Helping the marine and hydrokinetics industry with materials and protective coatings challenges

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

http://www.racerocks.ca/

http://tidalenergytoday.com/2016/01/12/icit-emec-study-biofouling-of-marine-energy-technologies/

Marine and Hydrokinetics Advanced Materials Program

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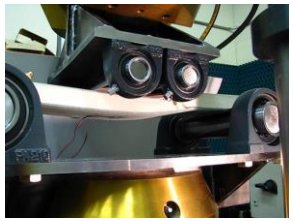
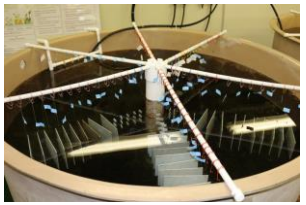
Marine and Hydrokinetics Advanced Materials Program:

Support the marine and hydrokinetics (MHK) industry through applied research and guidance on materials and 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 and Component: (LOADS! uncertainty in composite/design)**
- **Environmental Exposure Issues**
- **Cost (manufacture, O&M, reliability)**
- **Safety and 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

Program Strategic Priorities

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Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- **Conduct R&D for Innovative MHK systems & components**
- 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
- Exchange of data information and expertise

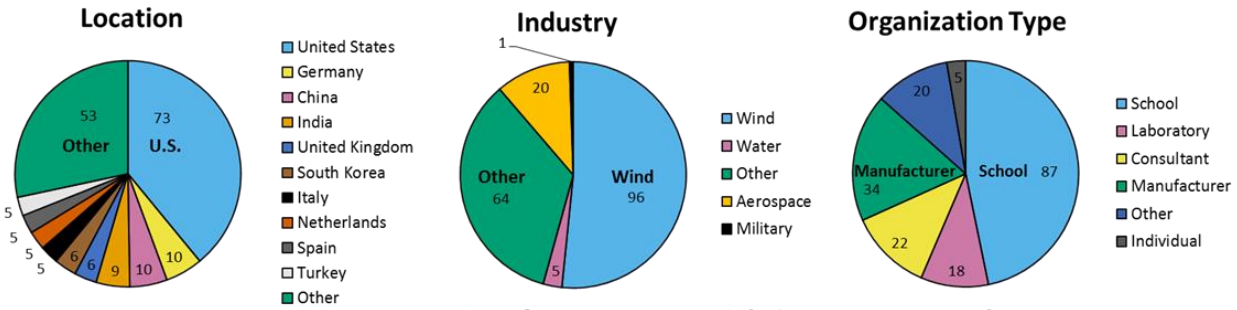
Project Strategic Alignment

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for innovative MHK systems & components
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

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 and Structures Database:** Benefits: open source, industry advised, backed with publications



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

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

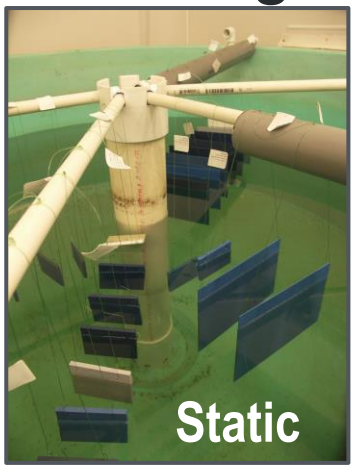
Biofouling and Environmental Exposure for MHK Coatings

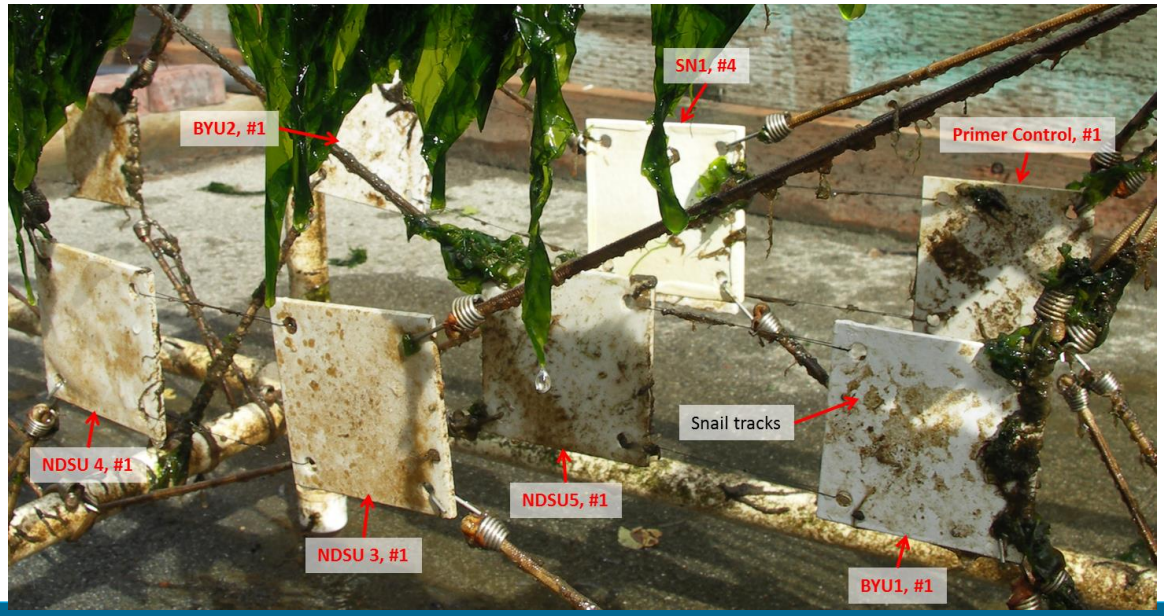
Pacific Northwest National Lab Marine Sciences Laboratory in Sequim , WA

Determine Environmental Exposure Effects on Commercial and Sandia MHK-specific Coatings.

Evaluate under static and flow conditions with <u>unfiltered natural seawater</u>.

- MHK not operating under shipping conditions!





Technical Approach

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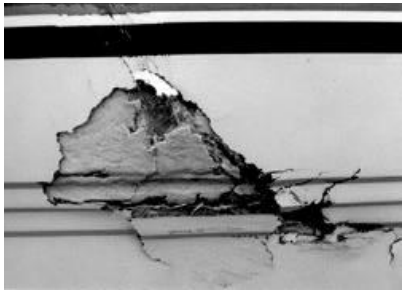
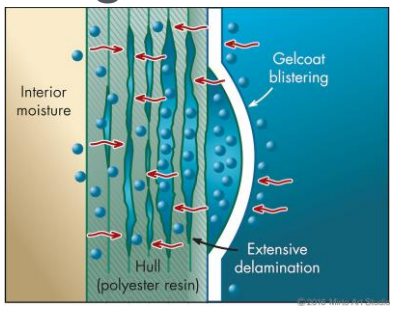
Engineering designs of MHK devices have difficult, although not unique, materials challenges

Lightweight, yet stiff



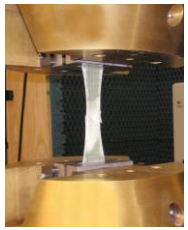
strong and durable



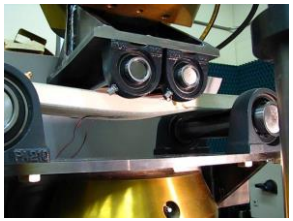
resist environmental degradation

Inexpensive and easy to integrate into manufacturing

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

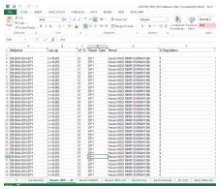


Coupons to Structural elements



Elements to Substructure

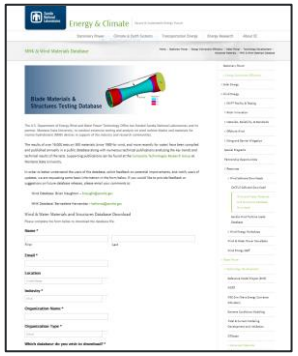
Testing to Dissemination



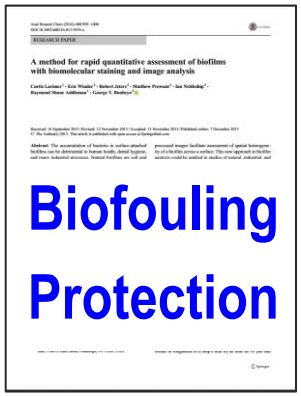
- **<u>Host Workshop to Identify Composite Related Barriers</u>** – What are the composite materials-related manufacturing science and engineering barriers that increase the cost of construction, deployment, and operation?

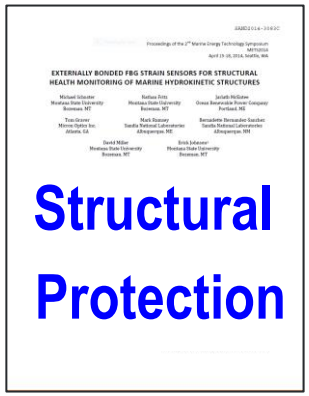
Accomplishments and Progress: (2014-2016) Helping MHK Industry

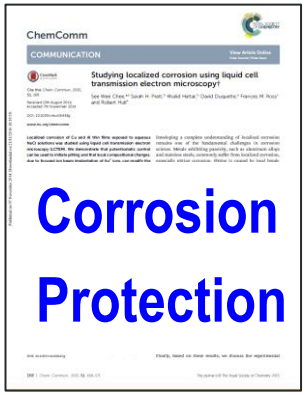
- Worked with MHK community, supply chain, composite/coatings manufacturers, U.S. Navy, oil and gas, and marine industries to understand needs and available resources to support MHK stakeholders.

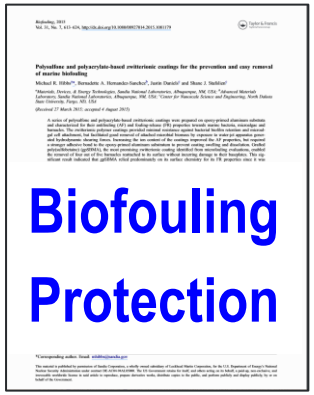


- Delivered open-source resources for MHK industry to use to further their design development, improve deployment, and manufacture.









ICOE
METS
MARINE ENERGY TECHNOLOGY SYMPOSIUM
IMREC
INTERNATIONAL MARINE RENEWABLE ENERGY CONFERENCE
NHA ANNUAL CONFERENCE

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

Project Plan & Schedule

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- Project initiated on October 2014, and 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
$100k (PNNL) $ 421.58k (SNL/MSU/BYU/ NDSU)	$0	$50k (PNNL) $400k (SNL/MSU/BYU/ NDSU)	$0	$285.17k (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 Pacific Northwest National Laboratory (PNNL) to support remaining environmental exposure characterization.
- All funds from FY14 through FY16 have been used.
- Other funding sources: None

Research Integration & Collaboration

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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: 2014-3083**C**

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>. 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/

Next Steps and Future Research

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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 and 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 and metal-carbon fiber interconnect corrosion in saltwater
- Examining MHK load challenges on composite material and substructure performance to improve design

Sandia National Laboratories | Pacific Northwest National Laboratory | NREL National Renewable Energy Laboratory | Montana State University | FAU Florida Atlantic University

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).