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)

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)

Wello Oy Penguin (0.5 MW)

Aquamarine Oyster (0.8 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**

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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)

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?

First Question – What are we studying?

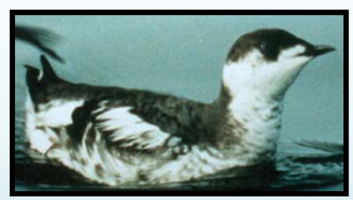
Stressor — *An alteration to the environment by installation, operation, or maintenance of a marine renewable energy convreter*

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

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Identify Commercial-Scale Impacts

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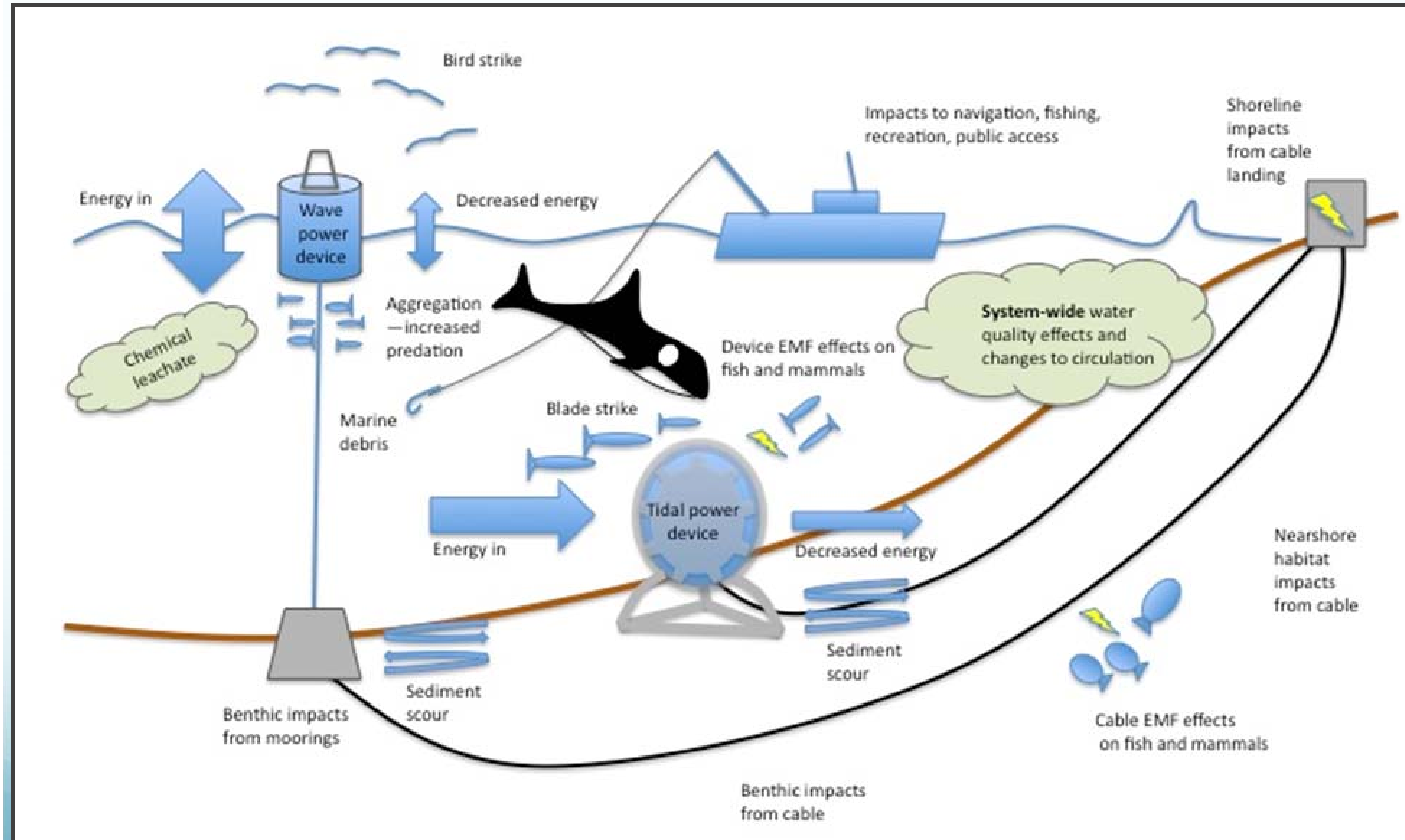
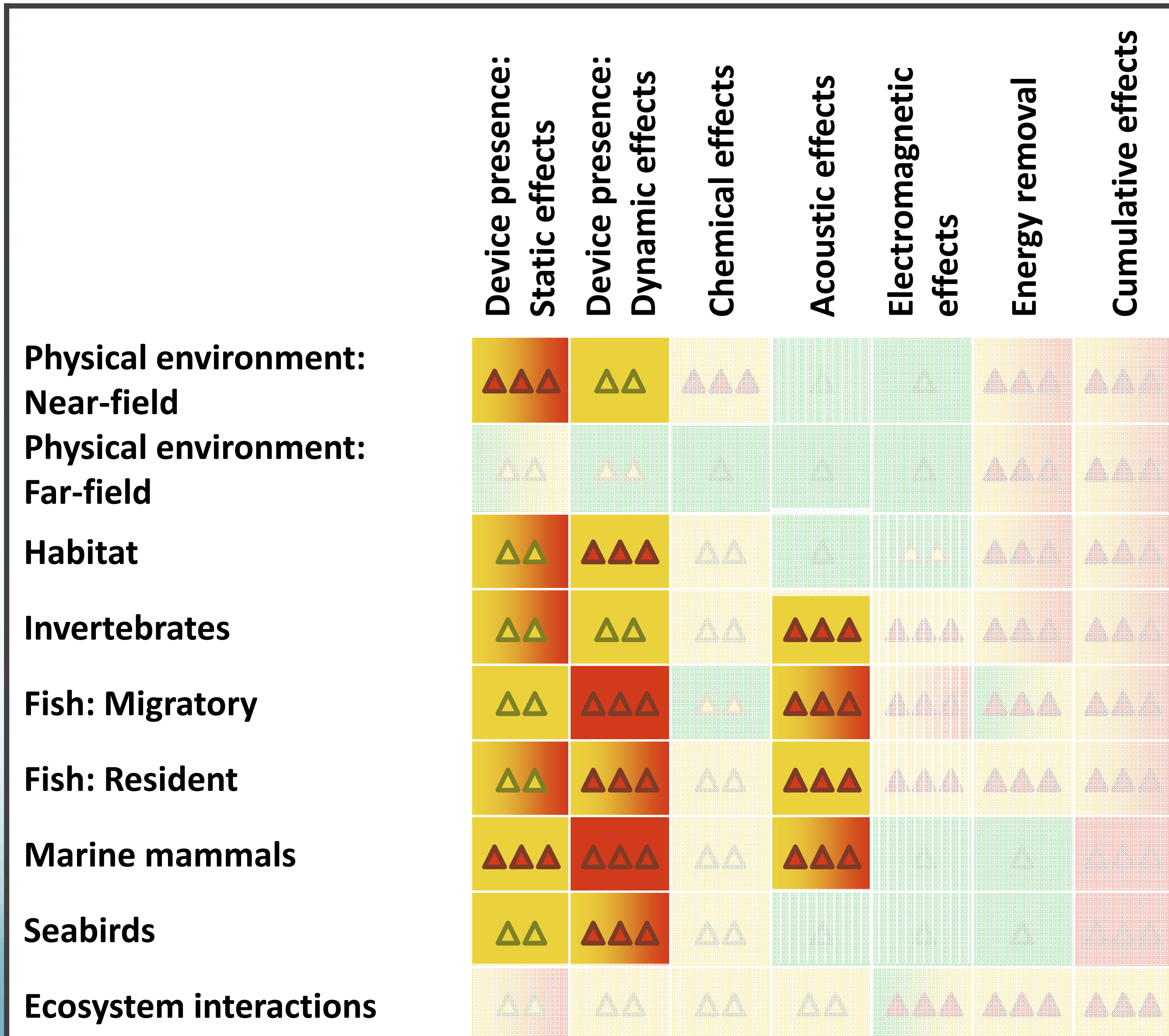
Pre-empt Impacts by Design

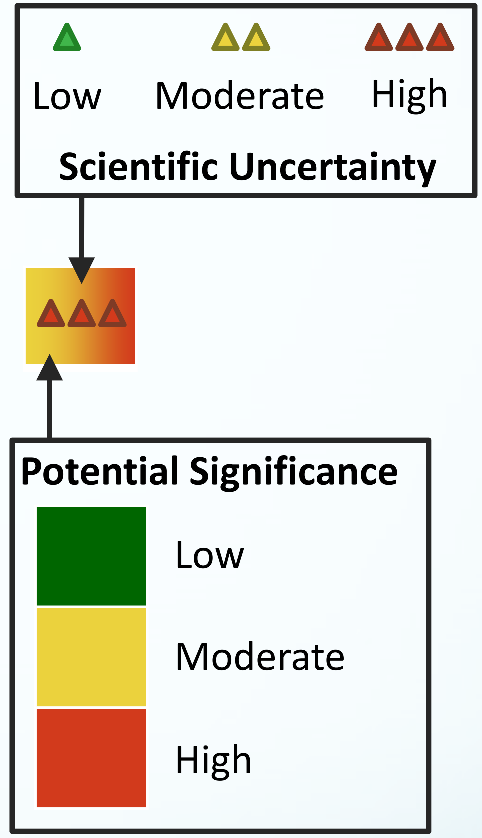
Third Question – What are the pathways?



Source: Simon Geerloffs, Pacific Northwest National Laboratory

Fourth Question – What are the priorities?





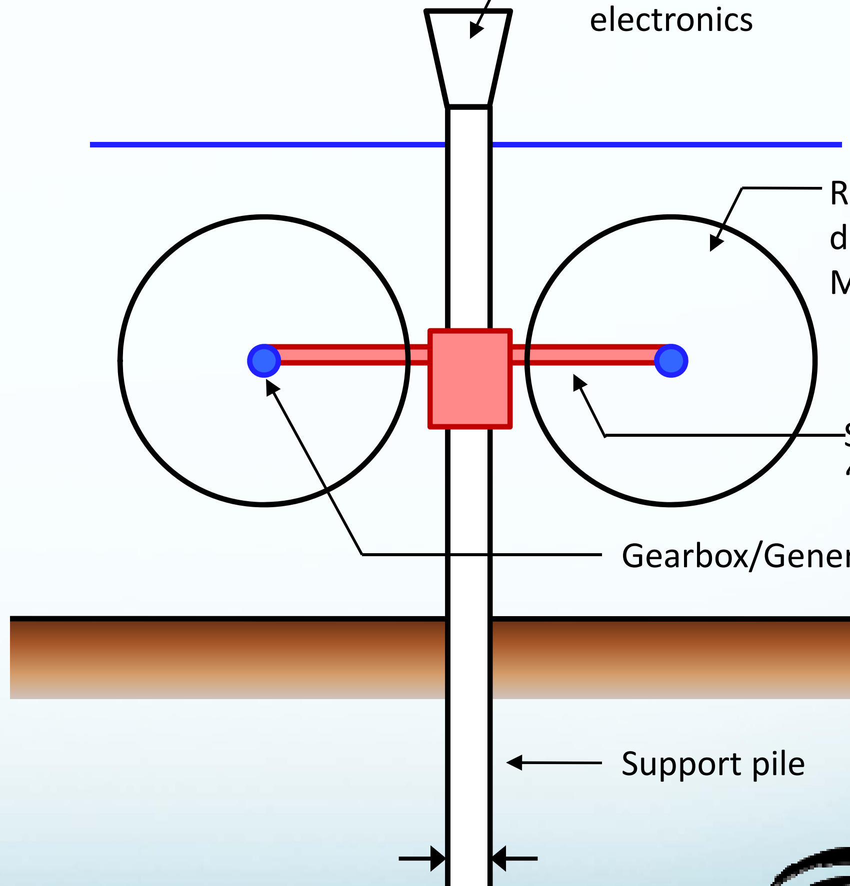
Polagye, B., B. Van Cleve, A. Copping, and K. Kirkendall (eds), (2011) Environmental effects of tidal energy development.

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

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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**

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?**

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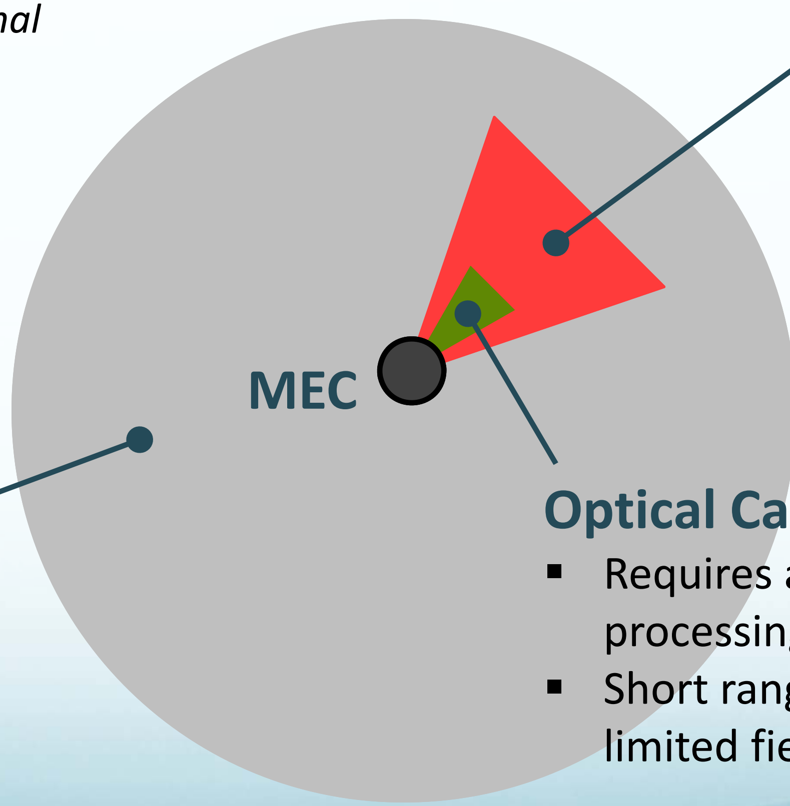
A Better Alternative? Integrated Packages

- **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

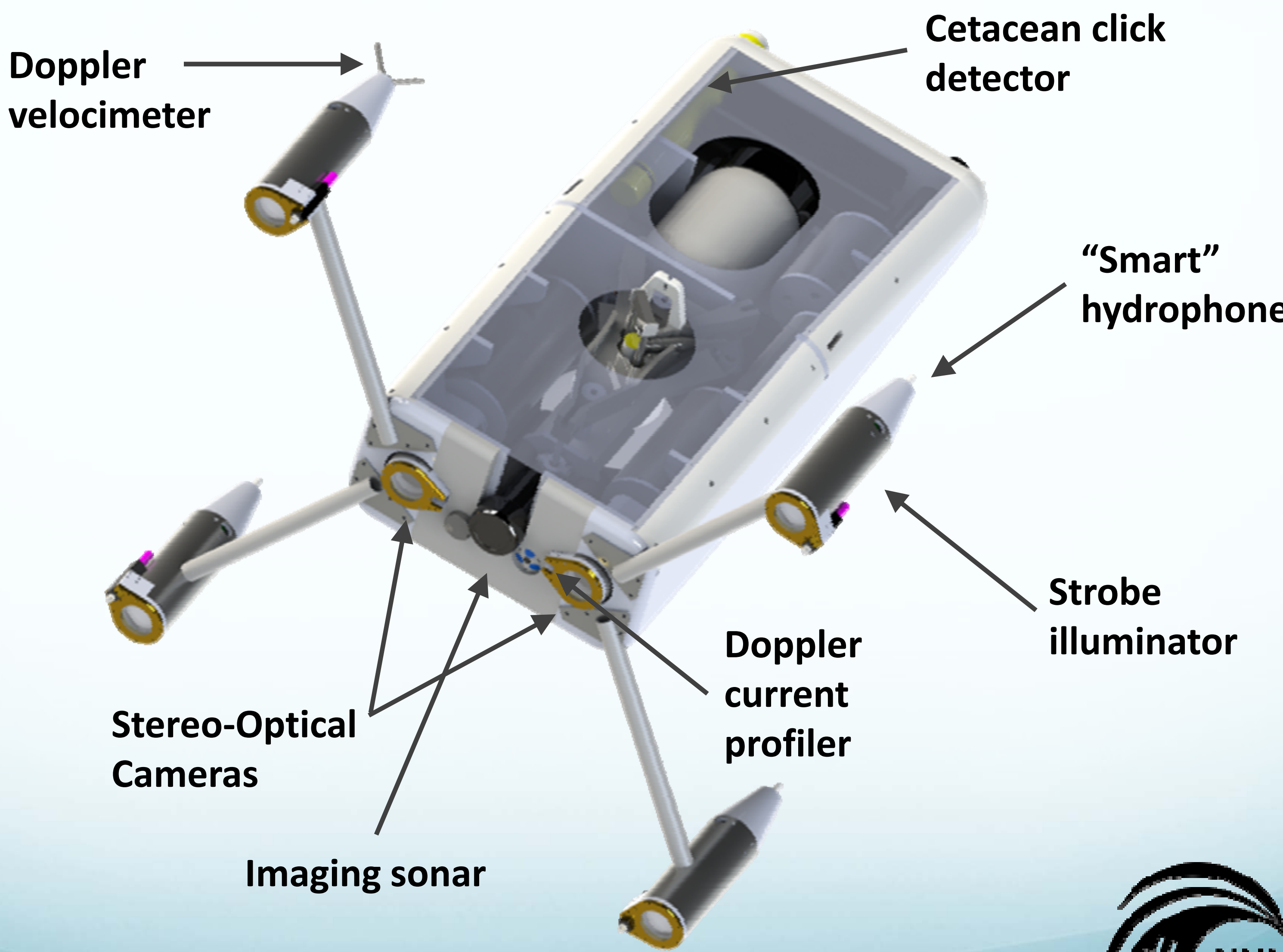
Passive Acoustic Detection

- 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…

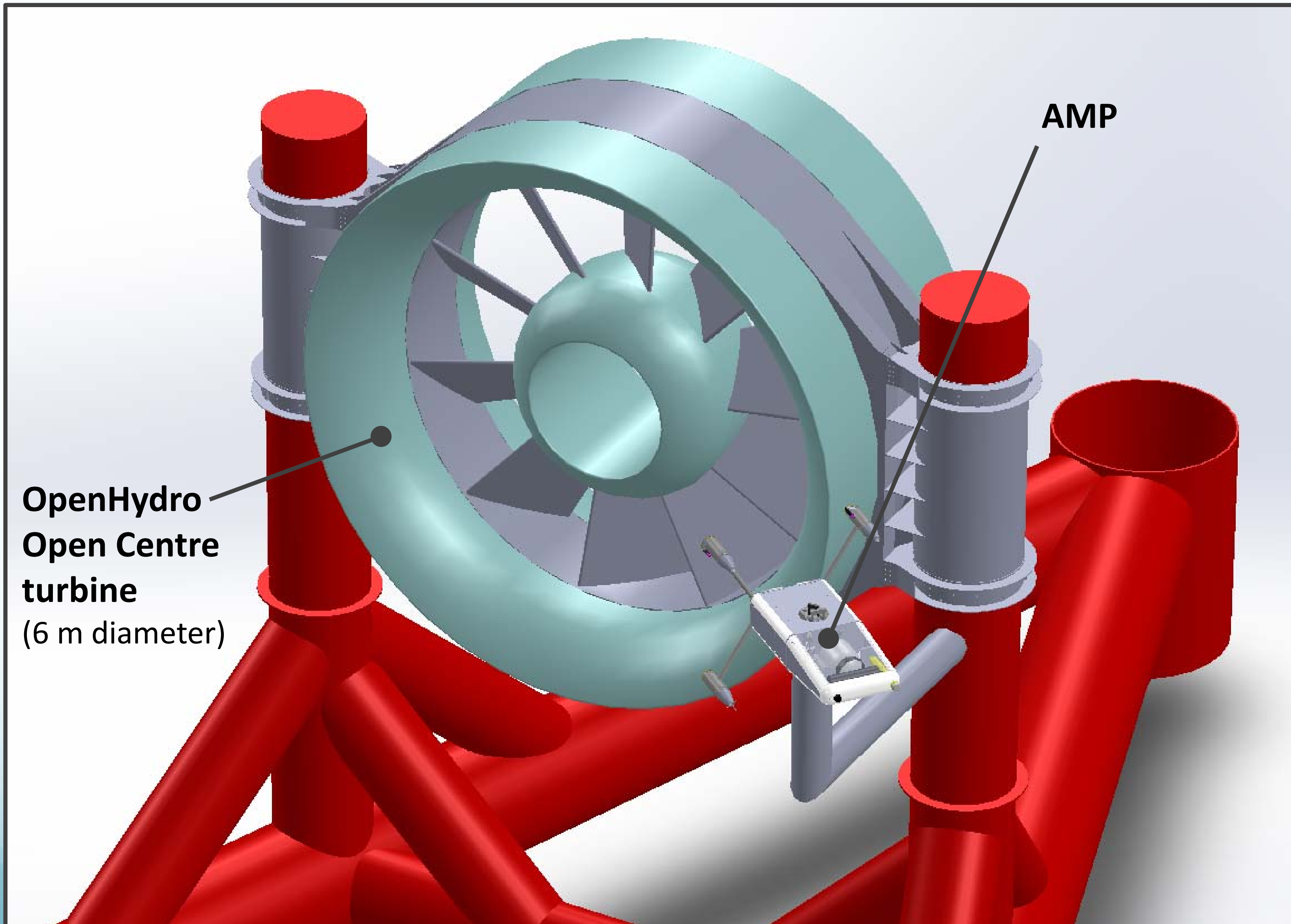
w/ Andy Stewart, James Joslin, Ben Rush, Paul Gibbs,…

Data and Power Needs

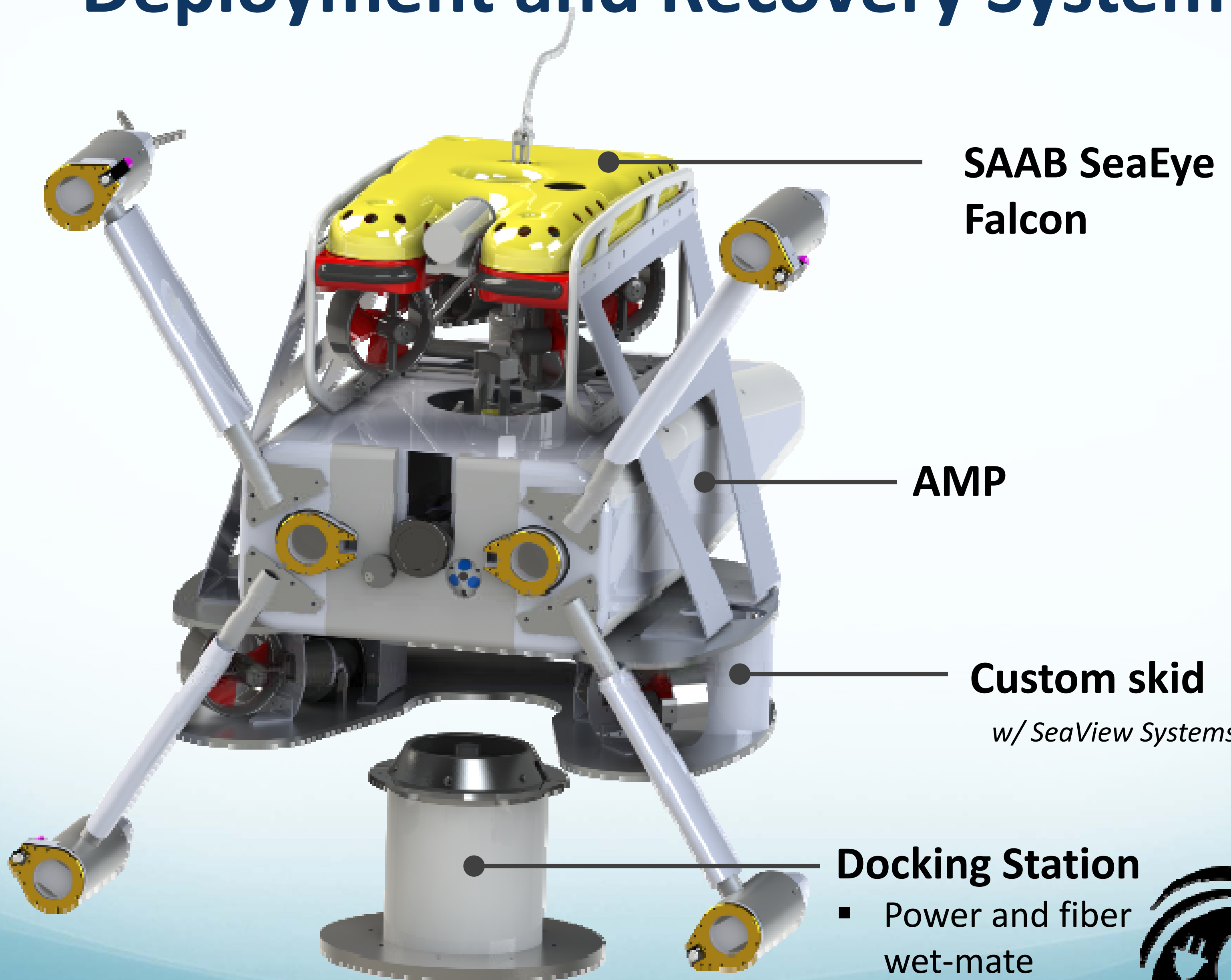
Need a cabled connection to shore…

…but so does the marine energy converter.

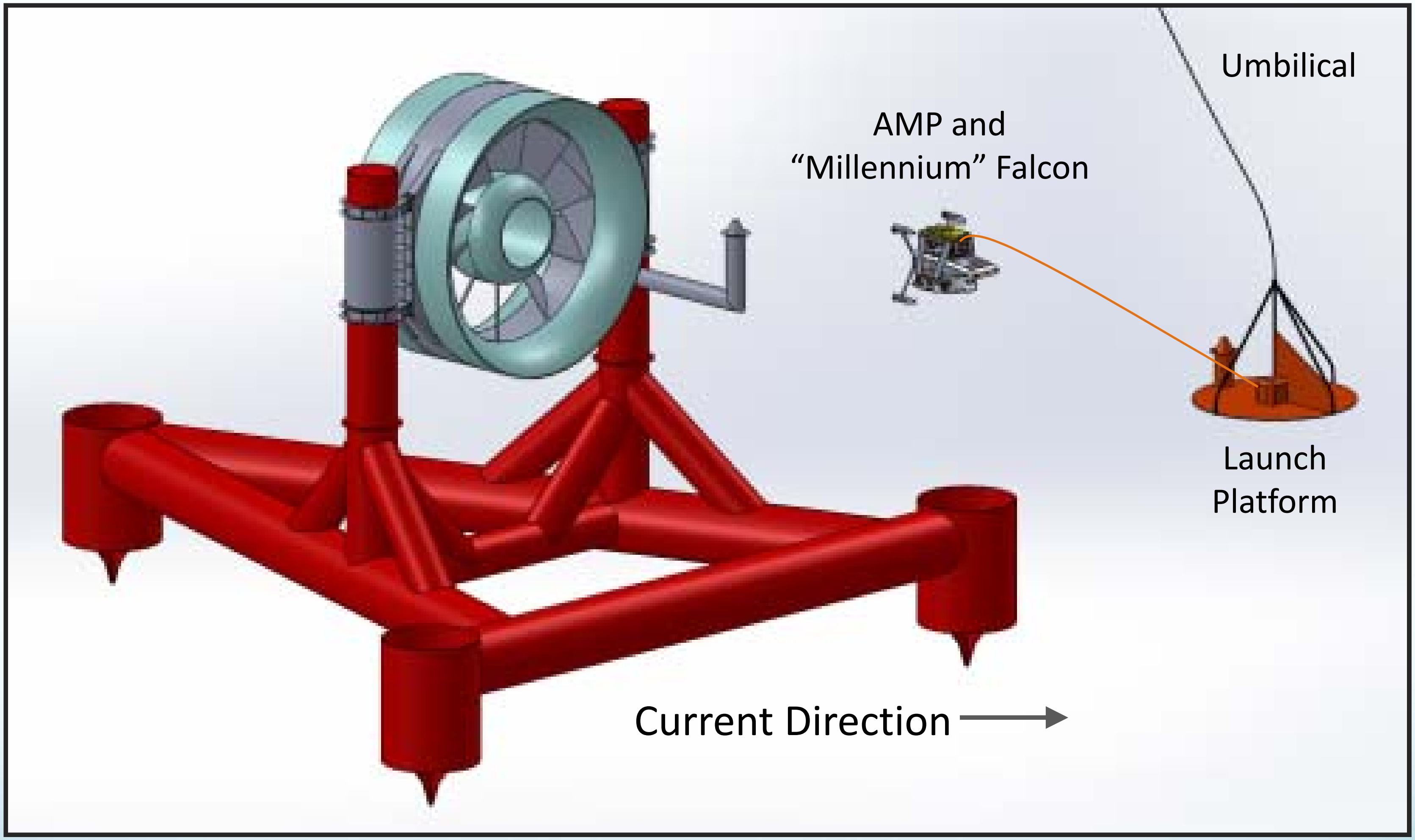
Integration with Marine Energy Converter



Deployment and Recovery System



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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