# Marine Renewable Energy and the Environment: Progress and Challenges

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# Motivation

- Increasing concern over impacts of climate change, particularly on ocean ecosystems
- Part of the solution is transitioning to low-carbon sources of power generation
- The oceans are a potential source of sustainable power

# Offshore Wind Energy

*Horns Rev*
*(160 MW Array)*

*Statoil Hywind*
*(2 MW demonstration platform)*

*Principle Power WindFloat*
*(2 MW demonstration platform)*

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# Tidal Current Energy

*Andritz Hydro/Hammerfest (1.0 MW)*

*Siemens/MCT SeaGen (1.2 MW)*

*Ocean Renewable Power Company (0.2 MW)*

*Alstom/Tidal General Limited (1.0 MW)*

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# Wave Energy

*Pelamis (0.8 MW)*

*Wave Dragon (4.0 MW)*

*Columbia Power Technology (< 0.1 MW)*

*Aquamarine Oyster (0.8 MW)*

*Wello Oy Penguin (0.5 MW)*

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# Power Generation Landscape

- **The United States has more than 107,000 MW of coal-fired generation capacity. Natural gas has a similar capacity and is expanding rapidly.**
- **The United States has more than 60,000 MW of terrestrial wind generation capacity (13,200 MW added in 2012)**
- **The United States currently has about *0 MW* of installed marine renewable generation capacity**

# Global Economic Challenge: Shale Gas

Hydraulic fracturing site in Bradford County, Penn
*Source: Appalachian Voices*

**Can marine renewable energy compete with electricity generation from shale gas?**

# Marine Energy Economics

| Generation Technology | Current | Long Term Projection |
|---|---|---|
| **Combined Cycle Natural Gas** | 40-80 $/MWh | ? |
| **Offshore Wind (deep water)** | 100-300 $/MWh | 60-100 $/MWh |
| **Tidal Current** | 300-400 $/MWh | 50-150 $/MWh |
| **Wave** | 400-500 $/MWh | 50-100 $/MWh |

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# Global Technical Challenge: Proving System Reliability


1 MW Alstom turbine mobilization (Orkney, UK)

**Can we prove that a turbine can reliably produce power over *N* years in much less than *N* years?**

# Tidal Energy: Engineering Approaches

**Lower Efficiency**

**Mechanical Simplicity**

**Higher Efficiency**

**Mechanical Complexity**

**Design Philosophy Spectrum**

*DCNS/OpenHydro (1.0 MW)*

*Siemens/MCT (1.2 MW)*

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# Global Social Challenge: Non-exclusionary Use of the Ocean

**Can marine renewable energy complement existing uses of the ocean or enable new uses?**

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# Societal Influences

- **Opportunity for society to help shape the evolution of marine energy technology**
- **Outreach is critically important – In the absence of information society draws its own conclusions.**
- **"Sustainability of Tidal Energy"**
  - — Integrated engineering, environmental and societal considerations
  - — NSF Sustainable Energy Pathway

*w/ Kiki Jenkins and Nicole Faghin*

# Global Environmental Challenge: "Retiring Risk"

**Can we prove whether or not a marine renewable energy development will have environmental impacts over in *N* years of operation in much less than *N* years?**

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# First Question – What are we studying?

**Stressor**

*An alteration to the environment by installation, operation, or maintenance of a marine renewable energy convreter*

**Change**

*A detectable or measurable alteration*

**Effect**

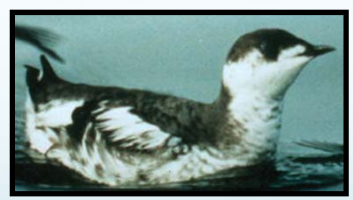
*A change threshold denoting biological importance – specific to site and project scale*

**Impact**

*Negative effect*

**Benefit**

*Positive effect*



*w/ John Horne at the NSF Workshop: Research at the Interface of Marine/Hydrokinetic Energy and the Environment, October 6, 2011*

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# Second Question – Why should we study?

**Satisfy Regulatory Requirements**

↓

**Identify Commercial-Scale Impacts**

↓

**Pre-empt Impacts by Design**

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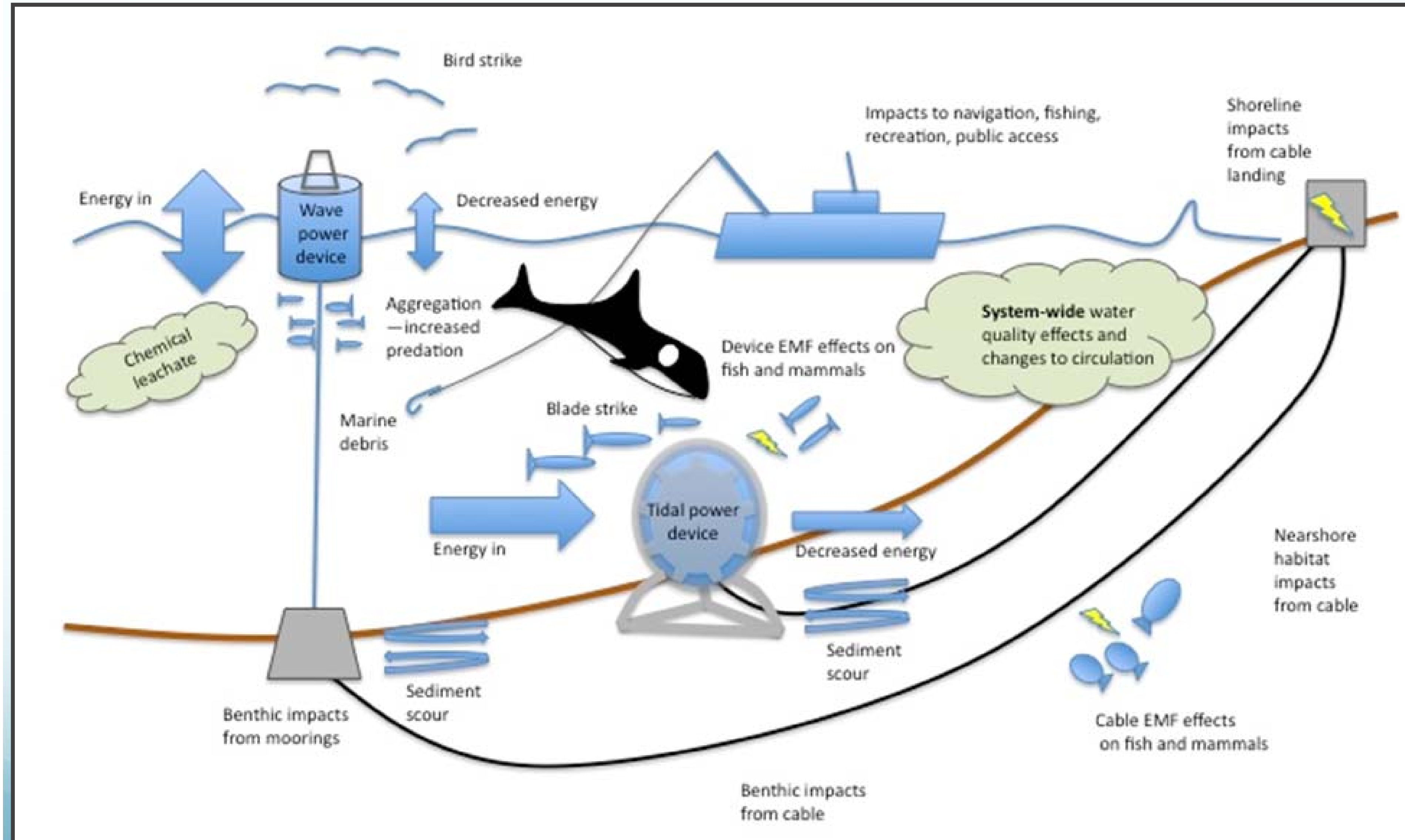
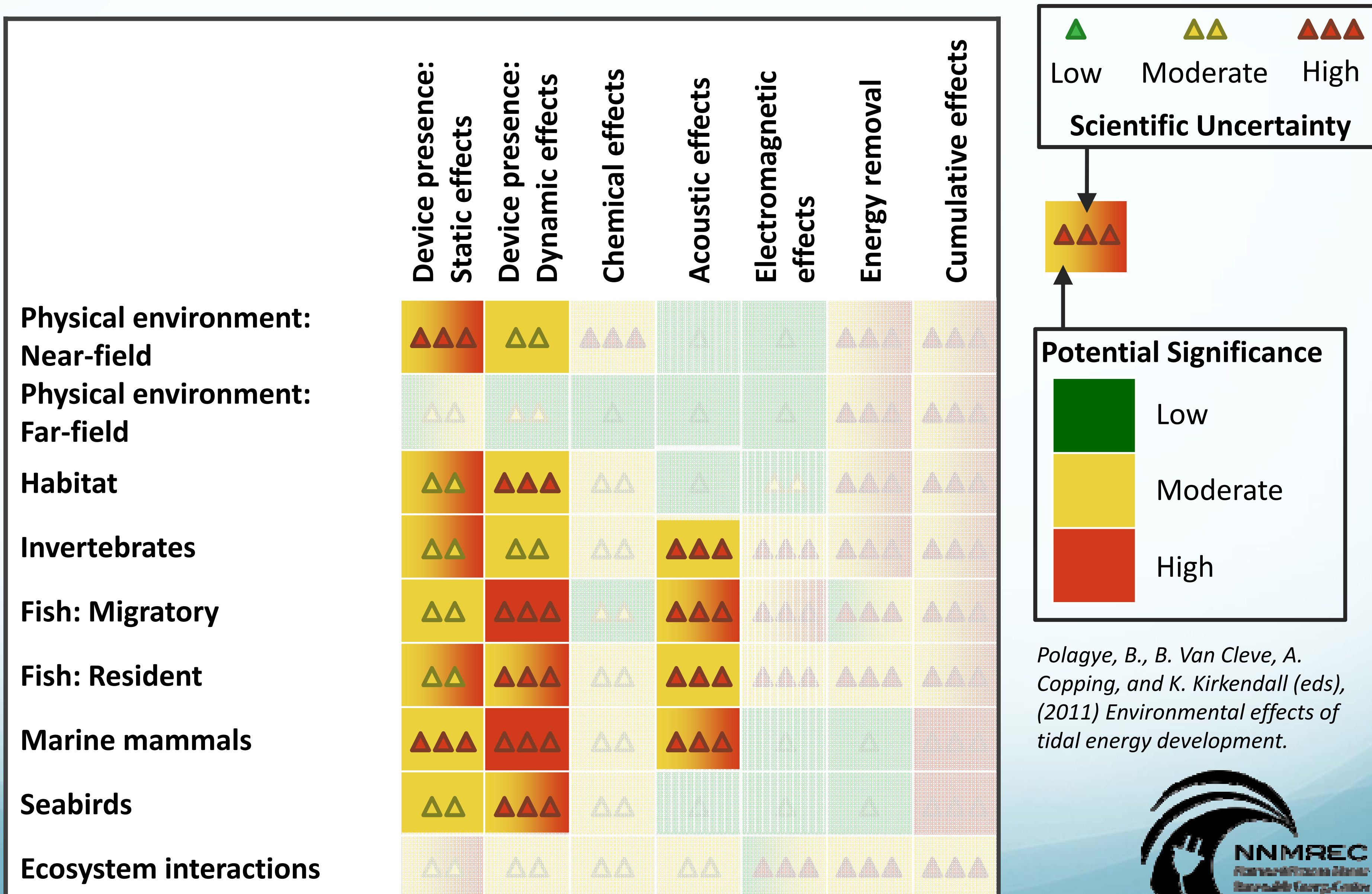
# Third Question – What are the pathways?




*Source: Simon Geerloffs, Pacific Northwest National Laboratory*

# Fourth Question – What are the priorities?




*Polagye, B., B. Van Cleve, A. Copping, and K. Kirkendall (eds), (2011) Environmental effects of tidal energy development.*

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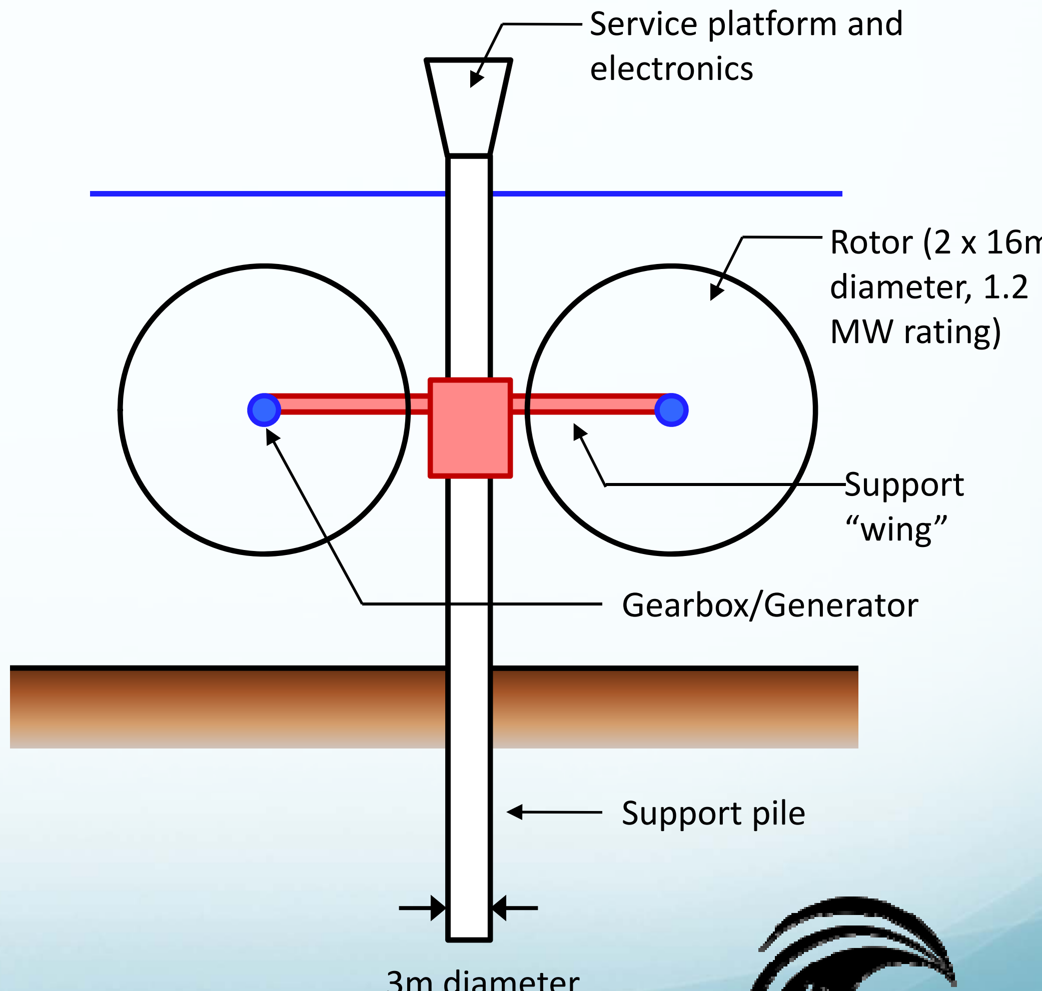
# Monitor Changes or Mitigate Risks?

***"The Lesson from Strangford Lough"***

Siemens/Marine Current Turbines SeaGen

*Northern Ireland*



# Strangford Lough Experience

- **SeaGen installed and commissioned in 2008**
- **Risk factors for *impacts* to harbor seals**
  - Activity in the Lough – foraging and transits to Irish Sea
  - Scale of project
  - Risk for injury (tip velocity, mechanism for tip contact)

- **Post-installation blade strike mitigation: "Shut down turbine when harbor seals within *X* m."**
  - *Problem 1*: How do you tell when a harbor seal is X m away from the turbine?
  - *Problem 2*: What information does this give us about the actual risks to harbor seals?

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# Progress on High-Priority Concerns

- **Since 2010 – multiple commercial demonstrations of wave and tidal technology in US and Europe, most with substantial monitoring programs**
- **Key Outcomes**
  - — Fish mortality for tidal turbines is infrequent (none observed to date)
  - — Marine energy converters produce sound
  - — Subsea structures are colonized by marine life

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# Environmental Monitoring Paradox

- **At existing proportion of total project cost, environmental monitoring is economically crippling to industry**
- **If early commercial projects cause environmental harm, the industry may also be crippled**
- **How do we avoid impacts without incurring high costs?**

*w/ Andrea Copping: Instrumentation for Monitoring around Marine Renewable Energy Converters*

# Challenge: “Retiring Risk”

- **Often, the objective of monitoring is to collect information that improves certainty in evaluating environmental risk** (frequency *x* outcome)
- ***Ideally*, over time:**
  - — Significant risks can be recognized and mitigated through changes to converter design or operation
  - — Insignificant risks can be selectively “retired” from monitoring programs
- **For high-priority risks, no agreed upon framework for reaching either of these end states**

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# Challenge: "Data Mortgages"

- **Often, risks of greatest concern are serious outcomes with low probabilities of occurrence**
- **Spatial *comprehensive* and temporally *continuous* monitoring of converters requires the least time to resolve risk – "collect everything"**
- **Data bandwidth for "brute force" approaches to this is problematic – "data mortgages"**

**Stereo-optical Cameras (2 Mpx @ 10 fps)** X **80 MB/s** X **3 months observations** = **600 TB of storage**

***Example***: *Continuous stereo-optical monitoring for a single system. Comprehensive monitoring would require multiple systems.*

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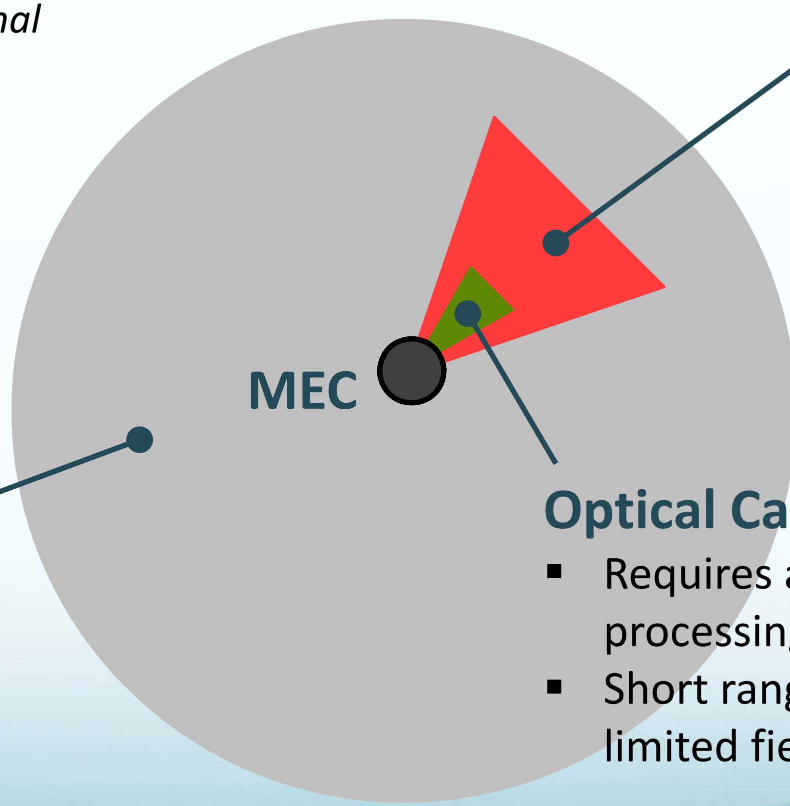
# Options to Retire Risk without Mortgages

- **Instruments that intrinsically produce information**
  - *Example*: recording and transponding tags
  - Tend to be expensive to deploy in large numbers
- **Automated processing that mines data for information**
  - *Example*: split-beam echosounders
  - Requires ability to "trash" raw data
- **Is it reasonable to expect a "silver bullet" software solution for all instruments?**

# A Better Alternative? Integrated Packages

- **Intermediate option to pure hardware or software solutions**

***Example****: Detect, track, and identify a marine mammal approaching a MEC*




### Split-beam Echosounder

- Processing in near real-time
- Tracking capability at ranges beyond 100 m

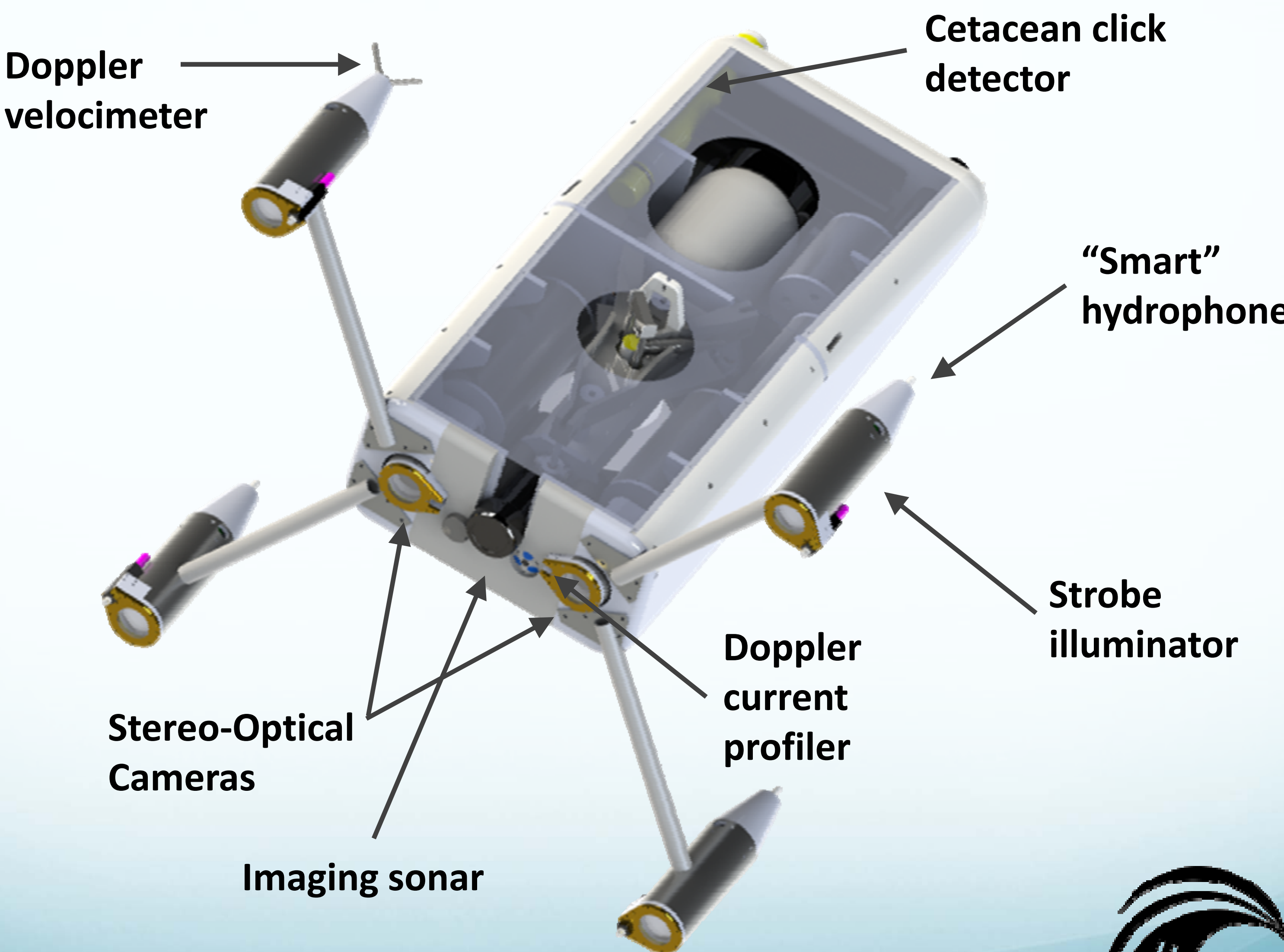
### Passive Acoustic Detection

- Processing in near real-time
- Omni-directional coverage at ranges on the order of 1 km

### Optical Camera

- Requires archival processing
- Short range and limited field of view

# Adaptable Monitoring Package (AMP)




***And more…***

*w/ Andy Stewart, James Joslin, Ben Rush, Paul Gibbs,…*

# Data and Power Needs


***Need a cabled connection to shore…***

***…but so does the marine energy converter.***

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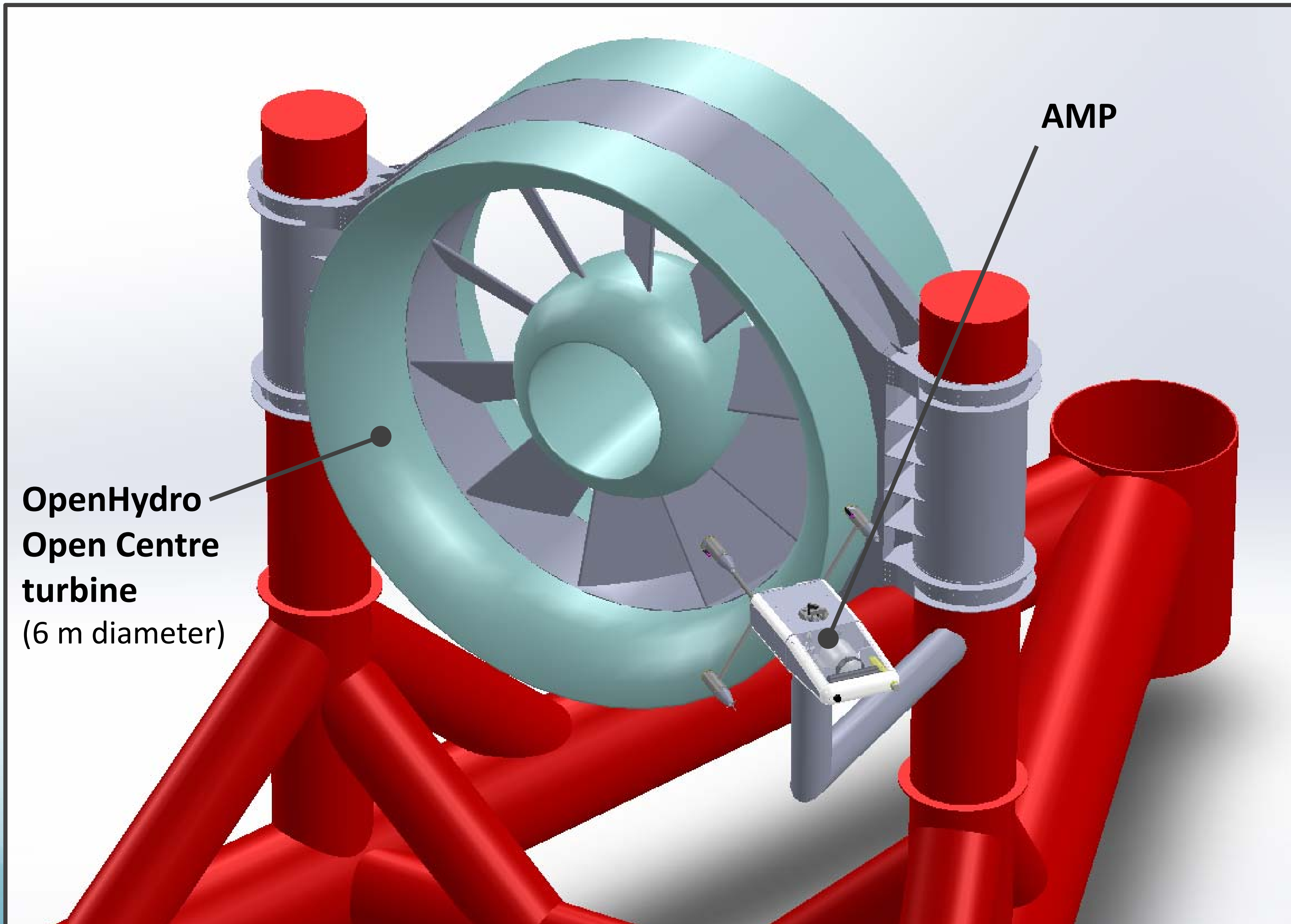
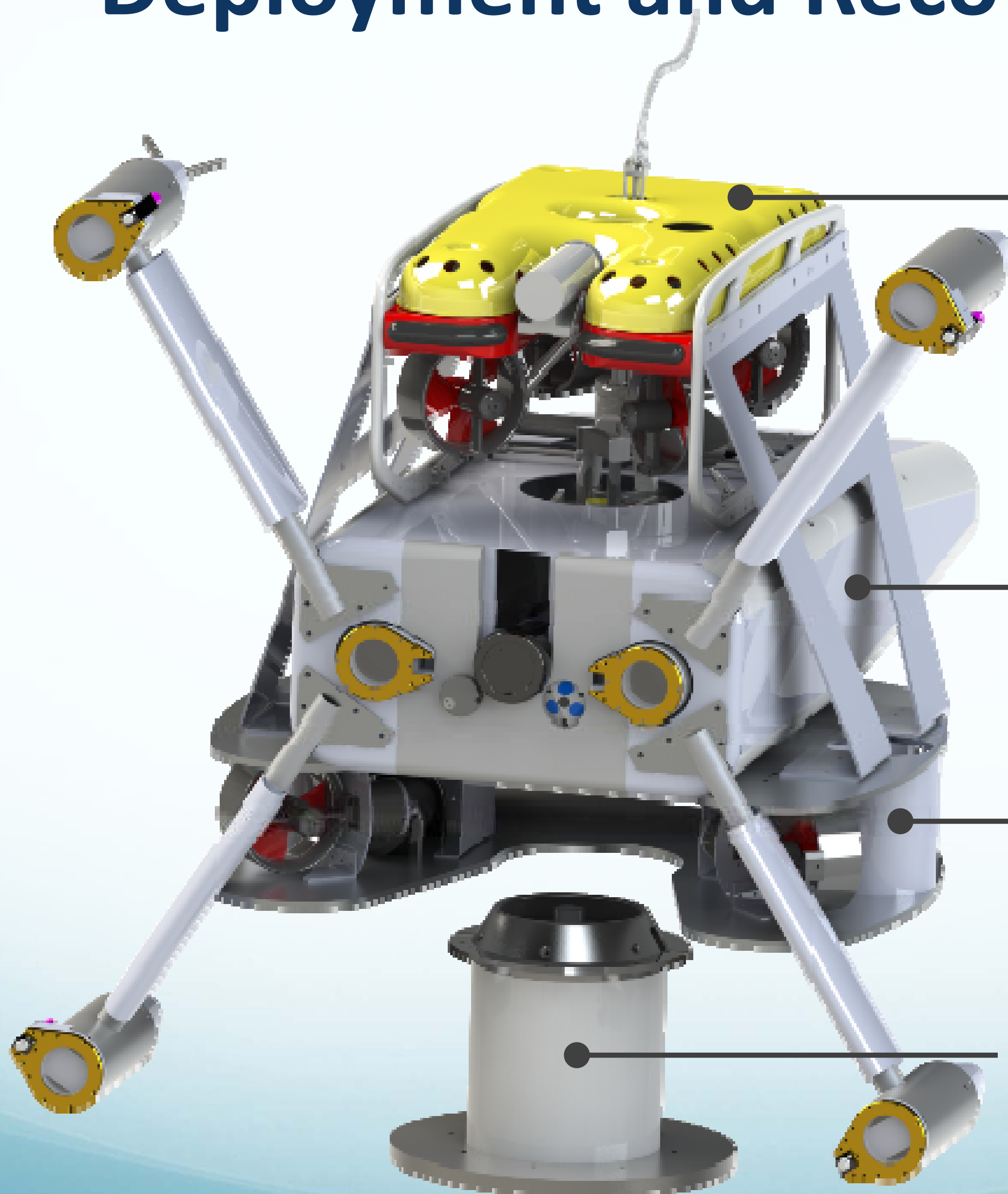
# Integration with Marine Energy Converter



# Deployment and Recovery System



**SAAB SeaEye Falcon**

**AMP**

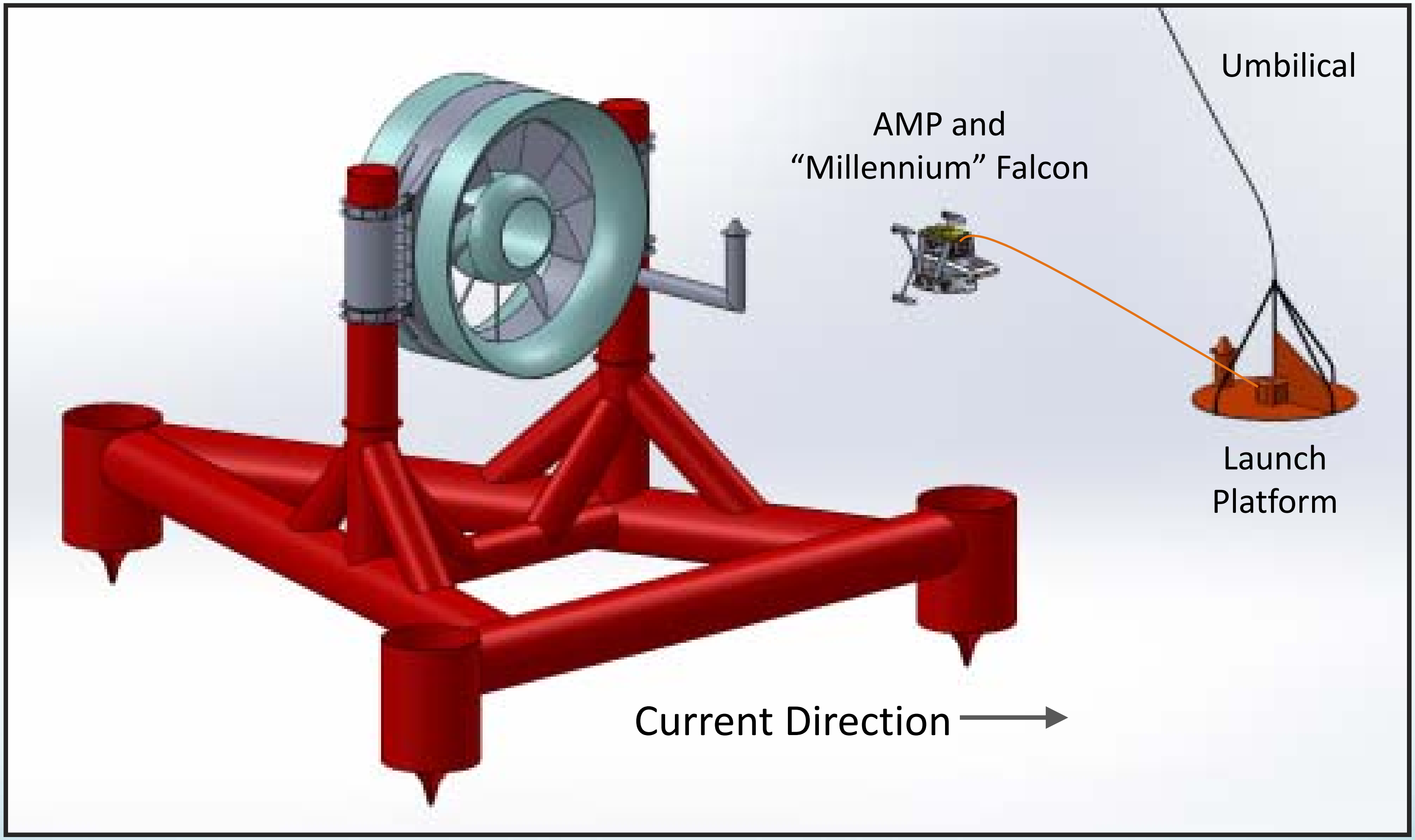
**Custom skid**

*w/ SeaView Systems*

**Docking Station**

- Power and fiber wet-mate

# AMP Deployment Approach




**At-sea flight tests starting by fall 2014…**

# Conclusions

- **Marine renewable energy must overcome significant challenges, but has significant potential**
- **Progress requires a coupled engineering, environmental, societal, and economic approach to problem solving**
- **Broad collaboration between researchers (multi-disciplinary), industry, regulators, and public required**

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*DOE Environmental Webinar series starts tomorrow morning – Monitoring Instrumentation*

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