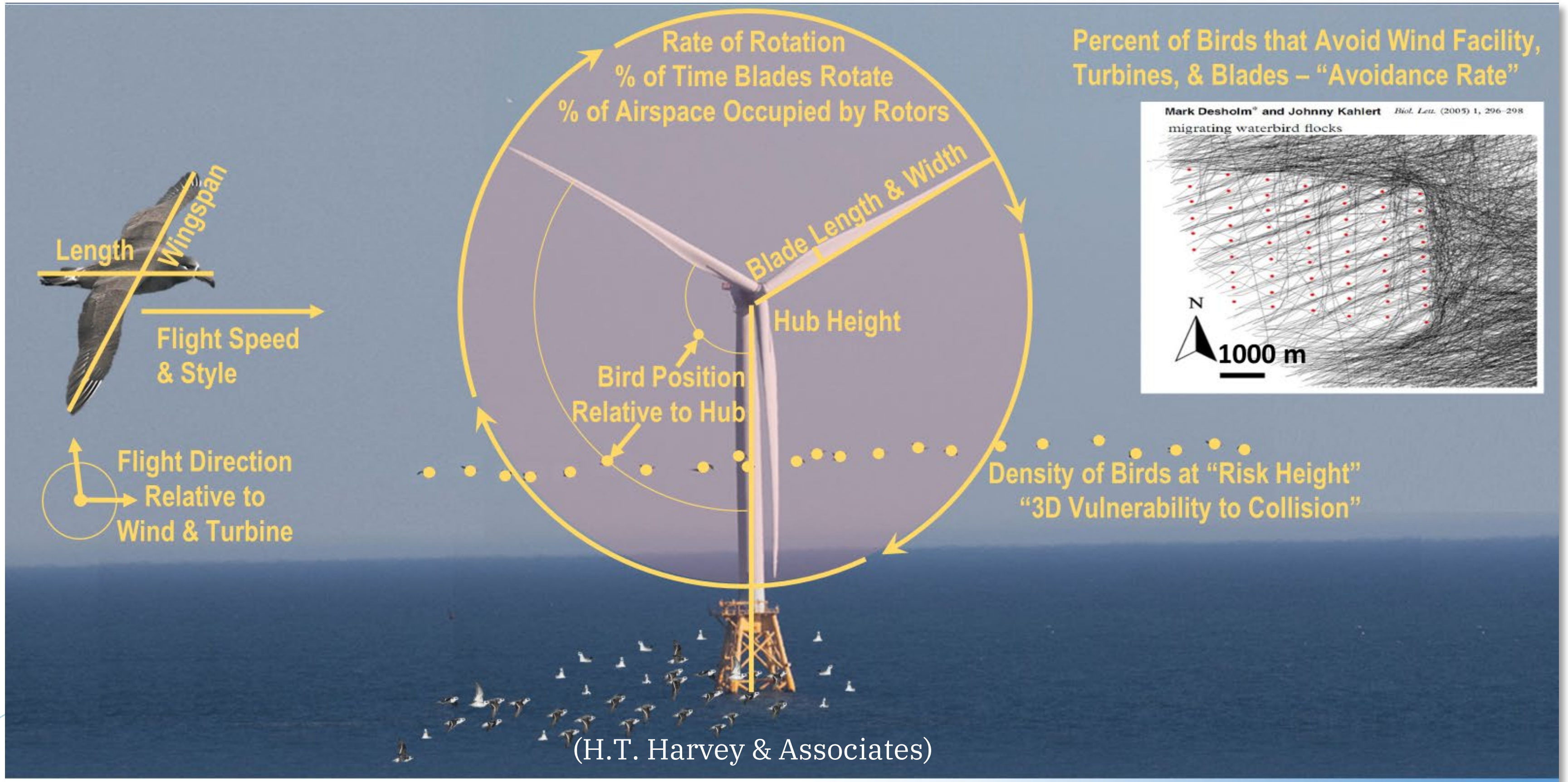
Ashy storm petrel

(Photos from eBird)

integral

Problem Statement

Offshore wind energy projects will likely be required to generate seabird and bat collision risk models to estimate species-specific impacts.

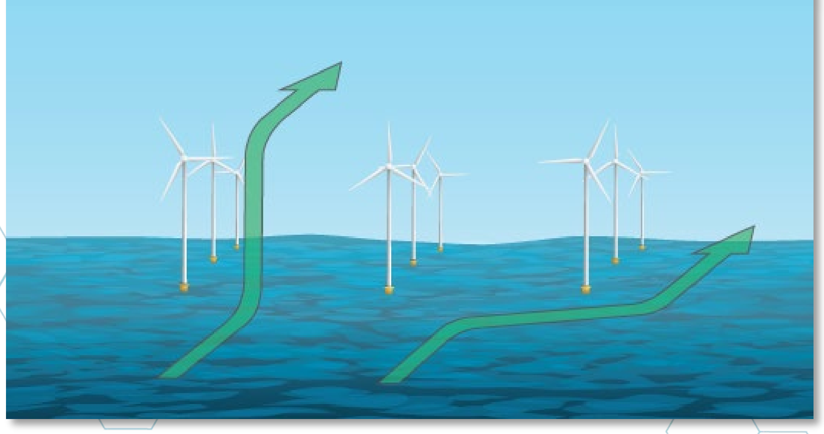


(H.T. Harvey & Associates)

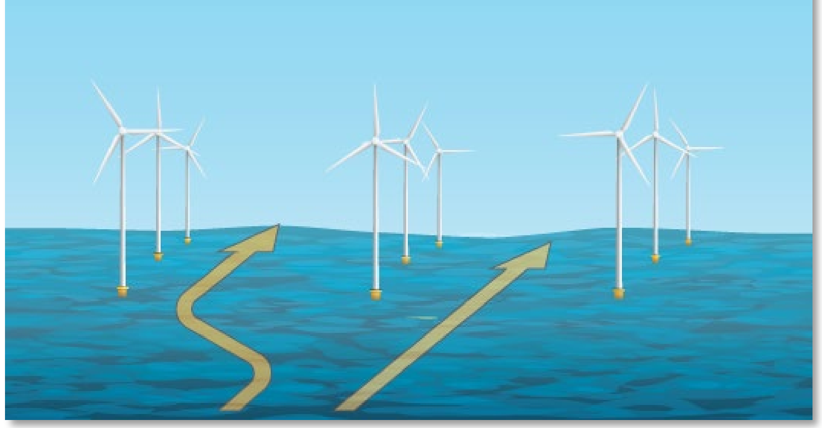
Problem Statement

Collision risk models are most sensitive to avoidance rate, which requires knowledge of seabird and bat interactions over multiple scales.

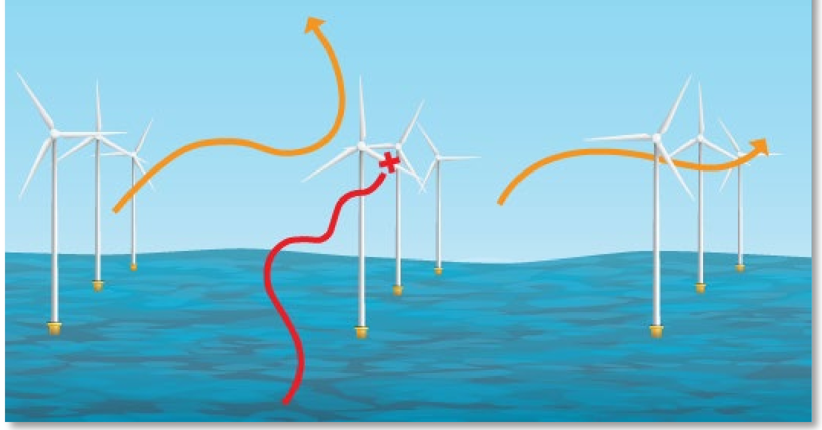
Macro: Whole wind farm avoidance



Meso: Avoidance of individual turbines or rotor-swept zones



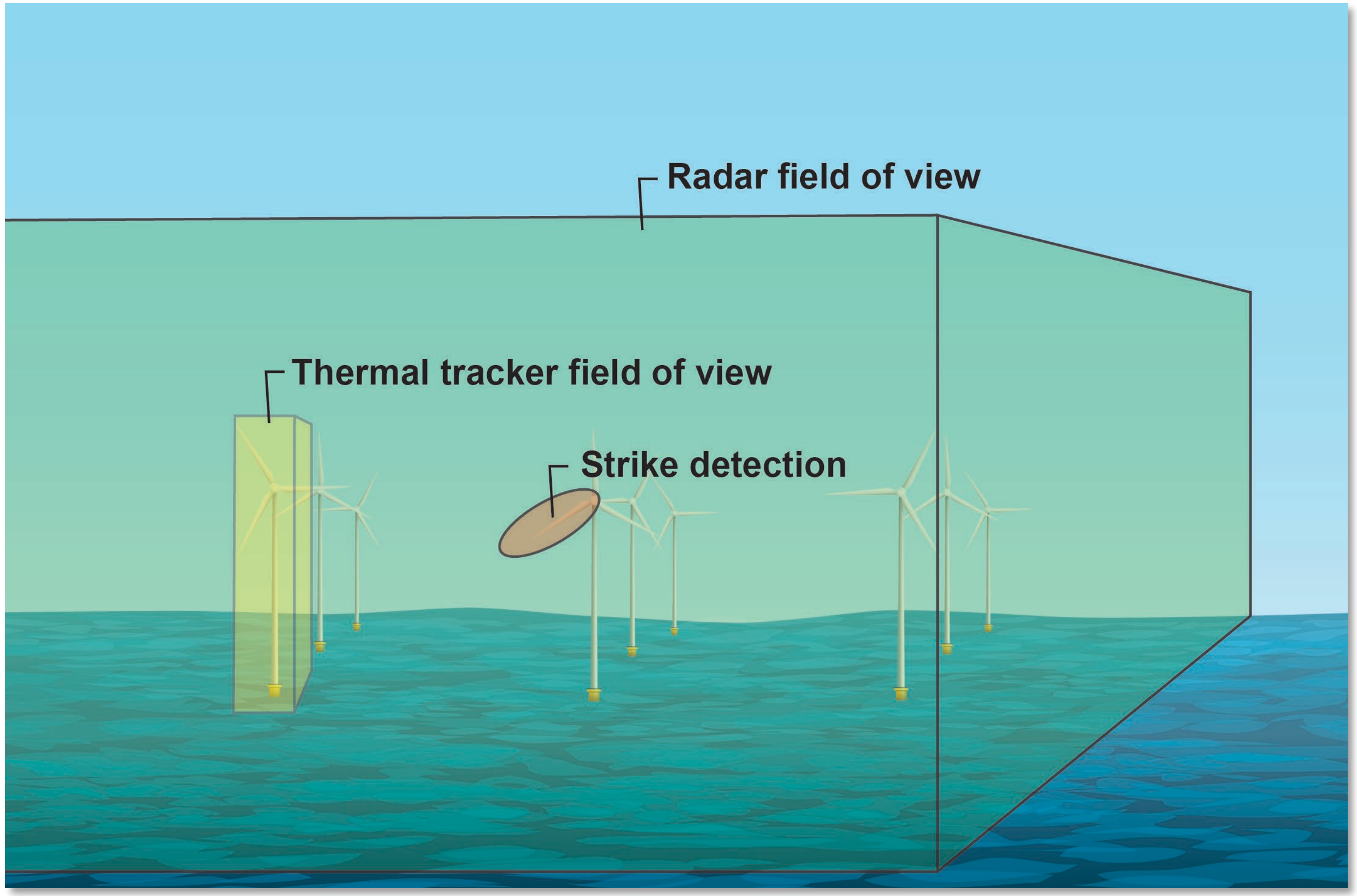
Micro: Last-second avoidance to avoid collision



integral

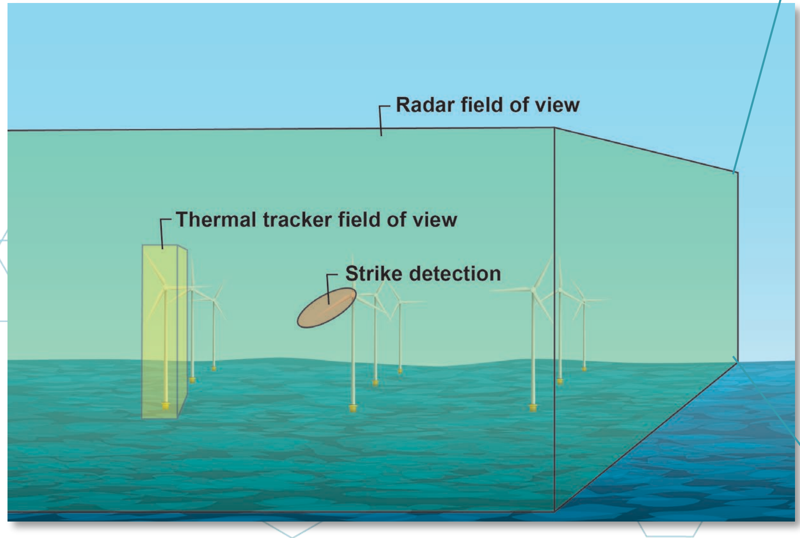
Project Goal

Integrate, test, and validate multiple real-time sensing technologies to quantify seabird and bat avoidance and collision risk across macro-, meso-, and micro-scales to improve wildlife monitoring and seabird and bat collision risk model-based forecasting.



Macro-scale

Abundance, relative size, and movement patterns in the far-field vicinity of a wind farm area



(DeTect Inc.)

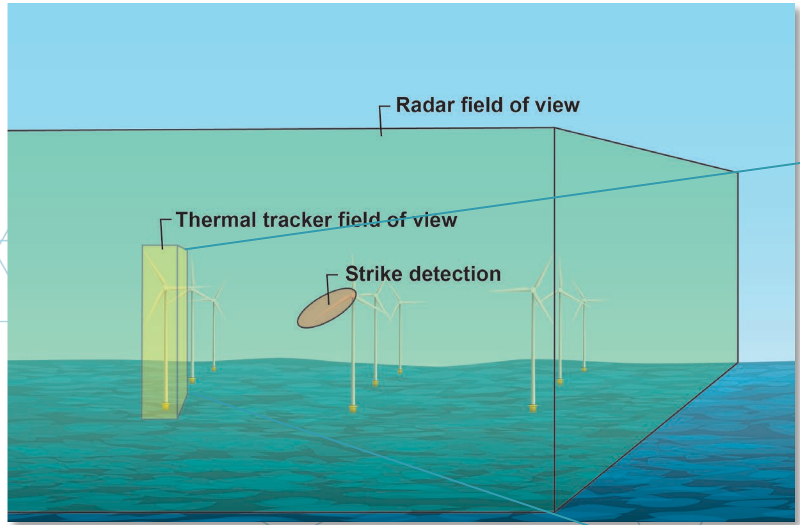
3D Radars (x2)

- Marine S-band, pulsed Doppler
- 360° at 45° elevation over 2-3 km range
- 90° at 12.5° elevation over 6-8 km range

integral

Meso-scale

3D flight trajectory with feature extraction for identification based on shape, size, and flight behavior

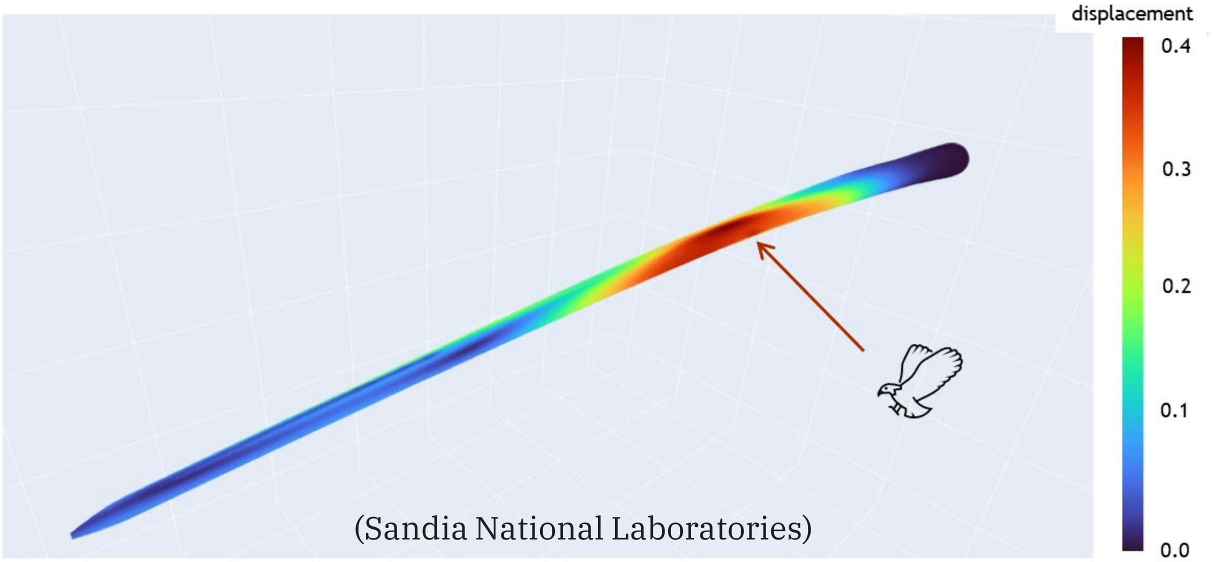


(Sightir, Inc.)

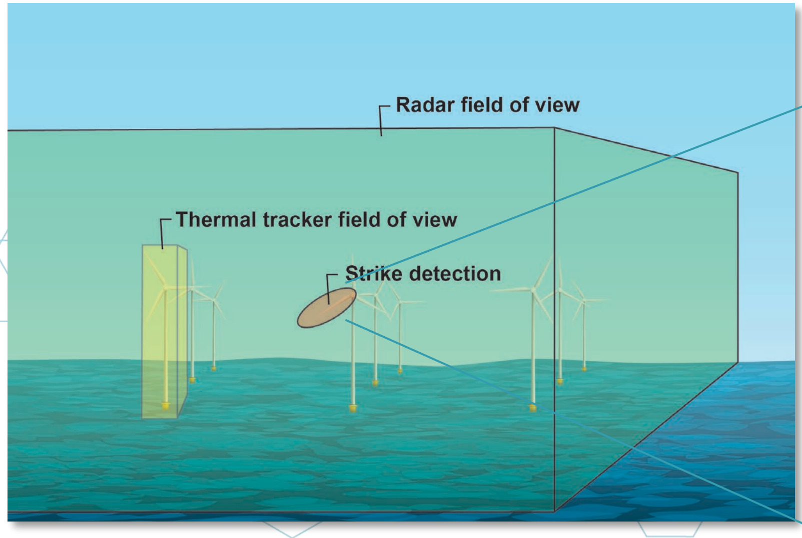
(Pacific Northwest National Laboratory)

Micro-scale

Detect and characterize blade strike events



(Sandia National Laboratories)



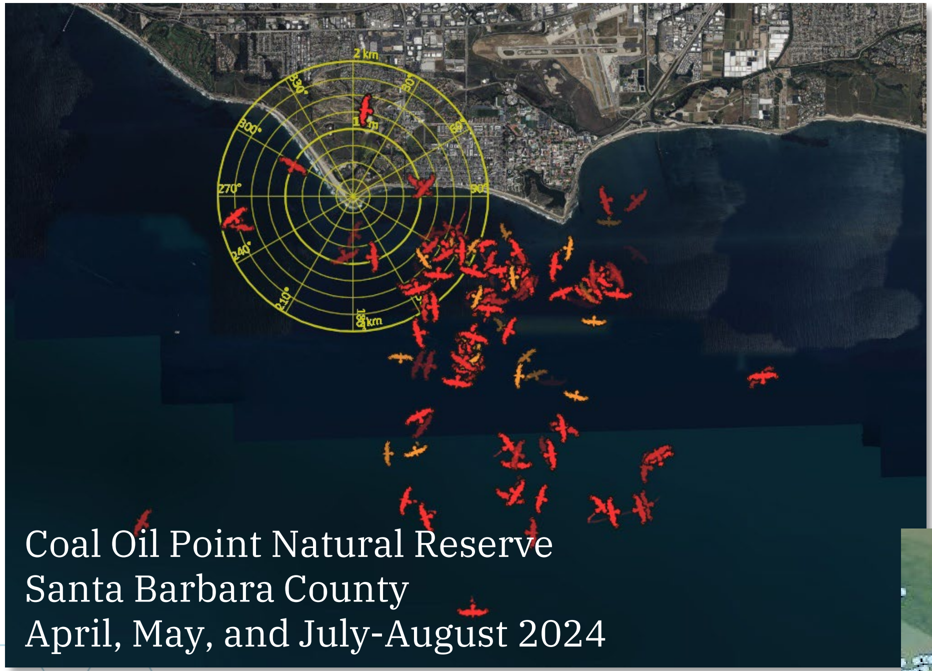

(Velvetwire)

Real-time vibration monitoring informed by model simulations

- IEA-15 MW and V27-220 kW
- Implicit, linear dynamic response to impact

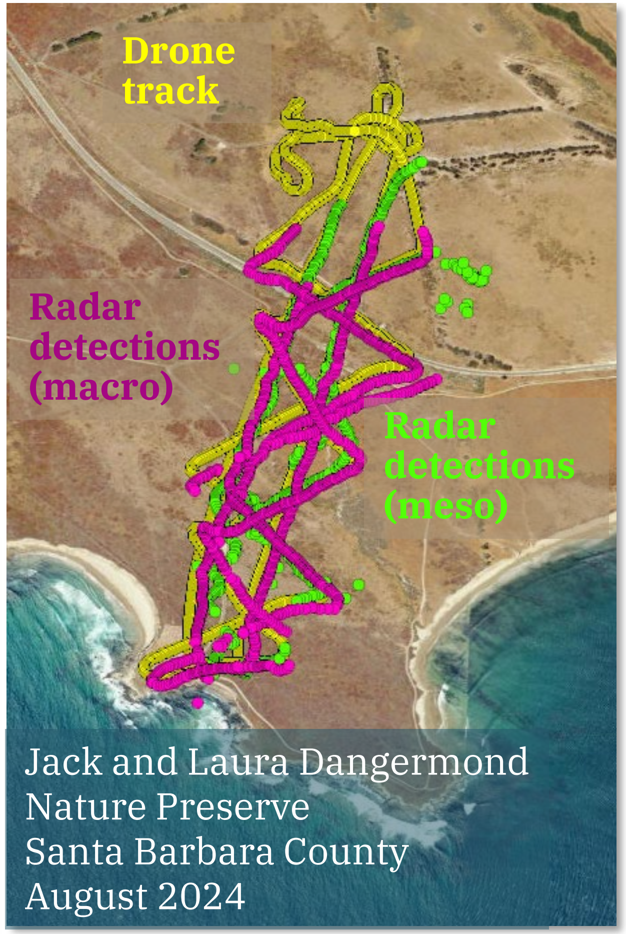
integral

Field Testing – Macro- and Meso-Scale

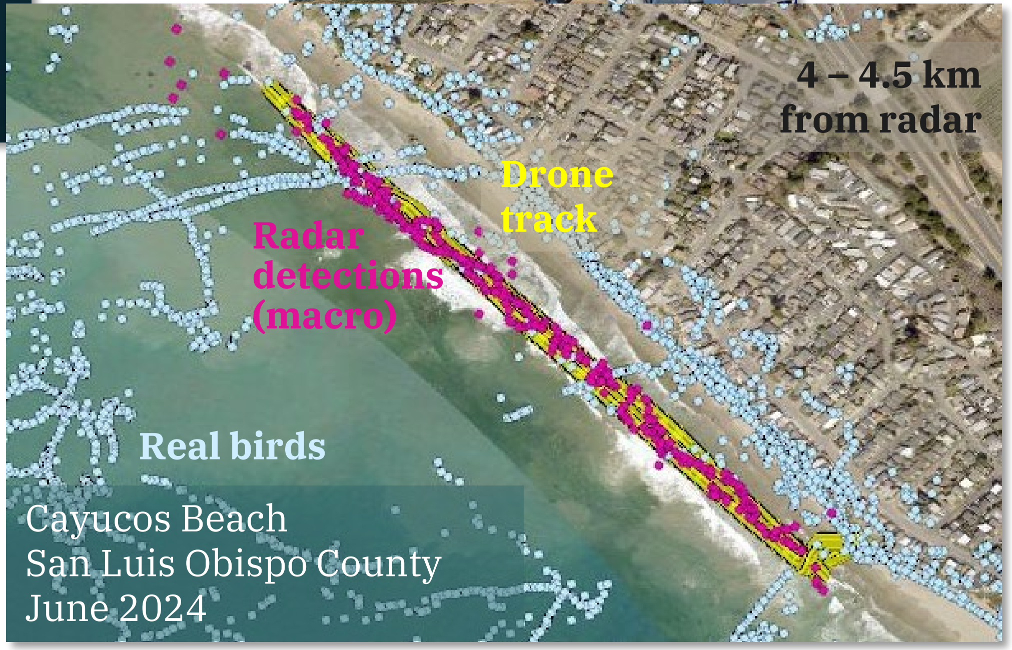


Coal Oil Point Natural Reserve
Santa Barbara County
April, May, and July-August 2024

Strauss Wind
Energy
Project
Santa
Barbara
County
August 2024



Jack and Laura Dangermond
Nature Preserve
Santa Barbara County
August 2024

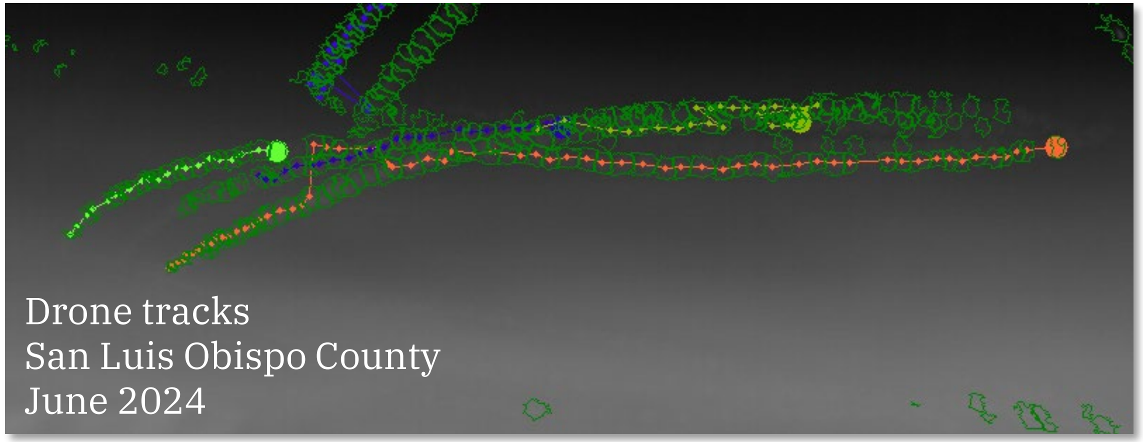


Cayucos Beach
San Luis Obispo County
June 2024

DJI Mavic Air 2
7” x 10” x 3” (L x W x H)

integral

Field Testing – Macro- and Meso-Scale

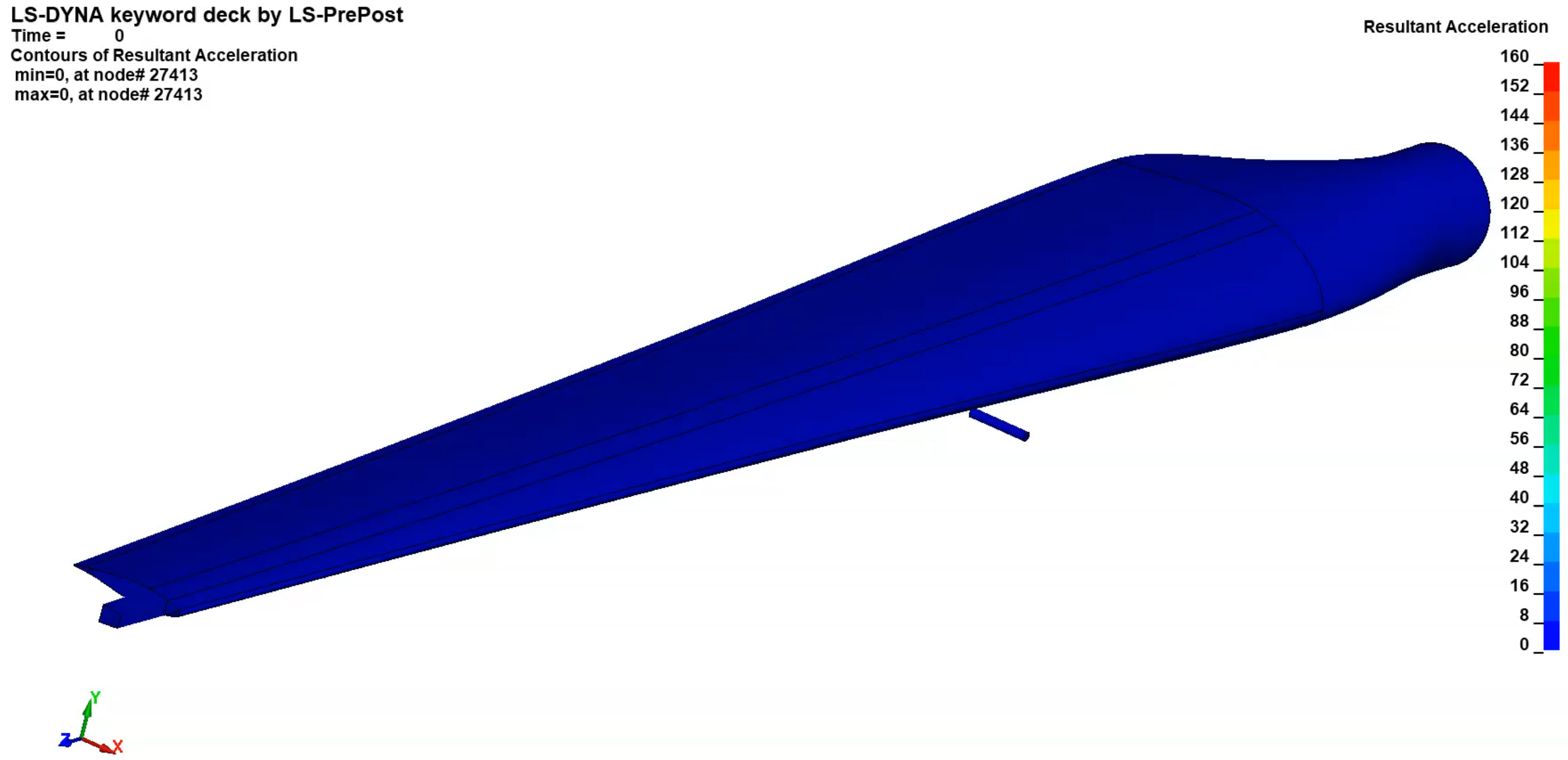


Drone tracks
San Luis Obispo County
June 2024

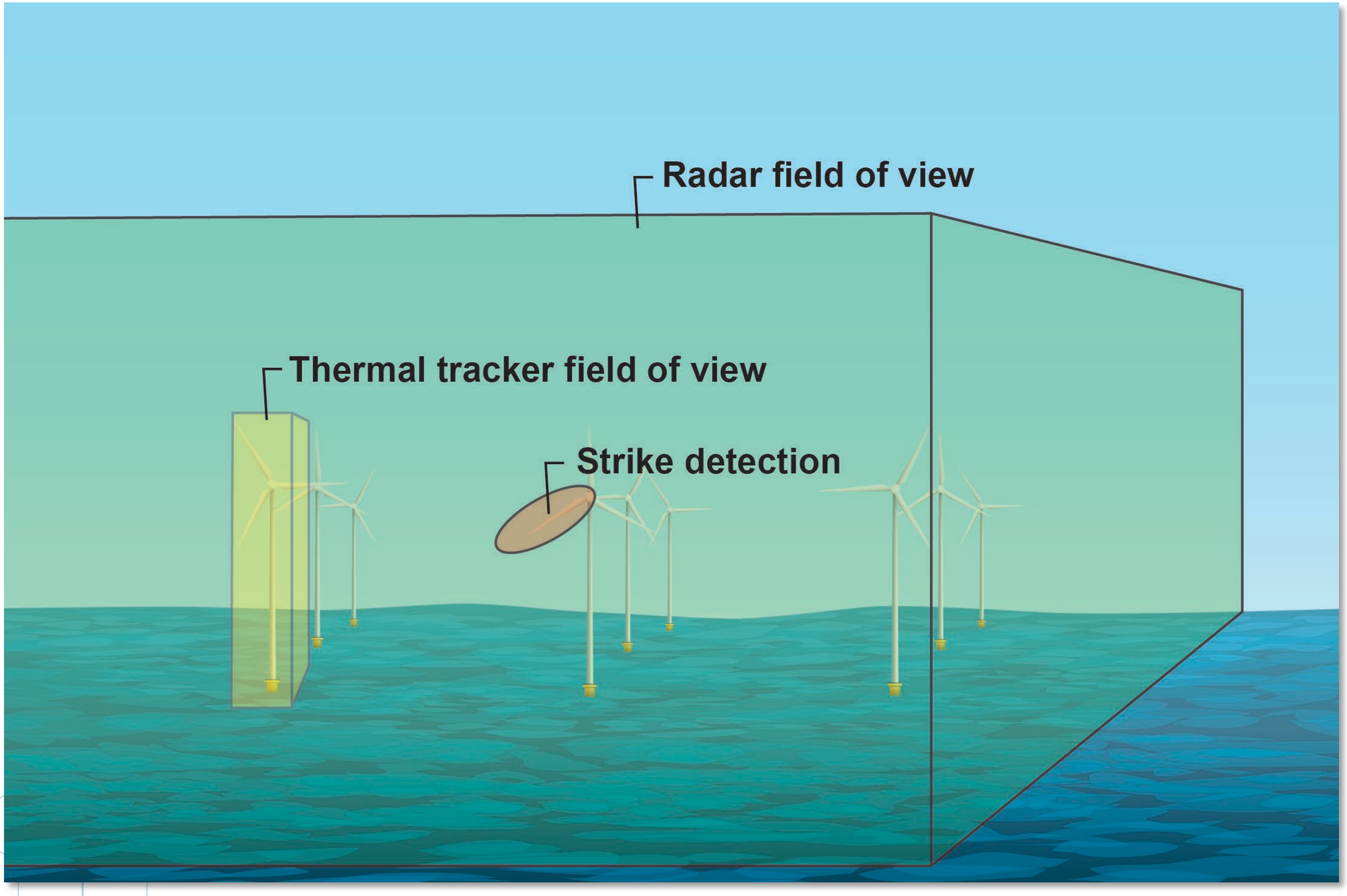
Bat
Santa Barbara County
August 2024

Pigeon
San Luis Obispo County
June 2024

Micro-scale Simulations



Summary


Radar field of view
Thermal tracker field of view
Strike detection

Team

Integral Consulting Inc.
Grace Chang, Ph.D.
Michael Macrander, Ph.D.
Daniel Doolittle
PRIME

Sightir Inc.
Marcus Chevitarese
Systems Engineering

H. T. Harvey & Associates
Sharon Kramer, Ph.D.
Stephanie Schneider
Bird and Bat Expertise

Sandia National Laboratories
Lawrence Cheung, Ph.D.
Turbine Blade

DeTect Inc.
Jesse Lewis
Radar

Pacific Northwest National Laboratory
*Shari Matzner, Ph.D.**
Thermal Tracker

GE Vernova
Charles Seeley, Ph.D.
Turbine Blade

Velvetwire
Eric Bodnar
Blade-Mounted Sensors

*Shari has just retired. The PNNL team is now led by Jenny Wehof.

integral

integral

THANK YOU!

Grace Chang

gchang@integral-corp.com

EARTH & ENVIRONMENTAL SCIENCES

BERKELEY LAB
Lawrence Berkeley National Laboratory

CEC Offshore Wind Seminar

INTEGRATED MONTORING OF FLOATING OFFSHORE WIND TECHNOLOGY & ENVIRONMENTAL IMPACTS ON THE PACIFIC COAST

Yuxin Wu (YWu3@lbl.gov)

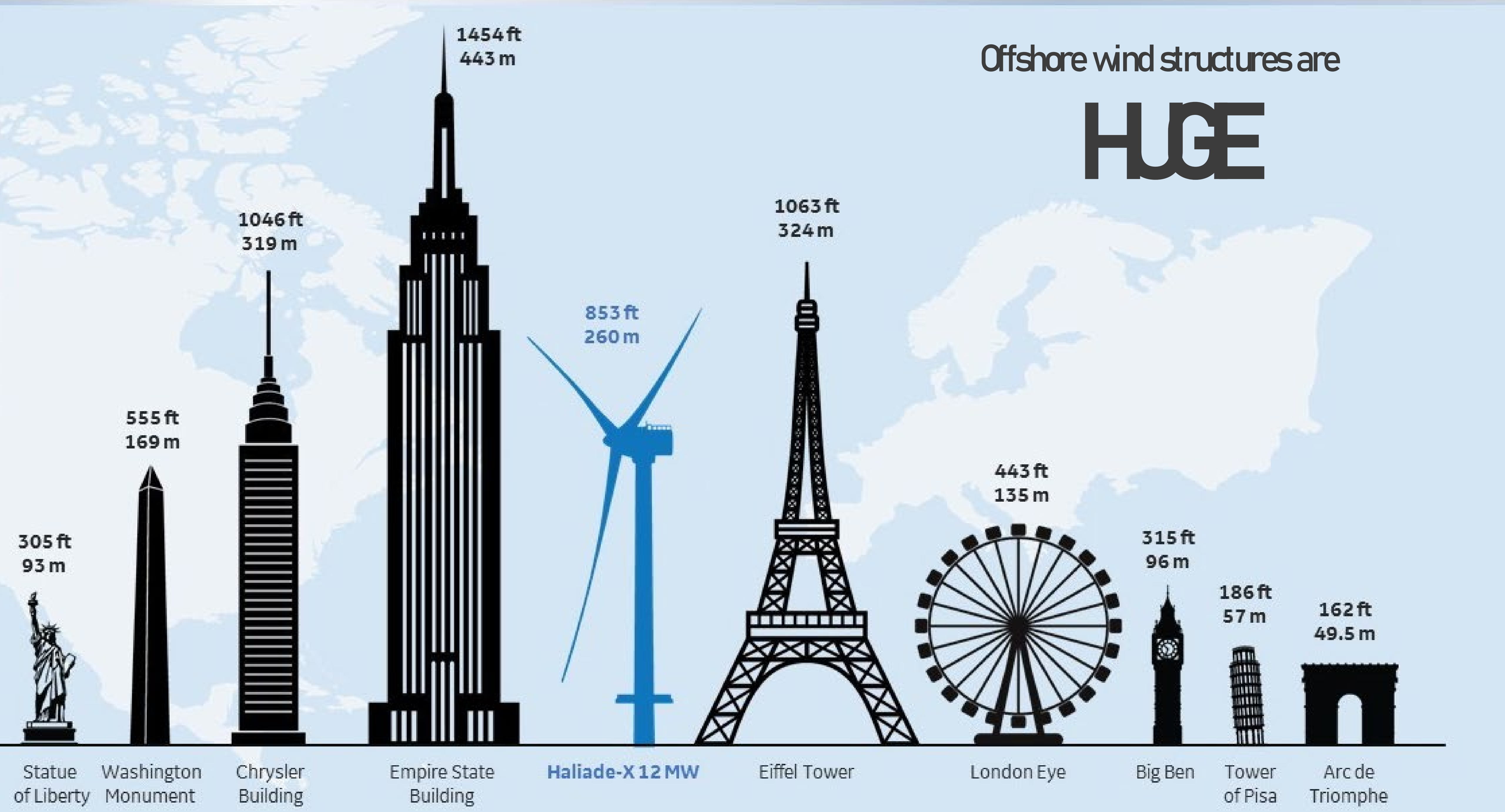
Staff Scientist, Geophysics Department Head

Earth & Environmental Sciences Area

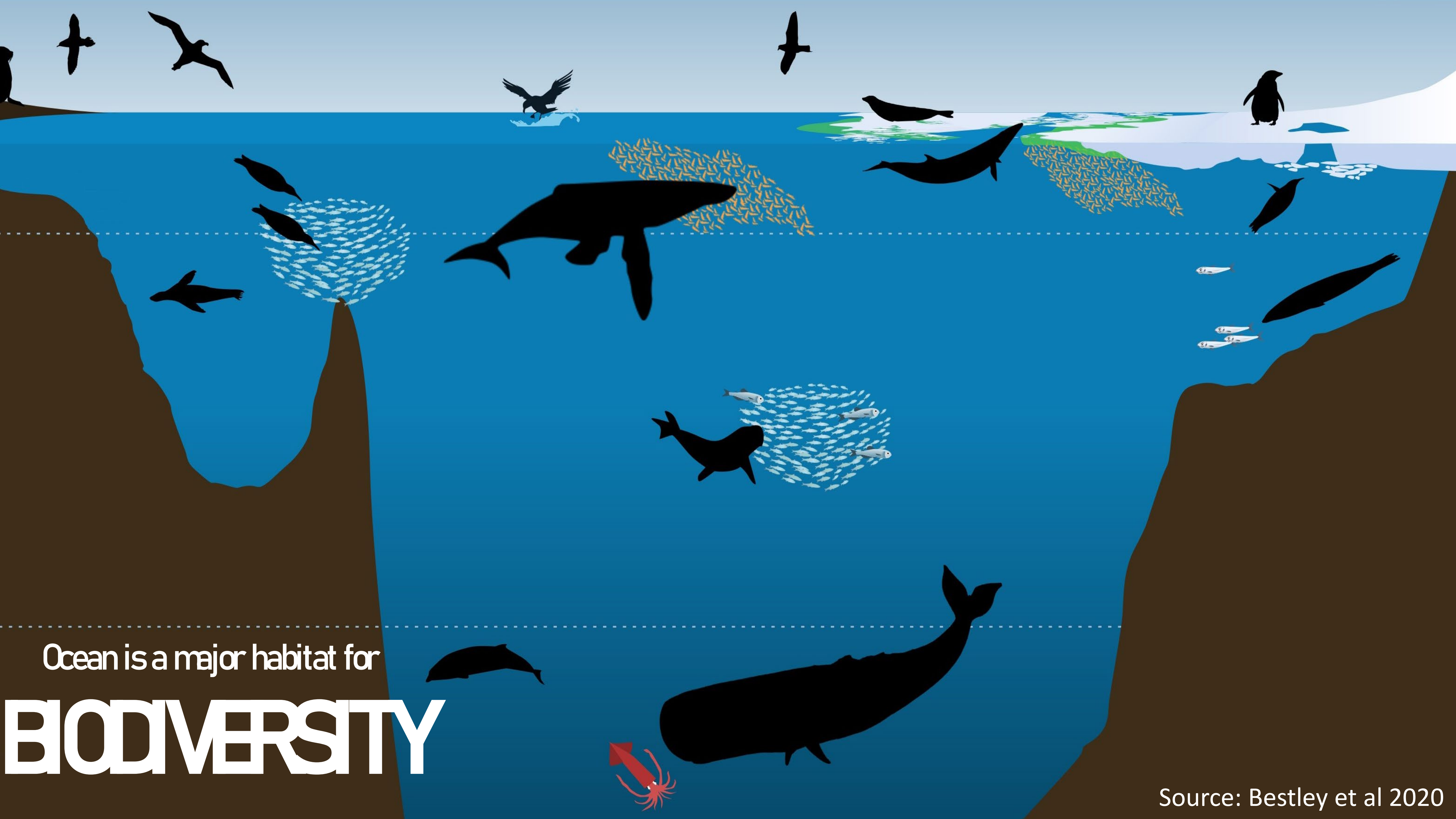
Lawrence Berkeley National Laboratory

Berkeley, CA

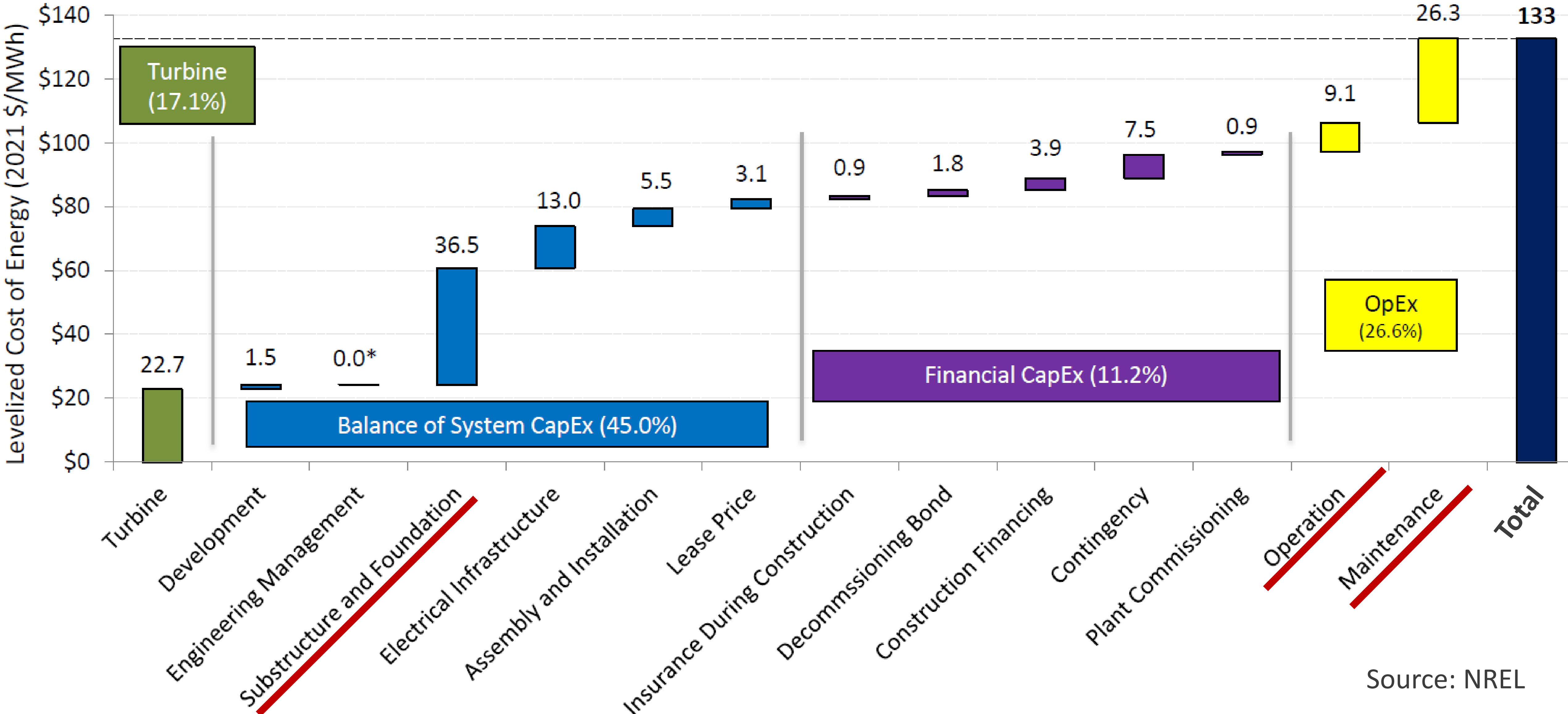
11/05/2024


Offshore wind structures are
HUGE
305 ft
93 m
Statue of Liberty
555 ft
169 m
Washington Monument
1046 ft
319 m
Chrysler Building
1454 ft
443 m
Empire State Building
853 ft
260 m
Haliade-X 12 MW
1063 ft
324 m
Eiffel Tower
443 ft
135 m
London Eye
315 ft
96 m
Big Ben
186 ft
57 m
Tower of Pisa
162 ft
49.5 m
Arc de Triomphe
Source: GE


2/3rd offshore wind resources require
TETHERING
Source: NREL


Ocean is a major habitat for
BIODIVERSITY
Source: Bestley et al 2020

Major Challenges for offshore wind deployment - COST

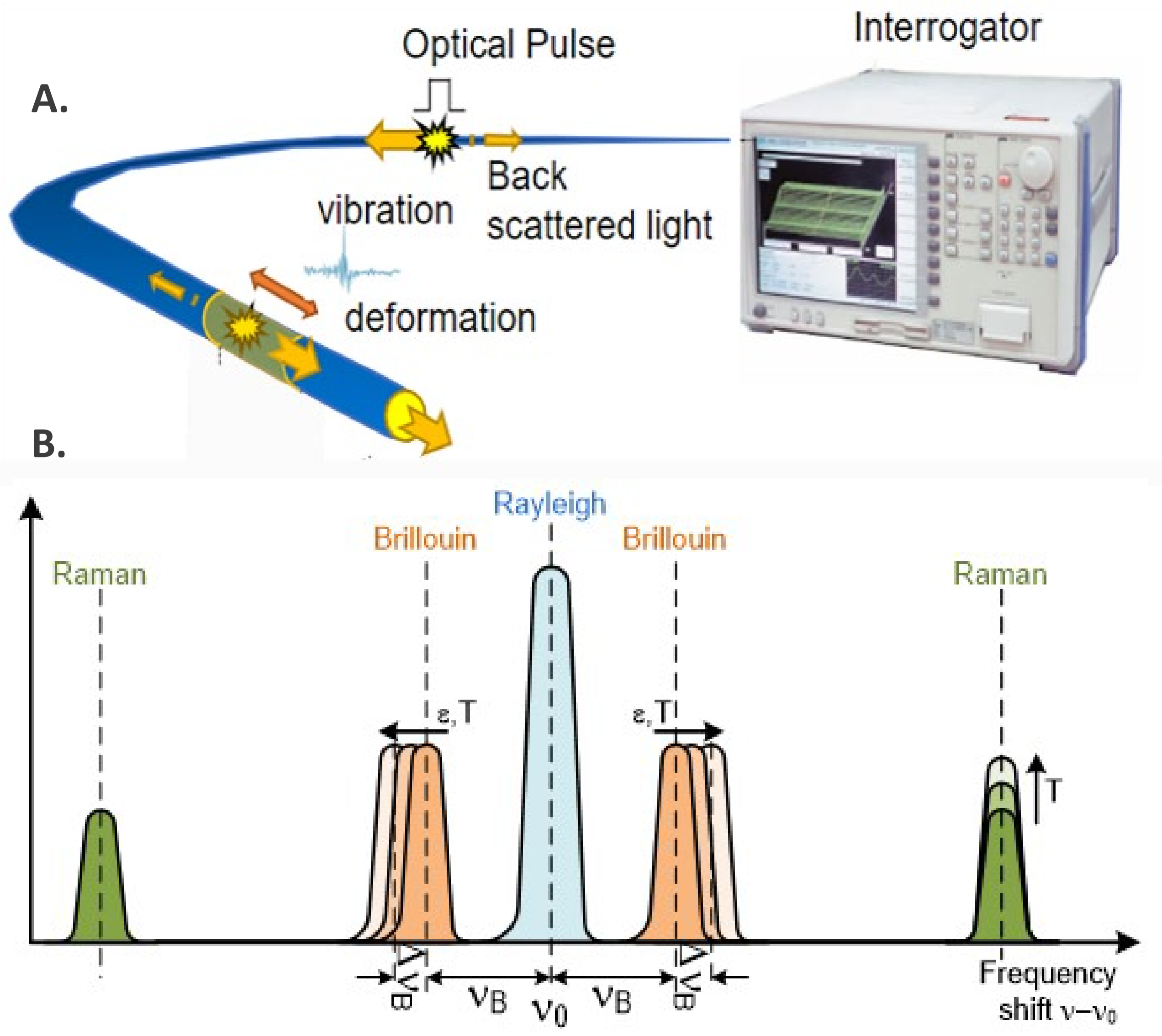


Source: NREL

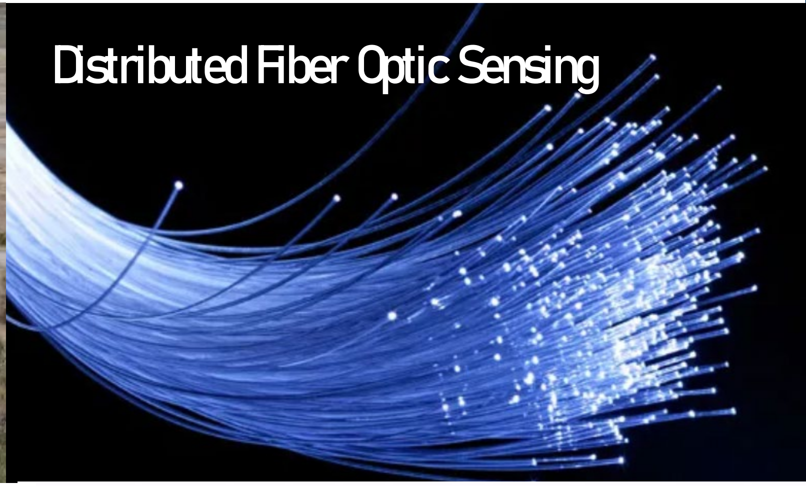
Major Challenges for offshore wind deployment - OCEAN CO-USE

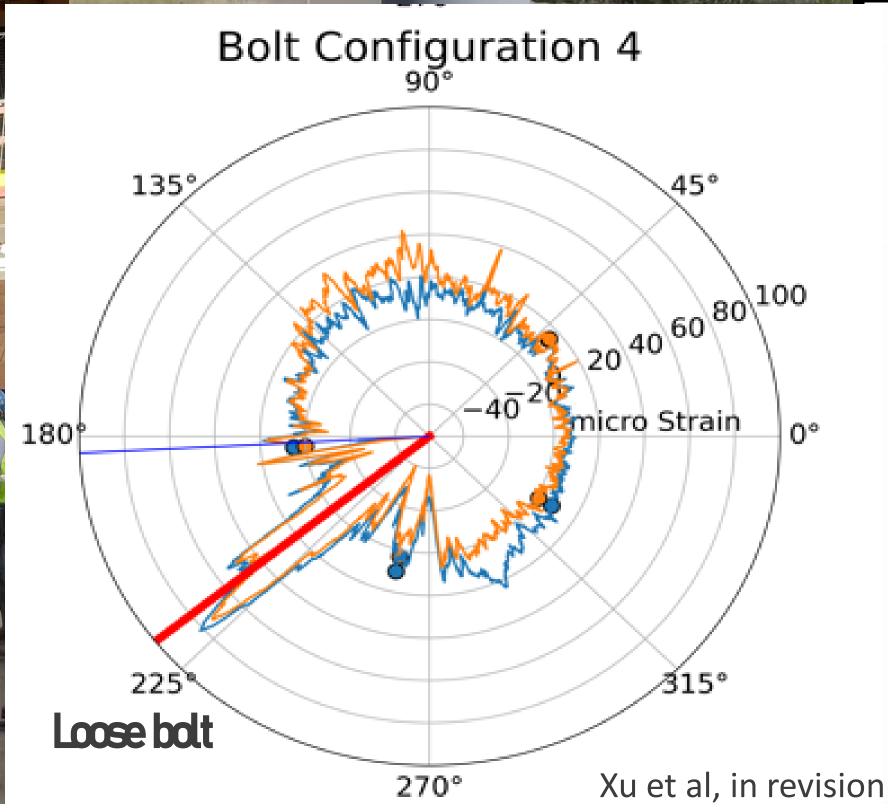
Source: LBNL

R&D Activities at LBNL - NOVEL SENSING for COST REDUCTION

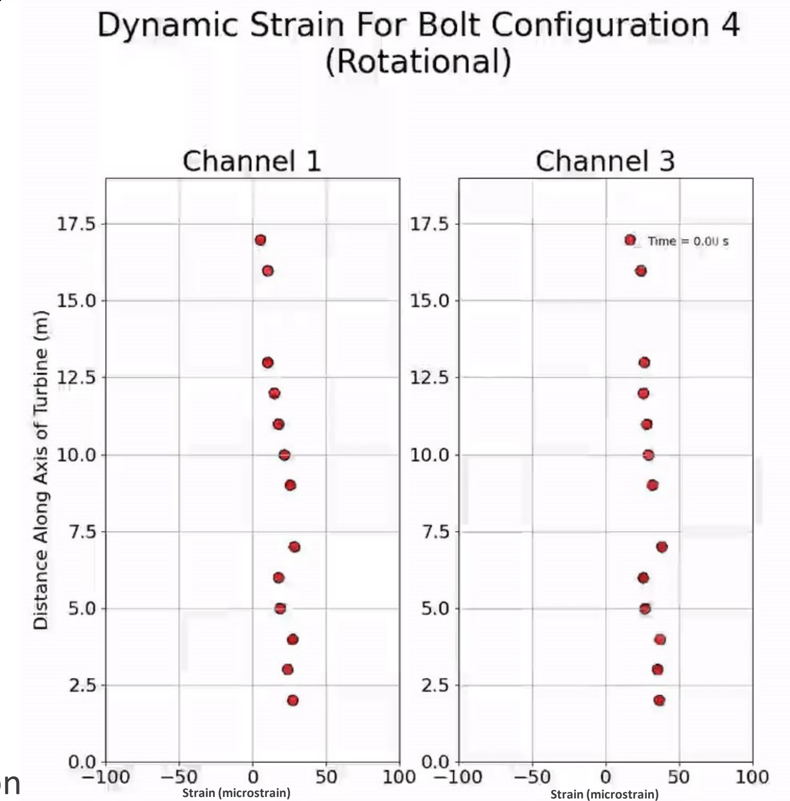


R&D Activities at LBNL - NOVEL SENSING for COST REDUCTION

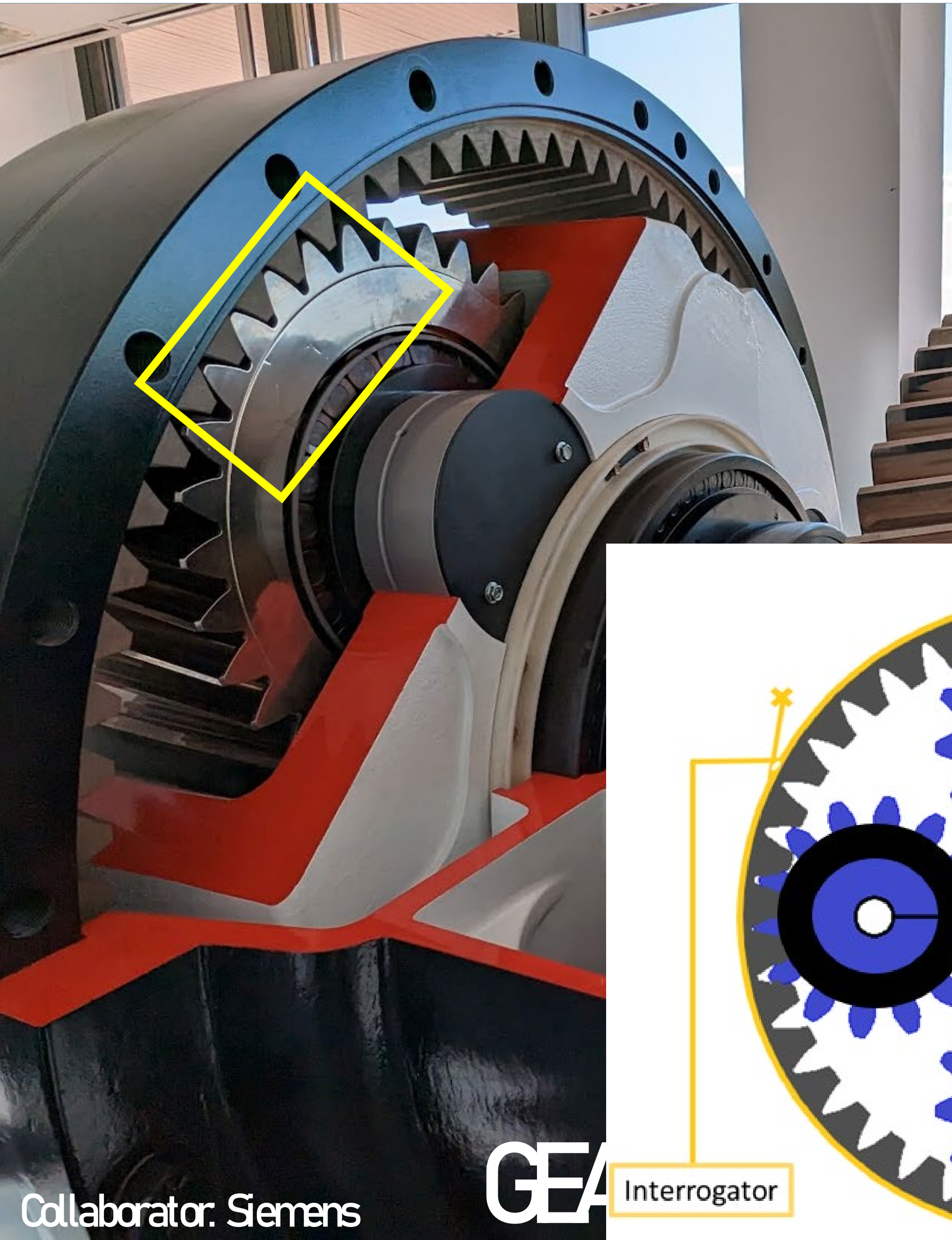


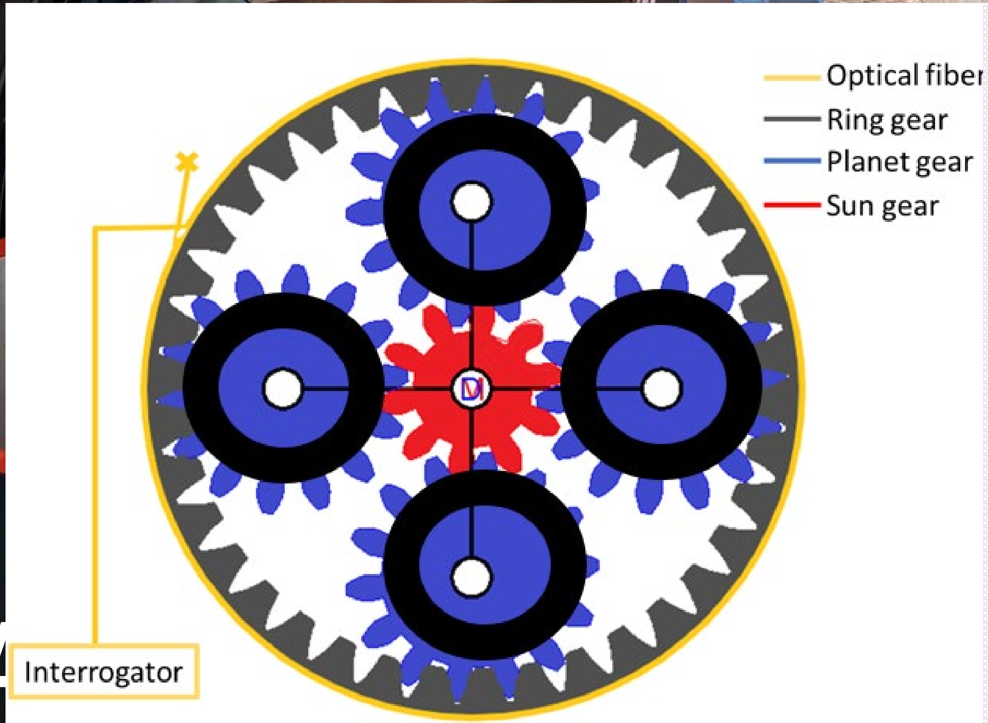


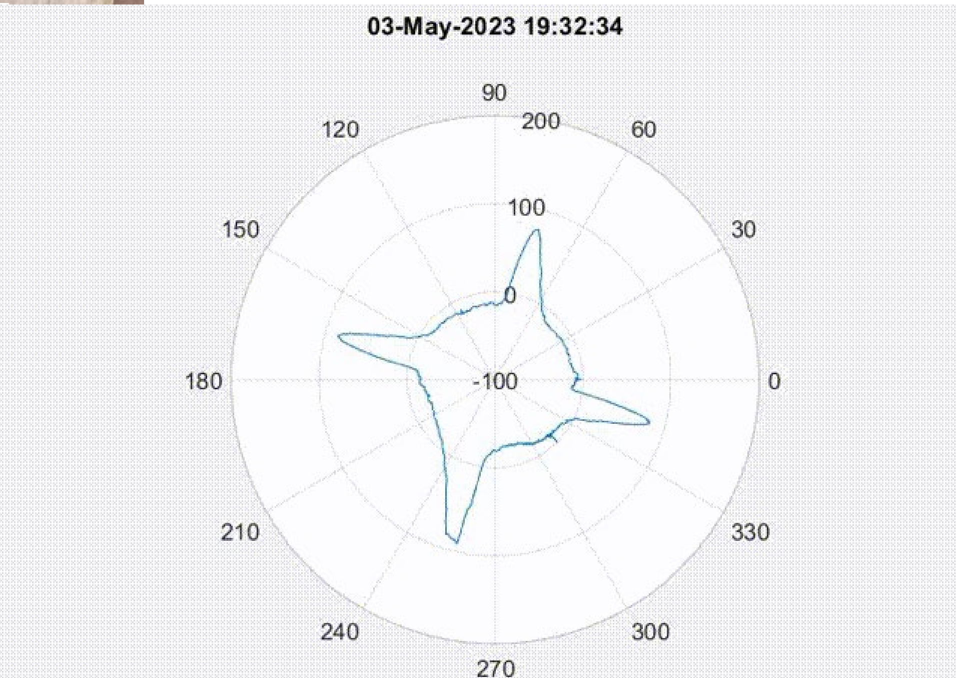
Xu et al, in revision



R&D Activities at LBNL - NOVEL SENSING for COST REDUCTION

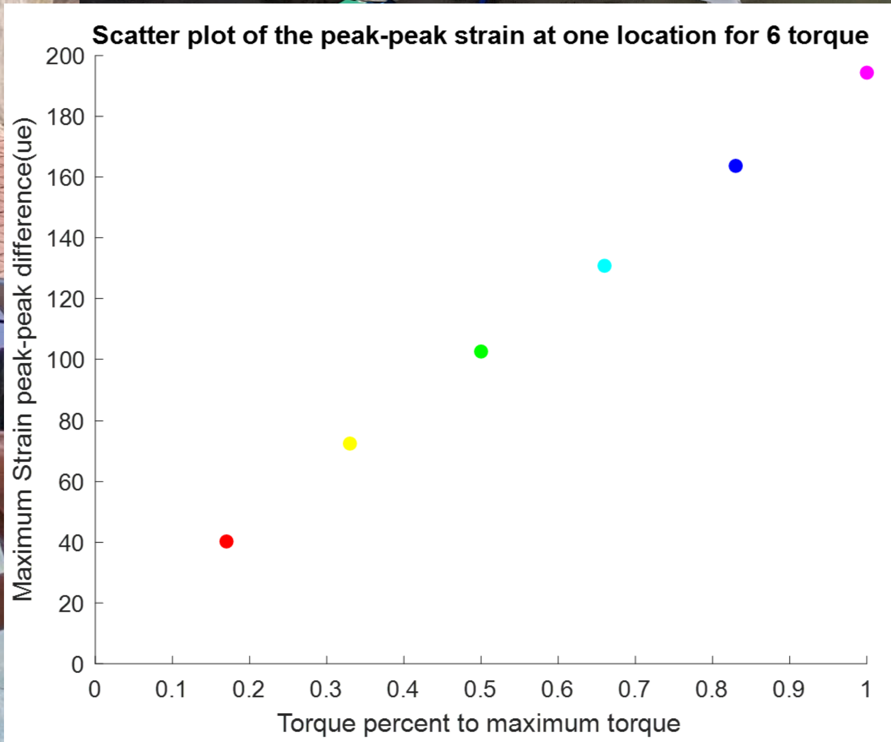




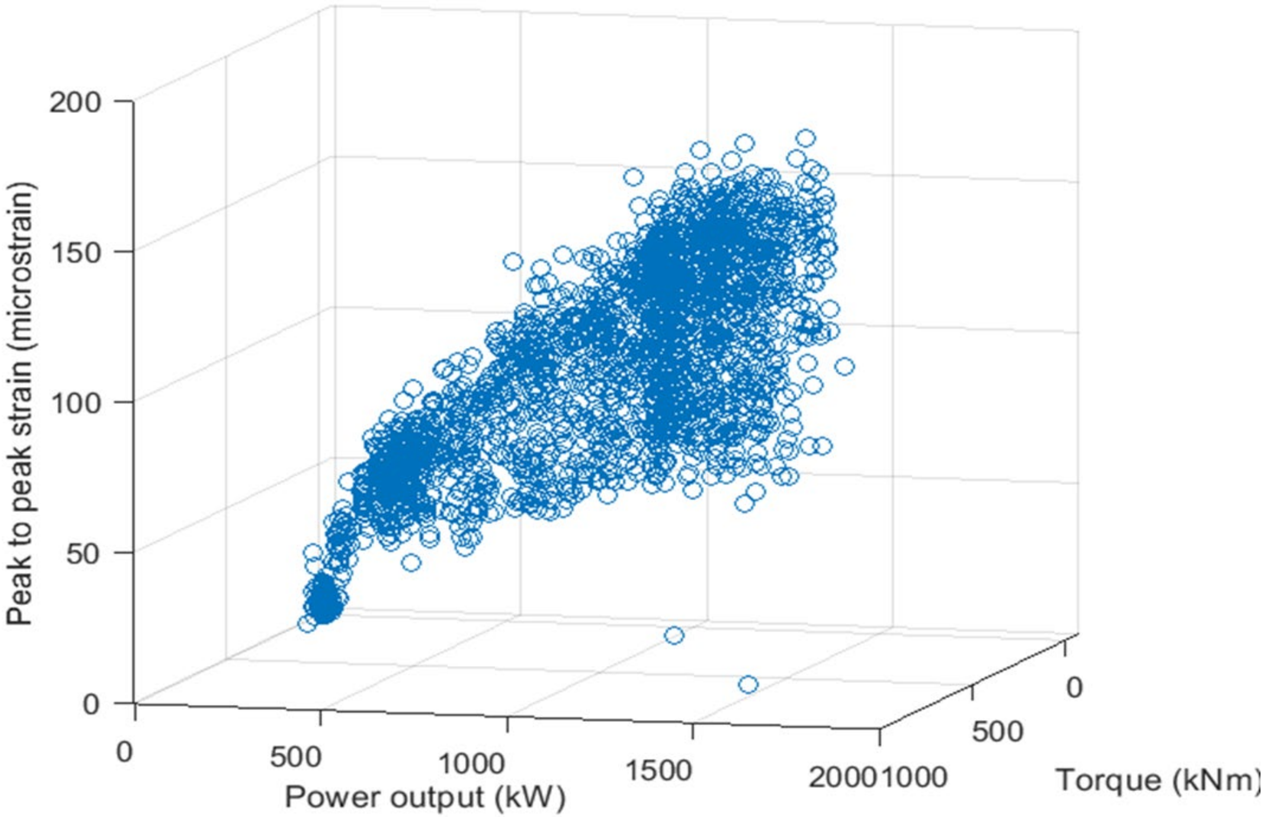


Luo et al, in prep.

R&D Activities at LBNL - NOVEL SENSING for COST REDUCTION

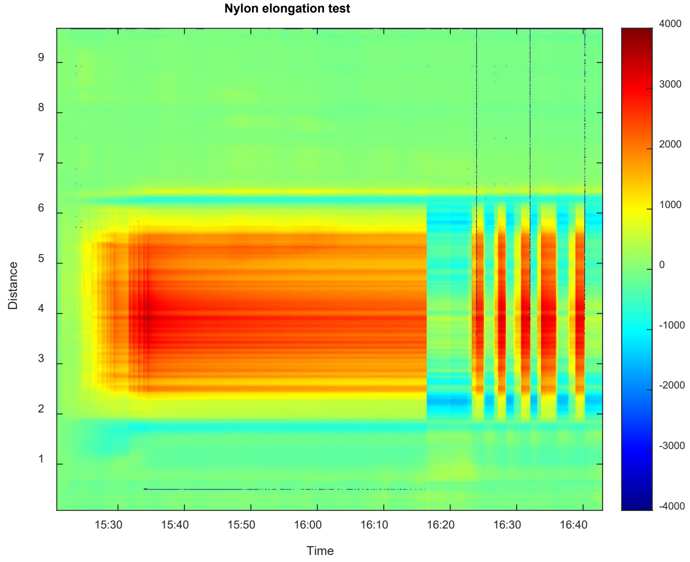


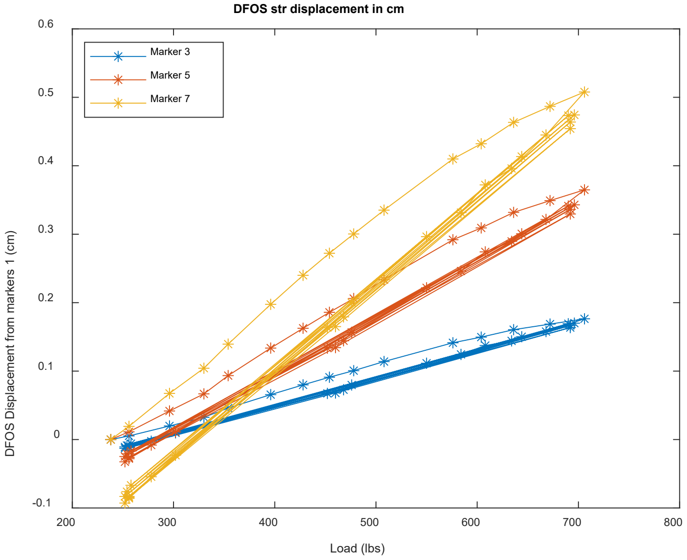
R&D Activities at LBNL - **NOVEL SENSING for COST REDUCTION**



- Field demonstration on an operating test turbine (1.5 MW) at NWTC @Flatiron, CO
- Very similar behaviors compared to bench tests

R&D Activities at LBNL - NOVEL SENSING for COST REDUCTION



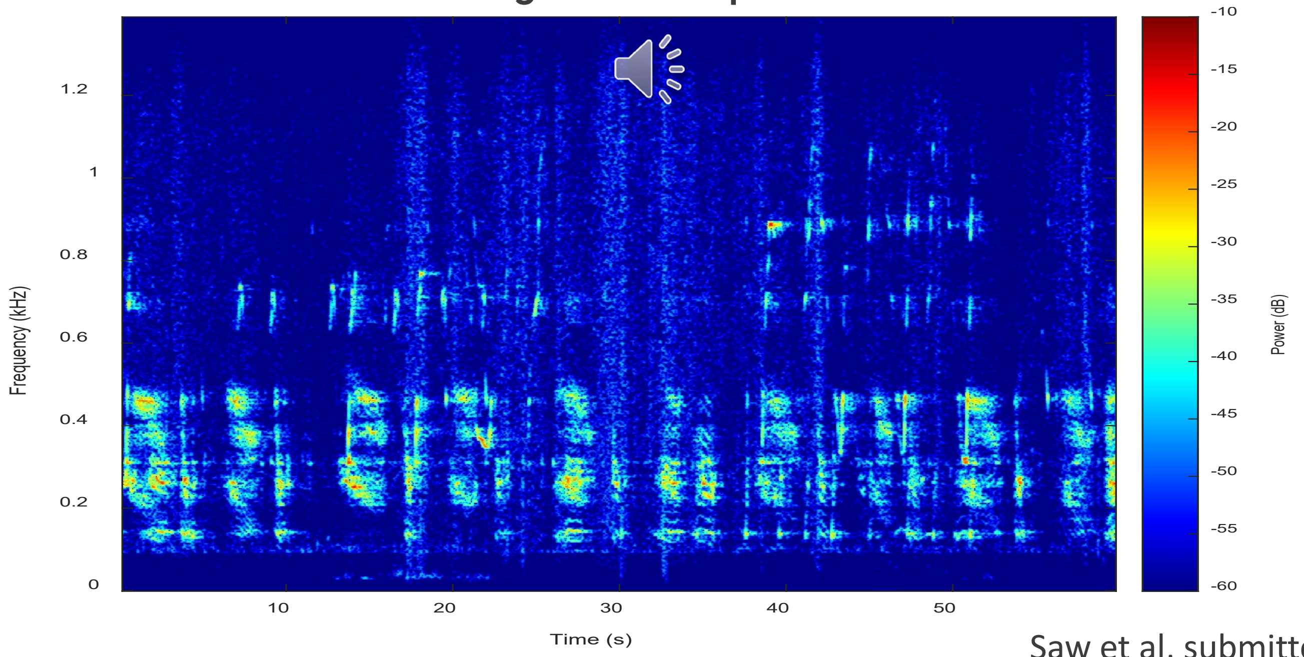


- Load distribution
- Load quantification
- Nuanced rope behaviors
- Shape sensing
- Environmental Impact monitoring

R&D Activities at LBNL - NOVEL SENSING for ENV. SUSTAINABILITY

R&D Activities at LBNL - NOVEL SENSING for ENV. SUSTAINABILITY

Whale songs heard on optical fiber

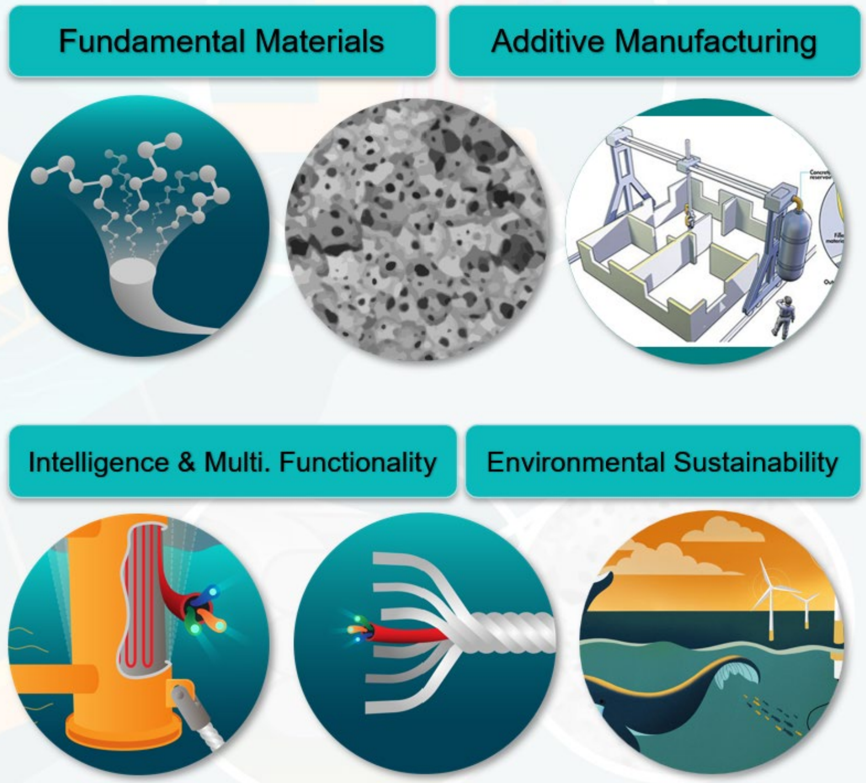


Saw et al, submitted

Future

VISION

System level co-designed floating wind with significant cost reduction and environmental sustainability




THANK YOU
CONTACT
YWu3@lbl.gov
Jeremy Snyder @LBN

FUNDING PROVIDED BY THE
CALIFORNIA ENERGY COMMISSION

sperra

Low-Cost, Environmentally-Friendly, Concrete Anchors Made in California

EPC-23-003

PI: Jason Cotrell; jason.cotrell@sperra.com

sperra

Leadership

Automated Construction – Renewable Energy – Commercialization

Jason Cotrell

Chief Executive Officer & Founder

MS, Mechanical Engineering, MBA

Gabriel Falzone

Chief Operating Officer

PhD, Materials Science

Vahid Azad

Chief Structural Engineer

PhD, PE, Civil Engineering

Taylor Marchment

Lead R&D Engineer

PhD, 3DCP Civil Engineering

Team

sperra

Automated Construction – Renewable Energy – Commercialization

Sonoko Watanabe
Structural Engineer
PhD, Civil Engineering

Mason Bell
Anchor Product Manager
BS, FE Civil Engineering

Evan Marquardt
Energy Storage Product Manager
MSc, Race Car Dynamics, MBA

Charlotte Marston
Proposal Manager | Technical Writer
BS, Biopsychology

Eduardo Rangel
Mechanical Engineer
BS, Mechanical Engineering

Jacob Blum
Material Engineer
BS, Material Engineering

We Are Hiring
Solar Product Manager
New York Printing Lead
R&D Interns

Sperra's California portside 3D concrete printing facility at AltaSea

sperra

About Us

Building a new foundation for clean energy

Sperra is a renewable energy startup leveraging our expertise in 3D concrete printing to accelerate clean energy development.

Our Vision:

To build clean energy that is abundant and sustainable for nature and communities.

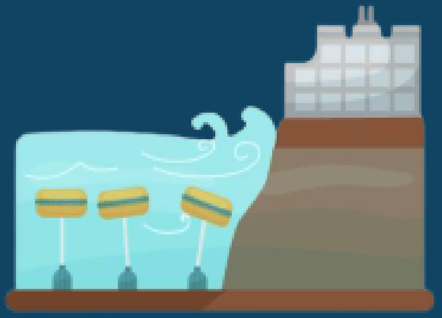
3D Concrete Printing

- Form-free process enables lean manufacturing with a small footprint
- Increases manufacturing efficiency
- Reduces physical burden
- Digital design: customization, complex geometries, structural optimization
- Sustainable locally sourced materials

Markets

Offshore Wind

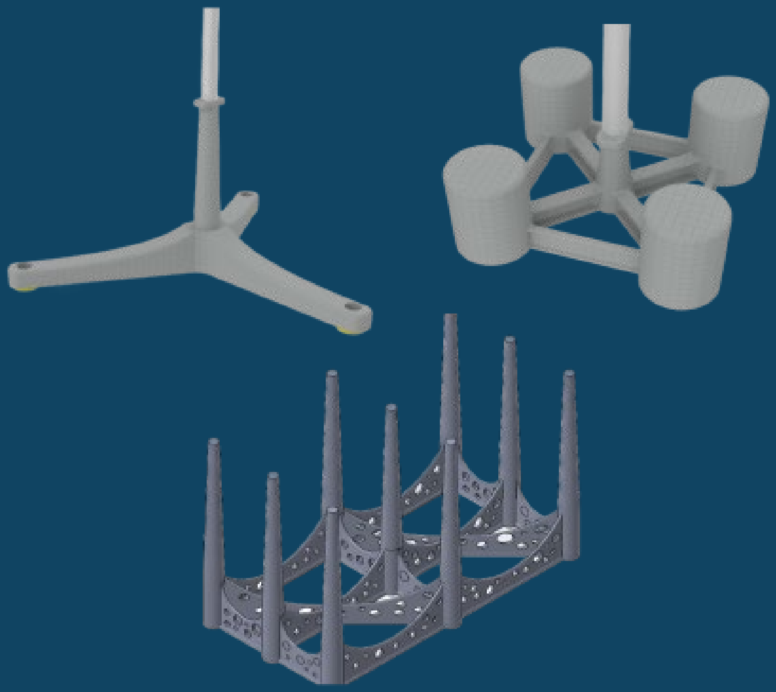
Offshore Solar



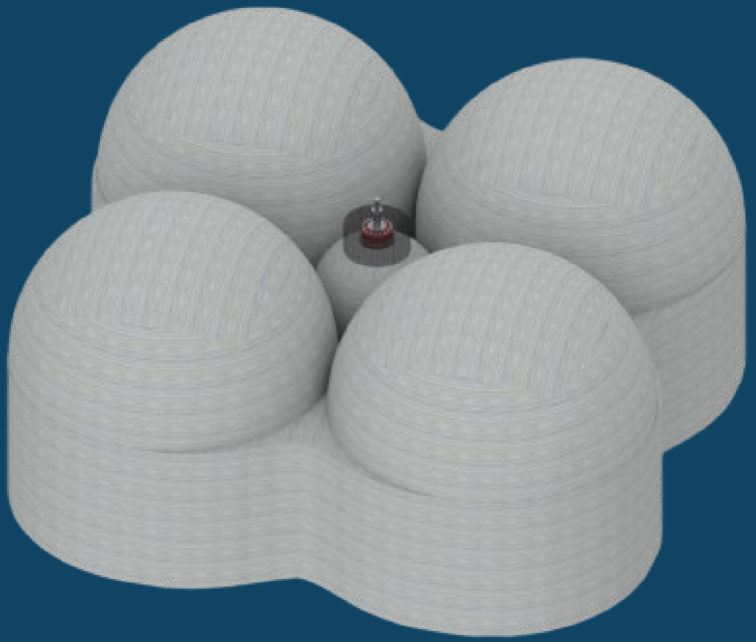
Wave Energy

Products

Anchors



Foundations and Docks



Subsea Energy Storage

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Project Overview

sperra

Project Purpose: To **develop a next-generation suction anchor and torpedo anchor** made from concrete **that cut manufacturing costs** between 37% to 82%, and **slash CO_2 emissions** between 55% to 96% compared to steel anchors.

Project Outcome: Advancement of Technology Readiness Level from 2 to 5 of a **scalable, low-cost, environmentally friendly anchor** that is **suitable for the majority of California's offshore wind** seabed areas, mooring types, and floating wind platforms.

Project Goals

1. Develop the lowest-cost environmentally friendly anchors for deployment in California wind energy areas.
2. Facilitate localized manufacturing in California ports.
3. Expand and accelerate the growth of California's concrete and floating wind workforce, R&D capabilities, and innovation ecosystem

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Project Team Organization Chart

Sperra
Project Prime

Project Advisory Panel

- RWE
- NIST – National Institute of Standards and Technology, U.S. Department of Commerce
- Federal Bureau of Investigation
- TechnipFMC
- BOEM – Bureau of Ocean Energy Management
- Catapult Offshore Renewable Energy
- Manson Construction Co.

UC San Diego
Hydrodynamic, Geotechnical Design & Testing

InterMoor
Steel Structural Design & Analysis

WSP USA
Concrete Structural Design

UC Irvine
Life Cycle Assessment

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Project Progress

sperra

Objective: Generate anchor design loads and seismic characteristics for a reference floating wind plant.

Status: Complete

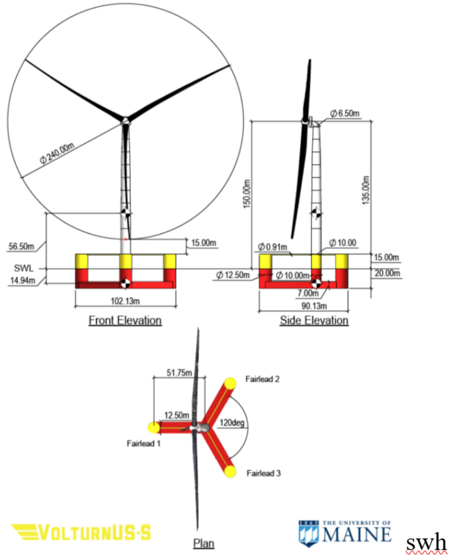


Figure 3. Target 15 MW wind turbine and tri-pod semi-submersible platform proposed for the reference wind site (Allen et al. 2020).

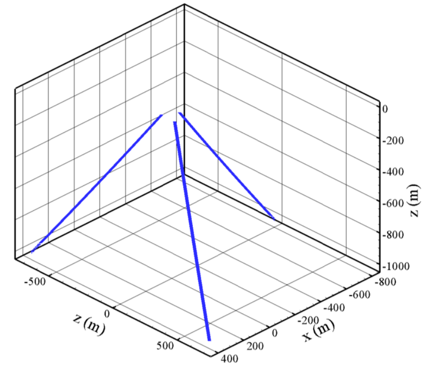


Figure 4. Taut mooring configuration in 1000 m deep water.

Humboldt Wind Energy Area

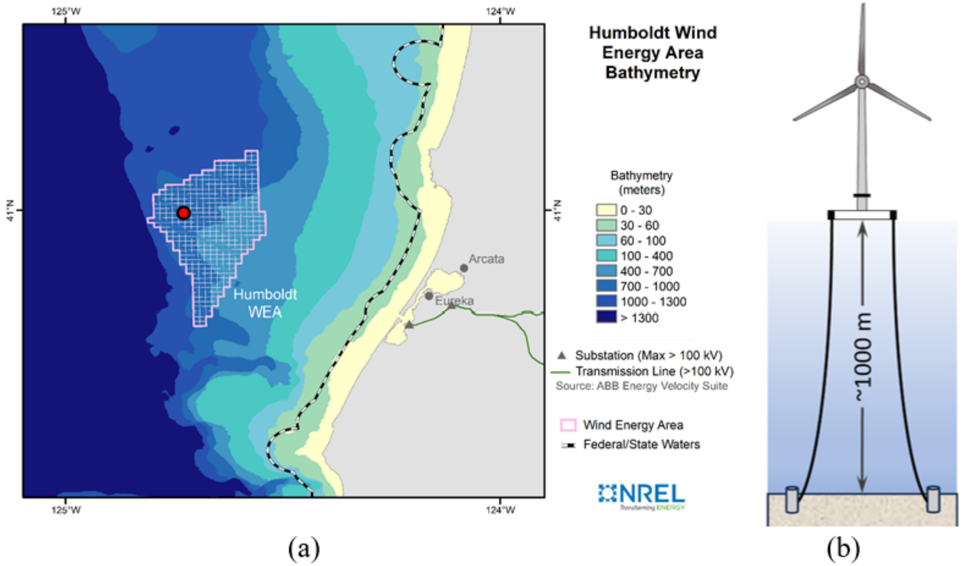


Figure 5. Proposed reference wind site for Humboldt WEA: (a) plan view of the bathymetry with selected site; (b) Schematic elevation view the selected site showing water depth.

Morro Bay Wind Energy Area

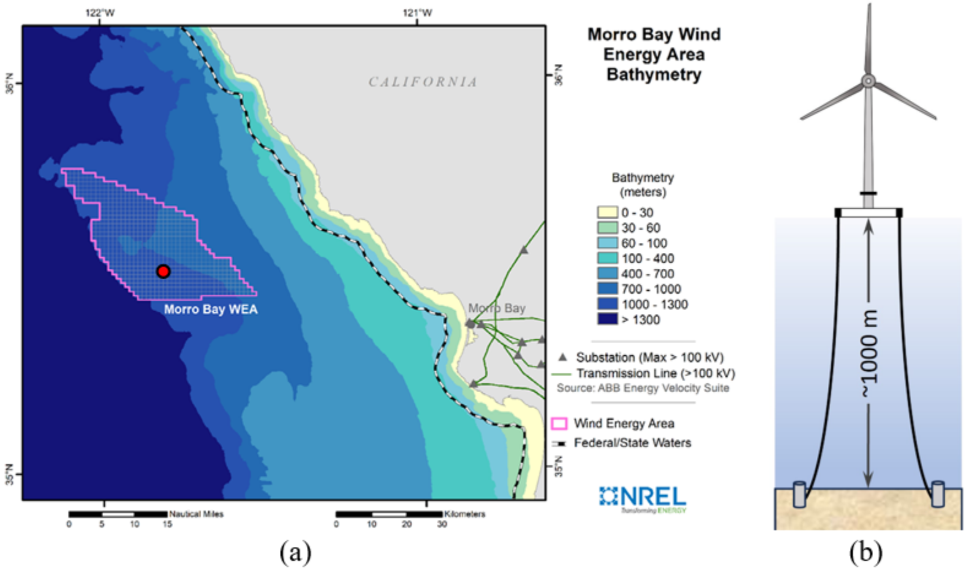


Figure 24. Schematic diagram of reference wind site for Morro Bay WEA: (a) plan view of the bathymetry with selected location; (b) Elevation view showing the depth to the soil layer.

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Project Progress

sperra

Objective: Generate anchor design loads and seismic characteristics for a reference floating wind plant.

Status: Complete

Table 5. Summary of the anchor loads at various extreme sea conditions.

	Static	Dynamic with wave loading	Dynamic with current loading	Dynamic with current and wind loading	Dynamic with wave, current, and wind loading	Dynamic with current loading and broken cable
Limit State	Normal	ULS 1	ULS 2	ULS 3	ULS 4	ALS
Closest DNV 0437 Limit State	4.1 (F)	6.4 (N)	5.1 (N)	1.1 (N)	1.1 (N)	8.6 (A)
State of the mooring system	Intact	Intact	Intact	Intact	Intact	With fractured cable(s)
Significant wave height (m)	0	10	0	0	10	10
Current speed (m/s)	0	0	1	1	1	1
Wind speed* (m/s)	0	0	0	33	33	33
Estimated peak anchor load (MN)	2.395	2.75	3.32	6.93	7.3	6.9
Partial Safety Factors	1.0	1.35	1.35	1.25	1.25	1.10
Factored Loads (MN)	2.395	3.375	4.482	8.662	9.125	7.590

*Assumes that the turbine is generating power if the wind speed is greater than 0.

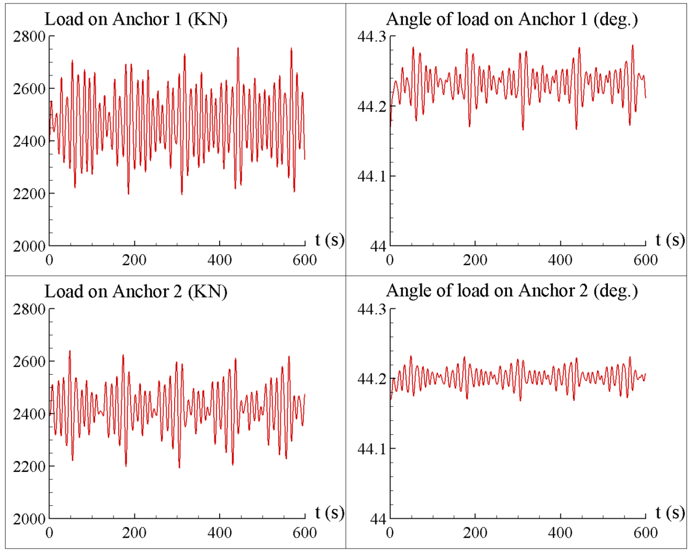


Figure 43. Load on anchors at $H_s = 10$ m.

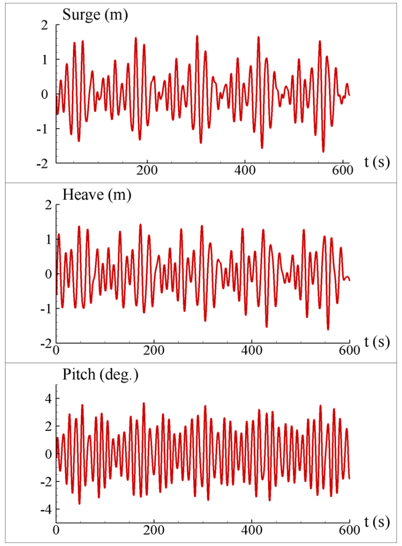


Figure 42. Displacements of the platform at $H_s = 10$ m.

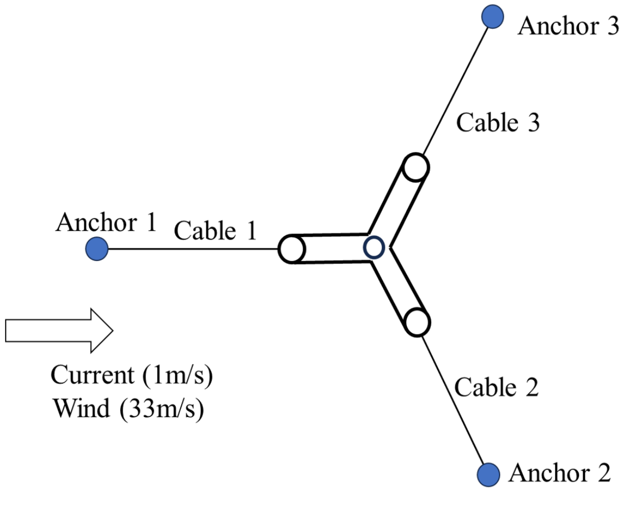


Figure 49. Setup for simulations of the current/wind effects.

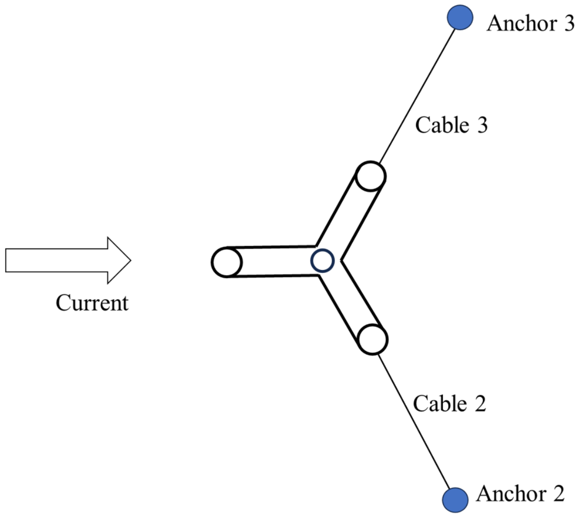
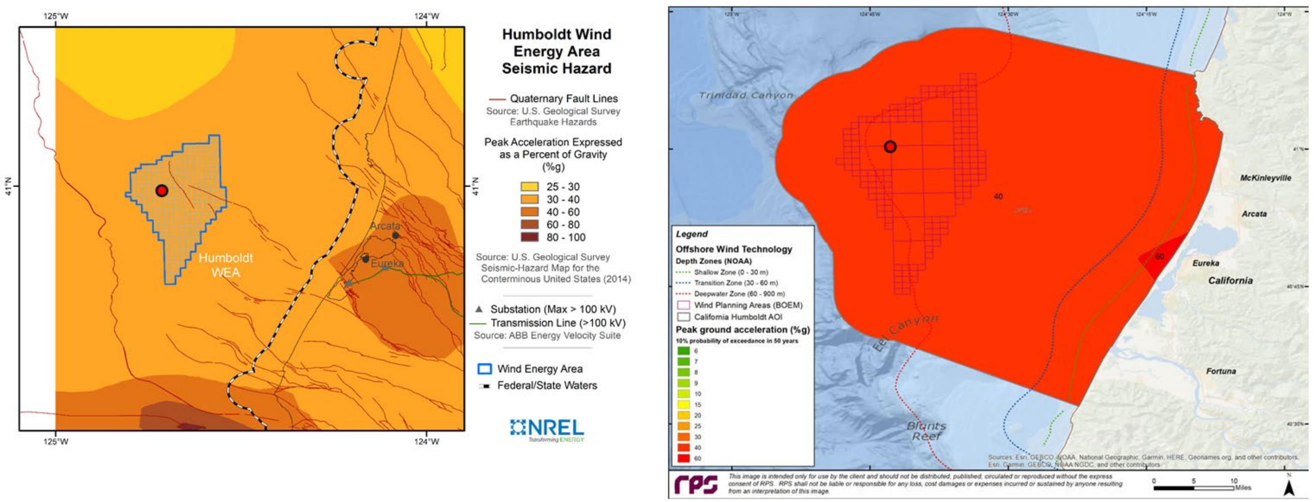


Figure 52. Setup (top view) for the analysis of response due to a fractured cable.

Project Progress

Objective: Generate anchor design loads and seismic characteristics for a reference floating wind plant.

Status: Complete

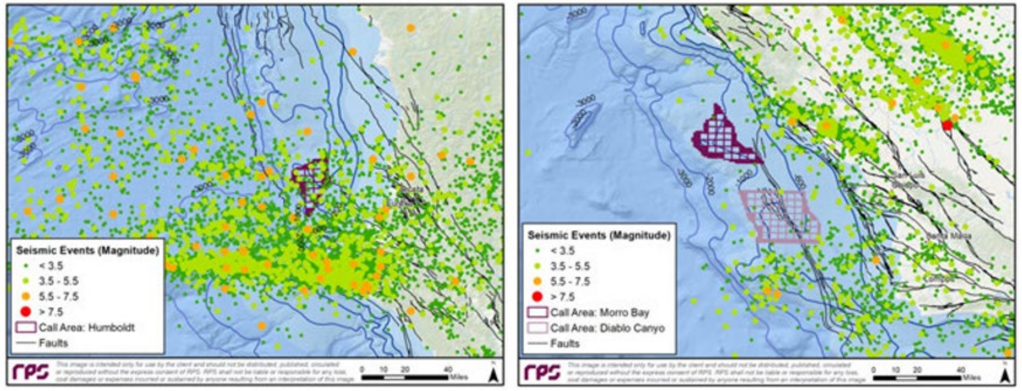


(a) (b)

Figure 14. Seismic hazard and quaternary fault lines of the Humboldt WEA: (a) PGA (Cooperman et al. 2022); (b) PGA (Tajalli Bakhsh et al. 2020).

Humboldt Wind Energy Area

Morro Bay Wind Energy Area



(a) (b)

Figure 4.1. Historic earthquakes close to the study areas of Humboldt and Morro Bay (USGS, 2019c; Tajalli Bakhsh et al. 2020).

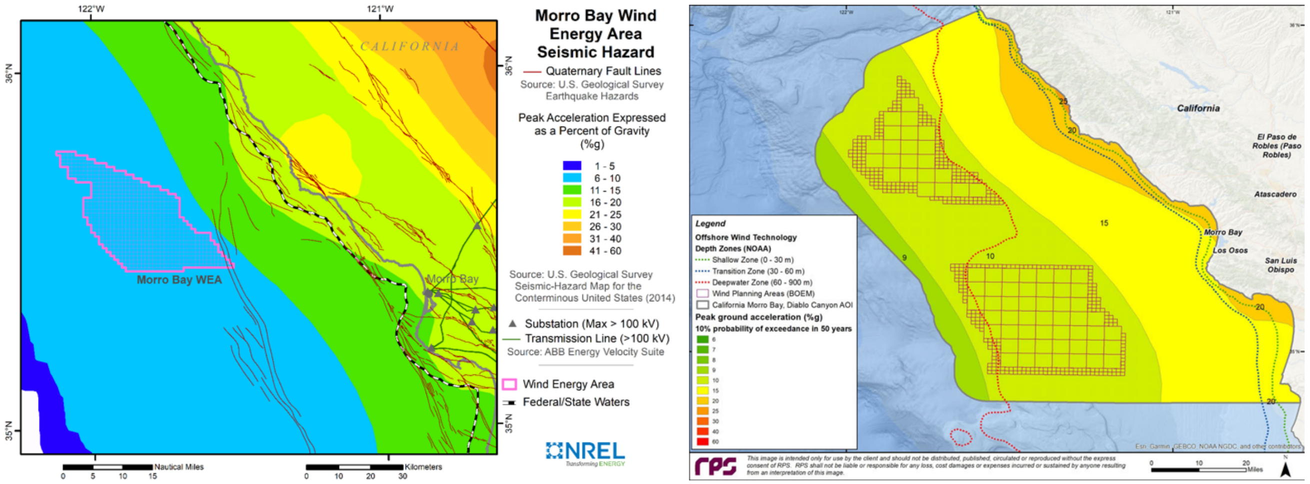


Figure 30. Seismic hazard quantified by PGA and quaternary fault lines of the Morro Bay WEA: (a) PGA (Cooperman et al. 2022); (b) PGA (Tajalli Bakhsh et al. 2020).

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Project Progress

Objective: Gather and assess California offshore wind energy area seabed composition information.

Status: Complete

Humboldt Wind Energy Area

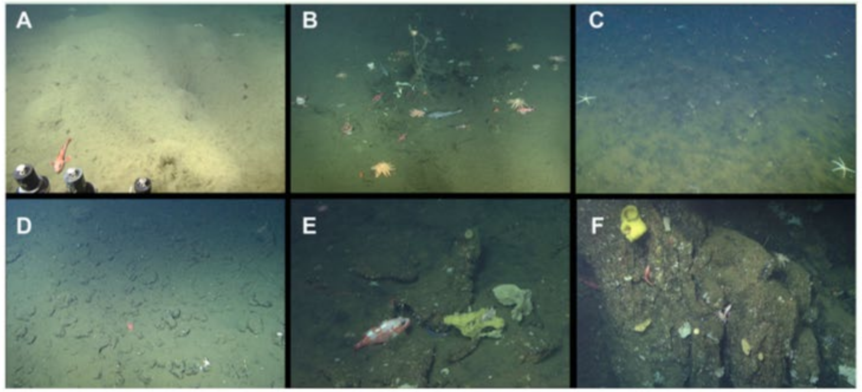
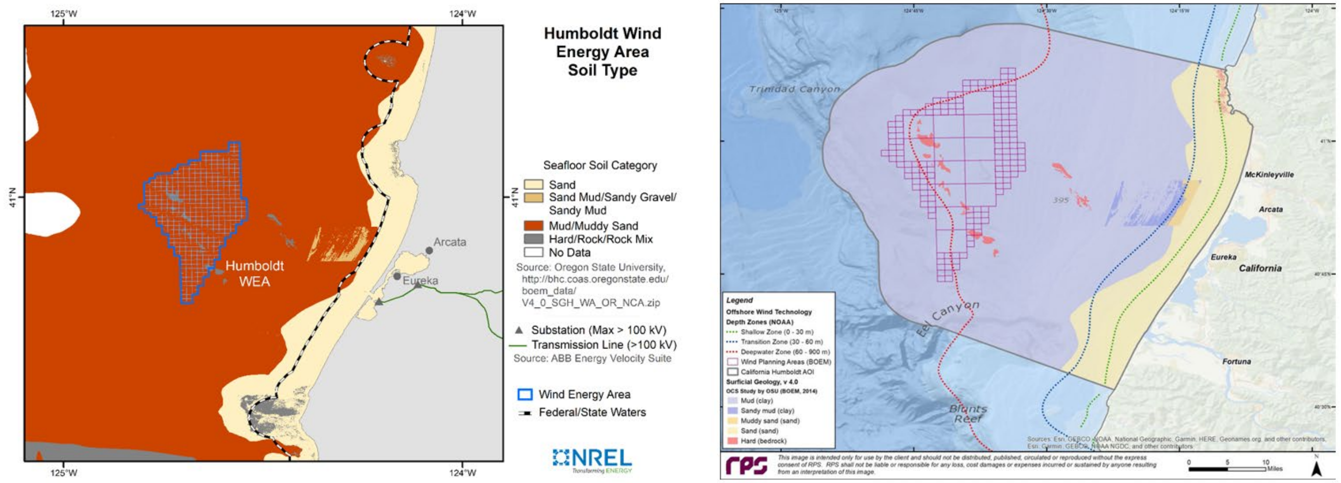


Figure 5.5. Seafloor habitats observed within the study region. A–C are soft substratum: A. hummocky mud (small, frequent mounds, 687 m depth) B. biological detritus and marine litter (935 m) and C. Greenish-black mud draped coarse sand (766 m). D and E are a mix of soft and hard substrata: D. cobble (575 m) and E. bedrock slabs (477 m). F. is the only type of completely hard substratum observed, referred to as bedrock outcrop (447 m) (Kuhnz et al., 2022).



(a) (b)

Figure 8. Soil types of the Humboldt WEA and surrounding regions: (a) Seafloor categories (Cooperman et al. 2022); (b) Surficial geology (Tajalli Bakhsh et al. 2020).

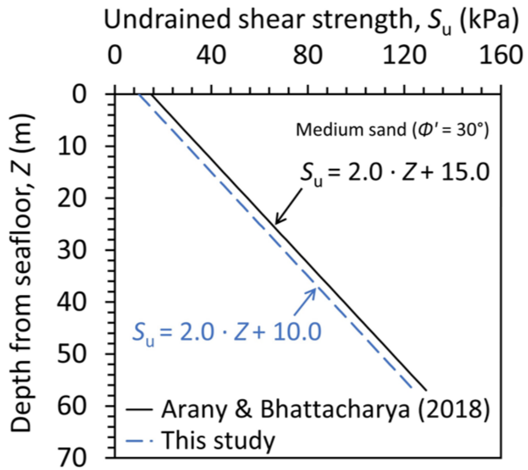


Figure 5.9. Schematic diagram of undrained shear strength of soil with depth from seafloor at Humboldt WEA.

Project Progress

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

sperra

Objective: Gather and assess California offshore wind energy area seabed composition information.

Status: Complete

Table 4. Summary of the key soil properties for the two reference wind sites.

	Humboldt WEA			Morro Bay WEA		
General soil type	Fine-grained sandy soil			Low plasticity clayey soil		
Bound	Low	Mean	High	Low	Mean	High
Total unit weight, γ (kN/m^3)	16	17	18	15	16	17
Drained friction angle, ϕ' (°)	30	32	33	28	30	32
Drained cohesion, c' (kPa)	0	0	0		0	
Undrained shear strength at ground surface, s_{u0} (kPa)	8	10	12	3.9	4.9	5.9
Rate of increase in undrained shear strength with depth s_{uz} (kPa/m)	2	2	2	1.9	1.9	1.9
Sensitivity, S	1.1	1.0	1.0	1.2	1.1	1.0

Morro Bay Wind Energy Area

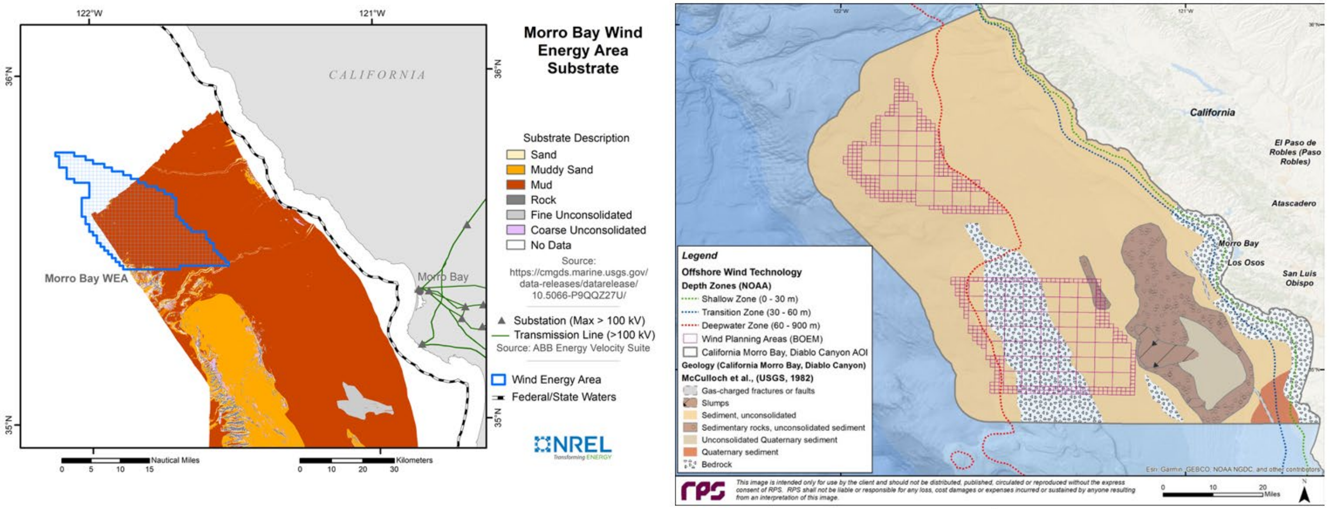


Figure 26. Soil types of the Morro Bay WEAs and surrounding regions: (a) Substrate descriptions (Cooperman et al. 2022); (b) Soil types (Tajalli Bakhsh et al. 2020).

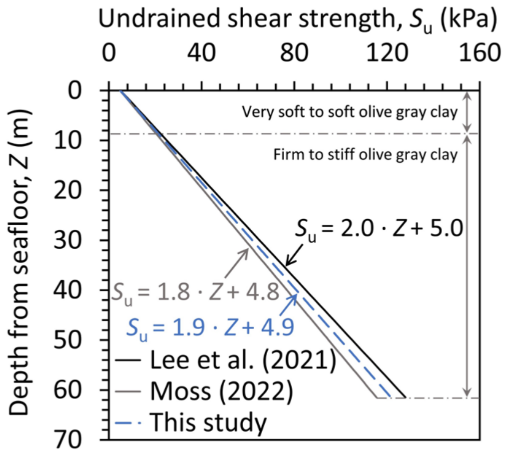


Figure 27. Schematic diagram of undrained shear strength of soil with depth from seafloor at Morro Bay WEA.

Objective: Conceptually design 6 next-generation concrete anchors and 2 steel reference anchors. **Status:** In Progress

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

sperra

Suction Bucket Anchors

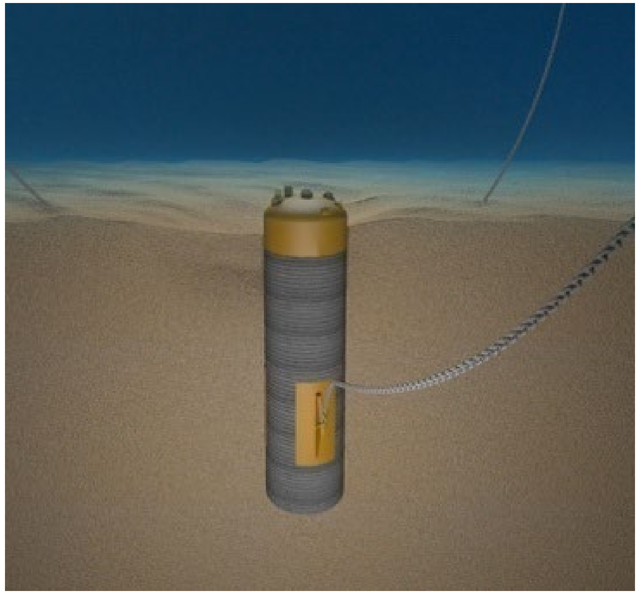
Operating Principal Suction anchors are installed into the ocean floor using suction, pile driving or by vibratory installation. When lifted the hollow bottom generates a pressure differential providing additional anchoring capacity.

Reference Steel Design #1

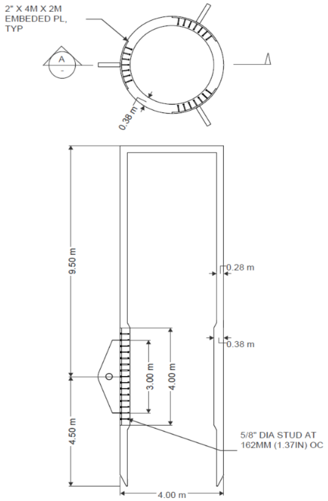
Parameter	Steel
Diameter, m	7
Length, m	20
Embedment, m	19
Avg. Wall, mm	44
Estimated Dry Weight, MT	193
Horiz. Safety Factor (1.6 required)	9.0
Vertical Safety Factor (2.0 required)	2.1
Estimated Cost (FOB), each anchor	$965,000

INNOVATIONS

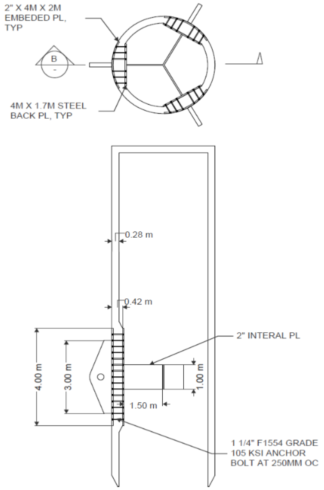
- Uses locally sourced concrete and local labor
- Combines 3DCP, reinforcement, and sprayed concrete to make a composite structure
- Structural optimization/efficient use of materials



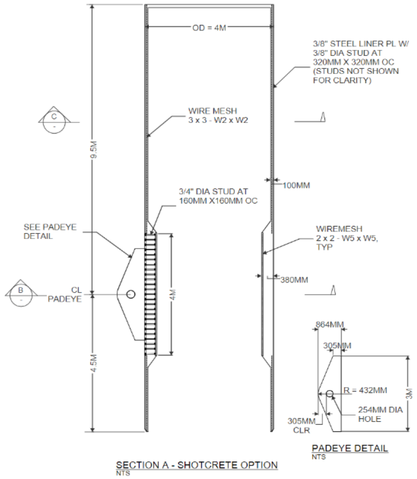
Concrete Design #1



Concrete Design #2



Concrete Design #3

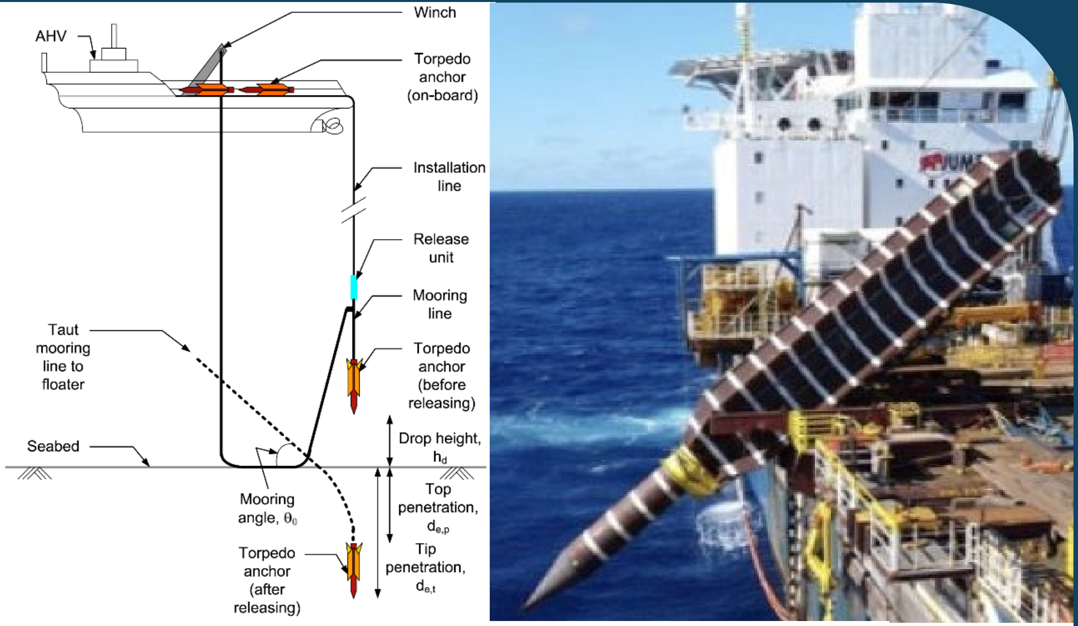


Objective: Conceptually design 6 next-generation concrete anchors and 2 steel reference anchors. **Status:** In Progress

Torpedo Anchors

Operating Principal Torpedo anchors rely on their momentum from being dropped off a ship to embed themselves deep in the ocean floor.

Reference Steel Design #2



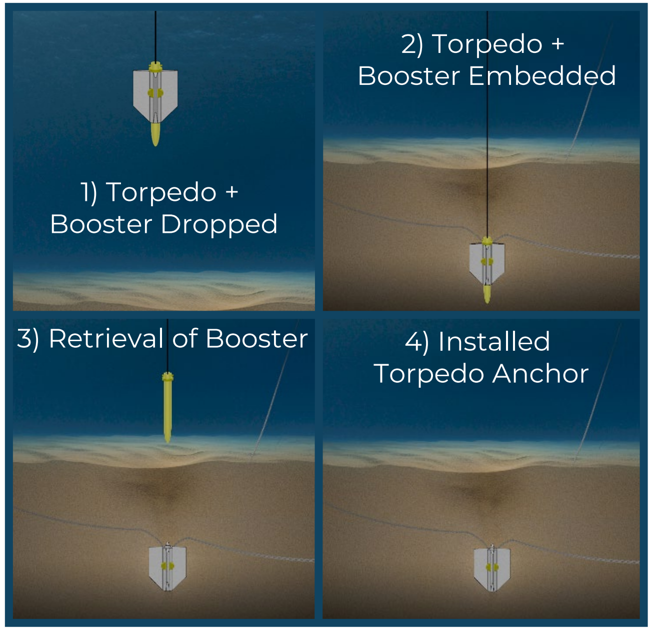
Cost estimate for steel torpedo pile (FOB) is $433,000 each.

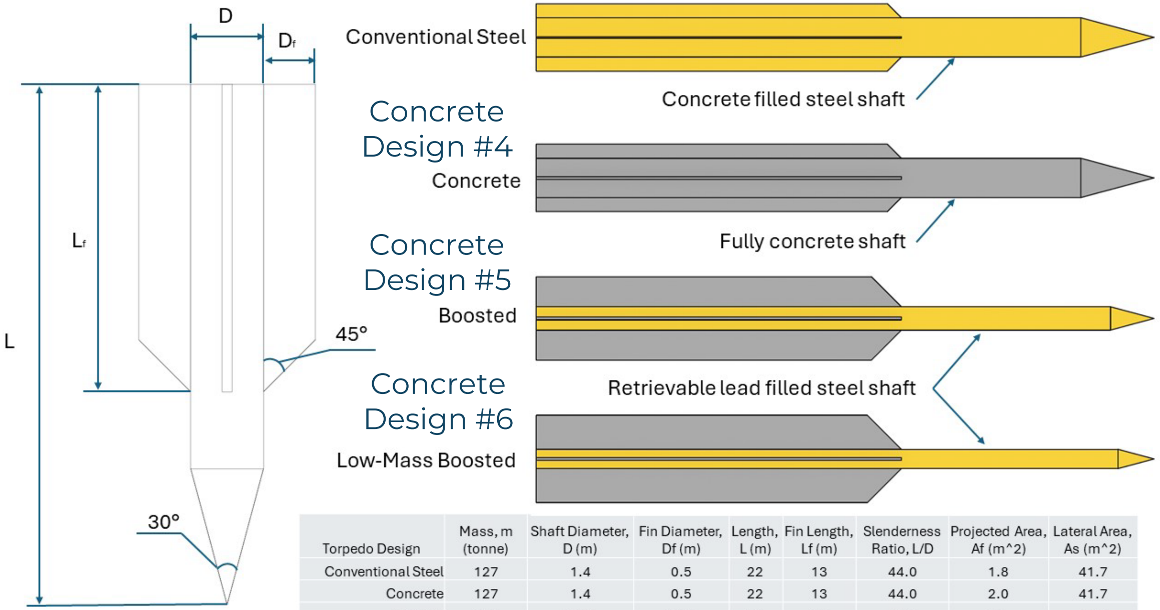
FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

sperra

INNOVATIONS

- Retrievable steel booster
- Hydrodynamic features to increase freefall speed
- Uses locally sourced concrete and local labor
- Combines 3DCP, reinforcement, and sprayed concrete to make a composite structure
- Structural optimization/efficient use of materials





Torpedo Design	Mass, m (tonne)	Shaft Diameter, D (m)	Fin Diameter, Df (m)	Length, L (m)	Fin Length, Lf (m)	Slenderness Ratio, L/D	Projected Area, Af (m^2)	Lateral Area, As (m^2)
Conventional Steel	127	1.4	0.5	22	13	44.0	1.8	41.7
Concrete	127	1.4	0.5	22	13	44.0	2.0	41.7
Boosted	127	0.83	1.07	22	13	20.6	1.1	44.3
Low-Mass Boosted	95	0.69	1.21	22	13	18.2	1.0	44.7

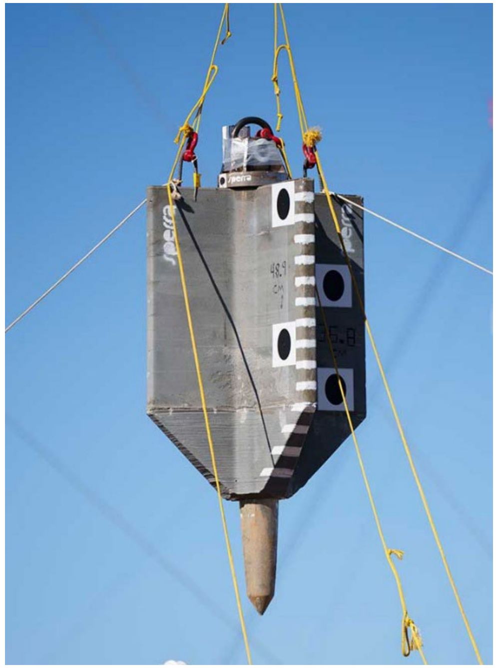
FUNDING PROVIDED BY THE
CALIFORNIA ENERGY COMMISSION

Objective: Demonstrate automated concrete manufacturing methods including 3D concrete spraying, 3D concrete printing, and casting in 3D printed formwork to fabricate anchors. **Status:** In Progress

1/8 Suction Bucket Anchor Prototype 3D Concrete Printed

1/10 Torpedo Anchor Prototype 3D Concrete Printed

1/10 Torpedo Anchor Prototype cast in 3D printed formwork

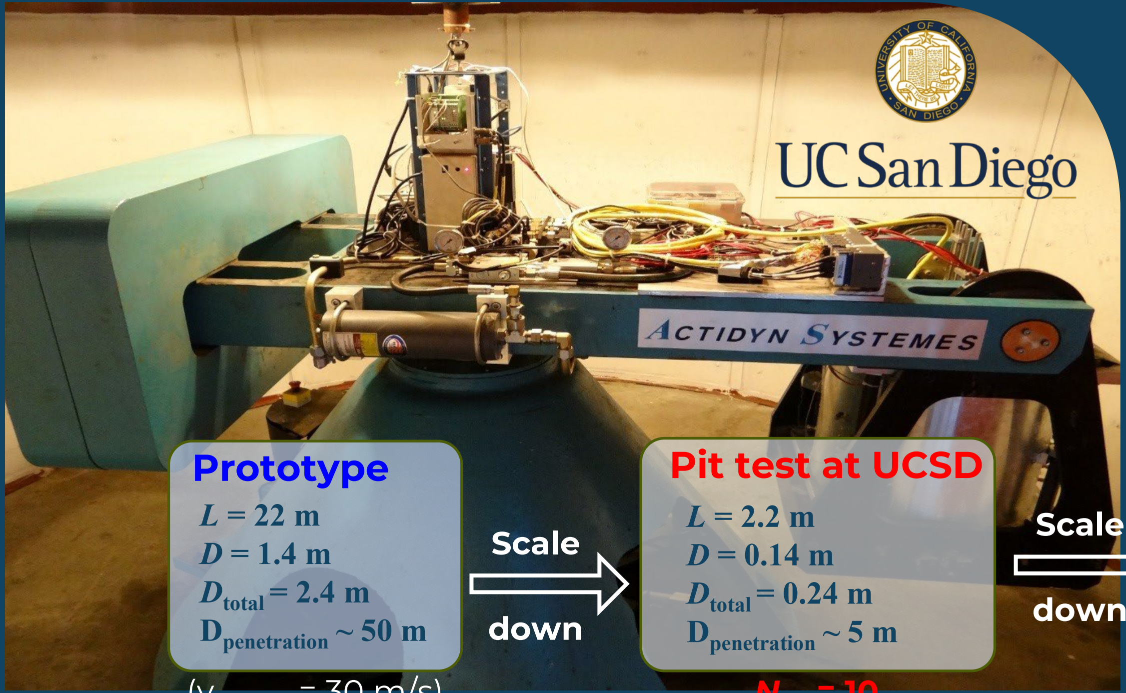


Objective: Perform lab experiments to validate structural, seismic, embedment, and load models.

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Geotechnical Centrifuge Testing

- Advanced physical modelling technique for studying the behavior of reduced-scale models under realistic stress states.



Prototype

$L = 22$ m
$D = 1.4$ m
$D_{total} = 2.4$ m
$D_{penetration} \sim 50$ m
($v_{impact} = 30$ m/s)

Scale down →

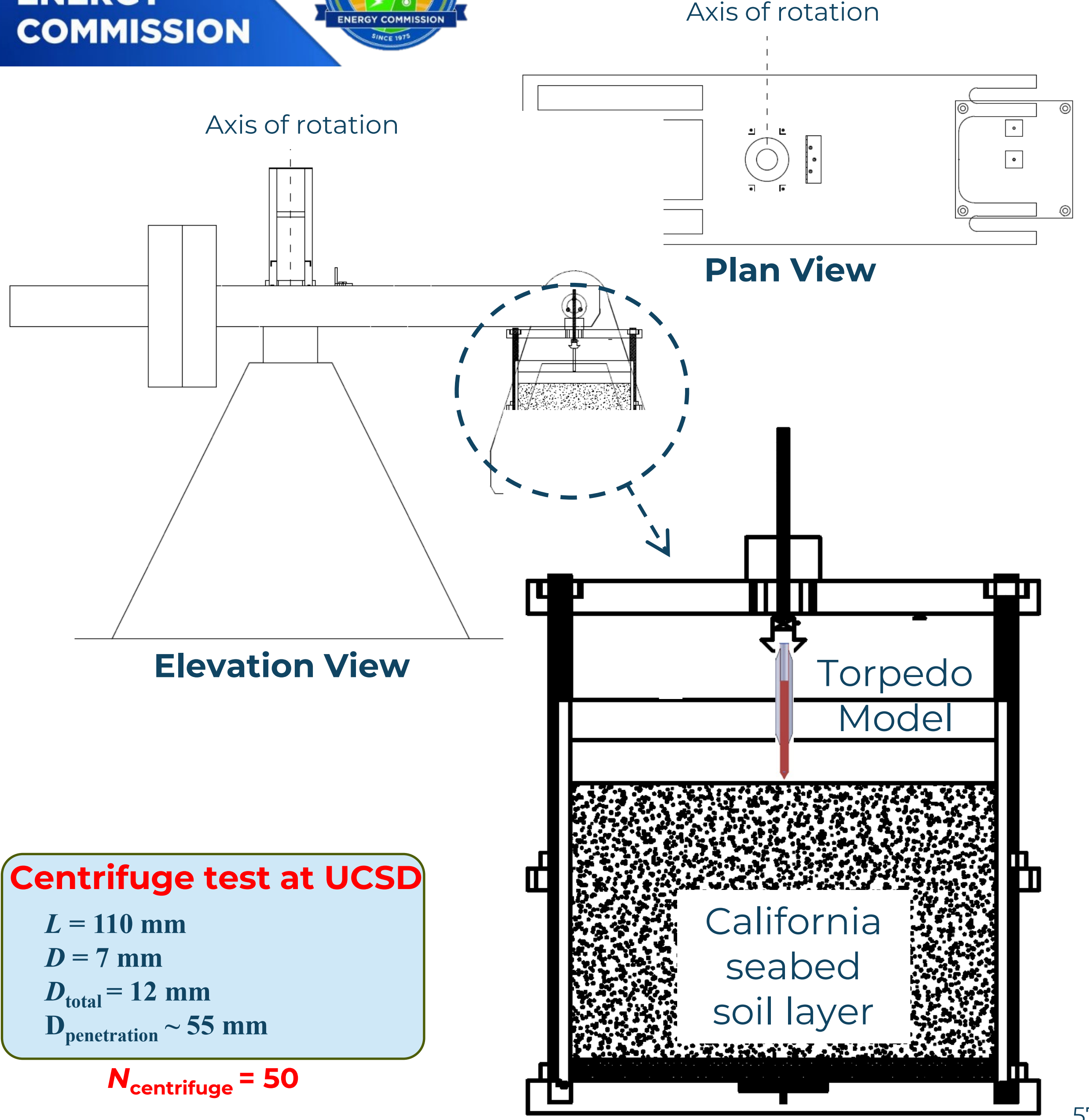
Pit test at UCSD

$L = 2.2$ m
$D = 0.14$ m
$D_{total} = 0.24$ m
$D_{penetration} \sim 5$ m
$N_{pit} = 10$

Scale down →

Centrifuge test at UCSD

$L = 110$ mm
$D = 7$ mm
$D_{total} = 12$ mm
$D_{penetration} \sim 55$ mm
$N_{centrifuge} = 50$



FUNDING PROVIDED BY THE
CALIFORNIA ENERGY COMMISSION

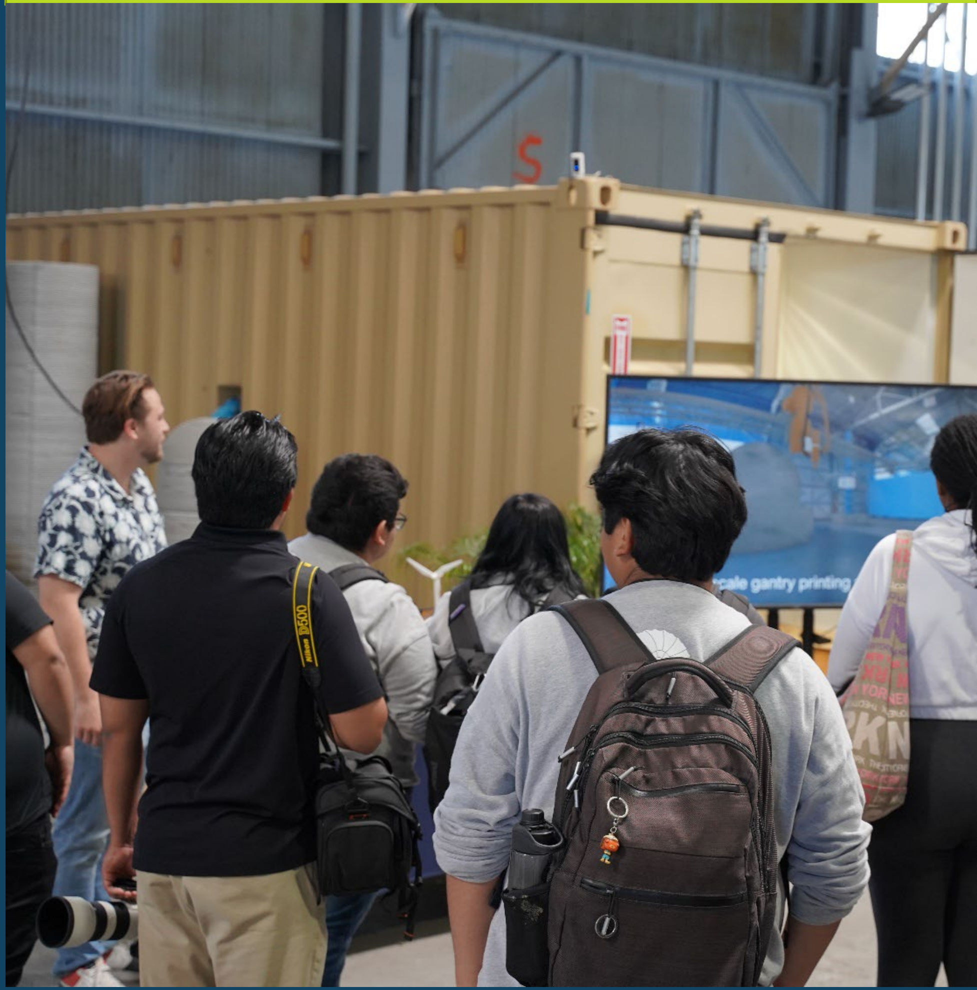
sperra

Objective: Disseminate project information to the developer advisory panel and publicly.

25+ industry events attended / presented at

3 appearances on Live TV

Over 1,000 tours of our R&D facility and counting



FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

sperra

Thank you!

Low-Cost, Environmentally-Friendly, Concrete Anchors Made in California

EPC-23-003

Jason Cotrell

CEO & Founder, Sperra

Jason.Cotrell@sperra.com

https://www.linkedin.com/in/jason-cotrell

Mason Bell

Anchor Product Manager, Sperra

Mason.Bell@sperra.com

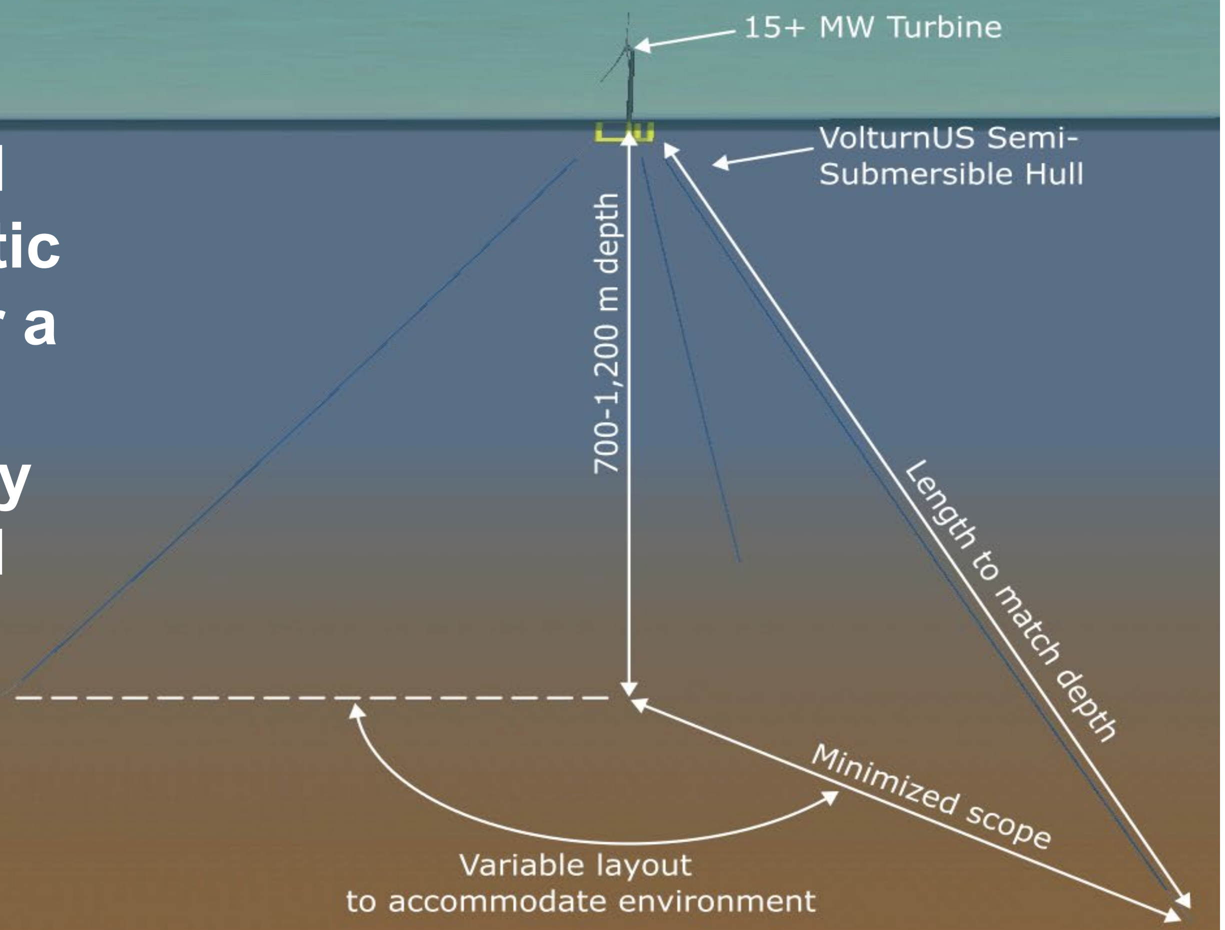
https://www.linkedin.com/in/mason-bell-sperra/

1865 THE UNIVERSITY OF MAINE

ADVANCED STRUCTURES & composites center

Design, Validation, and Certification of a Synthetic Mooring Line System for a 15+ MW Floating Wind Turbine in the Morro Bay and Humbolt Bay Wind Energy Areas

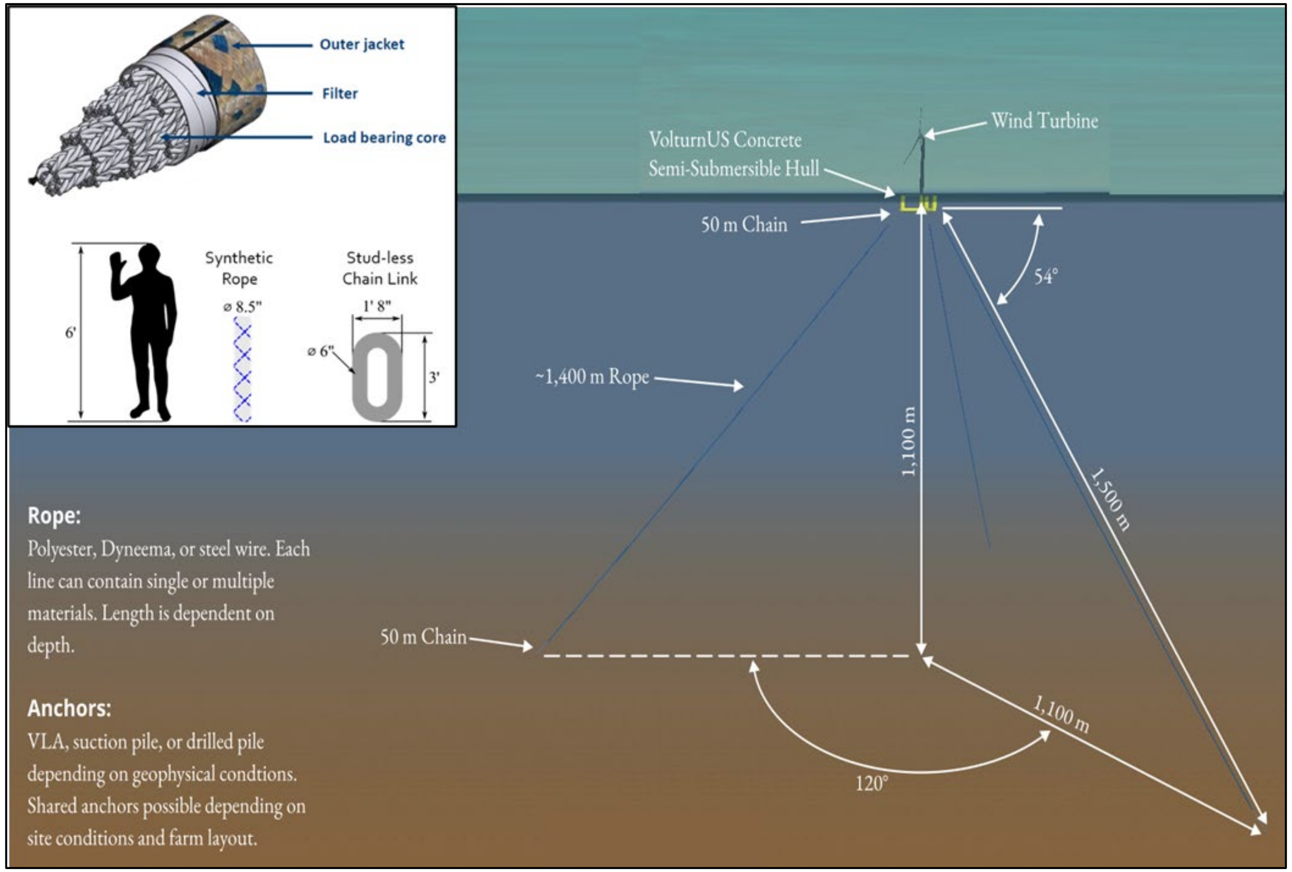
Dr. Spencer Hallowell,
University of Maine



Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Motivation

- 5 GW of offshore wind requires 1,000 km of mooring lines
- Develop a taut-synthetic mooring system to 50% FEED level
- Emphasize minimizing jewelry and connections, and increasing ease of installation
- Minimize environmental impact to the ocean resource



Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Collaborators

Affiliation	Role

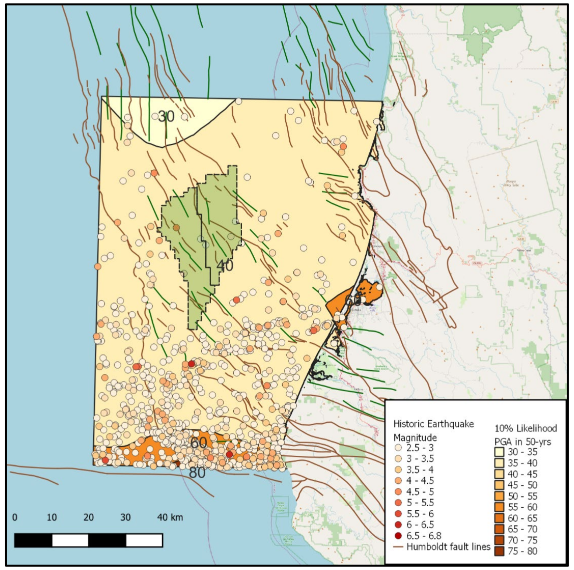
The University of Maine; Advanced Structures & Composites Center	• Principle Investigator
	• Coordinate subcontractors
	• Responsible for:
	  • Mooring design at 25% and 50% FEED Level
	  • 1:47 Scale Model Basin Test at Harold Alfond W^2
	  • Environmental Risk Assessment

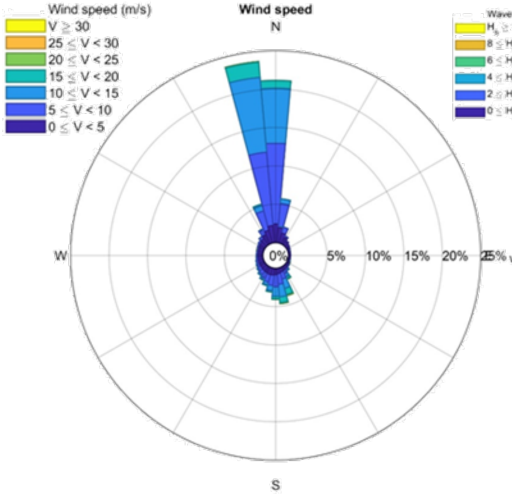
DELMAR	• Mooring design support • Cradle to grave installation, O&M, and decommissioning philosophy • Anchor design specific to mooring and CA environment, including seismicity • Mooring integrity management plan and risk workshops
BRIDON · BEKAERT THE ROPES GROUP	• Synthetic rope properties custom to mooring design • Support design of synthetic mooring components • Support cradle to grave installation, O&M, and decommissioning philosophy • Mooring integrity management plan and risk workshops
ABS	• Design document review: • Basis of design, mooring design, installation, O&M, and decommissioning philosophy, scale model test report, integrity management plan, design drawings • Provide subject experts for Risk Assessment Workshop • Approval in Principle (AIP) letter attesting to feasibility of design

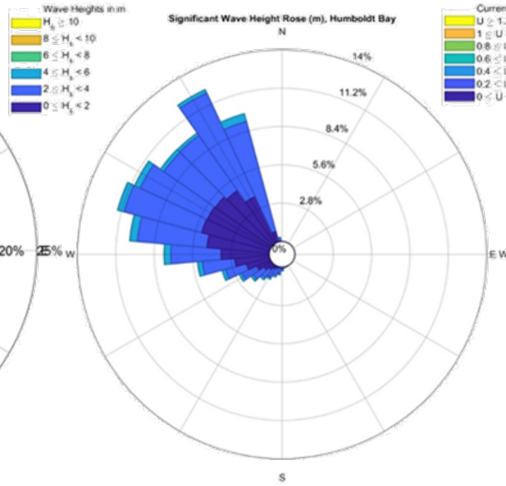
Project Accomplishments: Basis of Design

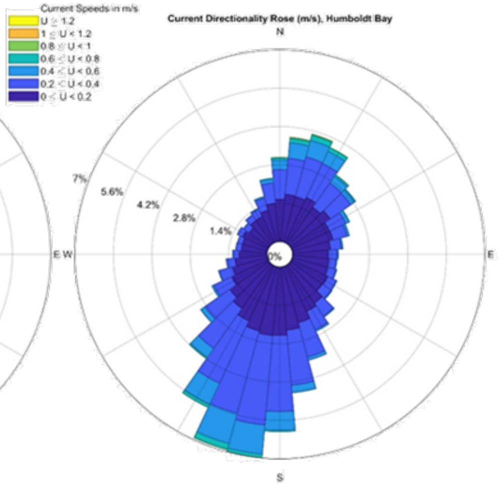
- Lays out design assumptions for 25% and 50% FEED
- Reviewed and approved by ABS as part of AIP

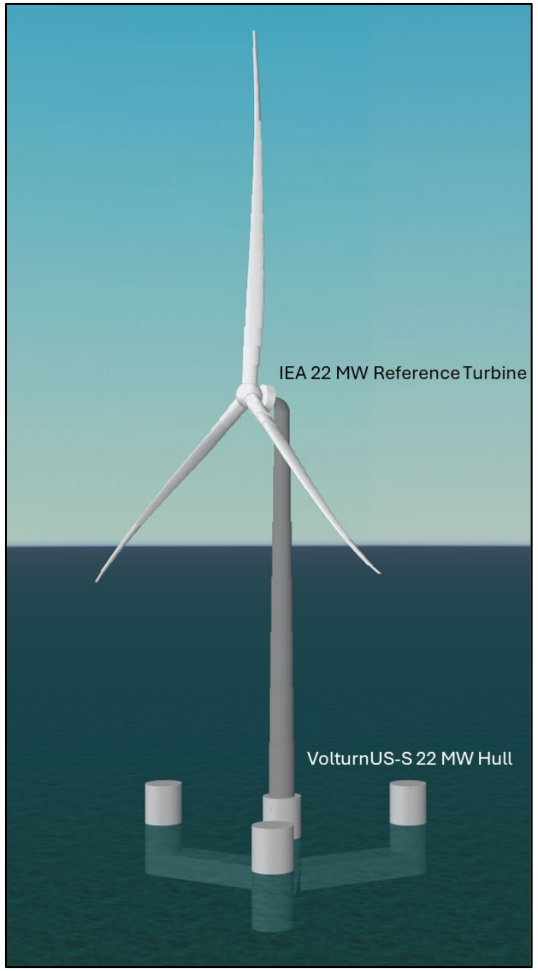
Return Period (years)	U_{150} (m/s)	H_S (m)	T_p (s)	Surface Current (m/s)
1	27.5	5.9	12.7	0.9
10	31.3	7.9	14.8	1.1
50	33.2	10.6	17.1	1.2
100	33.9	12.2	18.4	1.3
500	35.3	15.7	20.8	1.4











Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: 25% FEED Design Load Cases (DLC)

Turbine Condition	ABS DLC[1]
1) Power production	1.2
	1.6
6) Parked, standing still or idling	6.1
	6.2
10) Redundancy	10.1
SLC	I1
Seismic	S3
	S4
Environmental	E3

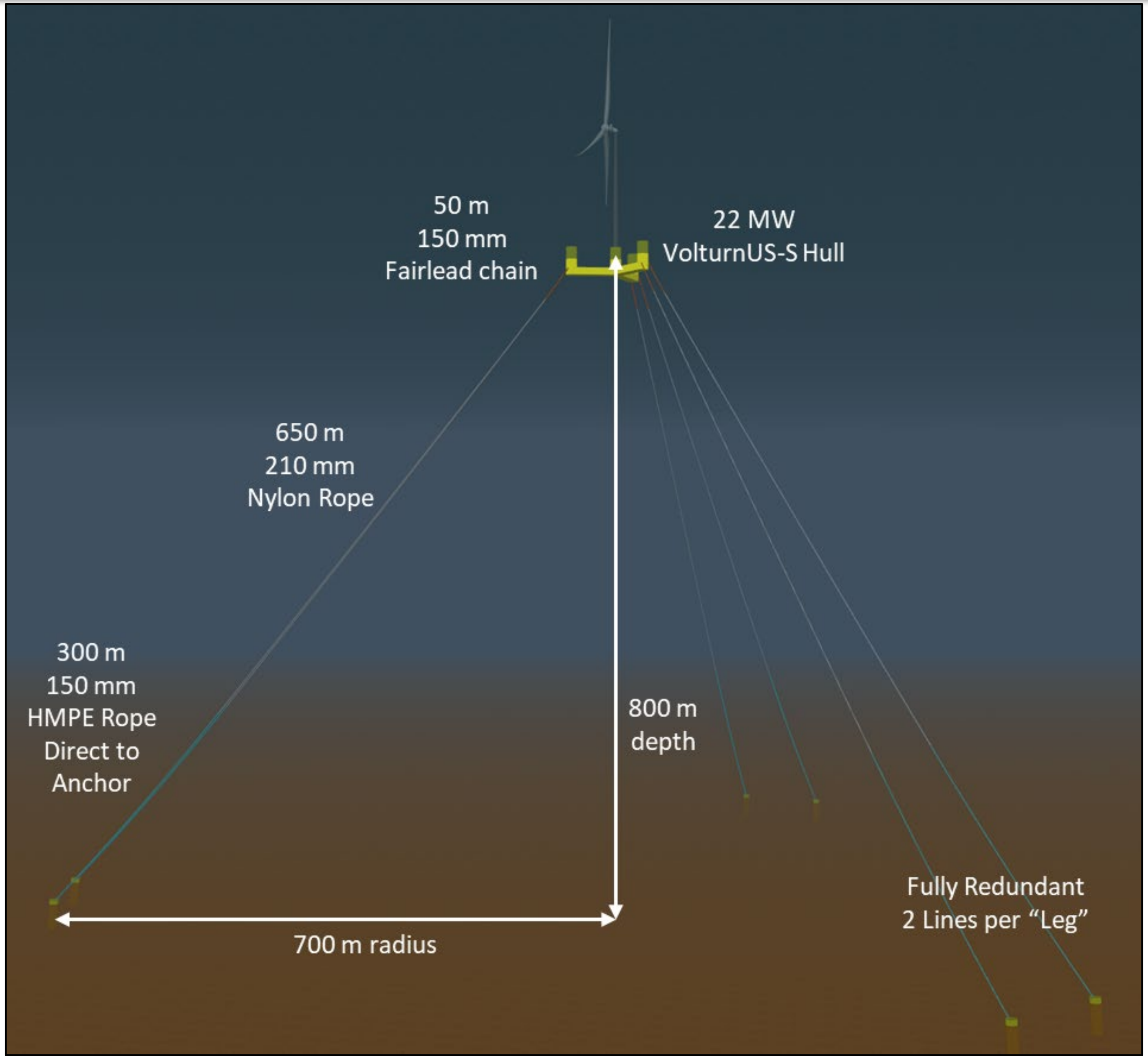
1 From American Bureau of Shipping. *Guide for Building and Classing Floating Offshore Wind Turbines*, Chapter 5 Section 2. July 2020 edition

For each turbine condition:

- Wind
- Waves
- Wind and wave directionality
- Current
- Water level
- Safety factor

Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

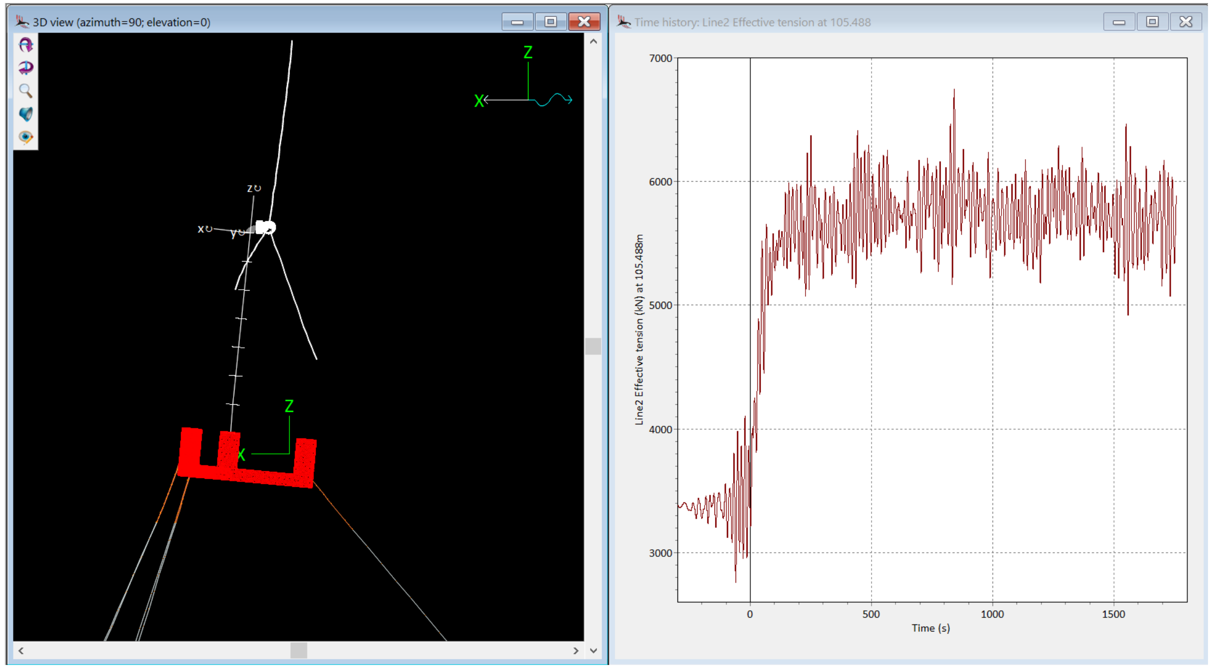
Project Accomplishments: Mooring Design

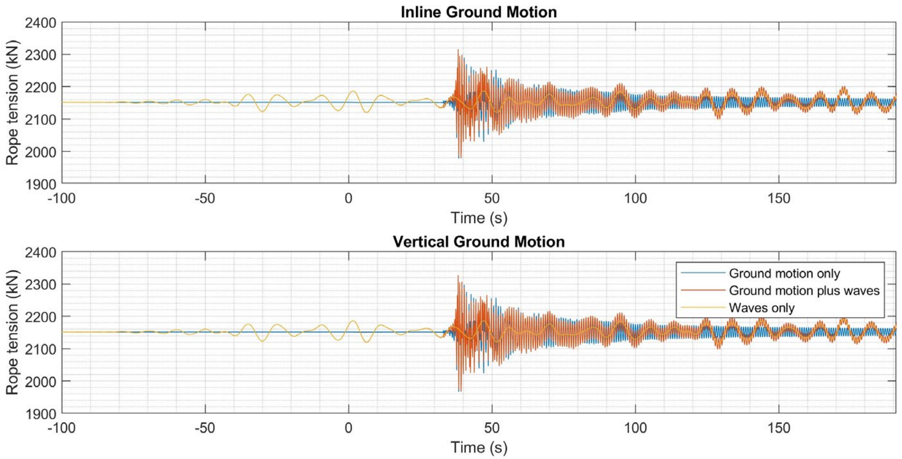


Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: Mooring Design Loads and Offsets

- Redundancy: 1-line failed condition
  - Peak tension occurs *after* turbine is arrested from transient state
  - Mean tension is greatly increased in line failed configuration (nearly doubled)
  - Stationkeeping is maintained
  - Factored tensions are less than other DLCs
- M6.2 Earthquake ground motions amplify line tensions by ~10%
- Peak tensions during average operational state much less than extreme cases (1.6 and 6.1)
- Further work to investigate combinations with higher seastates needed

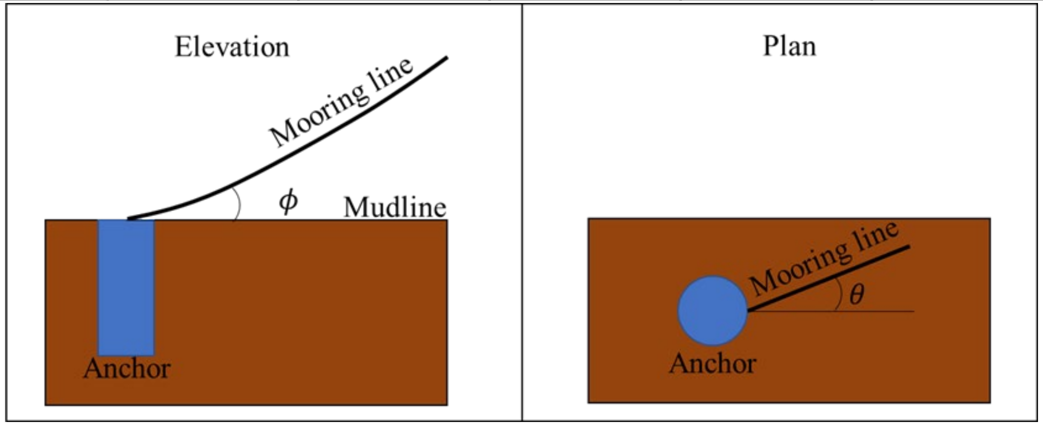


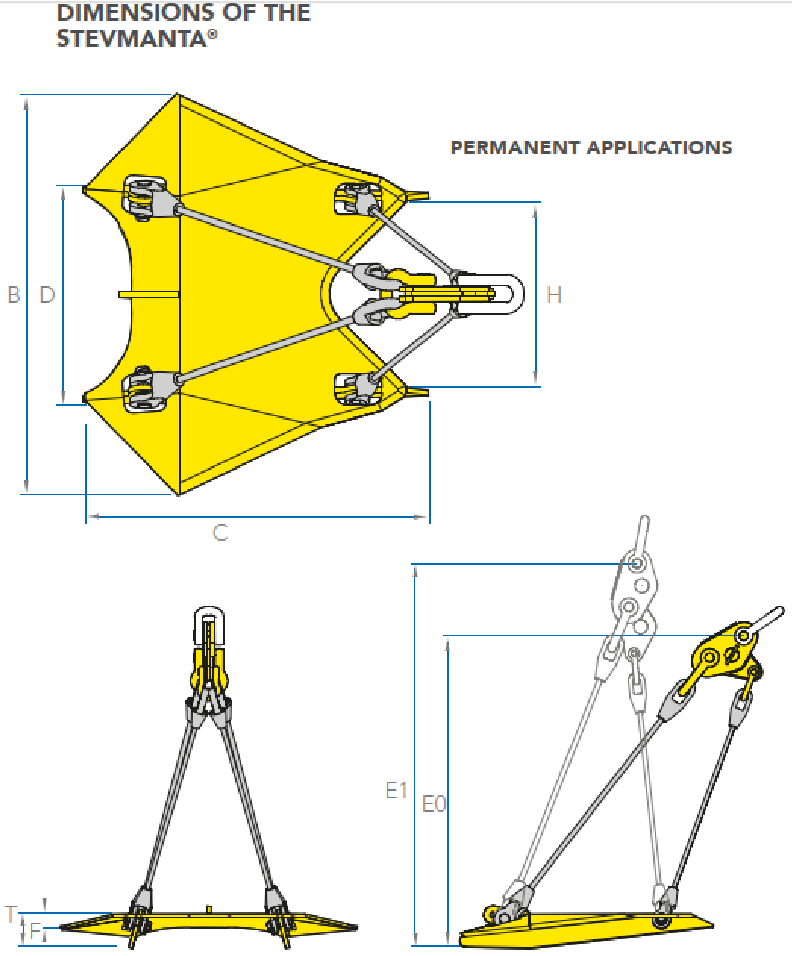


Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: Anchor Designs

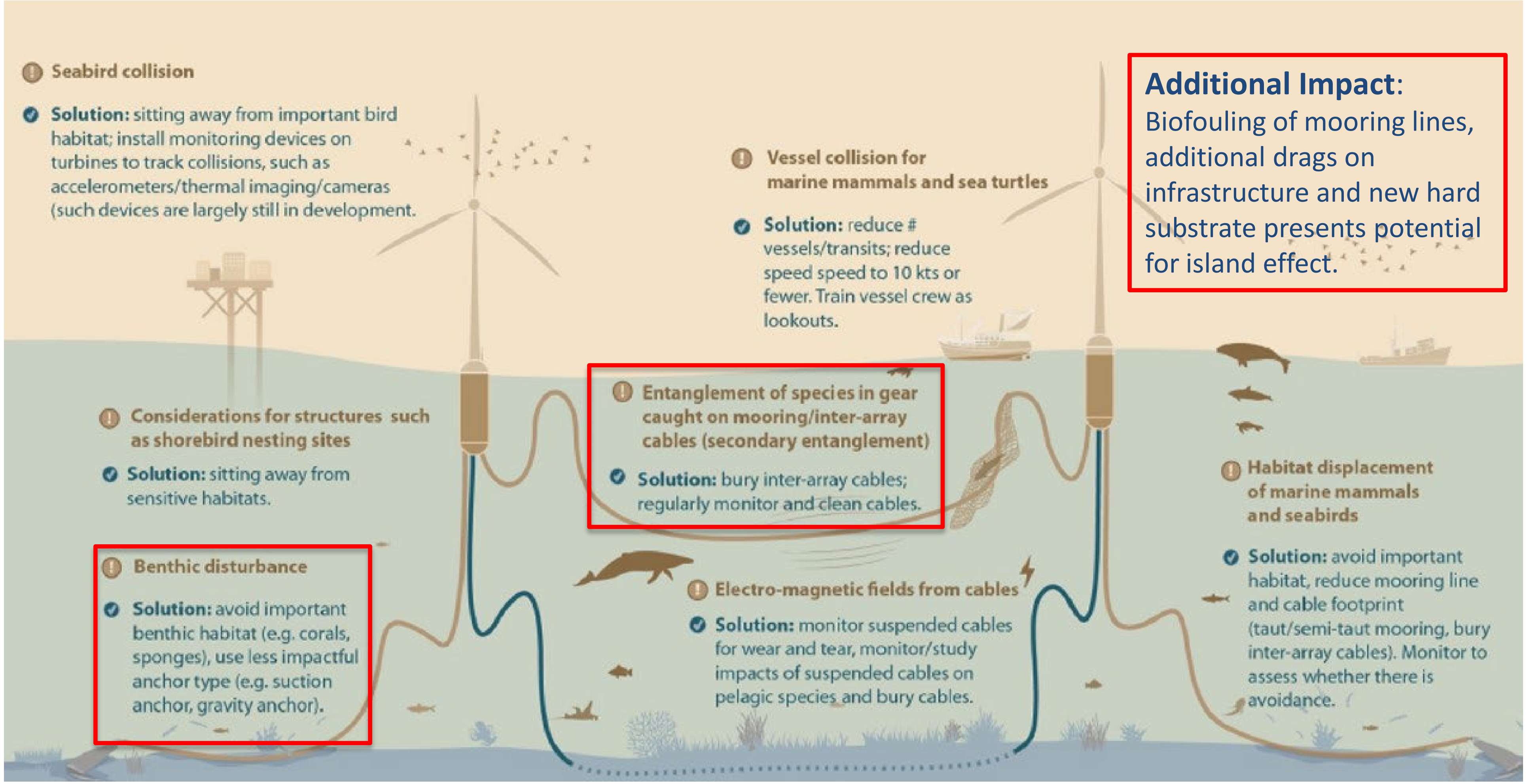
	Independent Variable	Dependent Variable $T(t)$	Dependent Variable $\phi(t)$	Dependent Variable $\theta(t)$	
DLC 1.6	T_{max}	3130	47.3	-0.1	
	ϕ_{max}	3121	47.4	-0.1	
	θ_{max}	2262	46.3	0.2	
DLC 6.1	T_{max}	4481	47.3	0.2	
	ϕ_{max}	4413	47.4	0.2	
	θ_{max}	3284	46.5	0.3	
SLC	T_{max}	6405	47.4	0.0	
	ϕ_{max}	6389	47.7	0.0	
	θ_{max}	4297	47.0	0.5	
Overall Maxima		6405	47.7	0.5	Controlling DLC
Overall Envelope	T_{max}	6405	47.4	0.0	SLC
	ϕ_{max}	6389	47.7	0.0	SLC
	θ_{max}	4297	47.0	0.5	SLC





Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: Environmental Impact



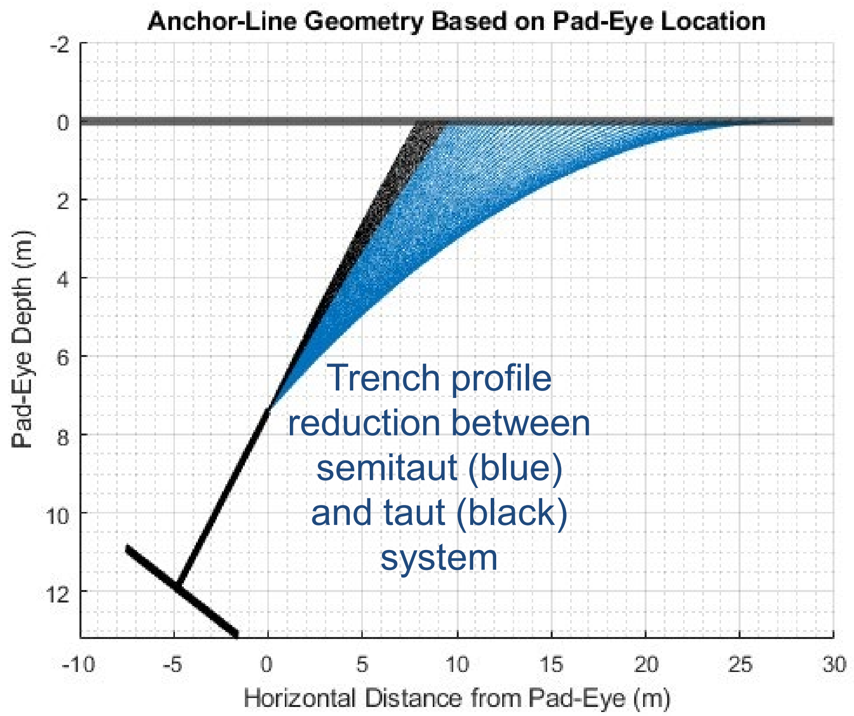
Additional Impact: Biofouling of mooring lines, additional drags on infrastructure and new hard substrate presents potential for island effect.

Potential floating offshore wind environmental impacts (figure from Maxwell et al. 2022).

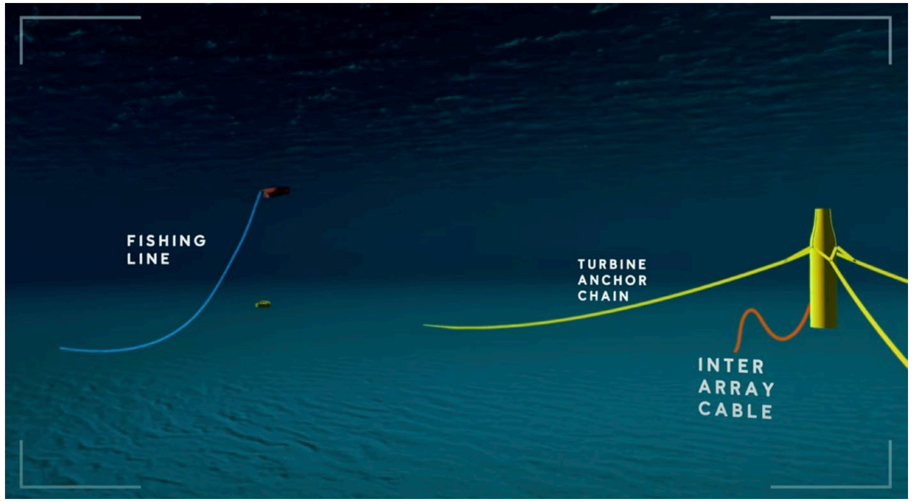
Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: Benthic Impact

- Trenching impacts are reduced from 275 m^3 to 50 m^3 per mooring between semi-taut and taut systems (825 m^3 vs. 300 m^3 total)
- Anchor impact of 790 m^3 over 3 anchors vs. 1590 m^3 over 6 anchors
- Surface sediment (biologically active) impacts are reduced while deep sediment (not biologically active) impacts are consistent



Fully developed fouling community (Holm et al. 2008).



Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

1865 THE UNIVERSITY OF MAINE

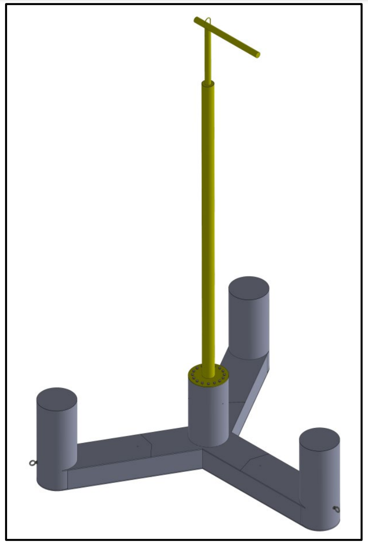
Project Accomplishments: Model Build Progress

ADVANCED STRUCTURES & composites center

General System	Full Scale	Test Scale	Units
Hull Displacement	31678	0.3319	m^3
Total Mass	31857724	333.78	kg
CGx	-0.326629323	-0.007	m
CGz	17.69	0.387	m
Ixx	84568506706	424.26	kg m^2
Iyy	84337872499	423.10	kg m^2
Izz	66907031143	335.65	kg m^2

RNA	Full Scale	Test Scale	Units
Hub height	189.23	4.14	m
RNA mass	1207946.484	12.66	kg
CGx	-8.614344308	-0.188	m
Cgy	-0.11	-0.002	m
CGz	189.7	4.15	m

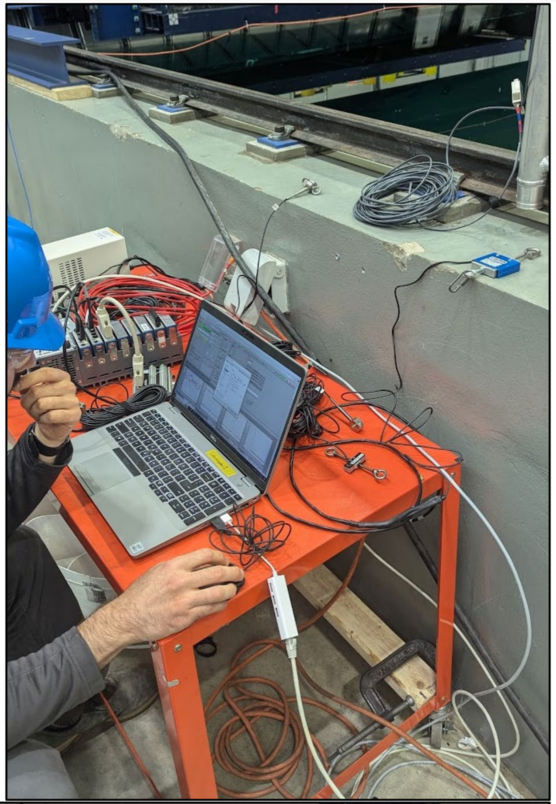
Tower	Full Scale	Test Scale	Units
Tower Length	149.4	3.27	m
Tower mass	1586518.217	16.62	kg
CGz	97.1	2.125	m

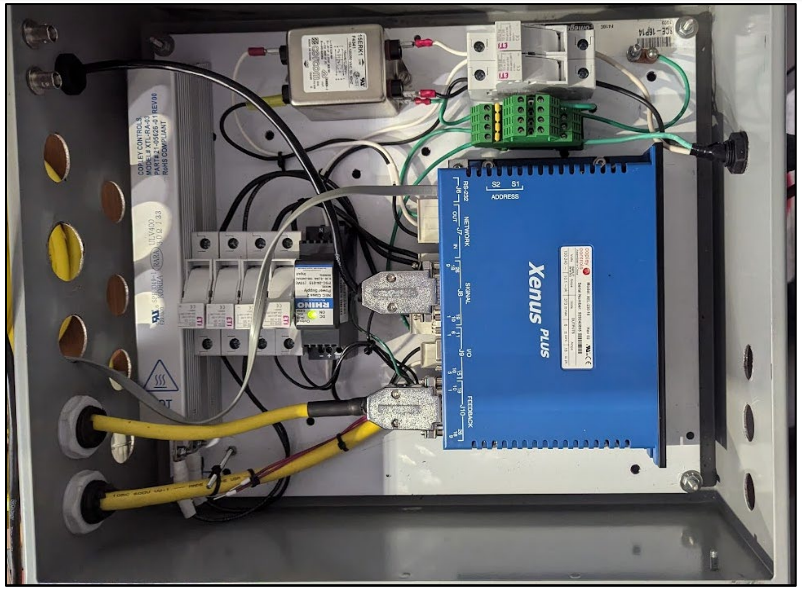


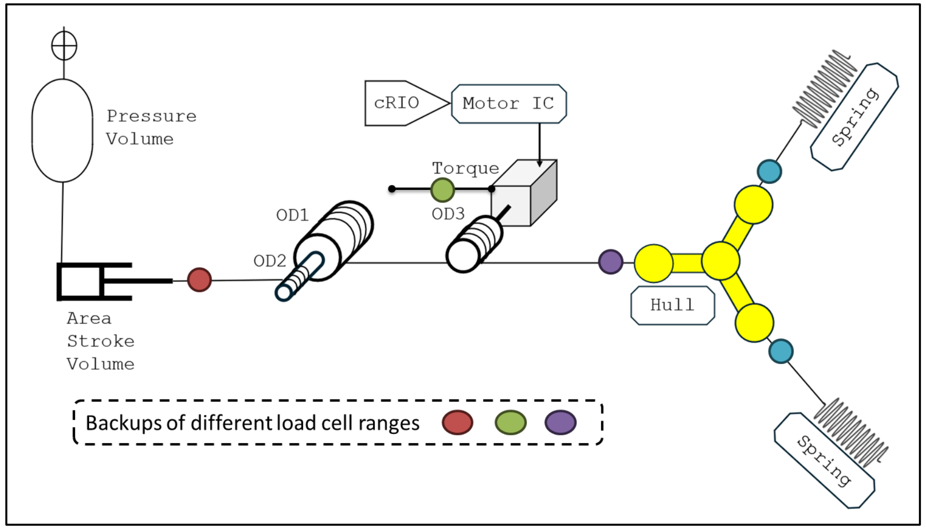
Nate Faessler, MBA – Test Engineer
nathan.Faessler@maine.edu

Research, Education, and Economic Development

Project Accomplishments: Active Mooring Update

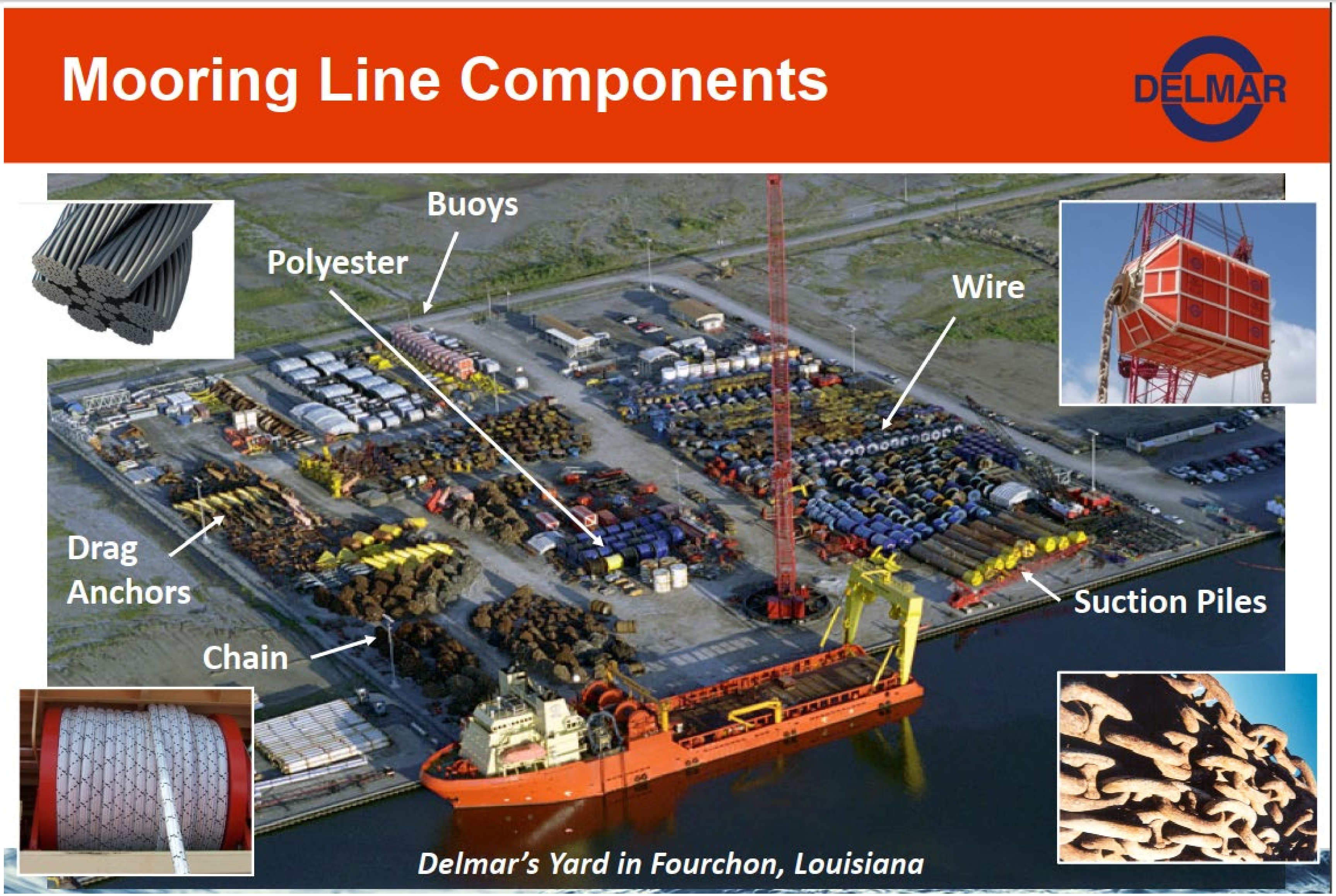







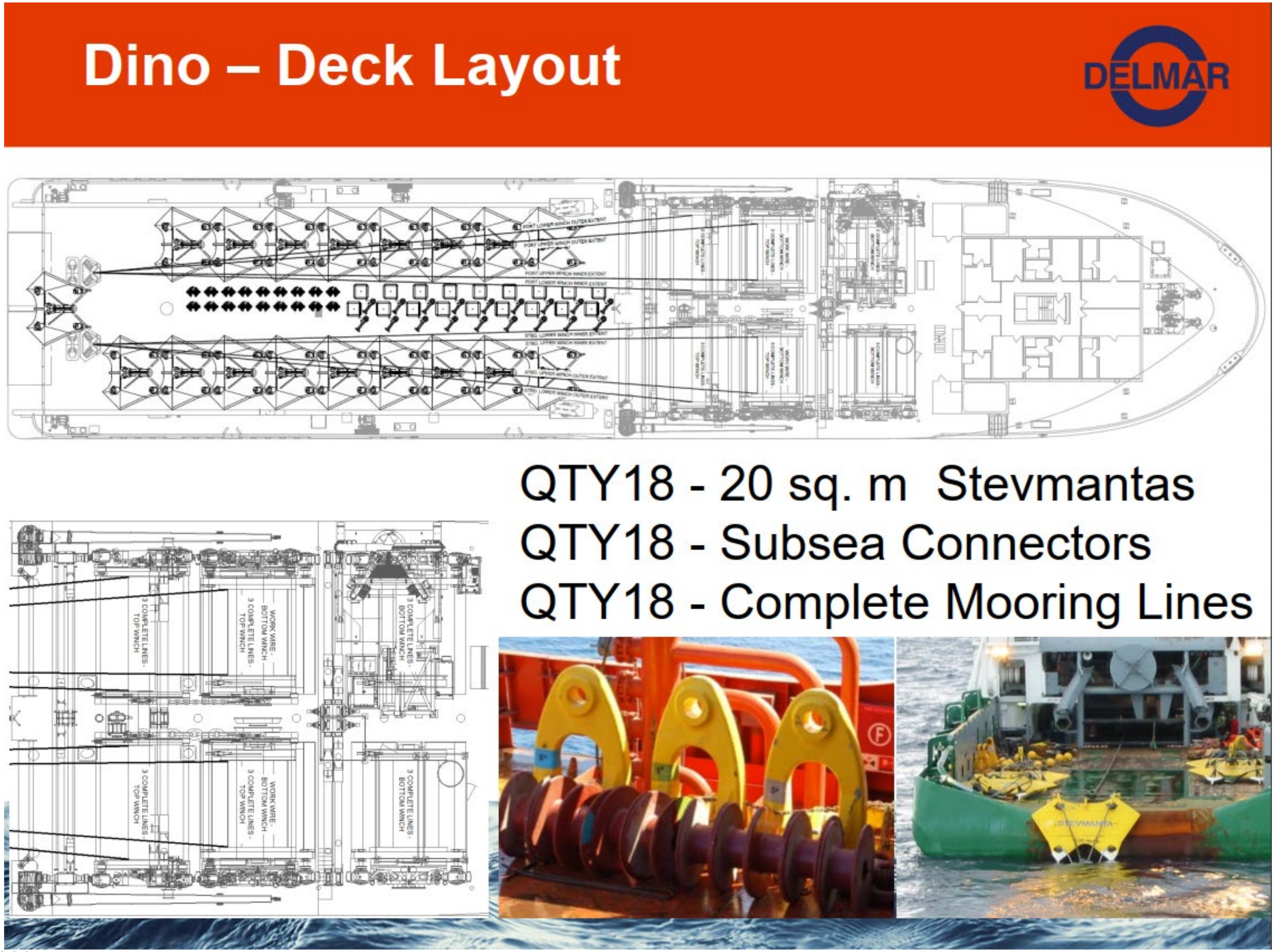
Nate Faessler, MBA – Test Engineer
nathan.Faessler@maine.edu

Project Accomplishments: Mooring Storage Requirements



Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Project Accomplishments: Vessel Requirements

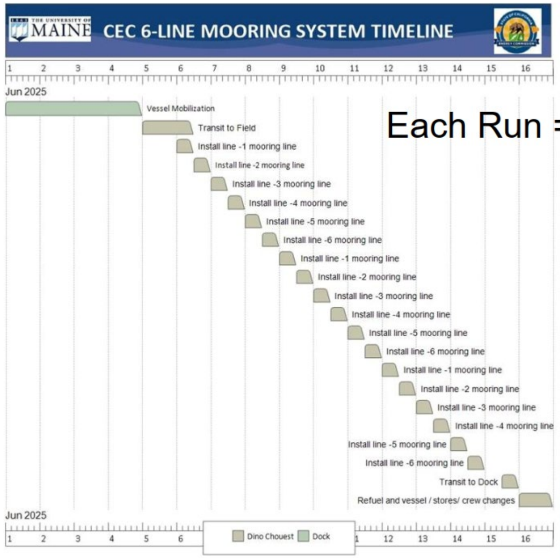


Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

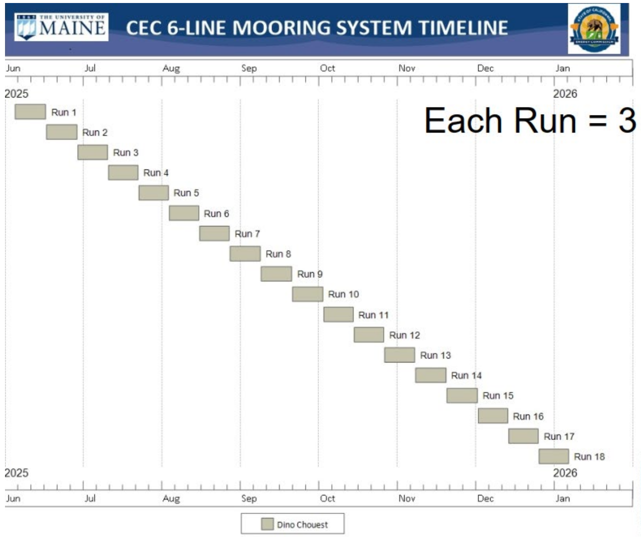
THE UNIVERSITY OF MAINE 1865

ADVANCED STRUCTURES & composites center

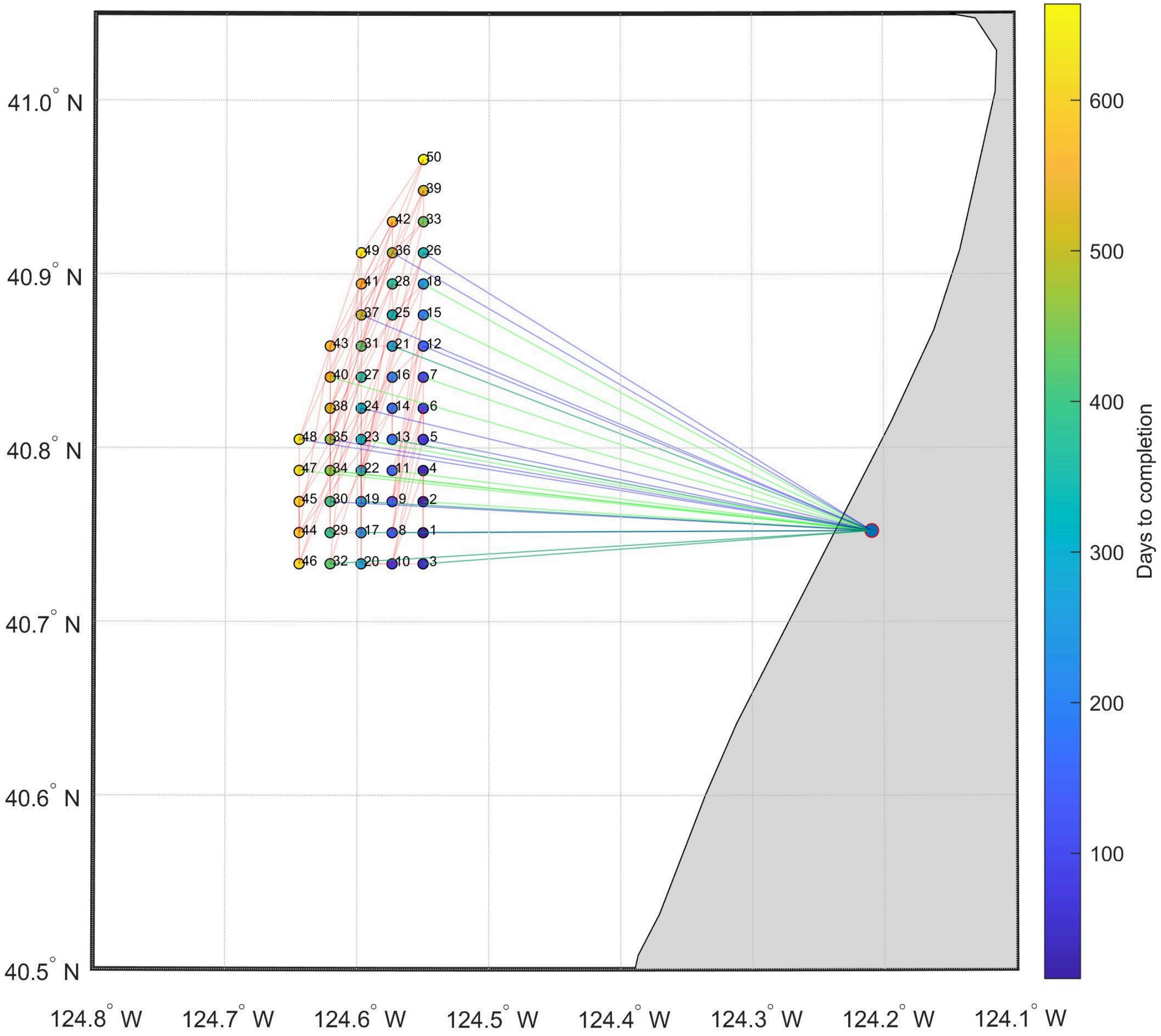
Project Accomplishments:
AHV Transit History



Each Run = 3 FOWT



Each Run = 3 FOWT



Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Research, Education, and Economic Development

Future Work

- 1:47 Scale basin test of 22 MW turbine with active control mooring system
- Finalized install, commissioning, decommissioning plan, mooring integrity management report, risk workshop
- Environmental risk analysis
- 50% FEED design of mooring system incorporating learnings from all the above
- ABS AIP

1:4 scale VolturnUS+ under construction. Will be deployed with fully redundant nylon semi-taut mooring system.

Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Acknowledgements

- Katherine Greenwald, Matthew Haro, Mark Danielson and CEC team
- Technical Advisory Committee
- Jack Clark, Everett Rzeszowski, Damian Brady, Nathan Faessler and the rest of the UMaine team
- Delmar, Bridon and ABS teams

Spencer Hallowell, Ph.D., Senior Engineer
spencer.hallowell@maine.edu

Mooring Sensors for Environmental Awareness (MoorSEA) Project Updates

Environmental Data Memo and Simulation Modeling
- Progress to Date -

Presenters:

Greyson Adams – *Schatz Center*
Erica Escajeda, Ph.D. – *H.T. Harvey & Associates*

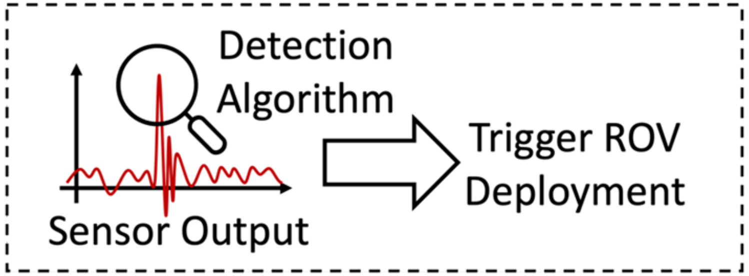
Schatz Energy Research Center

H. T. HARVEY & ASSOCIATES
Ecological Consultants

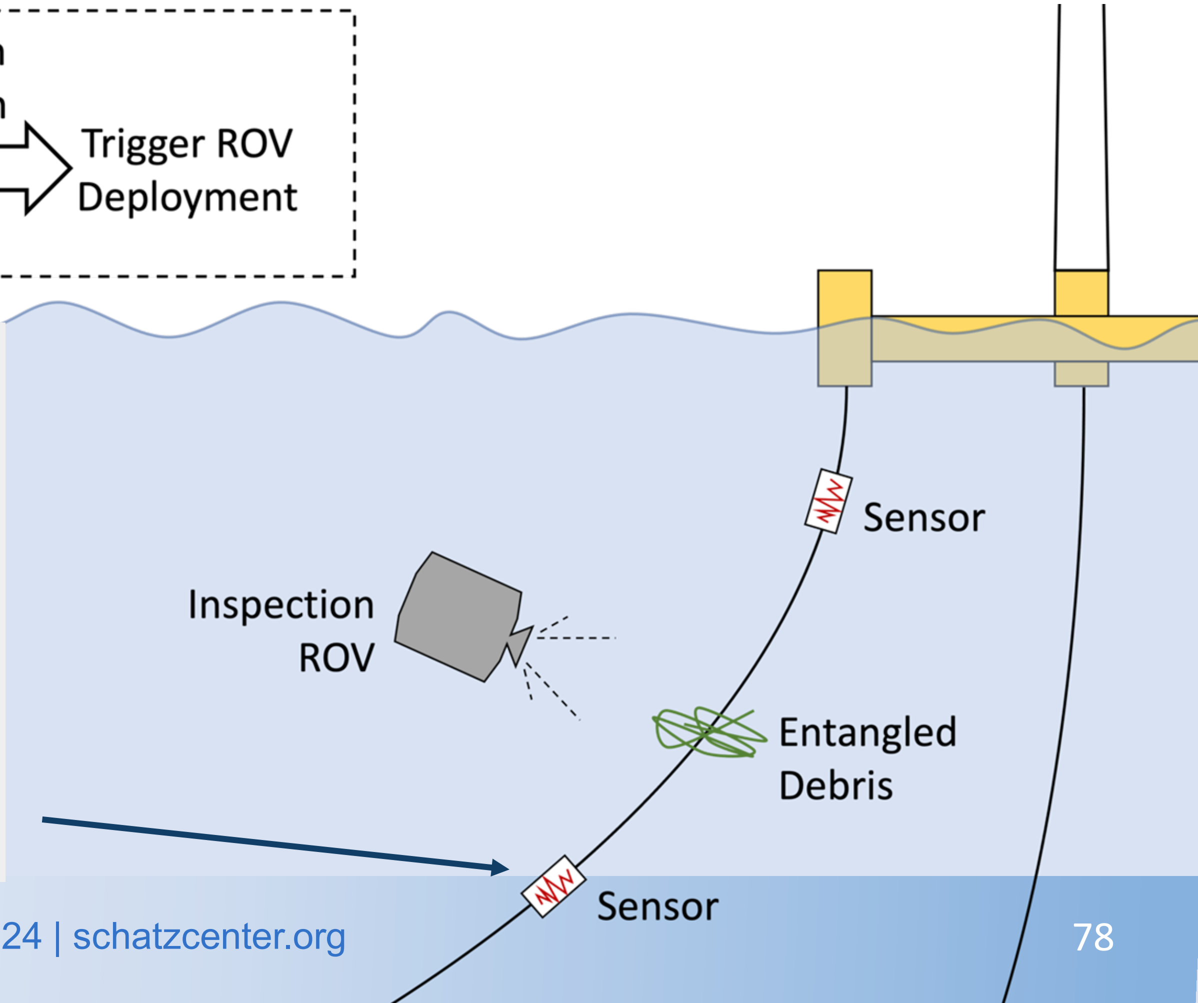
http://schatzcenter.org/wind/ - https://www.harveyecology.com/

Mooring Sensors for Environmental Awareness (MoorSEA)

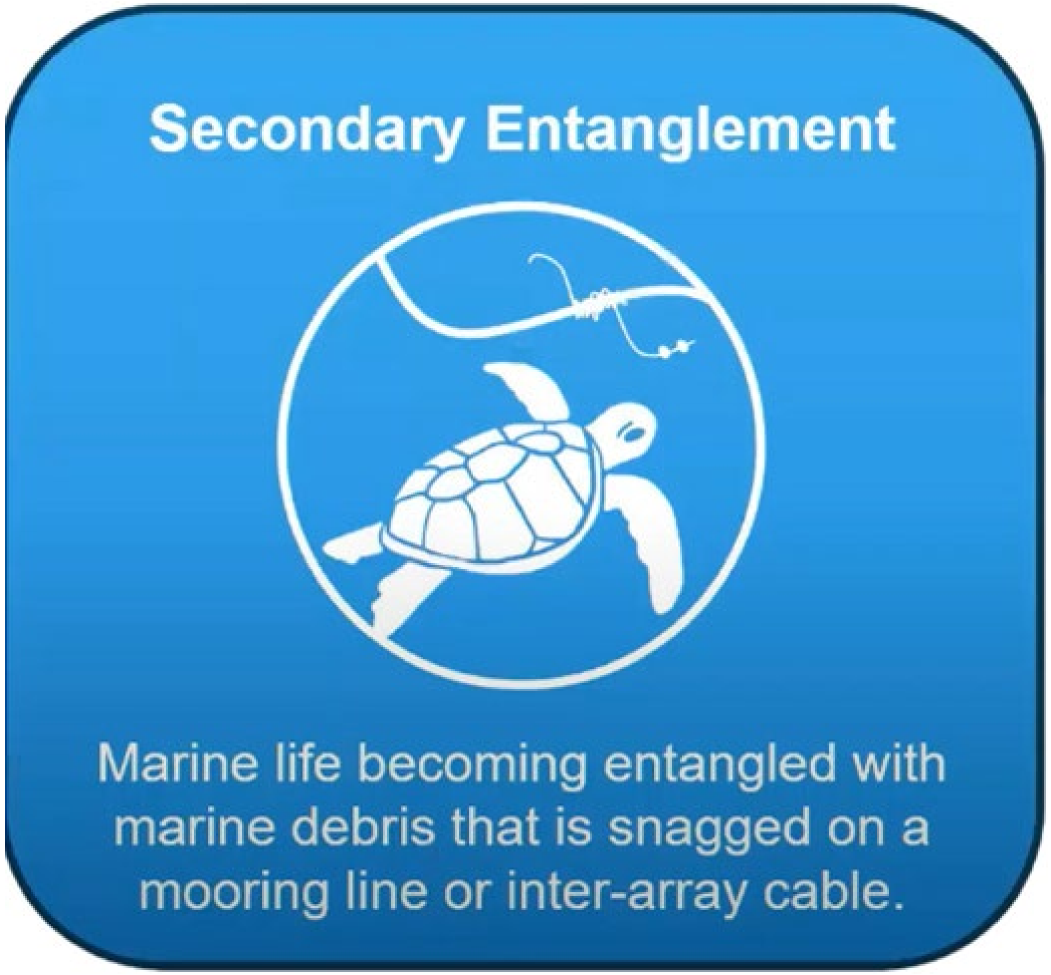
A potential monitoring solution



1) Model baseline and entanglement scenarios
2) Develop detection sensor package
3) Detection algorithm identifies entanglement
4) System notifies human operator
5) Operator dispatches inspection ROV

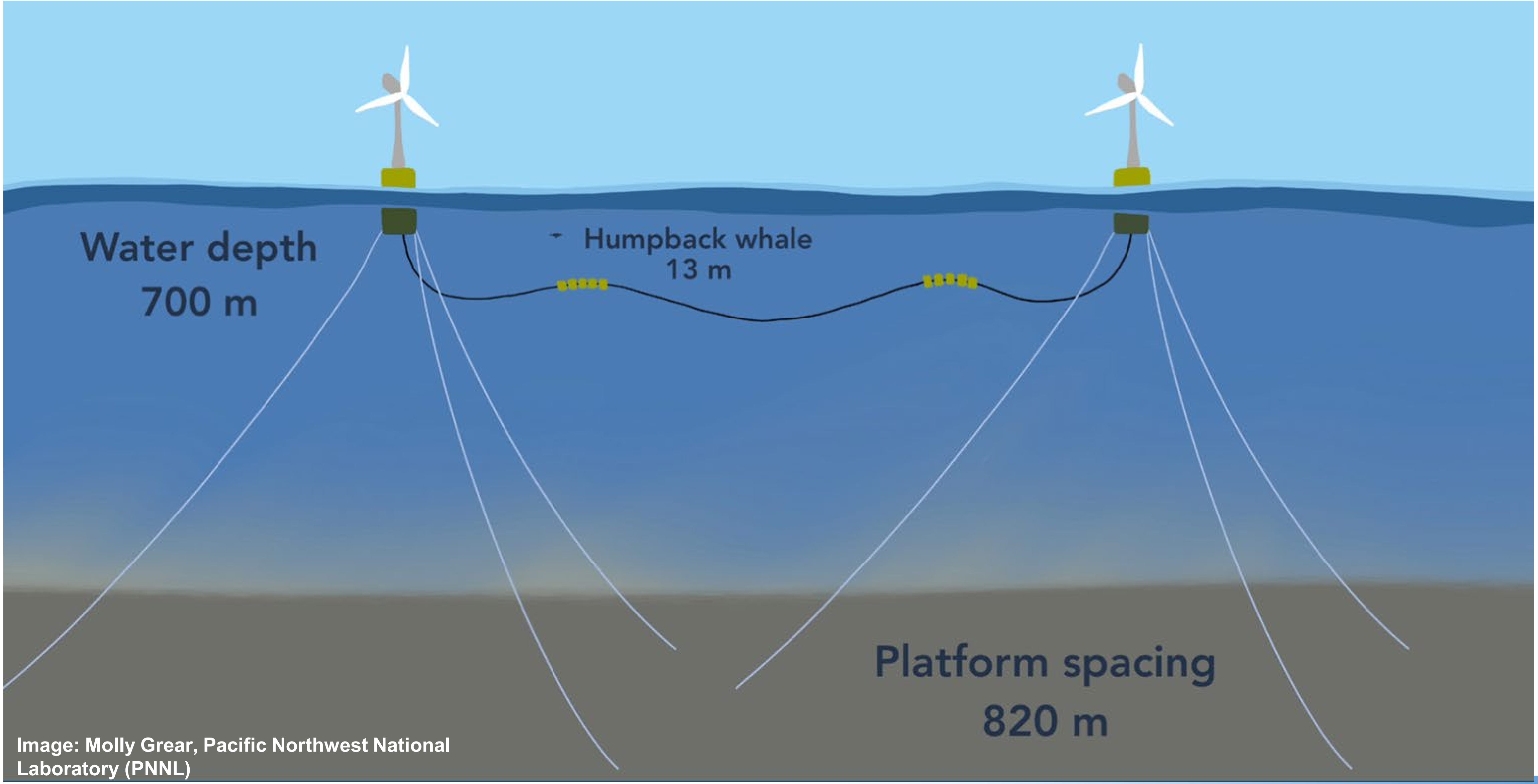


Entanglement and Floating Offshore Wind

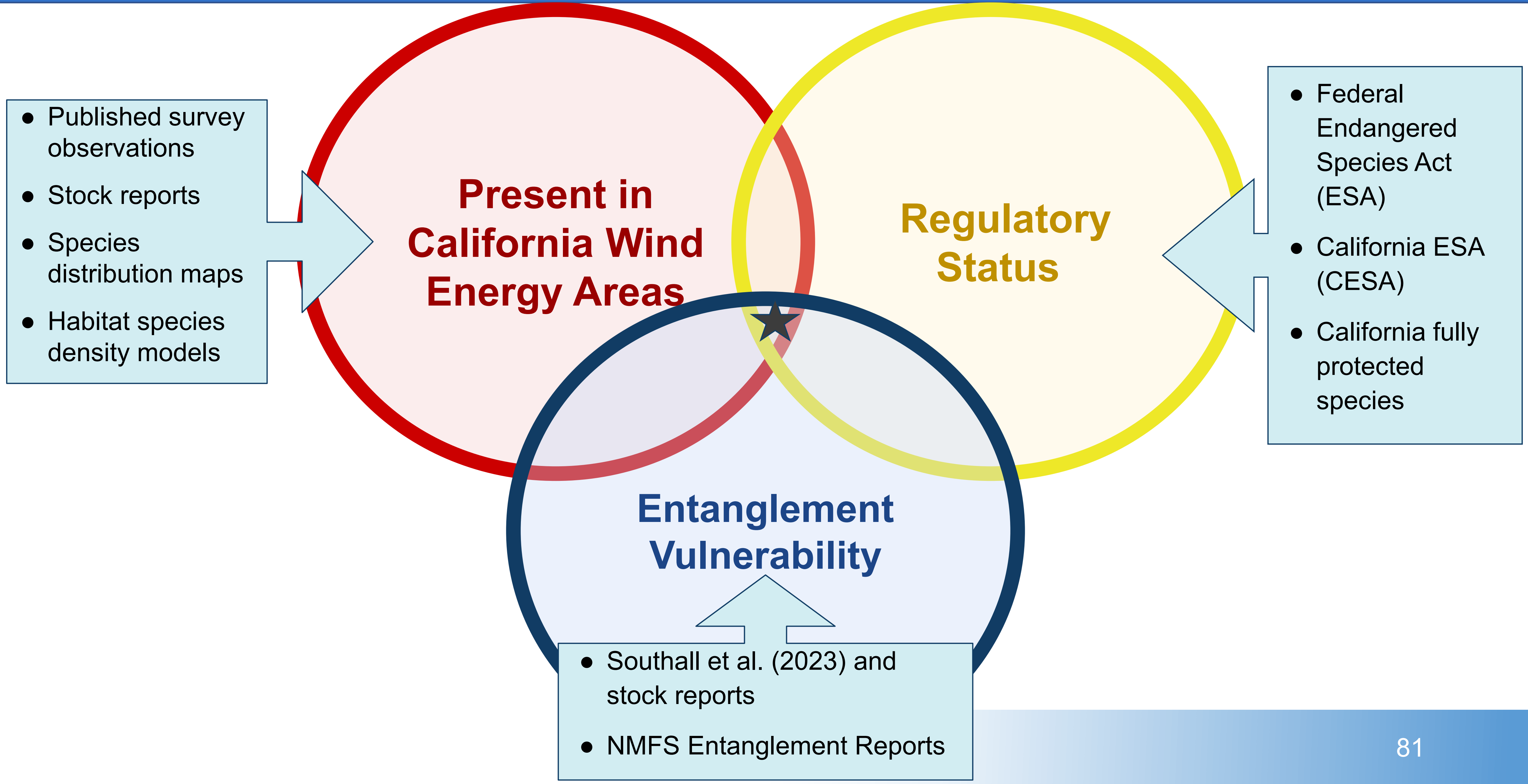


SEER
U.S. OFFSHORE WIND SYNTHESIS OF ENVIRONMENTAL EFFECTS RESEARCH

Floating Offshore Wind Installations



Key Species Selection Process



Selected Key Species

Baleen Whales

Humpback Whale

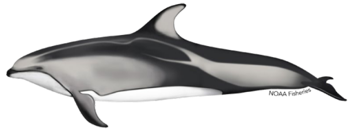
Blue Whale

Toothed Whales & Dolphins

Killer Whale

Sperm Whale

Pacific White-Sided Dolphin



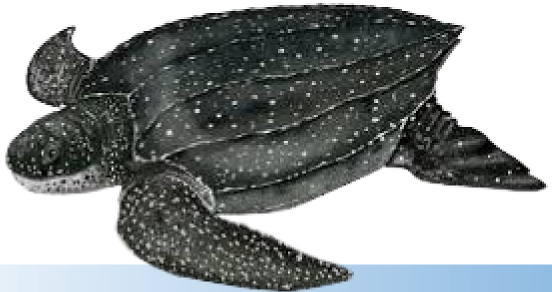
Pinnipeds

California Sea Lion

Northern Elephant Seal

Marine Reptiles

Leatherback Turtle



Illustrations: NOAA Fisheries

Fishing Gear and Other Marine Debris

Goal: identify the **types of fishing gear and other debris that are most likely to become entangled with FOSW infrastructure** on the U.S. West Coast

No information on gear/debris entanglement on offshore infrastructure so we examined reports on marine mammal entanglements with fishing gear

The following gear types are most often involved in reported entanglement events:

- Crab pots
- Longline gear
- Drag nets

**Efforts to collect info on fishing gear and other marine debris are ongoing*

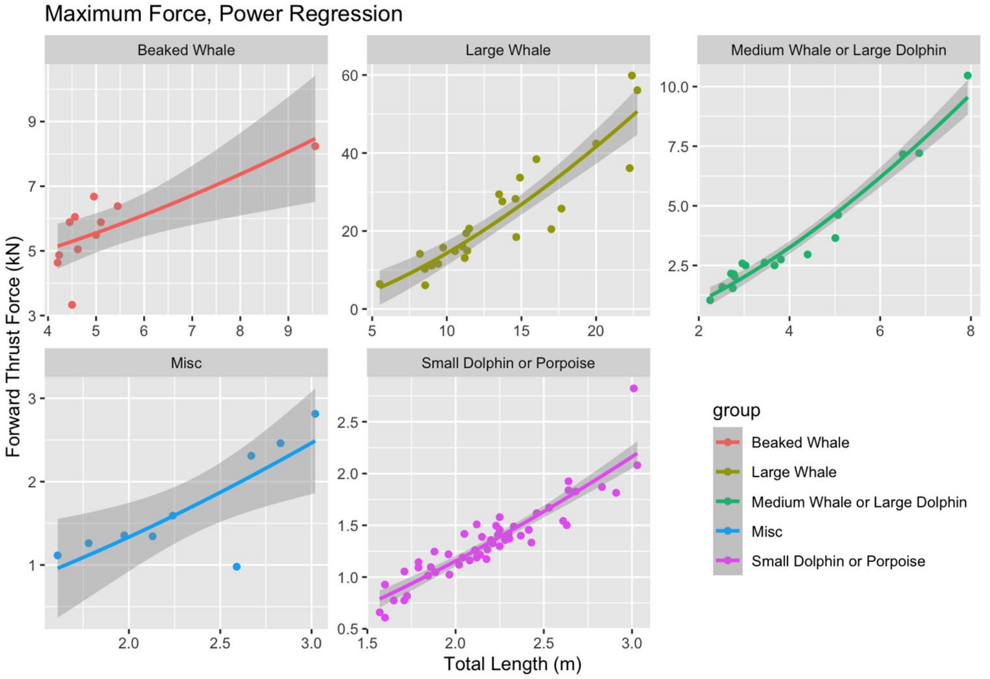
Force Calculations

Goal: estimate **minimum and maximum force of each megafauna species** to inform entanglement modeling efforts

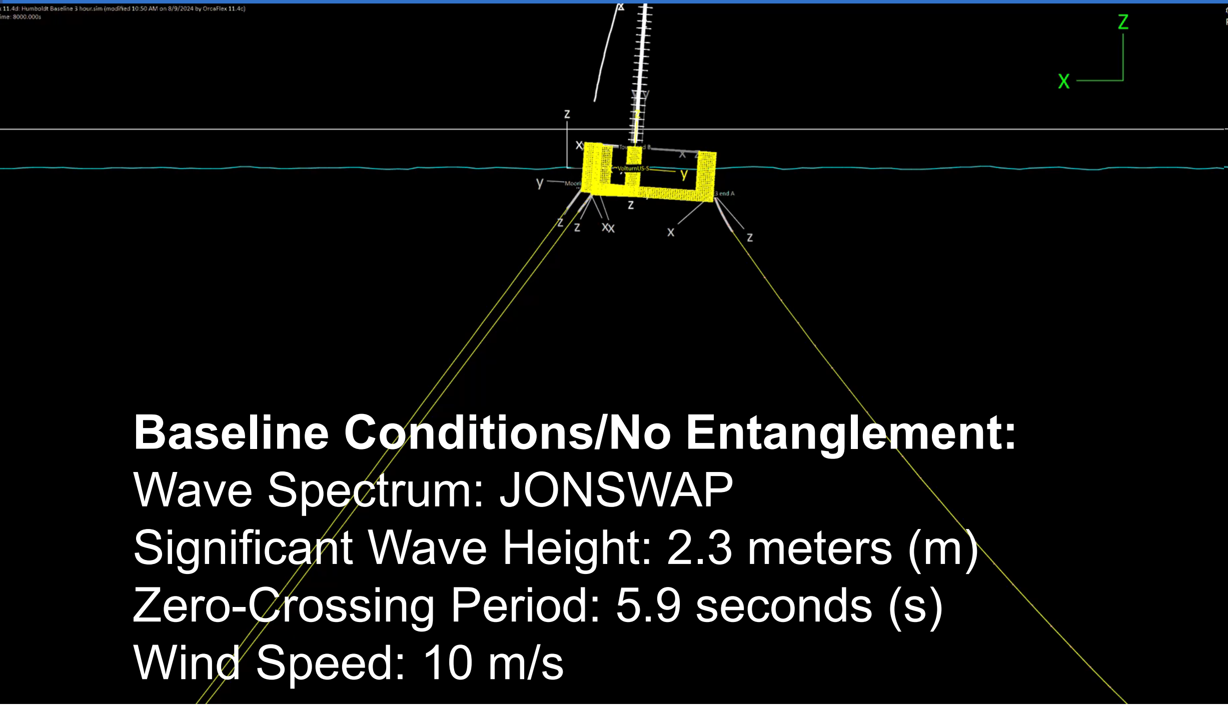
Methods:

1. Measure the cross-sectional area of the largest vertebrae → gives low and high force estimates for the measured individual (Arthur et al. 2015)
2. Measure length of that individual
3. Model relationship between length and force for each size class using linear and power regression

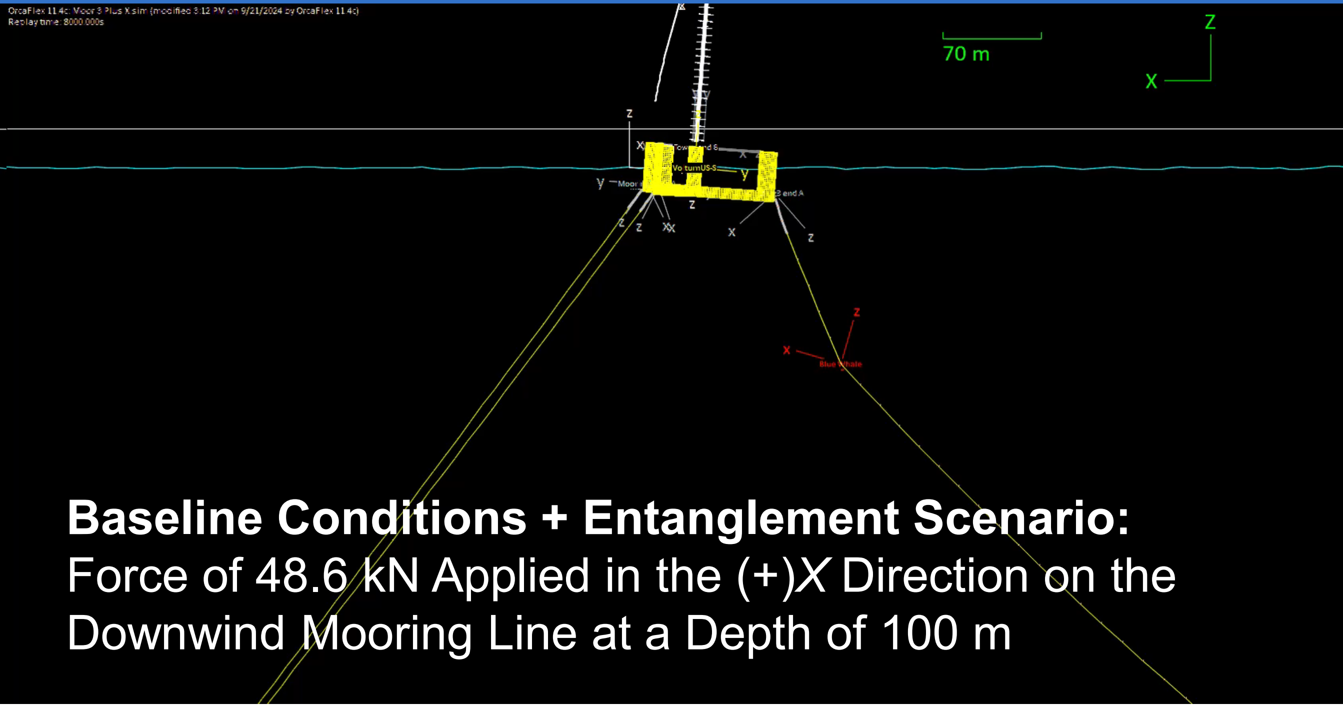
Graduate student researcher Ben Pridonoff holding whale vertebrae



Modeling Results – Current & Ongoing



Baseline Conditions/No Entanglement:
Wave Spectrum: JONSWAP
Significant Wave Height: 2.3 meters (m)
Zero-Crossing Period: 5.9 seconds (s)
Wind Speed: 10 m/s

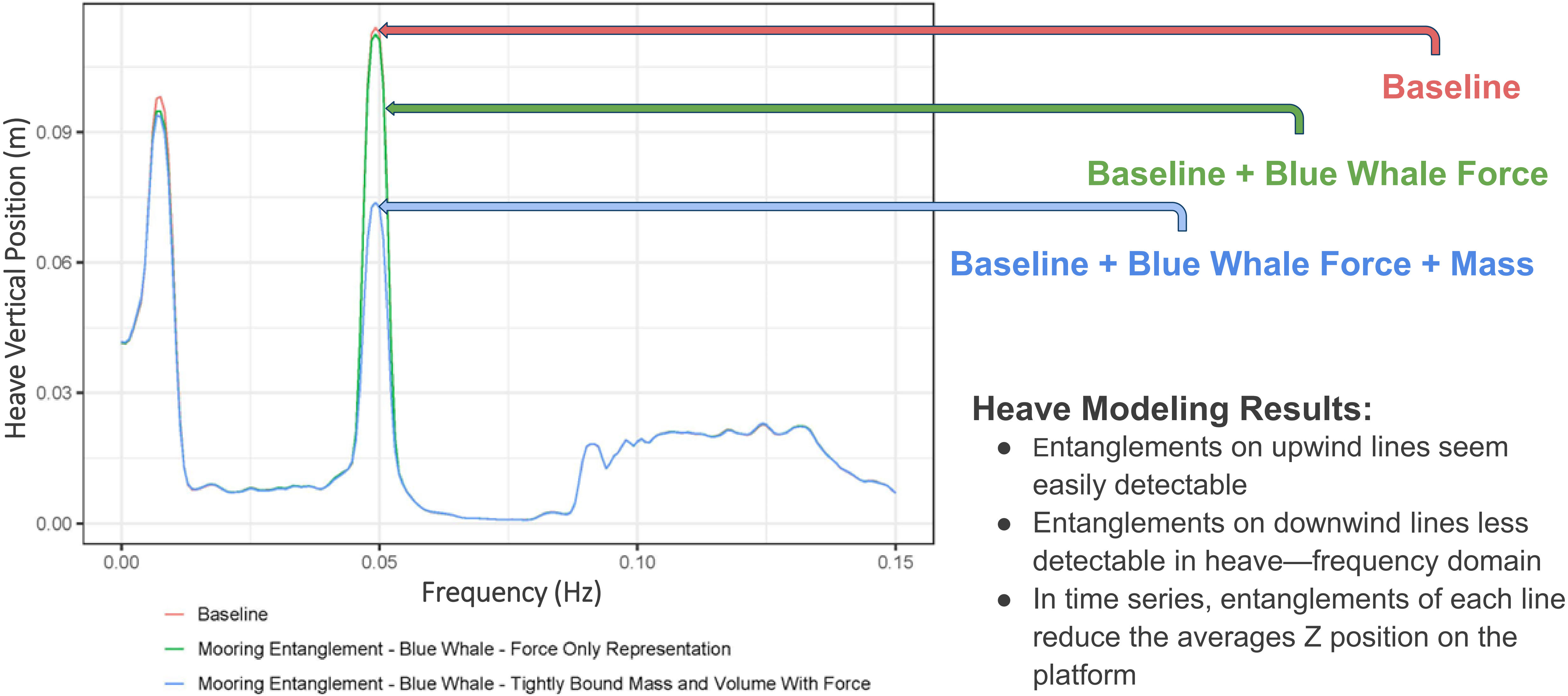


Baseline Conditions + Entanglement Scenario:
Force of 48.6 kN Applied in the (+)*X* Direction on the Downwind Mooring Line at a Depth of 100 m

Simulation Setup:

- 15-MW reference wind turbine on top of an UMaine's VolturnUS-S semi-submersible platform
- Semi-taut mooring system configuration, materials include chain fairlead sections and polyester mooring lines

Modeling Results – Current & Ongoing



Heave Modeling Results:

- Entanglements on upwind lines seem easily detectable
- Entanglements on downwind lines less detectable in heave—frequency domain
- In time series, entanglements of each line reduce the averages Z position on the platform

Looking Forward

Next Steps:

1. Complete sensitivity analyses
2. Finalize primary entanglement modeling and simulations
3. Continue collaboration with PNNL to finalize variables of interest and identify sensors
4. Refine dynamic animal entanglement scenario models and finalize a simplified model

Thank You!

Project Sponsor:

CALIFORNIA ENERGY COMMISSION

Agreement No. EPC-23-006

Full report expected early 2025:
https://schatzcenter.org/publications/

Project Team:

Schatz Team: Arne Jacobson (Lead), Greyson Adams (Project Manager), Charles Chamberlin, Maia Cheli, Maysam Mousaviraad, Eli Wallach, Ben Pridonoff, Ben Hung, Zane Husome, Elias Henderson. **H.T. Harvey Team:** Sharon Kramer, Erica Escajeda.

Schatz Energy Research Center

CAL POLY HUMBOLDT

Project Partners:

Pacific Northwest NATIONAL LABORATORY

MARE

H. T. HARVEY & ASSOCIATES Ecological Consultants

Principle Power

ABS FOUNDED 1862

TRITON ANCHOR™

November 5th, 2024 CEC FOSW Project Webinar

Zachary Miller – CTO

Advanced Anchoring System for California Floating Offshore Wind

Company introduction

We team up with leaders across the industry to advance technologies and derive innovations that are practical and target the pain points of the renewable space

Headquartered in Massachusetts, USA
with additional offices in NY, PA, RI, and TX

Our Mission is to provide cost effective anchoring systems and subsea technologies to the offshore renewable energy industries that are environmentally friendly and enable innovation across the value chain

Programs & grants

U.S. DEPARTMENT OF ENERGY
NATIONAL OFFSHORE WIND RESEARCH & DEVELOPMENT CONSORTIUM
MASSACHUSETTS CLEAN ENERGY CENTER
CALIFORNIA ENERGY COMMISSION
Ocean Energy Safety Institute
TEAMER Testing & Expertise for Marine Energy

MOUs, partners, & collaborators

ABS
INTERMOOR
CROWLEY
T.EN TECHNIP ENERGIES
UCDAVIS CENTER FOR GEOTECHNICAL MODELING
TEXAS A&M UNIVERSITY
THE UNIVERSITY OF RHODE ISLAND
University of Massachusetts Amherst
Katapult
RICE ALLIANCE Rice Alliance for Technology and Entrepreneurship
ossian
CALWAVE
Glosten
Triton Systems Driven to Innovate
wsp
HALEY ALDRICH

TRITON ANCHOR

Project Purpose

Develop an economically responsible and ecologically mindful anchor solution for California's floating offshore wind industry. This anchor solution will be **tailored to California's dynamic seismic environment** with a key focus on **ensuring local manufacturability**.

1. An efficient and proven anchor design based on site-specific soil data and seismic ground models from the California Wind Energy Areas (WEA) to optimize the use of material and configuration to best suite California's environmental and supply chain parameters.

2. A cost-effective, high-uplift capacity anchoring solution that gives developers and platform designers the ability to utilize taut, tension leg, and shared anchoring systems instead of large footprint catenary configurations that interfere with fishing and transportation industries and can disturb much of the seafloor.

3. A modular fabrication system to strengthen the local supply chain and labor industries with the ability to manufacture and assemble the anchors within California and the rate payer's regions.

4. An ecologically responsible, virtually silent installation methodology to enable more cost-effective installation practices with less interference with local and migrating marine life.

TRITON ANCHOR™

Program Objectives & Goals

1. Determine site-specific offshore geotechnical conditions with offshore investigation.
2. Identify, evaluate, and map marine life and habitats most critical to offshore anchor installations and operations for floating wind.
3. Identify, evaluate, and map information related to seismic hazards with respect to anchoring systems.
4. Determine liquefaction susceptibility of the offshore soils and site-specific response spectrum.
5. Develop anchor designs with reduced seabed space and shared mooring spreads.
6. Design site specific anchor designs validated through centrifuge testing and finite analysis modeling.
7. Create a feasible supply chain roadmap and local community's benefits summary.

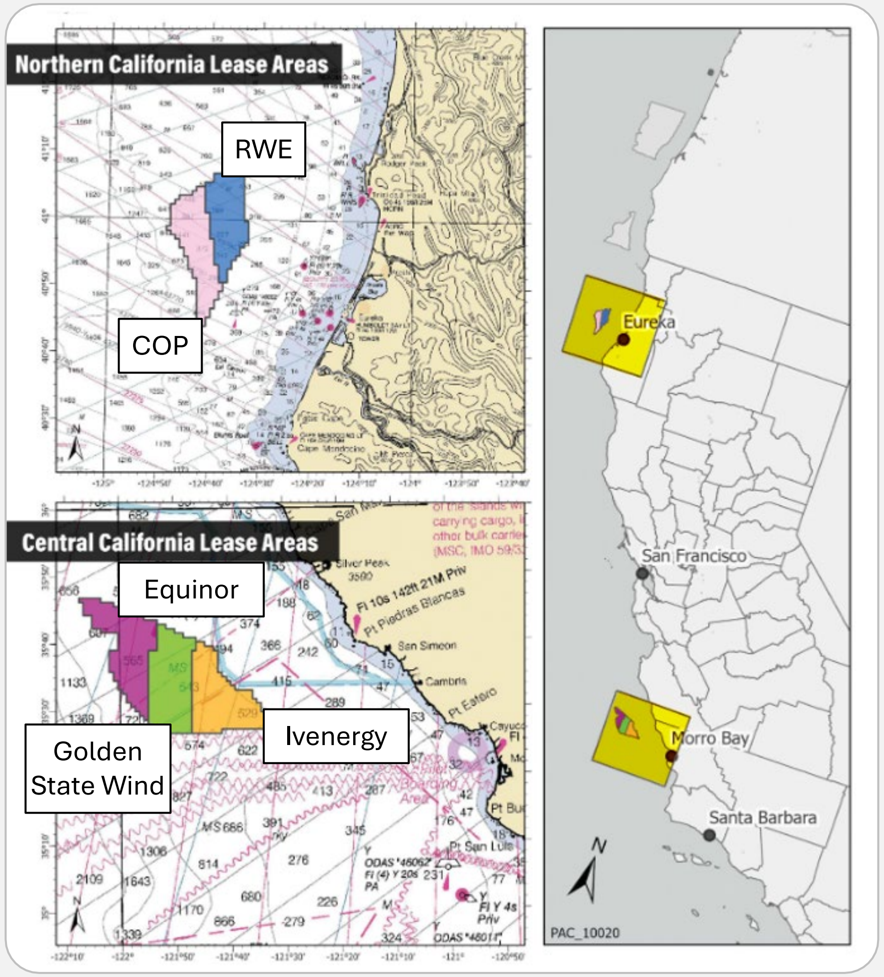
TRITON ANCHOR™

Task 2 – Geotechnical Investigation

Desktop study & In-field Offshore Campaign

- **Desktop study of Geotechnical Properties**
  - Soil composition
  - Seismic Events

- **In-field Geotechnical Investigation Campaign**
  - Cone Penetration Testing (CPT) to determine soil strength and layers
  - Shear Wave Velocity Measurements to determine seismic effects on soil make-up



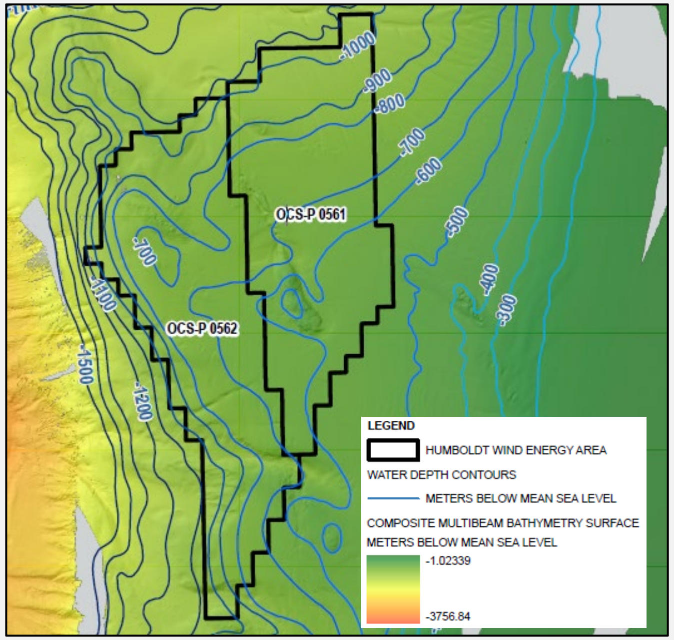
TRITON ANCHOR™

Task 2 – Geotechnical Investigation

Summary of Humboldt WEA

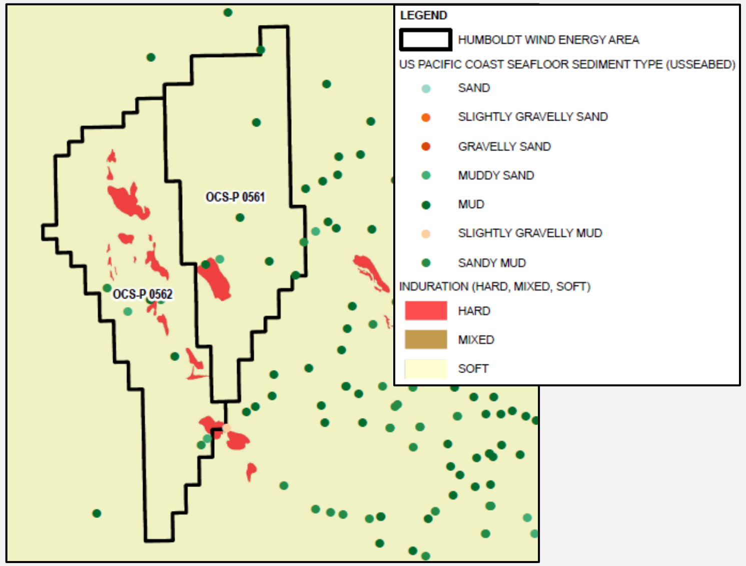
Water depth and bathymetry

- ***Water Depth:*** Approximately 500 to 1,100 meters (1,640 to 3,609 feet)
- ***Seafloor Slope:*** 0 to 10 degrees, with localized slopes over 20 degrees



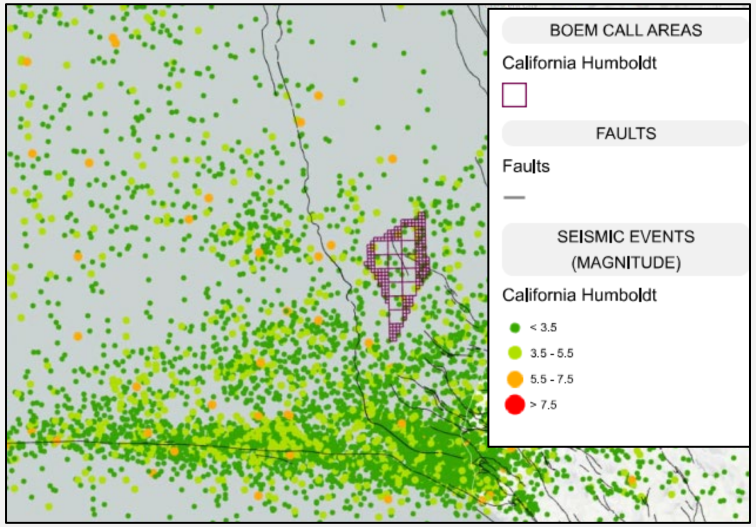
Sediment type

- ***Sediment Type:*** Mostly soft sediment ("mud") with localized hard areas (rock, outcrops, boulders)
- ***Sediment Depth:*** Greater than 500 feet



Seismic events

- ***Faults:*** ~10 mapped fault segments within the WEA
- ***Seismic Activity:*** Frequent low-magnitude events
- Low Liquefaction Risk



NOTES

ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE. SOURCE: CALIFORNIA OFFSHORE WIND ENERGY GATEWAY (https://caoffshorewind.databasin.org/). BACKGROUND SOURCE: ESRI. COMPOSITE MULTIBEAM BATHYMETRY SURFACE AND DATA SOURCES: 2018 AND 2019 MULTIBEAM DATA COLLECTED BY THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) AND THE U.S. GEOLOGICAL SURVEY (USGS). USSEABED SOURCE: https://www.fisheries.noaa.gov/inport/item/49600. AERIAL IMAGERY SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA). SEAFLOOR INDURATION SOURCE: OREGON STATE UNIVERSITY, ACTIVE TECTONICS AND SEAFLOOR MAPPING LAB (ATSML); NOAA FISHERIES, BUREAU OF OCEAN ENERGY MANAGEMENT. SEAFLOOR INDURATION SOURCE: OREGON STATE UNIVERSITY, ACTIVE TECTONICS AND SEAFLOOR MAPPING LAB (ATSML); NOAA FISHERIES, BUREAU OF OCEAN ENERGY MANAGEMENT

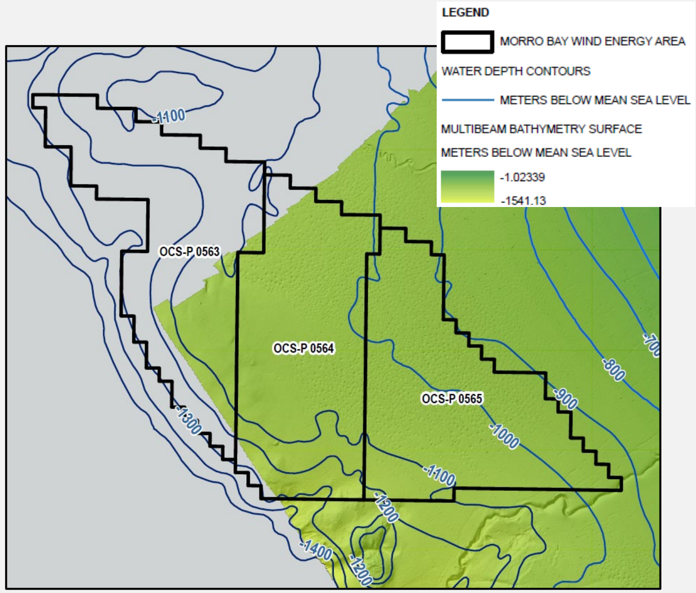
TRITON ANCHOR™

Task 2 – Geotechnical Investigation

Summary of Morro Bay WEA

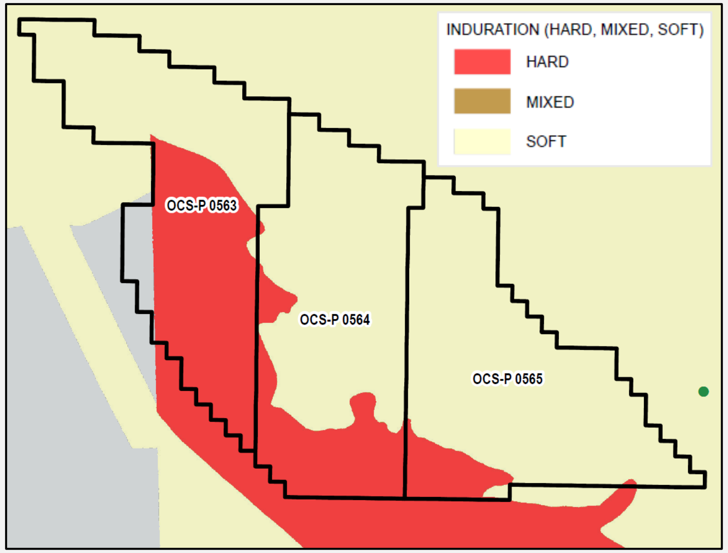
Water depth and bathymetry

- ***Water Depth:*** Approximately 900 to 1,300 meters (2,953 to 4,265 feet)
- ***Seafloor Slope:*** 0 to 5 degrees, with higher localized slopes



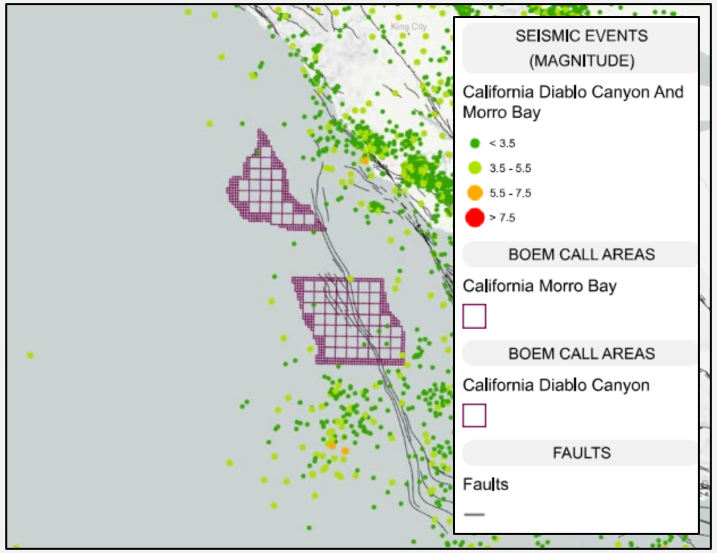
Sediment type

- ***Sediment Type:*** Mostly soft sediment ("mud") with localized hard areas in southern and western portions
- ***Sediment Depth:*** Greater than 100 m



Seismic events

- ***Faults:*** ~6 mapped fault segments within the WEA
- ***Seismic Activity:*** Within vicinity of Hosgri-San Gregorio Fault system; low-frequency low-magnitude events



NOTES
ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.. SOURCE: CALIFORNIA OFFSHORE WIND ENERGY GATEWAY (https://caoffshorewind.databasin.org/). BACKGROUND SOURCE: ESRI. USSEABED SOURCE: https://www.fisheries.noaa.gov/inport/item/49600. SEAFLOOR INDURATION SOURCE: MONTEREY BAY NATIONAL. MARINE SANCTUARY (https://caoffshorewind.databasin.org/datasets/06ba54fb5f9b4bf2bd75ae85fc5261af/). AERIAL IMAGERY SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) SEDIMENT THICKNESS SOURCE: NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION (NCEI) SEDIMENT THICKNESS MEASURED AS TWO-WAY TRAVEL TIME USING AN ASSUMED SEISMIC VELOCITY OF 2,000 M/S (1 MS = 1 METER)

TRITON ANCHOR™

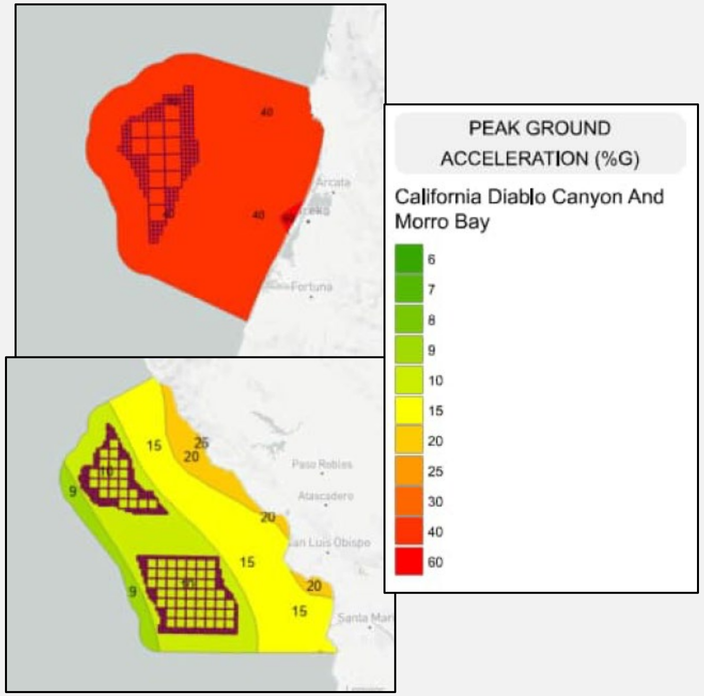
Task 2 – Geotechnical Investigation

Major Geological Hazard Considerations:

- Ground Shaking
- Liquefaction
- Submarine Landslides
- Tsunamis

Summary:

- Humbolt and Morro Bay deep-water areas mainly consist of fine grained soil and rock material, therefore their potential for liquefaction is considered low.
- Ground motion primarily affects the anchors, which are the embedded portion of the foundation, Nevertheless, the ground shaking hazard needs to be assessed for both northern and southern study areas



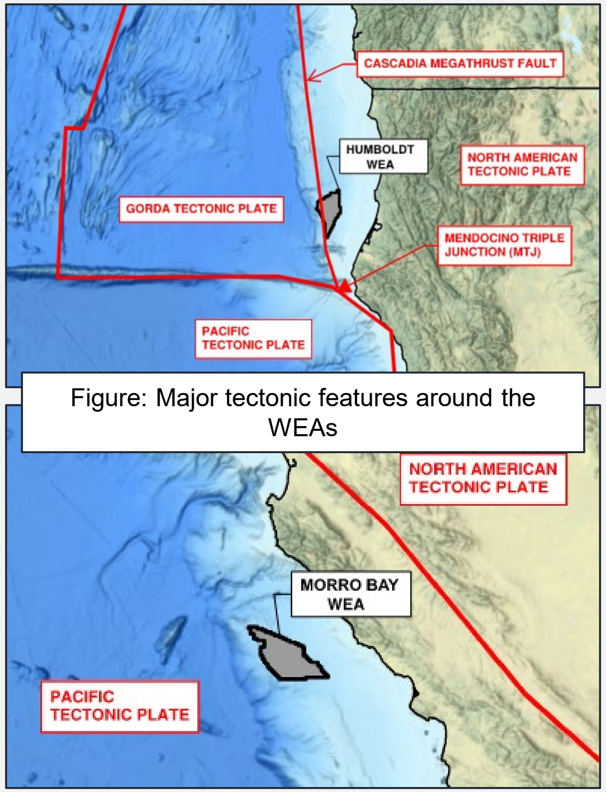


Figure: Major tectonic features around the WEAs

Primary references

- United States Geological Survey (USGS)
- National Oceanic and Atmospheric Administration (NOAA)
- Monterey Bay Aquarium Research Institute (MBARI)
- Bureau of Ocean Energy Management (BOEM)

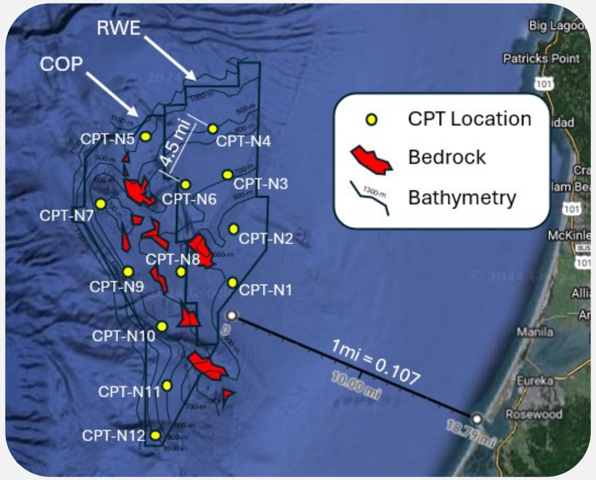
Task 2 – Geotechnical Investigation

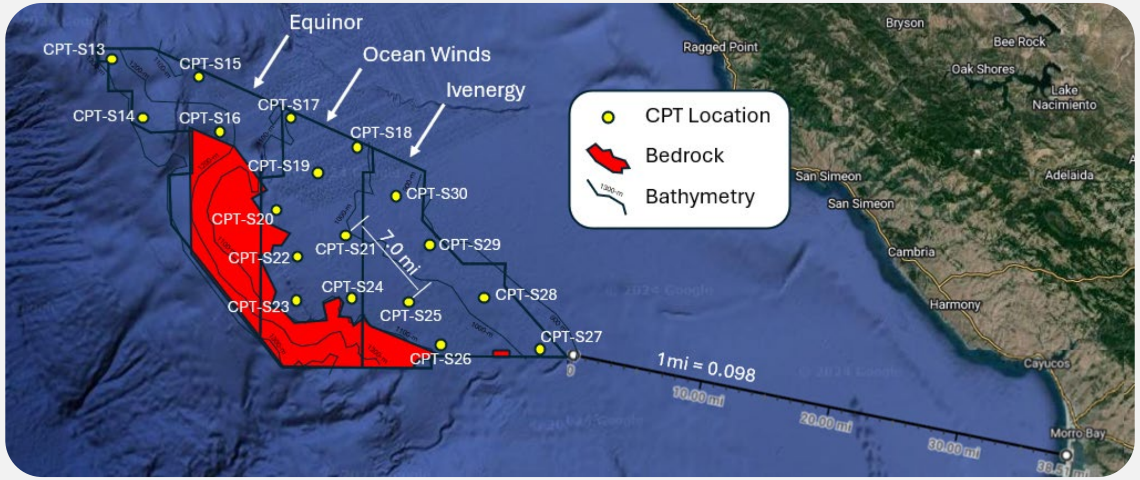
Offshore Investigation Planning

Operation Parameters:

Average CPTs/day [#]:	4
Maximum 'at-depth' transit speed [knots]:	1.5
Maximum 'on-surface' transit speed [knots]:	10
Launch to Depth [hrs]:	2.5
Recovery Time from Depth [hrs]:	2.5
Budgeted Count of Days [days]:	15
Estimated Individual CPT Time [hrs]:	6
Distance from North to South [miles]:	400

Geotechnical Investigation Campaign Scenarios			Number of CPTs	
Scenario	*CPT Expectation*	*Region*	*North*	*South*
1	Minimum	North & South	12	18
2	Maximum	North & South	17	24
3	Minimum	North	40	-
4	Maximum	North	48	-
5	Minimum	South	-	35
6	Maximum	South	-	44

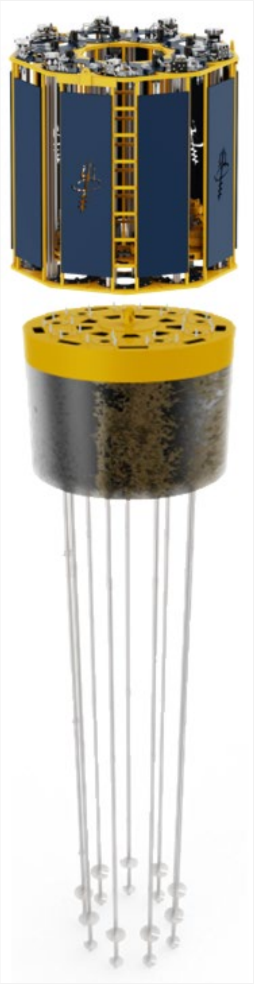


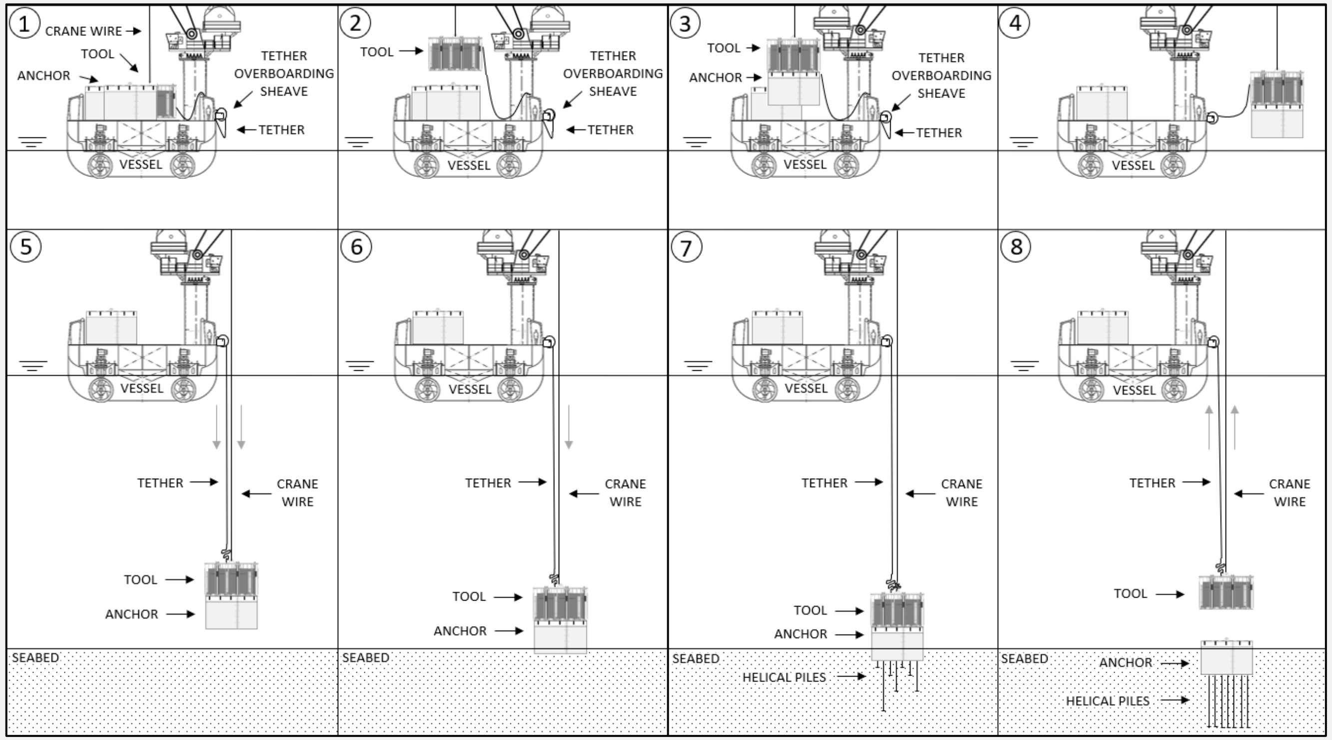


Task 3 – Marine Life and Habitat Assessment

Estimated Anchor Sizing:

- Helical piles quantities: 6 to 30
- Helical pile lengths: 7 to 25 meters
- Skirt diameters: 3 to 13 meters
- Skirt lengths: 3 to 10 meters
- Total anchor weights: 3 to 70 metric tons





TRITON ANCHOR™

Task 3 – Marine Life and Habitat Assessment

Species and Habitat

Federally listed species and critical habitats that have the potential to be affected by the proposed project are listed below:

Common Name	Scientific Name	Test Sites Present	Status	Final Rule	Critical Habitat in Study Area
Blue whale	*Balaenoptera musculus*	Morro Bay, Humboldt	EN	35 FR 18319; December 2, 1970	N/A
Fin whale	*Balaenoptera physalus*	Morro Bay, Humboldt	EN	35 FR 18319; December 2, 1970	N/A
Gray whale Eastern – North Pacific DPS	*Eschrichtius robustus*	Morro Bay, Humboldt	EN	35 FR 18319; December 2, 1970	N/A
Humpback whale – Mexico DPS	*Megaptera novaeangliae*	Morro Bay, Humboldt	TH	81 FR 62260; September 8, 2016	86 FR 21082; April 21, 2021
Humpback whale – Central America DPS	*Megaptera novaeangliae*	Morro Bay, Humboldt	EN	81 FR 62260; September 8, 2016	86 FR 21082; April 21, 2021
Sperm whale	*Physeter macrocephalus*	Morro Bay, Humboldt	EN	35 FR 18319; December 2, 1970	N/A
Guadalupe fur seal	*Arctocephalus townsendi*	Morro Bay, Humboldt	TH	50 FR 51252; December 16, 1985	N/A
Leatherback sea turtle	*Dermocheyls coriacea*	Morro Bay, Humboldt	EN	35 FR 8491; June 2, 1970	77 FR 4170 January 26, 2012
North Pacific loggerhead sea turtle DPS	*Caretta caretta*	Morro Bay	EN	76 FR 58868; September 22, 2011	N/A

Statuses: DPS = Distinct Population Segment, EN = endangered, TH = threatened, FR = final rule; CH = critical habitat.

Blue Whale

Gray Whale

Fin Whale

Guadalupe Fur Seal

Sperm Whale

North Pacific Loggerhead Sea Turtle

Photo Credits to NOAA

TRITON ANCHOR™

Task 3 – Marine Life and Habitat Assessment

Underwater Noise: Sources of underwater noise from the project would be minimal and anticipated to only include **vessels** and **installation of the helical screws**.

- **Installation of the anchor →** Expected to be within the same frequency intensity ranges as geotechnical survey sources (standard penetration tests/cone piezometer tests) which is below the level that would result in injury or behavioral disturbance to any species considered here.
- **Vessels →** Sounds from mobile sources, like vessels, are continuous and, therefore, vessel noise is characterized as a non-impulsive sound source.

Source (Vessel)	Source Level Range (dB re 1 µPa SPL_{rms})
Large vessels (149 to 294 feet)	177 to 188
Small support vessels (<100 feet)	150 to 180
Tug	177 to 188

Key: dB re 1 µPa SPLrms = decibels relative to 1 micropascal root mean squared sound pressure level

Installation of our Anchor:
Vessel traffic would be minimal as only 1-2 vessels are required to complete the installation of a single anchor.
Installation noise associated with the installation tool will be evaluate, indications show that the noise to be in normal levels

Task 3 – Marine Life and Habitat Assessment

Common name	Scientific name	Determination
Blue Whale	*Balaenoptera musculus*	NLAA
Fin Whale	*Acipenser brevirostrum*	NLAA
Gray Whale – Western North Pacific DPS	*Eschrichtius robustus*	NLAA
Humpback Whale – Mexico DPS	*Megaptera novaeangliae*	NLAA
Humpback Whale – Central America DPS	*Megaptera novaeangliae*	NLAA
Southern Resident killer whale	*Orcinus orca*	NLAA
Sperm whale	*Physeter macrocephalus*	NLAA
Guadalupe Fur Seal	*Arctocephalus townsendi*	NLAA
Leatherback Sea Turtle	*Dermocheyls coriacea*	NLAA
Loggerhead Sea Turtle – North Pacific DPS	*Caretta caretta*	NLAA

Key: NLAA = not likely to adversely affect. *critical habitat species*

Following our **3rd party analysis performed by WSP** of the **silent and precise installation** of Triton's helical anchor system;

- All NLAA Marine Wildlife Species = ***insignificant impact to habitats***
- Specific NLAA **Critical Habitat** Species = ***all effects are extremely unlikely***

Photo Credits to NOAA

Task 4 – Local Communities Impact

Economic Impacts:

Scenario 1: 5GW by 2030

- 334 Platforms --> 1,334 Anchors

	Employment	Labor Income	Value Added	Output
Direct	1,645	$142,918,417	$98,398,769	$253,658,304
Indirect	601	$54,054,002	$84,541,684	$155,058,871
Induced	843	$60,156,848	$110,634,420	$178,360,849
Total	**3,089**	**$257,129,267**	**$293,574,873**	**$587,078,024**

*Equivalent to 620 workers employed for 5-years

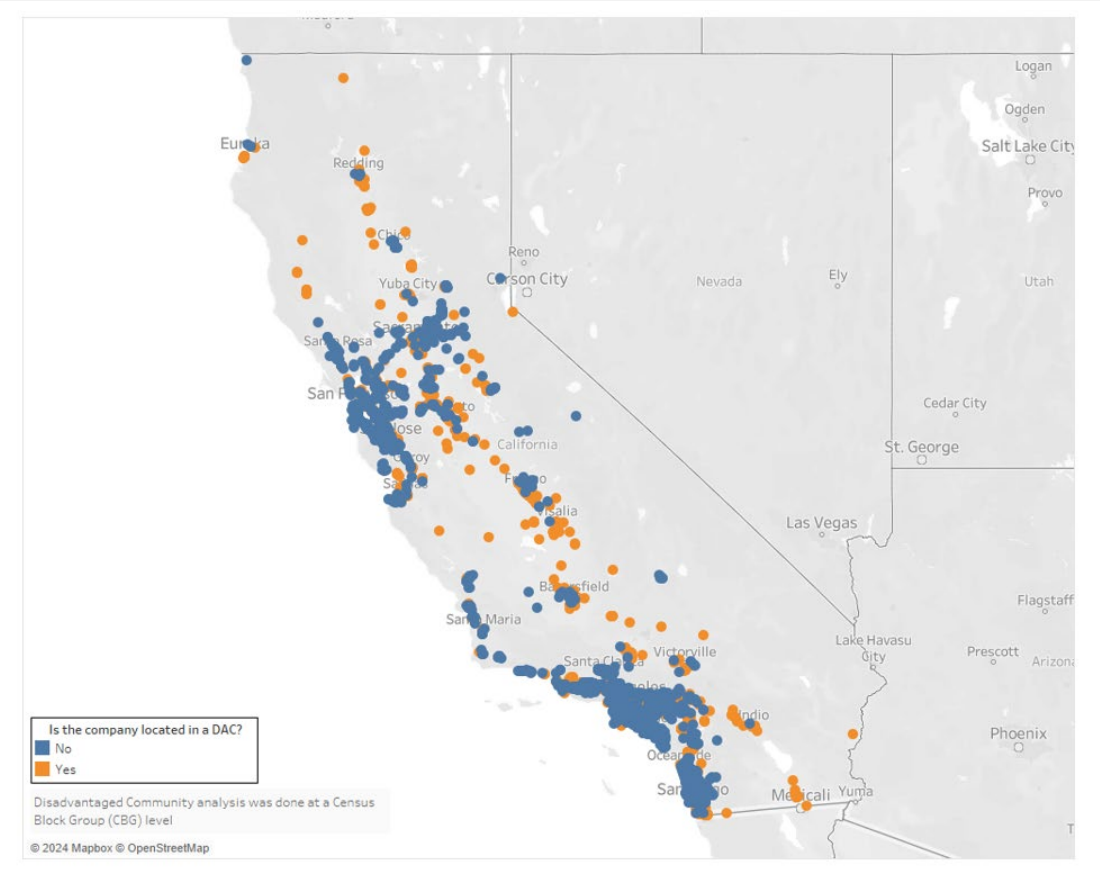
Scenario 2: 25GW by 2045

- 1,667 Platforms --> 6,667 Anchors

	Employment	Labor Income	Value Added	Output
Direct	8,209	$713,308,385	$491,110,022	$1,266,013,152
Indirect	2,998	$269,784,495	$421,949,066	$773,901,609
Induced	4,210	$300,243,909	$552,178,377	$890,202,201
Total	**15,417**	**$1,283,336,789**	**$1,465,237,465**	**$2,930,116,962**

*Equivalent to 770 workers employed for 20-years

Map of All Relevant Manufacturing Firms

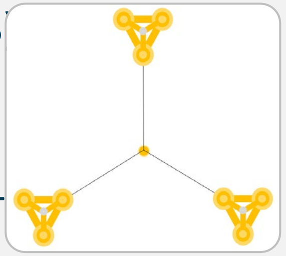


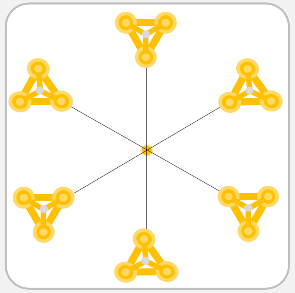
DAC: Disadvantaged Community

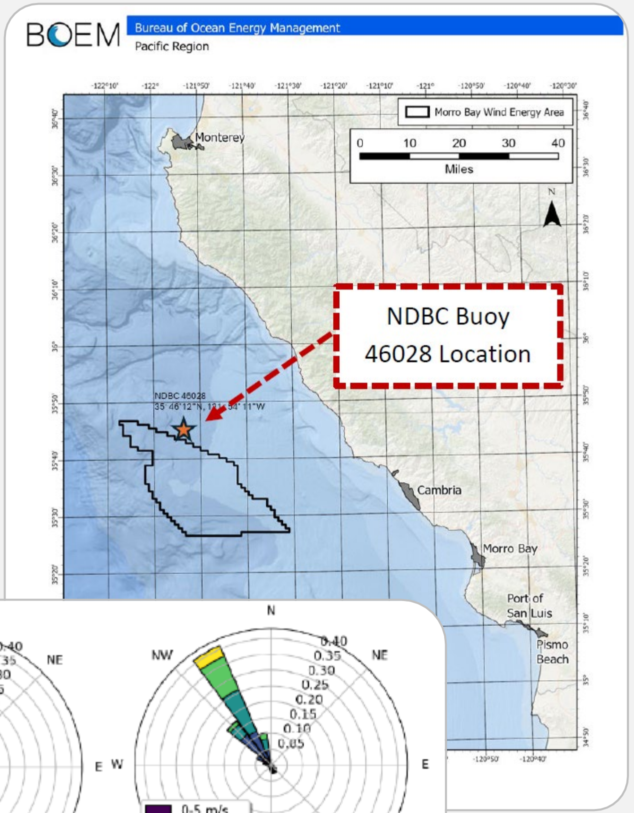
Task 7 – Floater Mooring Analysis

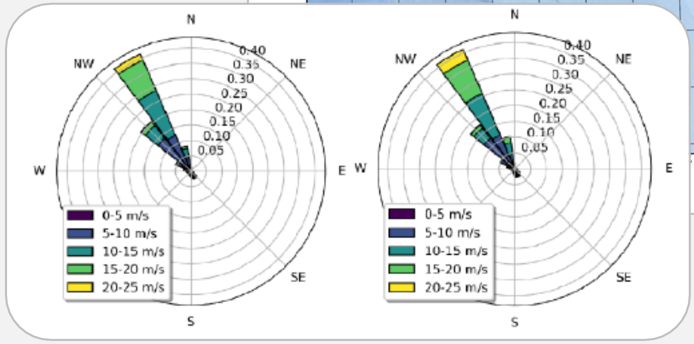
Goal: Determine site-specific anchor load cases for semi-submersible (SS) platforms and tension leg platforms (TLPs)

- Assuming an IEA 15-MW turbine semi-submersible platform in 1,000-m WD.









Scenario 1: 3-line shared anchor, 1,500-m line length

Vertical	Horizontal
[kN]	[kN]
16,443	5,518

Scenario 2: 6-line shared anchor, 2,100-m line length

Vertical	Horizontal
[kN]	[kN]
12,762	9,385

TRITON ANCHOR™

TRITON ANCHOR

Zachary Miller
Email: zmiller@tritonanchor.com

Nathan Krohn
Email: nkrohn@tritonanchor.com

Triton Anchor LLC
330 Billerica Road
Chelmsford, MA 01824

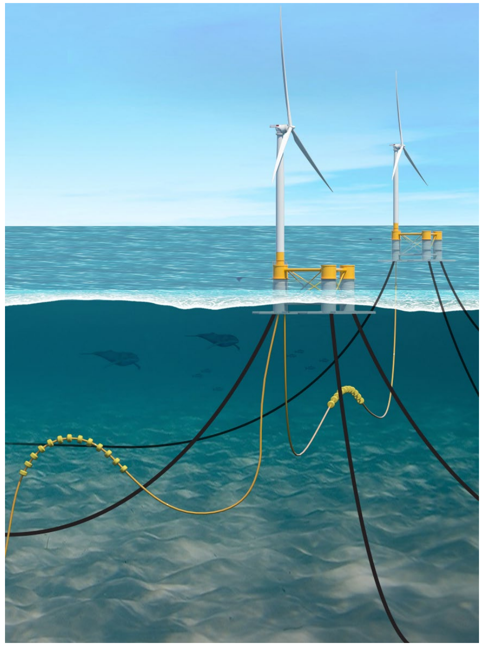
NREL
Transforming ENERGY

Comprehensive Shared-Mooring Solutions to Minimize the Cost, Risk, and Footprint of GW-Scale Floating Wind Farms

Matt Hall
National Renewable Energy Laboratory

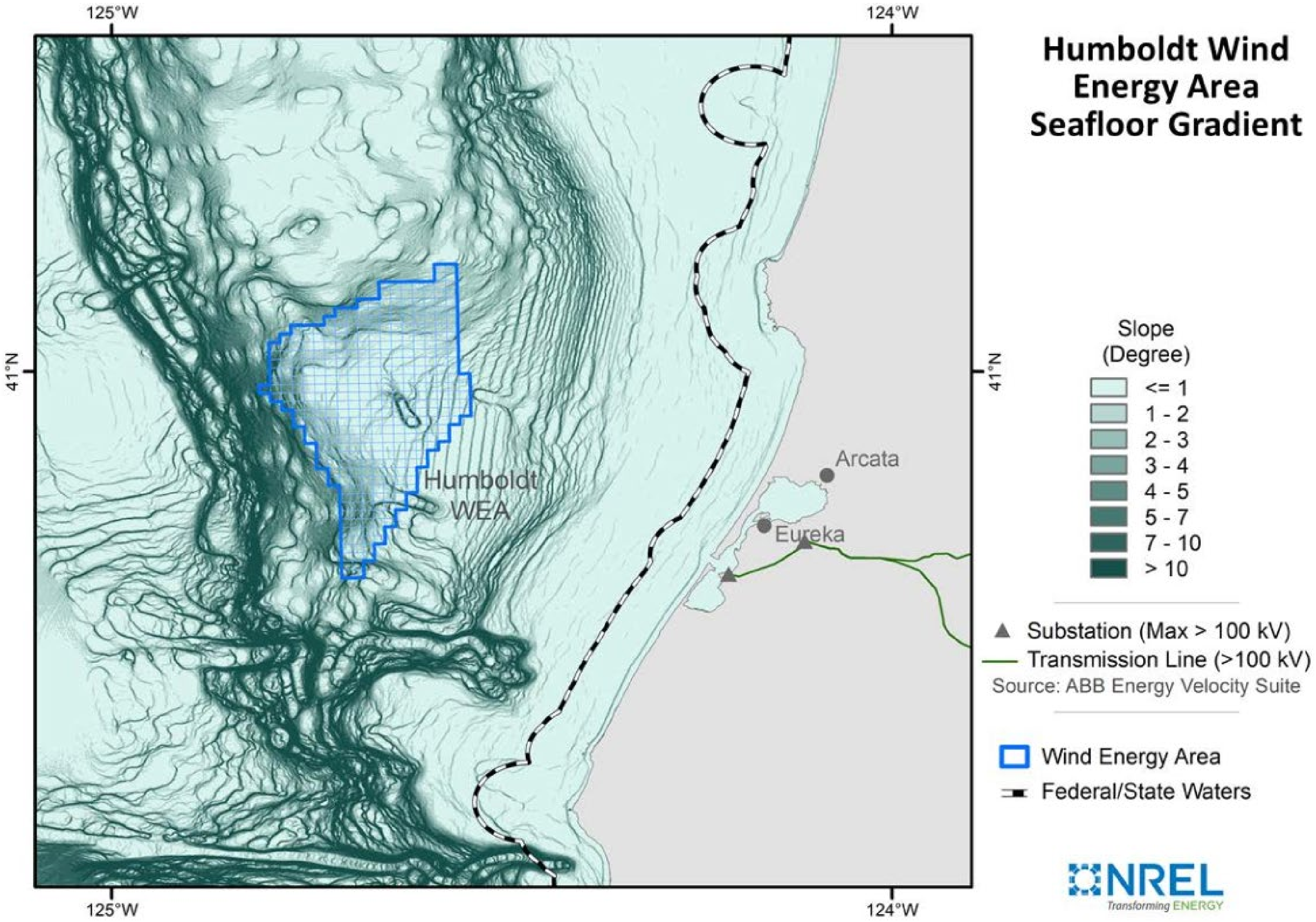
November 5, 2024

Mooring Floating Wind Turbines in California

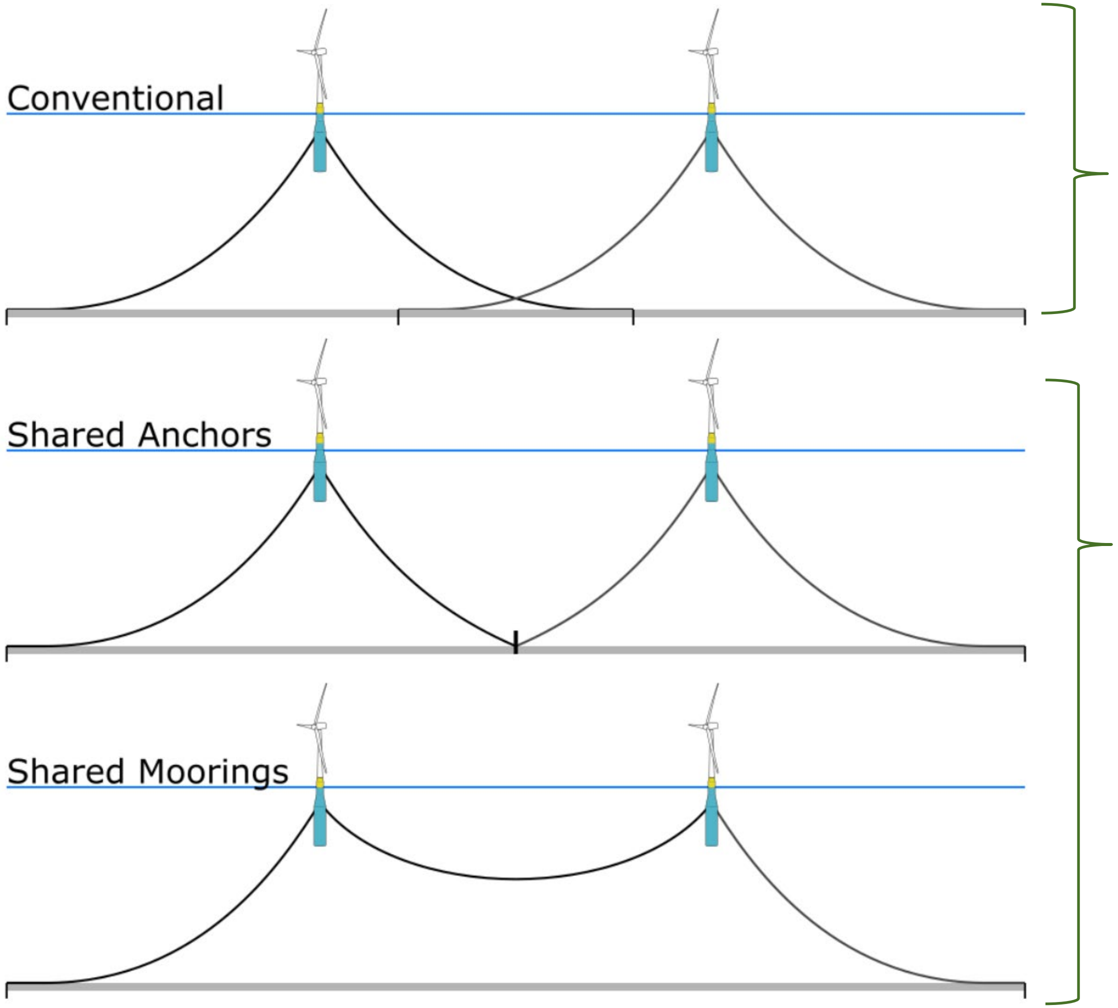


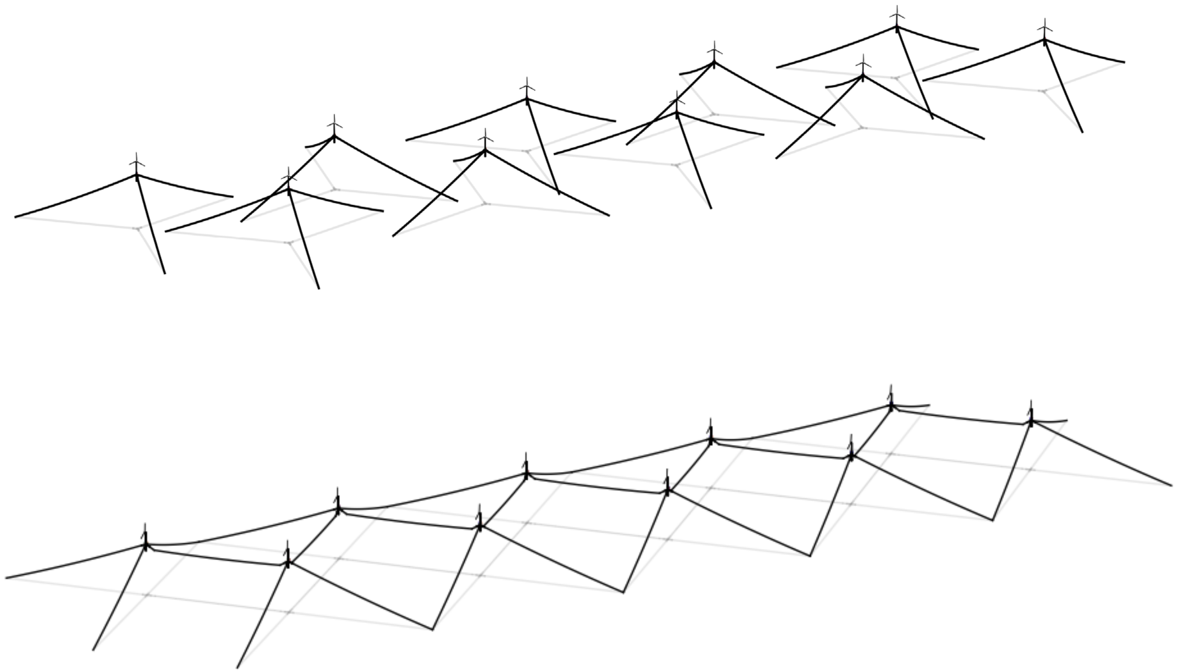
Challenges:

- Supply chain
- Water depth
- Depth variation
- Extreme events



The Concept of Shared Mooring Systems





- Challenges: Complexity
- Benefits:
  - Reduce mooring component quantities
  - Reduce contact points with the seabed
  - Reduce sensitivity to failure

Our Project

- Goal: develop comprehensive shared mooring system solutions that minimize the costs, failure risks, and environmental impacts of GW-scale floating wind farms in California site conditions

- Key elements of the approach:
  - State-of-the-art techniques for shared mooring lines and anchors
  - Installation and maintenance innovations that result in additional cost reductions and reliability improvements
  - Strategic use of shared mooring lines will make floating wind farms especially resilient to mooring system failures

Project Team

Prime Recipient
- Shared mooring system innovations
- Mooring design optimization methods
- Economic and infrastructure analysis

Subrecipient – Floating System
- Industrial floating system design
- Shared anchor applications

Subrecipient – Moorings
- Integrated mooring solution
- Installation and maintenanc

Subrecipient – Anchors and Geotech
- Shared anchor loading and strength
- Geotechnical anchor strength analysis

Subrecipient – Regional Expertise
- California offshore wind analysis
- Local stakeholder engagement

Subrecipient – Environmental
- Comprehensive environmental effects
- Offshore wind mooring env. impacts

Subrecipient – Wave Basin Testing
- Scale model fabrication
- Large-area wave basin testing

Subrecipient – Classification Society
- Hazards identification
- Design review, Approval in Principle

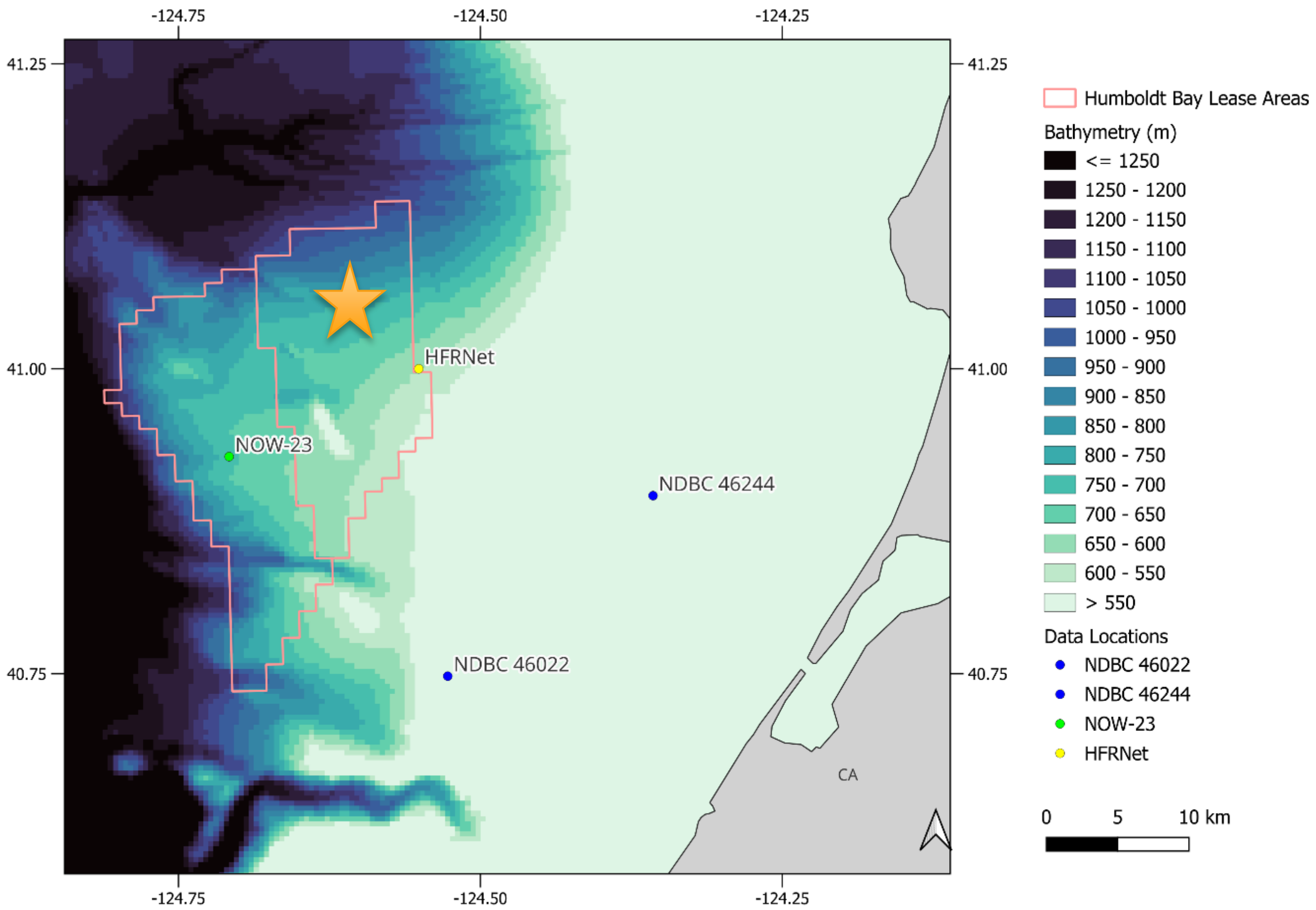
Design and Innovation

Acceptability and Impact

Validation and Reliability

Project Design Basis

Location: Humboldt Bay lease area

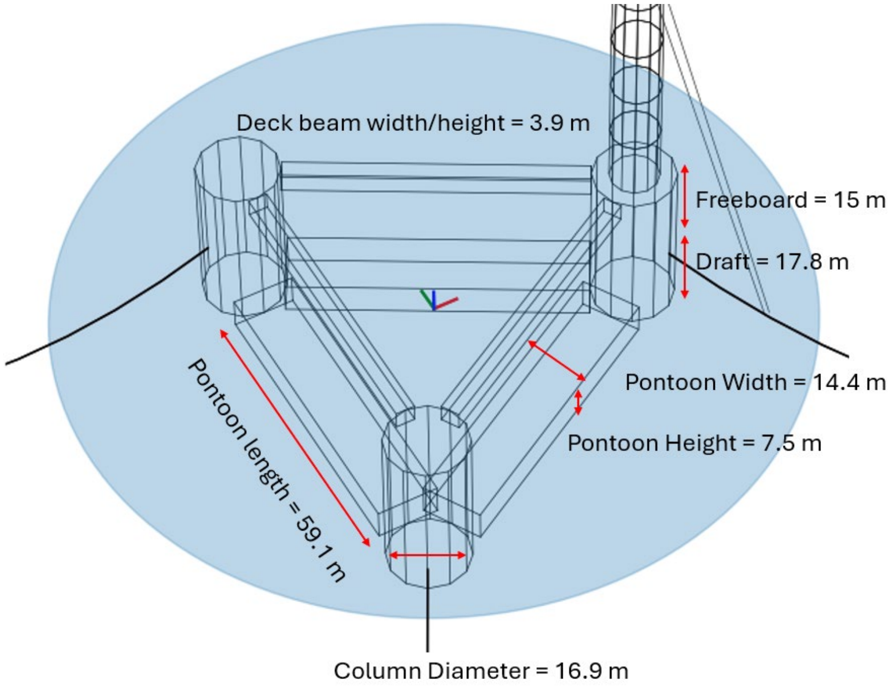


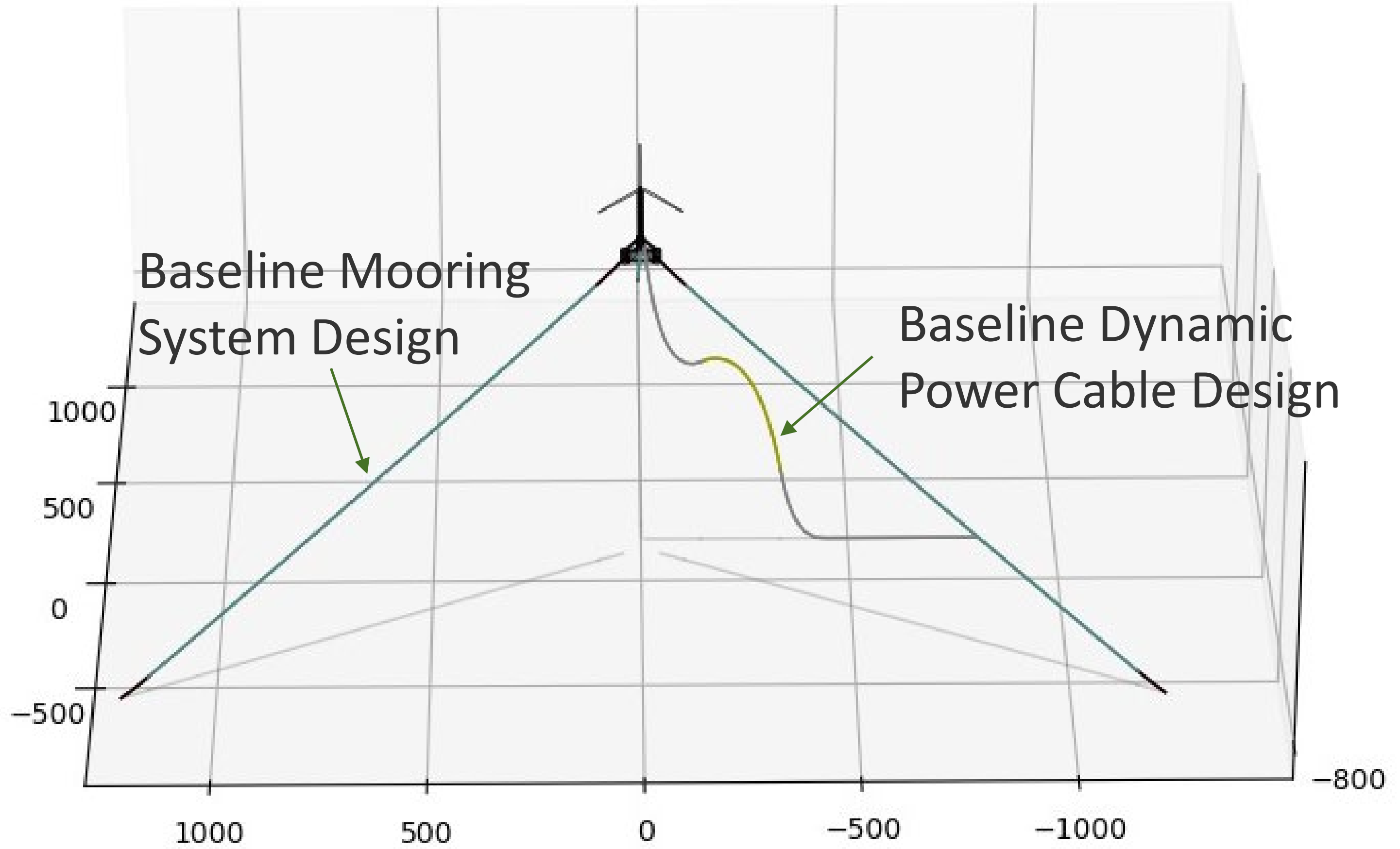
Wind Turbine: 15-MW
Platform: Semisubmersible (2 options)

UMaine VolturnUS-S

INO WindMoor

Recently Completed: Baseline Design



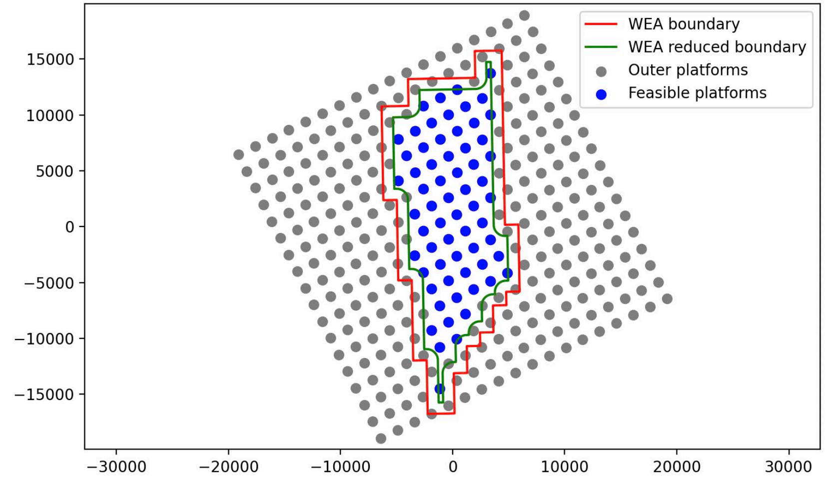


- Upscaled INO Windmoor platform for the IEA Wind 15-MW turbine
- Taut mooring system mainly using 200 mm polyester rope
- Lazy wave dynamic power cable

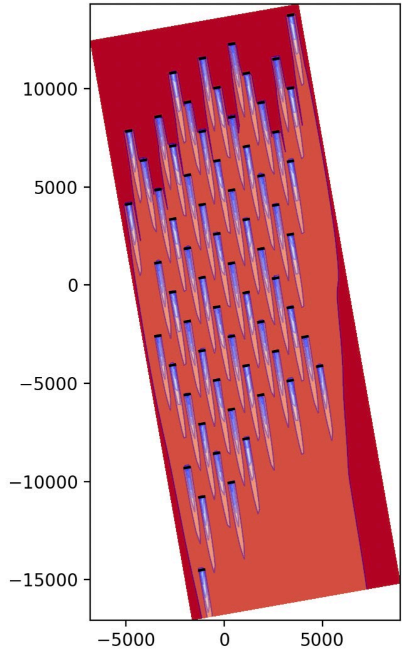
Baseline design OpenFAST input files are available on GitHub: https://github.com/FloatingArrayDesign/SharedMoorings/tree/main/IEA-15-240-RWT-INOSemiUpscaled

Ongoing Work: Large-Scale Shared-Mooring Design

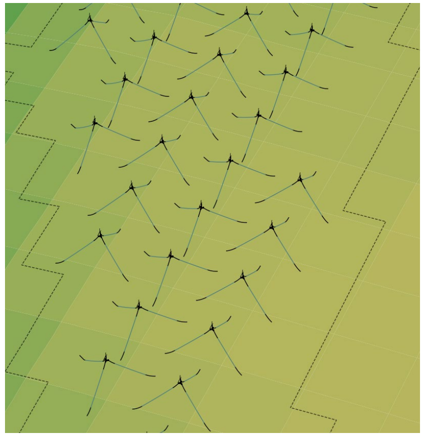
Turbine Layout Optimization



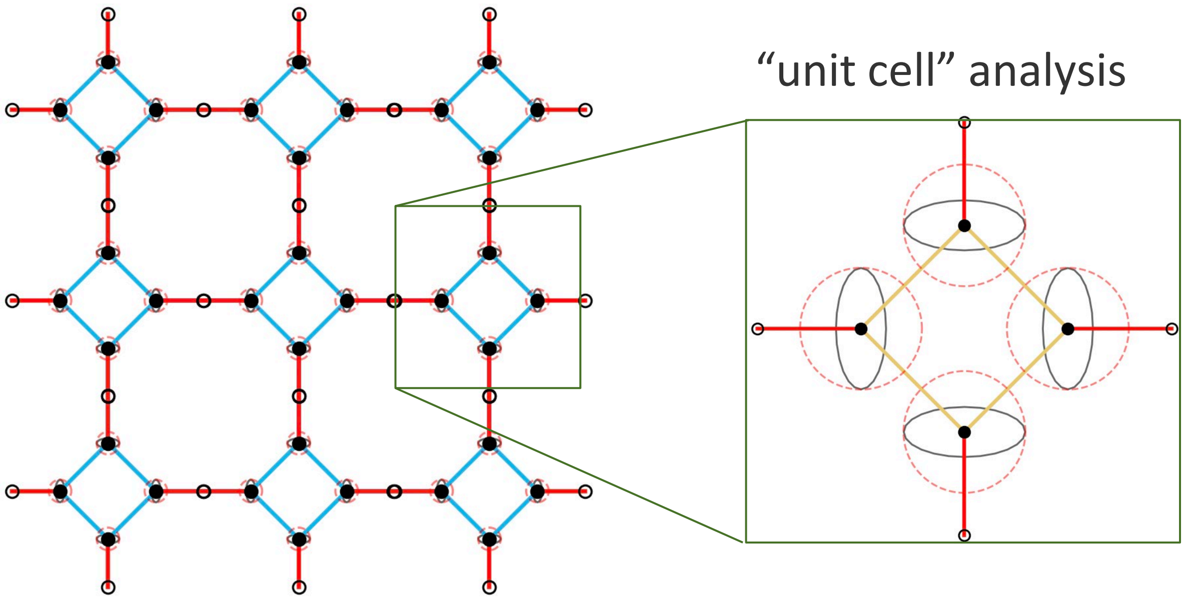
Wakes Analysis



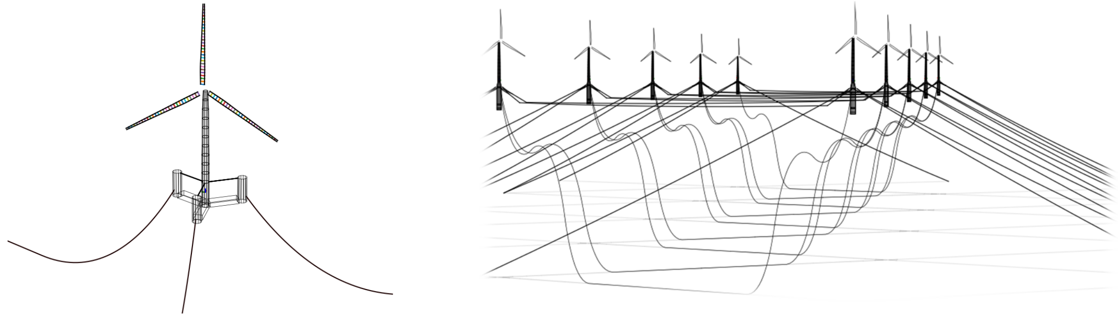
Mooring System Arrangement/Fit



Methods for Modeling Large Shared Mooring Systems



Ultimate Evaluation: Simulation of System Dynamic Response



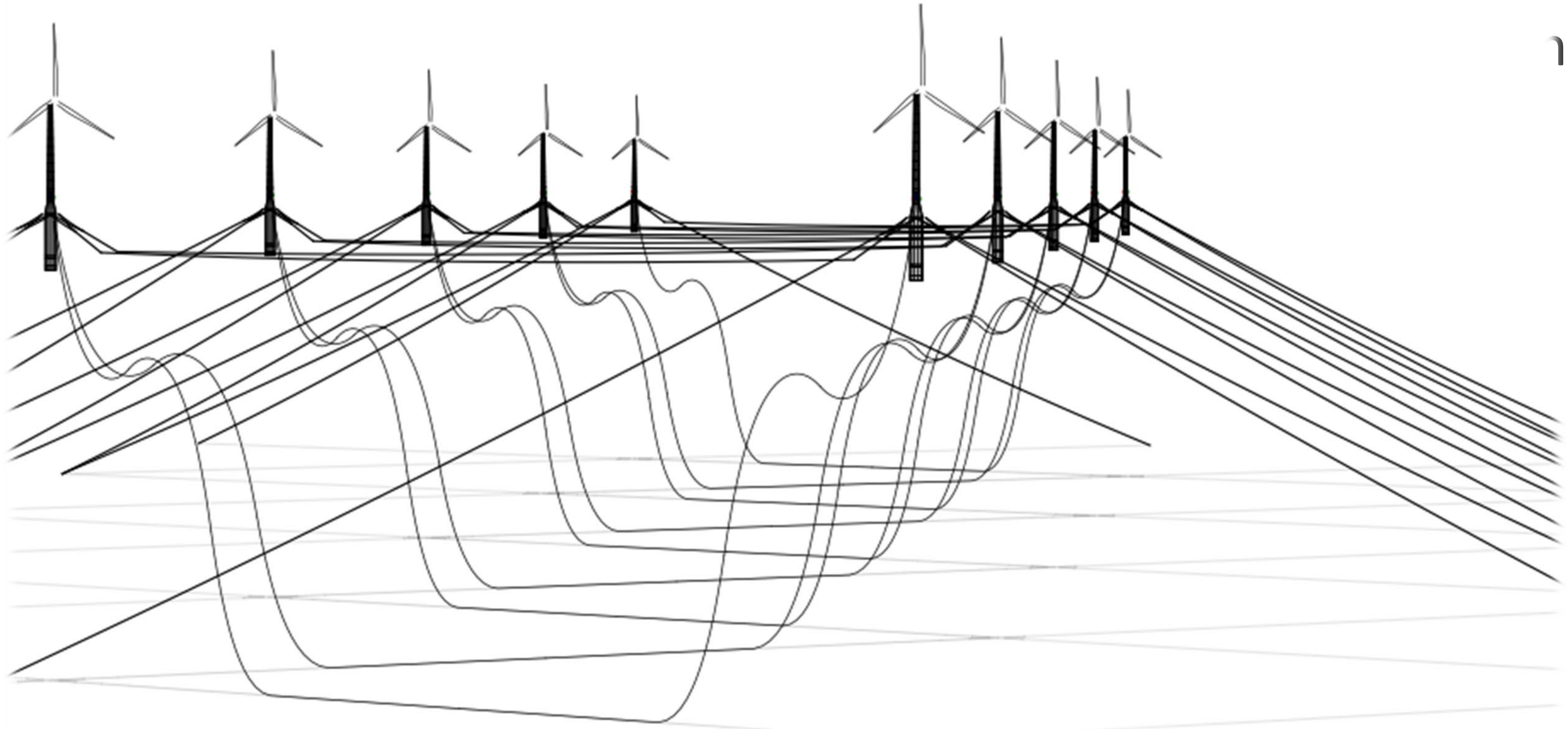
Expected Project Benefits

- Key findings to report on:
  - Shared mooring system innovations including installation and maintenance approaches
  - Assessment of array-level risks including extreme waves and earthquakes
  - Analysis of technical, reliability, economic, and environmental benefits/impacts compared to conventional mooring approaches

- Key outputs:
  - Baseline design definitions/files ✓
  - Installation and maintenance methods and assumptions
  - Design framework in open-source toolset
  - Final shared-mooring design definitions/files
  - Technical reports on design performance, cost, environmental impact

Thank You

ntact: matthew.hall@nrel.gov



Break

We will resume at 11:28am PT

Energize Innovation

1. https://www.energizeinnovation.fund/projects/seabird-3d-distribution-and-relative-risk-california-offshore-wind-turbines
2. https://www.energizeinnovation.fund/projects/integrated-monitoring-cetacean-and-ocean-environmental-impacts-floating-offshore-wind
3. https://www.energizeinnovation.fund/projects/low-cost-environmentally-friendly-concrete-anchors-made-california
4. https://www.energizeinnovation.fund/projects/design-validation-and-certification-synthetic-mooring-line-system-15-mw-floating-wind
5. https://www.energizeinnovation.fund/projects/integrated-monitoring-approach-reduce-entanglement-hazards-floating-offshore-wind
6. https://www.energizeinnovation.fund/projects/advanced-anchoring-system-california-floating-offshore-wind
7. https://www.energizeinnovation.fund/projects/comprehensive-shared-mooring-solutions-minimize-cost-risk-and-footprint-gw-scale-floating

Thank You!

https://www.energy.ca.gov/event/webinar/2024-11/floating-offshore-wind-research-and-development-portfolio-showcase-webinar

https://www.energizeinnovation.fund/search?keywords=offshore+wind/

https://www.energy.ca.gov/funding-opportunities/solicitations