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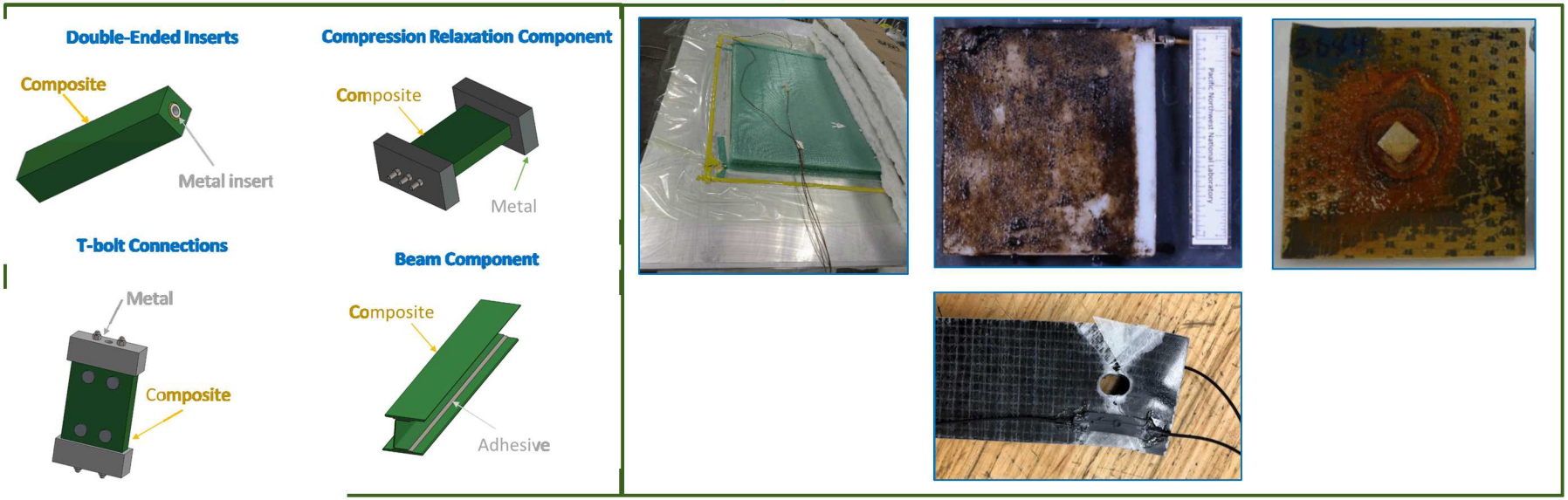

Material Design Tools for MHK Composite Structures

WC0101000/(CPS) 25536

Marine and Hydrokinetics Program

October 8, 2019

Bernadette A Hernandez-Sanchez

Sandia National Laboratories

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Project Overview

Project Summary

- **Problem:** MHK technologies manufactured with composites are promising to increase efficiency and improve LCOE metrics; however, composites in marine energy applications are largely untested.
- **Goal:** is to reduce risk/uncertainty in using composite designs by demonstrating their potential advantages.

Project Objective & Impact

- **Objective:** (1) assess coupons supplied by industry, (2) identify relevant substructures for fabrication/testing with industry, and (3) provide a descriptive resource of materials properties and solutions to address priority needs (2015 Workshop).
- **Impact:** reduce materials risk and overcome engineering challenges, inform supply chain industry about scale-up of suitable materials, accelerate manufacture, and assess performance/reliability.

Project Information

Project Principal Investigator(s)

Bernadette A. Hernandez-Sanchez (PI) SNL

WPTO Lead

Lauren Moraski

Project Partners/Subs

Budi Gunawan, SNL
George Bonheyo, PNNL
Scott Hughes, NREL
David Miller, MSU
Francisco Presuel-Moreno, FAU

Project Duration

- Project Start Date: FY2017
- Project End Date: FY20/Q2

Alignment with the Program

Marine and Hydrokinetics (MHK) Program Strategic Approaches

Data Sharing and Analysis

Foundational and Crosscutting R&D

Technology-Specific Design and Validation

Reducing Barriers to Testing

Alignment with the MHK Program

Foundational and Crosscutting R&D

- Drive innovation in components, controls, manufacturing, materials and systems with early-stage R&D specific to MHK applications
- Develop, improve, and validate numerical and experimental tools and methodologies needed to improve understanding of important fluid-structure interactions
- Improve MHK resource assessments and characterizations needed to optimize devices and arrays, and understand extreme conditions
- Collaboratively develop and apply quantitative metrics to identify and advance technologies with high ultimate techno-economic potential for their market applications

- Understand MHK environmental/load effects on composite materials to provide industry guidance for future materials selection, manufacture, and design.
- Experimental design with MHK conditions were used to evaluate marine industry coatings.
- Produced new standardized biofouling characterization methods.
- Evaluated composite performance under seawater/simulated saltwater conditions for corrosion, biofouling, and load (IEC Technical Specification/Wave Energy Scotland).

Alignment with the MHK Program

Data Sharing and Analysis

- Provide original research to assess and communicate potential MHK market opportunities, including those relevant for other maritime markets
- Aggregate and analyze data on MHK performance and technology advances, and maintain information sharing platforms to enable dissemination
- Support the early incorporation of manufacturing considerations/information into design processes
- Leverage expertise, technology, data, methods, and lessons from the international MHK community and other offshore scientific and industrial sectors

- Delivered U.S. DOE MHK Materials & Structures Database with metrics similar to the DOE Wind Materials & Structures Database (*open resource*) http://energy.sandia.gov/energy/renewable-energy/water-power/technology-development/advanced-materials/mhk-materials-database/
- Team engaged industry & stakeholders to identify needs.
- Provided outreach to share results and progress from experiments to gain feedback on approach/methods.

Project Budget

Lab	FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Lab	Costed	Costed	Costed	Total Costed	Total Authorized
SNL	$255K	$319K	$149K	$629K	$886K
PNNL	$134K	$203K	$135K	$472K	$639K
NREL	$18K	$42K	$33K	$93K	$341K
TOTAL	$407K	$564K	$317K	$1,194K	$1,866K

- FY17 & 18 devoted budget to coupon testing (SNL, PNNL, MSU ($100K), FAU ($75K)) & industry surveys (NREL, Team) to identify subcomponents.
- FY19 delay in budget execution for subcontracts to MSU caused delay in subcomponent fabrication.
- To mitigate, a no cost extension was approved to finalize work through FY20/Q2.

Management and Technical Approach

Materials & Loads

Biofouling

Subcomponent & Full-scale Testing

Composite Performance

Corrosion

FY17

Salt Water Effects on Composite Performance Testing

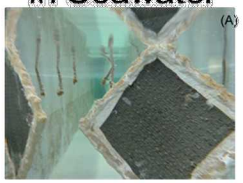
Biofouling & Environmental Effects on Composites

Coupons provided by:

- Composites Engineering Research Laboratory
- Composites Technology Development Inc.
- Hygrateck
- Janicki Industries
- Ocean Renewable Power Company
- Polyone
- Verdant Power

FY18

Metal – Carbon Fiber Composite Interconnects in Seawater



Industry directed sub scale elements & joined coupon fabrication/testing (Simulated & Actual Seawater)

FY19

Industry directed full scale subcomponent testing (Simulated & Actual Seawater)

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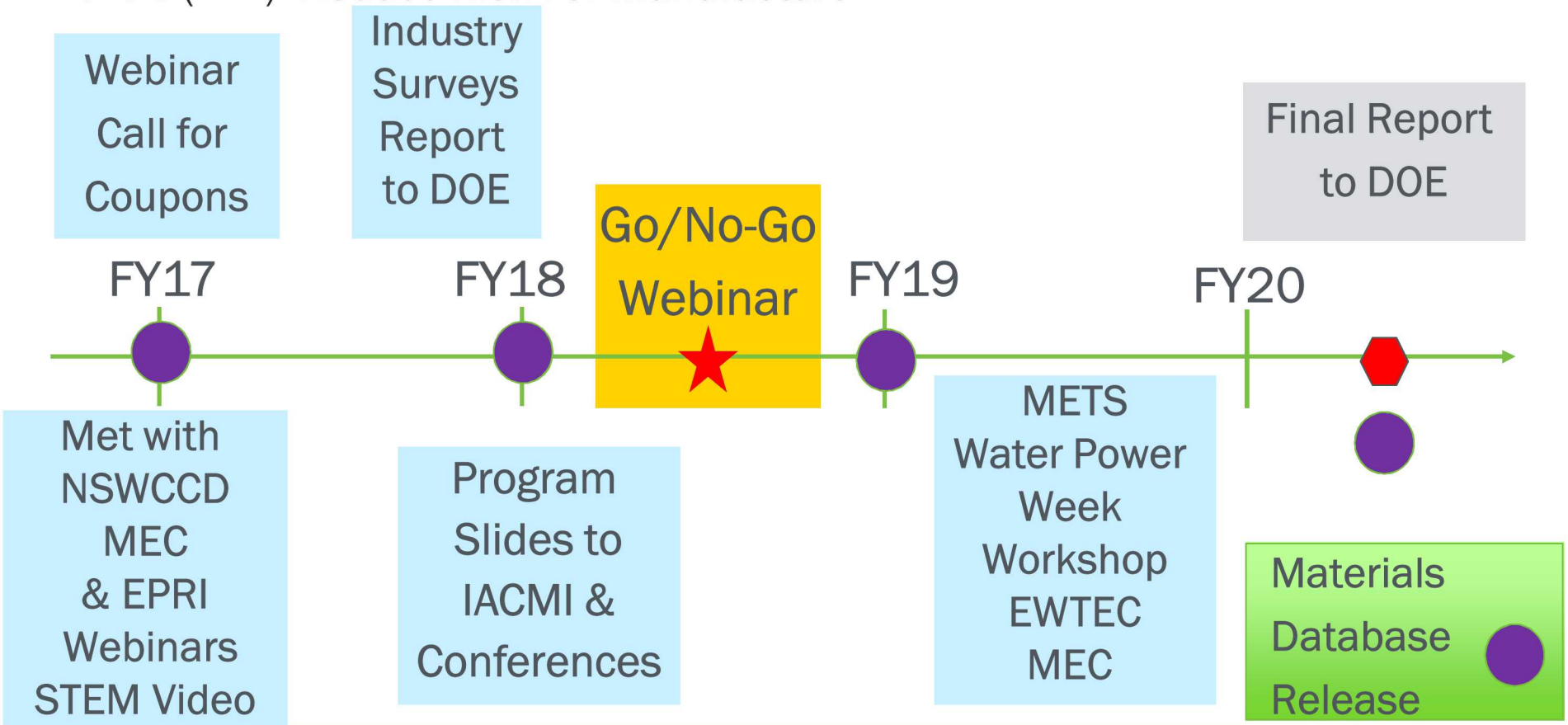
End-User Engagement and Dissemination Strategy

- Target Beneficiaries: MHK developers; composites stakeholders (e.g., supply chain, manufactures, Institute for Advanced Composites Manufacturing Innovation (IACMI)); WPTO to inform R&D strategy and Industry Integration Programs to advance technology performance levels (TPL)/technology readiness levels (TRL). Reduce Risk For Manufacture



Technical Accomplishments

- Performances testing on over 1000 Coupons
  - Submitted by MHK Industry & Stakeholders on materials of interest
- Biofouling Testing at PNNL
  - Unfiltered Seawater (MHK Conditions)
- Corrosion Studies at FAU
  - Carbon composite-metal (Interconnects)
- Delivered annual DOE Materials Database on properties for designers

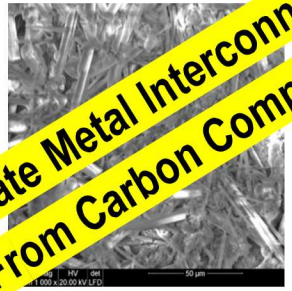
Composite Performance

MSU Material	Layup	Average V_f for static tests %	% Moisture	Longitudinal Direction			Transverse Direction		
				E, GPa	UTS, MPa	% strain	E, GPa	UTS, MPa	% strain
CE1	[V/[+/-45]g/0₄]s	49.9	0	56.1	786	1.38	10.7	98.3	3.17
			1.2	56.3	787	1.38	8.54	68.3	1.84
CE2		35.8	0	54.8	773	1.40	9.02	83.3	3.25
			1.33	56.3	725	1.30	7.79	58.9	1.84
CE3		49.7	0	54.1	792	1.48	9.96	95.3	3.67
			1.1	52.1	691	1.31	8.62	[illegible]	1.92
CE4		36.1	0	53.7	774	1.36	[illegible]	[illegible]	3.69
			1.2	53.1	712	1.30	[illegible]	[illegible]	1.82
CE5		36.4	0	56.5	733	[illegible]	[illegible]	77.8	3.54
			0.31	57.9	695	[illegible]	[illegible]	68.6	2.05
CE6	[V/[0/45/-45/0/V]	42.3	0	29.2	[illegible]	[illegible]	12.0	109	2.52
			0.36	28.7	[illegible]	[illegible]	16.6	126	2.36

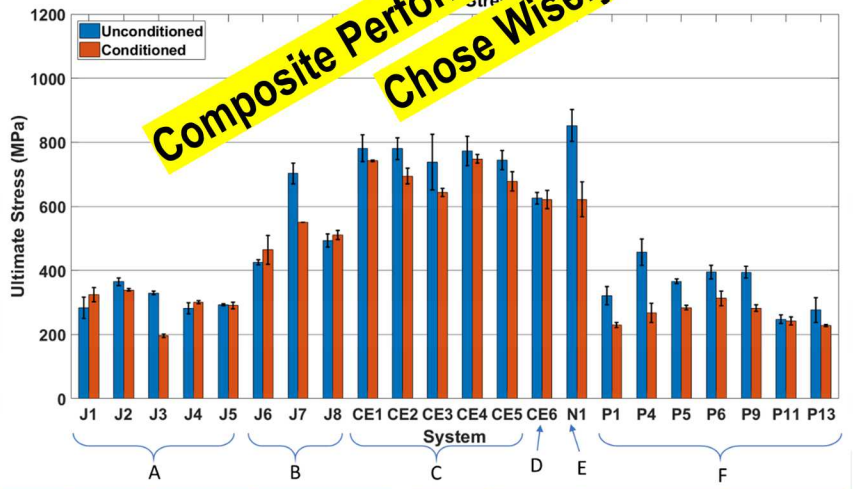
Composite Performance Degradation

Chose Wisely

Biofouling study on commercial & research grade coatings & composites



Calcaerous deposit from corrosion study CF/VE8084 + anode



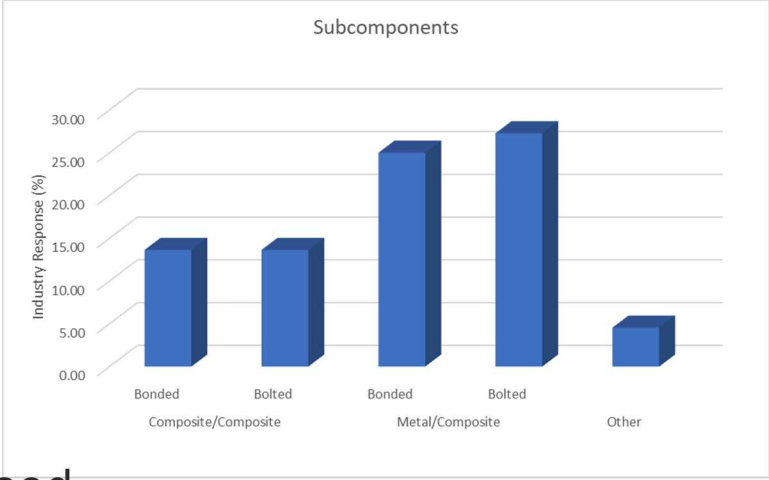
Group	Fiber	Matrix	Layup Type
A	Glass	Thermoset	Quasi-Isotropic
B	Carbon	Thermoset	Quasi-isotropic
C	Hybrid	Thermoset	[45/-45/0]s

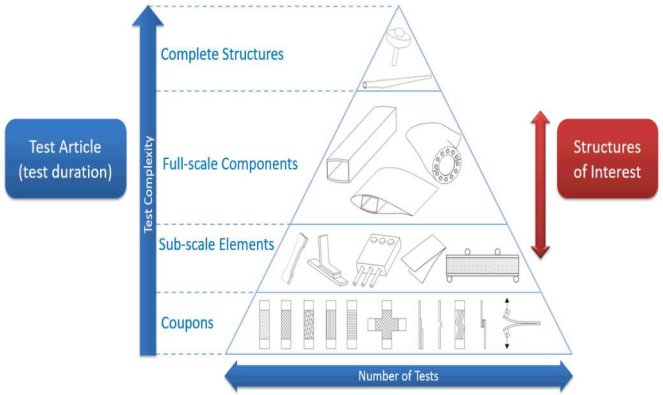
Group	Fiber	Matrix Type	Layup Type
D	Glass	Vinyl ester	[0/45/-45/0]
E	Glass	Elium	[0b]s
F	Glass	Thermoplastic	[0/90]n

Technical Accomplishments (Cont.)

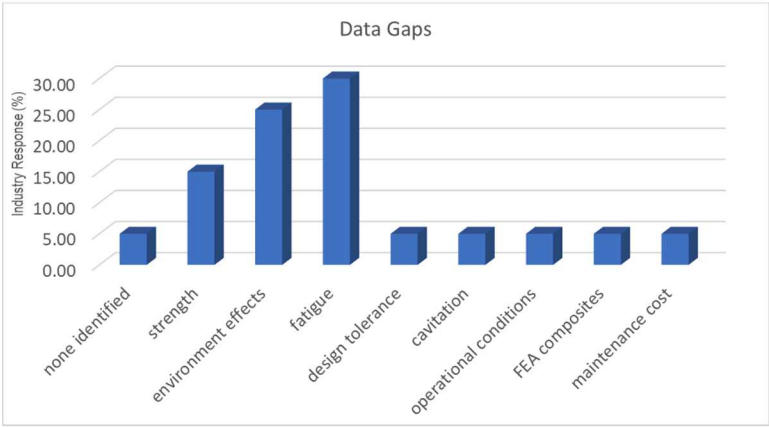
Public Results from Industry Surveys

- Questionnaire for industry input
- Phone interviews
- Identify:
  - What materials are being used?
  - Gaps in existing data
  - Design and manufacturing challenges
  - Components where composites may be used
- Results informed the development of subcomponent types



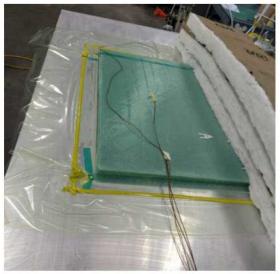


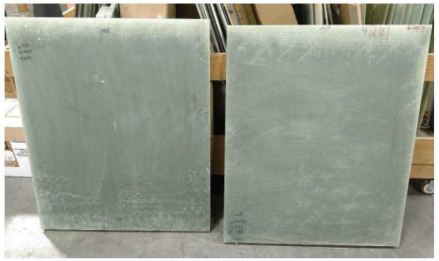
(Internal Report) DOE WPTO: Industry Assessment on Composite Structures



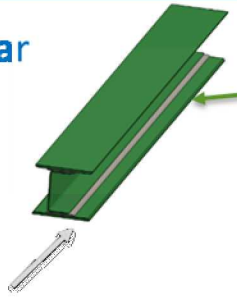
Progress Since Project Summary Submittal

Subcomponent Fabrication

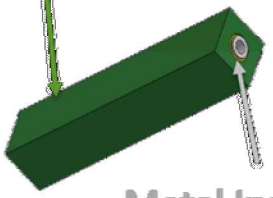




Adhesively shear specimens



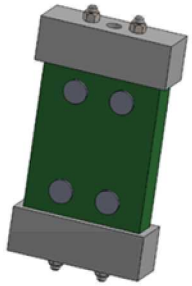
Adhesively bonded inserts



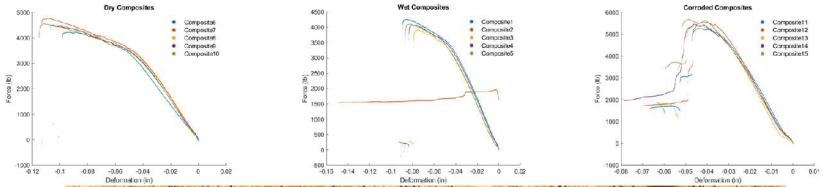
Corrosion Studies on Connections

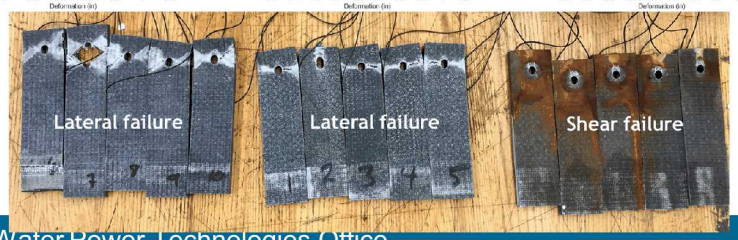
Use a super-austenitic or super-duplex stainless steel
Use a more corrosion resistant Ni based alloy
Use a Ti alloy that performs well in sea water

T-bolt connections

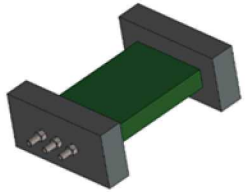


Joined Material Load Behavior



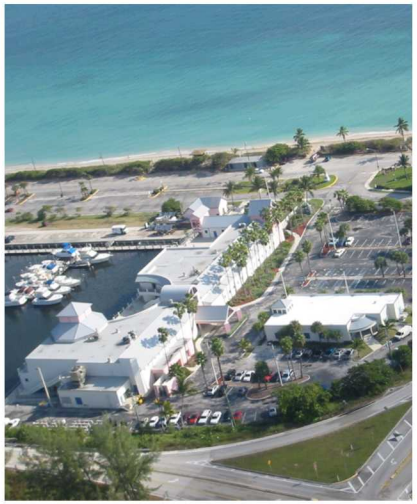


Compression Relaxation specimens



Future Work

- FY20 Q1–Q2
- No Cost Extension
  - Seawater conditioning subcomponents at PNNL and FAU.
  - Testing pre-/post-conditioned samples with FBG sensors in Q1.
  - Project will be finalized by testing at NREL in FY20 Q2.



- Results will demonstrate how subcomponents perform under load after exposure to seawater.
- Reduce risk: “What are the benefits of using composites?”