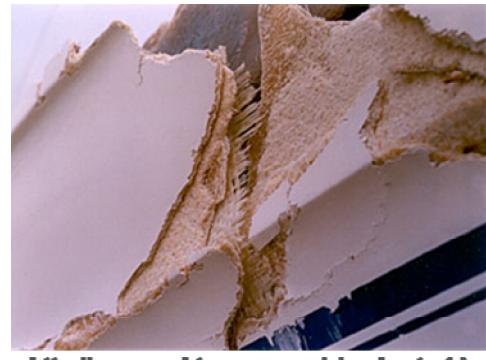


## Helping the MHK industry with materials & protective coatings challenges



<http://www.yachtsurvey.com/glassboats-1.jpg>



<http://www.racerocks.ca/>



ICIT & EMEC  
<http://tidalenergystoday.com/2016/01/12/icit-emeec-study-biofouling-of-marine-energy-technologies/>

## Marine and Hydrokinetics Advanced Materials Program

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February XX, 2017

## Marine and Hydrokinetics Advanced Materials Program:

support the MHK industry through applied research and guidance on Materials & Coatings to enable viability, lower the cost of energy (COE), and accelerate commercialization.

**The Challenge:** Proper structural/component materials and coatings are

critical to reducing engineering barriers, COE, and commercialization time

- **Structure Design & Component:** (LOADS! uncertainty in composite/design)
- **Environmental Exposure Issues**
- **Cost (Manufacture, O&M, Reliability)**
- **Safety & Certification**



## Partners:



- **Sandia National Laboratories (Lead):** Materials Evaluation & Coatings
- **Pacific Northwest National Laboratory:** Biofouling & Environmental Exposure
- **Montana State University:** Composite Materials Evaluation & Development
- **North Dakota State University:** Antifouling Coatings & Biofouling Evaluation
- **Brigham Young University:** Antifouling Coatings

## Increase MHK deployment in opportune markets

### Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance

- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

### Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

### Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

### Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets

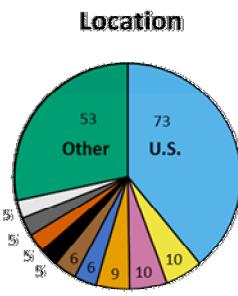
## Increase MHK deployment in opportune markets

### Technology Maturity

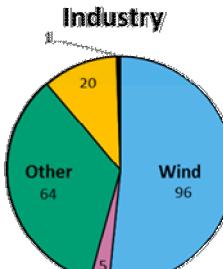
- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance

**The Impact:** Our R&D tests supply chain products and novel solutions to (1) validate performance and (2) lower risk for design/manufacture.

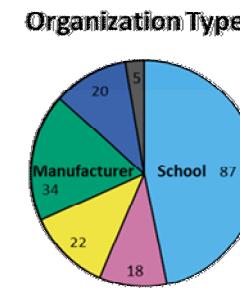
- **U.S. DOE MHK Composite Materials & Structures Database:** Benefits: Open Source, Industry Advised, Backed with Publications.



Legend:  
■ United States  
■ Germany  
■ China  
■ India  
■ United Kingdom  
■ South Korea  
■ Italy  
■ Netherlands  
■ Spain  
■ Turkey  
■ Other



Current User Community of U.S. DOE Materials & Structures Database



Legend:  
■ School  
■ Laboratory  
■ Consultant  
■ Manufacturer  
■ Other  
■ Individual

- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

- **Composite Workshop:** Identify barriers (short, mid, long-term goals)
- **Protective Coatings Performance Validation:** MHK specific coatings identified.

# Technical Approach

## Biofouling & Environmental Exposure for MHK Coatings

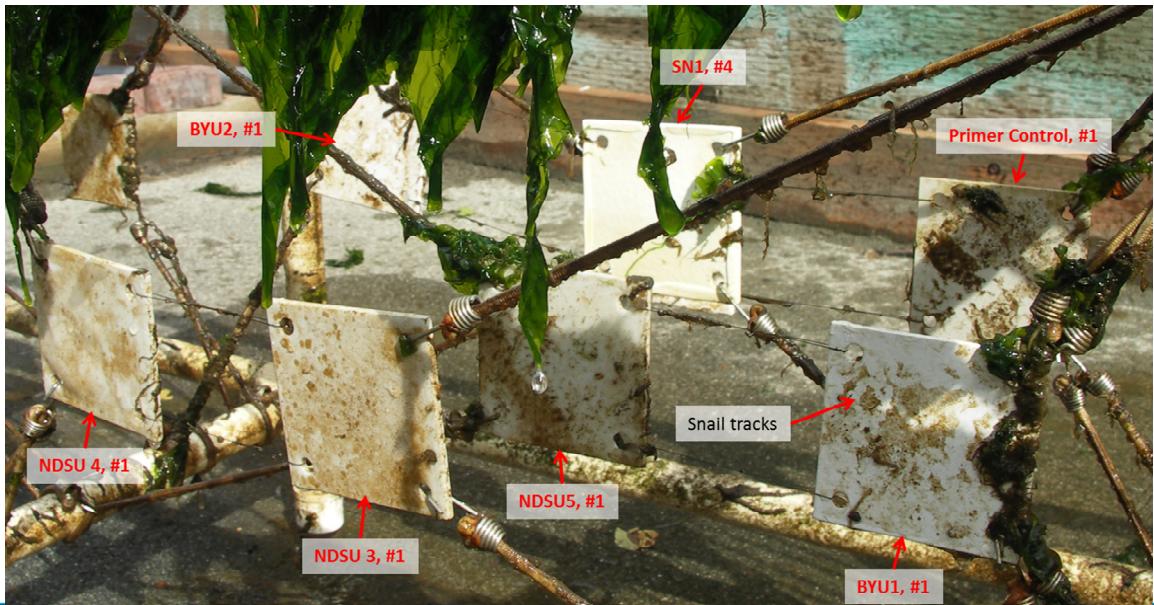
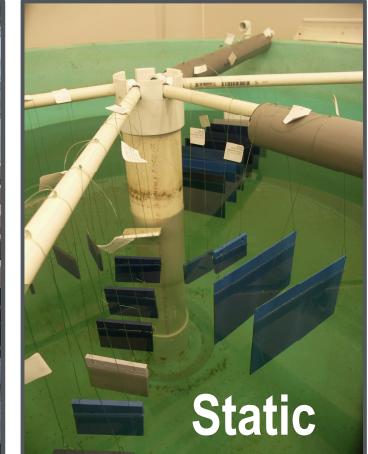


PNNL Marine Sciences Laboratory in Sequim, WA

Determine Environmental Exposure Effects on Commercial & Sandia MHK Specific Coatings.

Evaluate under static & flow conditions with unfiltered natural seawater.

- MHK not operating under shipping conditions!

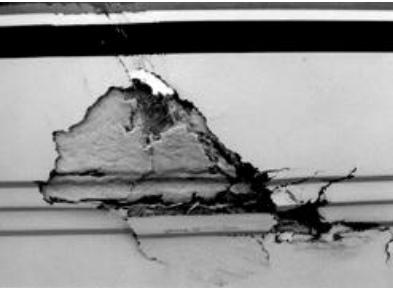


# Technical Approach

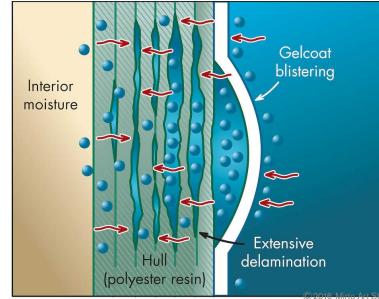
## Engineering designs of MHK devices have difficult, although not unique, materials challenges



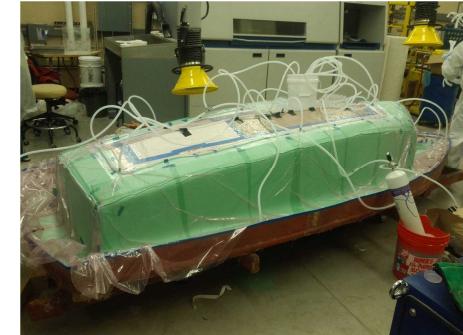
lightweight yet stiff



Strong & durable

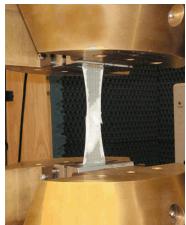


resist environmental degradation

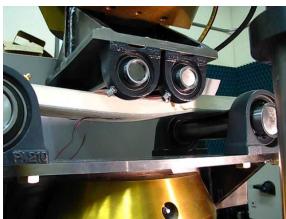


inexpensive & easy to integrate into manufacturing

bridge the technology gaps and knowledge that span across all four of these materials challenges through....



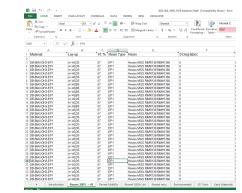
Coupons to Structural elements



Elements to Substructure



Testing to Dissemination



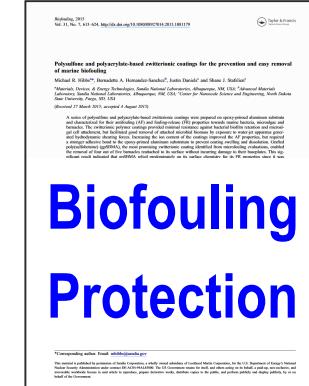
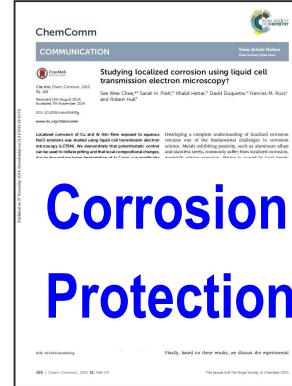
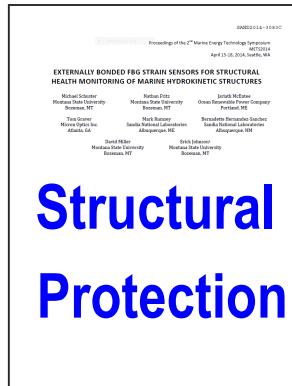
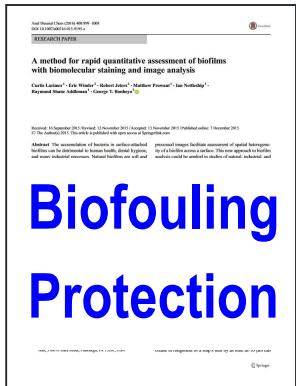
- **Host Workshop to Identify Composite Related Barriers** – What are the composite materials related manufacturing science and engineering barriers that increase the cost of construction, deployment, and operation?

# Accomplishments and Progress: (2014-2016) Helping MHK Industry

- Worked with MHK community, supply chain, composite/coatings manufactures, U.S. Navy, Oil & Gas, and Marine Industries to understand needs and available resources to support MHK stakeholders.



- Delivered open source resources for MHK industry to use to further their design development, improve deployment, and manufacture.



- Provided leadership, R&D also supported student pipeline & STEM initiatives

- Project initiated on October 2014 & Project planned completion was September 2016.
- Slipped schedule in FY 14 due to coatings synthesis delays in scale up. First time team scaled up mg to Kg quantities to support environmental exposure coupon testing. This pushed testing back in to FY 15.
- Go/no-go decision points FY16: During Workshop, Industrial advisors to review new database parameters to determine if content is valued and research worthy of continued development.

# Project Budget



Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$100,000 (PNNL) \$ 421,576 (SNL/MSU/BYU/ NDSU)	\$0	\$50,000 (PNNL) \$400,000 (SNL/MSU/BYU/ NDSU)	\$0	\$285,172 (SNL/MSU)	\$0

- Sandia subcontracted to Montana State University, North Dakota State University, and Brigham Young University
- Additional \$50K in FY 15 was sent to PNNL to support remaining environmental exposure characterization.
- All funds from FY14 through FY16 have been used.
- Other funding sources: None

**Partners, Subcontractors, and Collaborators:** Lead: **Sandia National Laboratories** (Hernandez-Sanchez, Denton, Hibbs); Biofouling Partners: **Pacific Northwest National Laboratories** (Bonheyo, Park, Jeters); **North Dakota State University** (Stafslien); **Brigham Young University** (Savage); Composites Partners: **Montana State University** (Miller)

## Communications and Technology Transfer:

### Journal Publications:

1. Larimer C., Winder E, Jeters R., Prowant M., Nettleship I., Addleman R.S. and Bonheyo G. T. **2016**. A Method for Rapid Quantitative Assessment of Biofilms with Biomolecular Stains and Image Analysis. *Anal Bioanal. Chem.* 408(3):999-1008. doi: 10.1007/s00216-015-9195-z.
2. Hibbs, M. R.; Hernandez-Sanchez, B. A.; Daniels, J.; Stafslien, S. J. [“Polysulfone and Polyacrylate-based Zwitterionic Coatings for the Prevention and Easy Removal of Marine Biofouling,”](#) in *Biofouling: The Journal of Bioadhesion and Biofilm Research*, **2015**, Volume 31, Issue 7, 613-624.
3. Chee, S. W. Pratt, S. H.; Hattar, K. Duquette, D.; Ross, F. M; Hull, R. [“Studying localized corrosion using liquid cell transmission electron microscopy,”](#) *Chem. Comm.*, **2015**, 51 , 168–171
4. Schuester, M.; Fritz, N.; McEntee, J.; Graver, T.; Rumsey, M.; Hernandez-Sanchez, B. A; Miller, D.; Johnson, E. [“Externally Bonded FBG Strain Sensors for Structural Health Monitoring of Marine Hydrokinetic Structures, Global Marine Renewable Energy Conference,”](#) Proceedings of the 2nd Marine Energy Technology Symposium, METS **2014**, April 15–18, 2014, Seattle, WA. SAND Number: 2014-3083C

### In preparation or submitted:

1. Jeters R., Park J., Winder E. M., Addleman R. S., and Bonheyo G. T. “A novel quantitative method to rapidly measure biofilms and biofouling on surfaces using non-purgeable organic carbon (NPOC) analysis. (in preparation)
2. Winder E., Jeters R.; Larimer C.; Addleman S.; and Bonheyo G. “Staining Enhanced Image Analysis of Marine Fouling”. (in preparation)
3. Nunemaker, J.; Miller, D. (2016, May 26). “Effects Of Saltwater Saturation On The Static Strength And Acoustic Emission Signatures Of Epoxy Glass Composites. Paper presented at SAMPE 2016, Long Beach CA.” and Nunemaker, J., MS Thesis, Montana State University, Nov. 2016.”
4. Yubo Li, Xiaobo Gu, Jiyeon Park, Bernadette A. Hernandez-Sanchez, George Bonheyo, Paul B. Savage “Ceragenin-containing coatings for use in inhibiting marine biofouling” (in preparation)

### Presentations:

Antifouling Coatings For Marine Energy Applications: Criteria, Challenges, and Analysis

[https://www.researchgate.net/publication/304628913\\_Antifouling\\_Coatings\\_For\\_Marine\\_Energy\\_Applications\\_Criteria\\_Challenges\\_and\\_Analysis?ev=prf\\_pub](https://www.researchgate.net/publication/304628913_Antifouling_Coatings_For_Marine_Energy_Applications_Criteria_Challenges_and_Analysis?ev=prf_pub). G. Bonheyo, J. Park, A. Avila, R. Jeters, E. Winder, C. Larimer, B. Hernandez-Sanchez , M. Denton, M. Hibbs, P. Savage, S. Stafslien. Presented at the 18th International Congress on Marine Corrosion and Fouling (ICMCF), Toulon, France. June 19-24, 2016.

**Workshops:** Marine and Hydrokinetic Energy Composite Materials Workshop, May 2015, Sandia National Laboratories, Albuquerque, New Mexico,

**Database:** <http://energy.sandia.gov/energy/renewable-energy/water-power/technology-development/advanced-materials/mhk-materials-database/>

## FY17/Current research: Material Design Tools for Marine and Hydrokinetic Composite Structures

**Objective:** Helping MHK industry reduce uncertainty in using composites in their designs

- Providing an *industry approved* U.S. DOE MHK Composite Materials & Structures Database (*open resource*): <http://energy.sandia.gov/energy/renewable-energy/water-power/technology-development/advanced-materials/mhk-materials-database/>
- Mitigating composite biofouling/environmental effects & metal-carbon fiber interconnect corrosion in saltwater
- Examining MHK load challenges on composite material & substructure performance to improve design



## Proposed future research:

### Support Domestic Manufacturing

- Expand on substructure to full scale testing at NREL
- Expand on composites manufacturing process with developers to examine component/materials reliability
- Include near or full-scale process demonstrations and validation for candidate manufacturing methods
- Develop MHK non-destructive inspection guidelines for quality assurance (manufacturing, transport, operation, maintenance).

