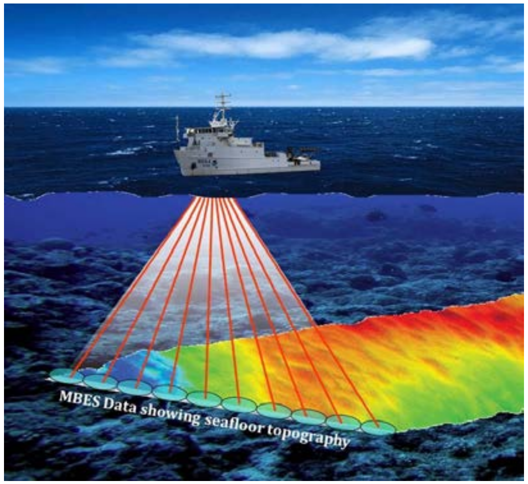
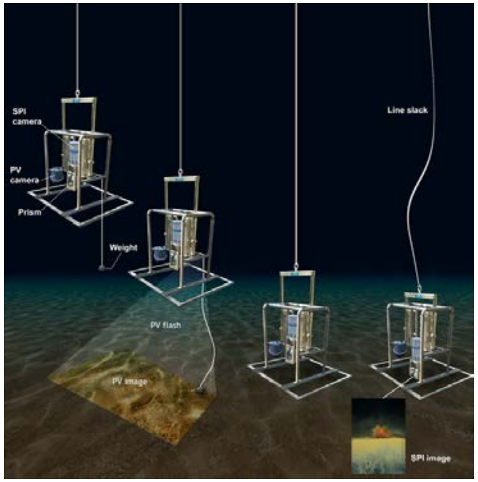
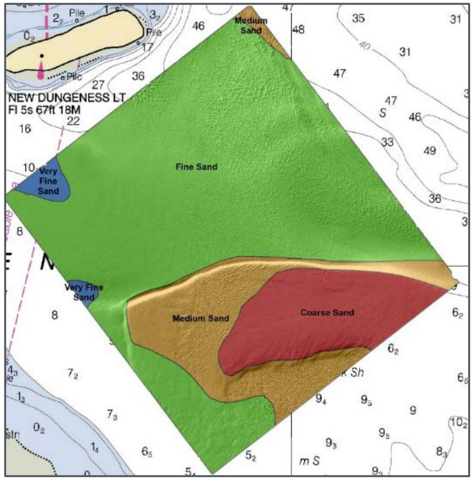






A Benthic Habitat Monitoring Approach For MHK Sites

DE-EE0007826

Marine and Hydrokinetics Program

October 9, 2019

Gene Revelas

Integral Consulting Inc.

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary

A seafloor survey approach for generating detailed benthic habitat maps at MHK sites was developed. This approach combined multibeam bathymetry and acoustic backscatter mapping with sediment profile imaging and plan view (SPI/PV) imaging as a rapid, cost-effective protocol. A primary technical innovation was the development of image processing software that automatically identifies and measures key features in the images. We also designed, built, and tested a power SPI camera system that is effective in sampling firm substrates.

Project Objective & Impact

It is important to document the physical and biological seabed habitat conditions at MHK sites before, during, and after device deployment. The objective of this project was to design and demonstrate a consistent, repeatable, and semi-automated seafloor survey method for generating broad-scale, high-resolution benthic habitat maps of MHK sites. The approach developed provides cost-effective, contiguous spatial coverage over broad areas, can be communicated universally, and can be used to inform the siting, permitting, and monitoring needs of regulators, developers, and other stakeholders.

Project Information

Project Principal Investigator(s)

Gene Revelas
Brandon Sackmann, Ph.D.
Craig Jones, Ph.D.

WPTO Lead

Samantha Eaves

Project Partners/Subs

Solmar Hydro, Inc.
H.T. Harvey & Associates
Sandia National Laboratories
Marine Sampling Systems
Oregon State University

Project Duration

- December 2016
- December 2019

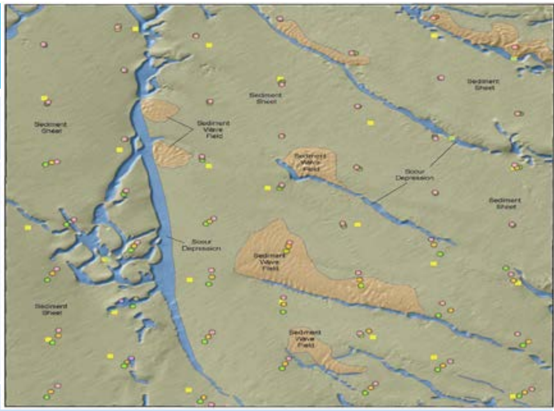
Project Objective & Impact (continued)

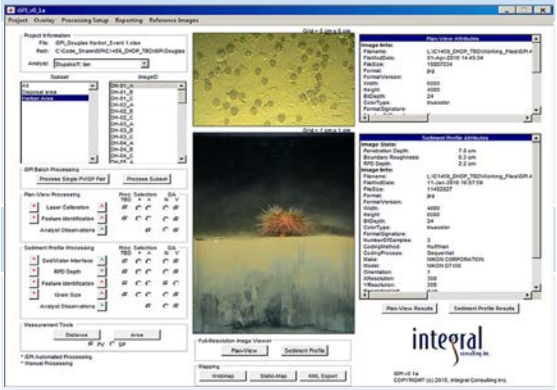
Key Project Achievements

1. Detailed benthic habitat mapping of three areas, including the PacWave South Wave Energy Test Site off Newport, OR.

2. Developed Computer Vision Image Analysis Platform (*iSPI*) that automatically identifies and measures key features in the images, such as grain size, redox depth, biogenic structures, and biota.

3. Designed, built, and tested a prototype *Power* SPI camera that achieves improved penetration in firm substrates.





Passive SPI, 3 cm penetration | Piston only, 16 cm penetration | Water injection, 20+ cm penetration

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

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Reducing Barriers to Testing

- Work with agencies and other groups to ensure that existing data is well-utilized and identify potential improvements to regulatory processes and requirements
- Support additional scientific research as needed, focused on retiring or mitigating environmental risks and reducing costs and complexity of environmental monitoring

A variety of tools and techniques, applied in different combinations, have been used in baseline benthic characterization and monitoring at MHK sites. The lack of standard approaches for many of these tools and techniques creates challenges in data interpretation.

This project developed and demonstrated a repeatable and cost-effective approach for rapidly mapping benthic habitat conditions over broad areas of the seafloor by combining state-of-the-art acoustic and imaging techniques. The approach aims to minimize challenges in traditional benthic assessment and monitoring.

Alignment with the Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

Data Sharing and Analysis

- Leverage expertise, technology, data, methods, and lessons from the international MHK community and other offshore scientific and industrial sectors

The primary mapping tools used in this project, multibeam echosounder surveying and SPI/PV imaging, have been and are being used (typically separately and not in tandem) in both the offshore wind and oil and gas sectors to map and monitor benthic impacts associated with offshore energy siting, facility development, and operations.

Our innovations in this project include: 1) the focused combination of these technologies; 2) the computer automation and standardization of the image analysis data generation process; and 3) improvements to the data collection hardware, i.e., improved SPI prism penetration in firm substrates.

Project Budget

FOAs

Total Project Budget – Award Information		
DOE	Cost-share	Total
[$684,431	[$171,100]	[$855,531]

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Actual Costs FY17–FY19 Q1 & Q2 (October 2016 – March 2019)
Costed	Costed	Costed	Total
[$278,552]	[$258,254]	[$94,728]	[$631,534]

Management and Technical Approach

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PROJECT TEAM

Integral Consulting Inc.
Benthic Habitat Mapping
Image Processing
Hardware Modifications

Solmar Hydro, Inc.
Multibeam Echosounder Surveys

H.T. Harvey & Associates
Biological Data Review
NEPA Permitting
Stakeholder Outreach

Sandia National Laboratories
Geophysical Data Review
Stakeholder Outreach

Marine Sampling Systems
Hardware Design and Fabrication

PNNL
Logistics and Funding Support
NEPA Permitting
Technology Development

Oregon State University
PacWave Logistics & Sampling Support
Benthic Data Sharing and Review

Technical Performance Summary

Habitat Mapping	8, 7, and 6 km^2 MBES/SPI surveys completed. Total field time per survey is ~1 week. High-resolution seafloor maps completed within 60 days.
Image Processing Algorithms	Automated plan view laser calibration, SPI sediment-water interface, grain size identification and semi-automated aRPD delineation completed/met performance criteria; SPI biological feature identification undergoing final testing.
Power SPI System for Firm Substrates	Prototype system was successfully field-tested in 2019. Additional resources are needed to simplify/commercialize system.

Benthic Mapping Gantt Chart	BP1				BP2				BP3				
Task	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**
First Field Test – MBES/SPI/PV Survey - Sequim Bay	■	■	■										
Update Training Data Set			■	■									
Algorithm Development - Physical/Geochemical Features	■	■	■	■									
Hardware Modification Plan			■	■									
Algorithm Integration into iSPI (Bridge task)				■	■								
SPI/PV Camera Frame Hardware Modifications					■	■							
Second Field Test – MBES/SPI/PV Survey - Dungeness Spit					■	■	■	■					
Prototype Power SPI Field Test 1							■						
Update Training Data Set							■	■					
Algorithm Development - SPI Biological Features					■	■	■	■	■	■	■	■	
BP2 Algorithm Integration into iSPI (Bridge Task)									■	■			
Third Field Test – MBES/SPI/PV Survey - PacWave SETS									■	■	■		
Prototype Power SPI Field Test 2									■				
Update Training Data Set										■	■		
Refinements of BP1 and BP2 Image Processing Algorithms										■	■	■	
iSPI Updates and BP3 Algorithm Integration												■	
Regulatory Outreach			■	■	■	■	■	■	■	■	■	■	■
Final Reporting												■	■

End-User Engagement and Dissemination Strategy

- **Introduced to Regulators and Stakeholders at Conferences/Workshops**
  - Marine Energy Technology Symposiums (April 2018 and 2019), including the MHK Environmental Compliance Cost Assessment Project – 2019 Strategies Workshop
  - Marine and Hydrokinetic (MHK) Environmental Compliance Cost Assessment Project Regulatory Webinar - June, 2019
  - Battelle Sediments Conference (February 2017 and 2019)
  - Offshore Technology Conference (May 2018 and 2020); manuscript published in OTC 2018 Proceedings; if accepted, manuscript will be published in 2020 proceedings
  - Marine Geological and Biological Habitat Mapping Conference (May 2018)
  - Western Dredging Association Conference (November 2017)
- **Integral Webinar to Regulators and Stakeholders**
  - August 29, 2019
  - Follow-up questionnaire (response compilation in progress)
- **Dissemination Objectives**
  - Engagement and education of all stakeholders
  - Feedback on usefulness of approach, concerns, potential improvements
  - Develop consensus on monitoring needs and appropriate tool box

Technical Accomplishments

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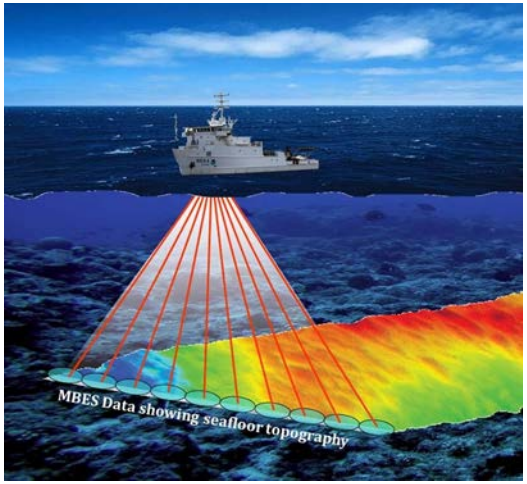

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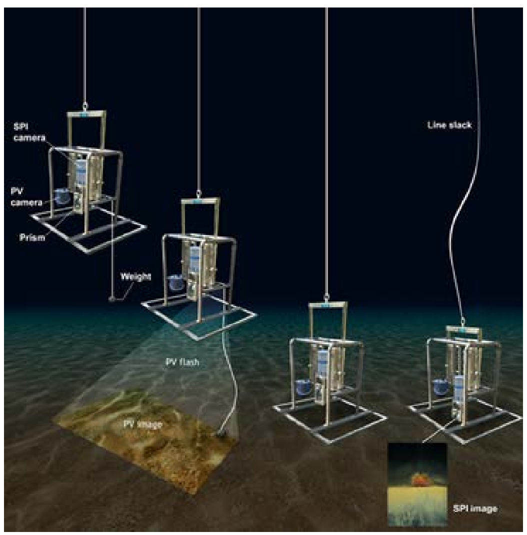

CMECS Substrate Maps

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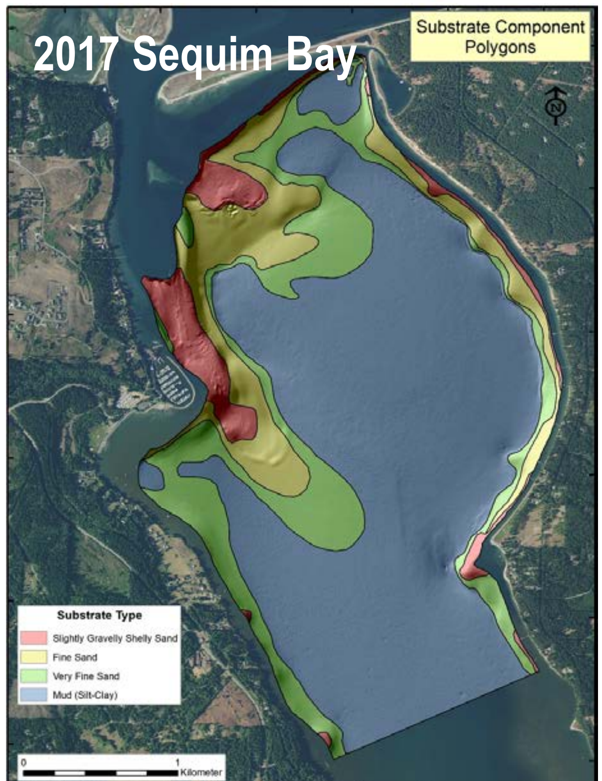

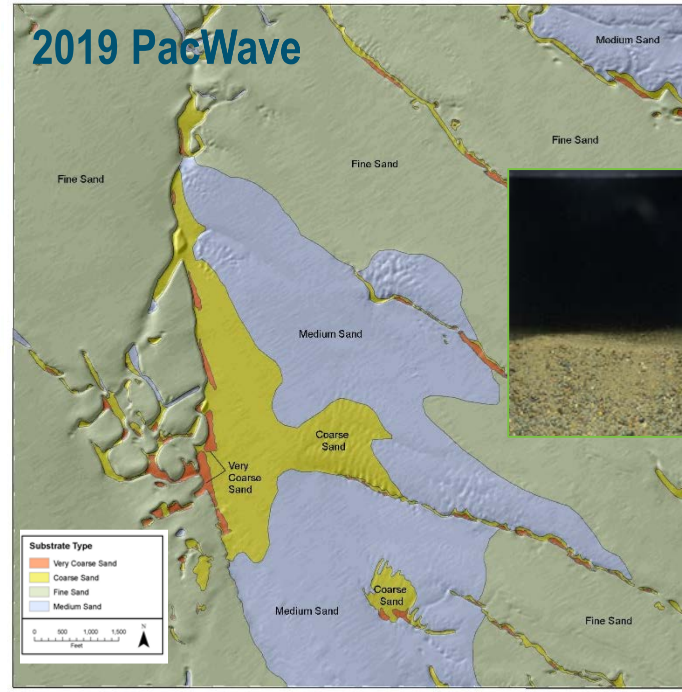

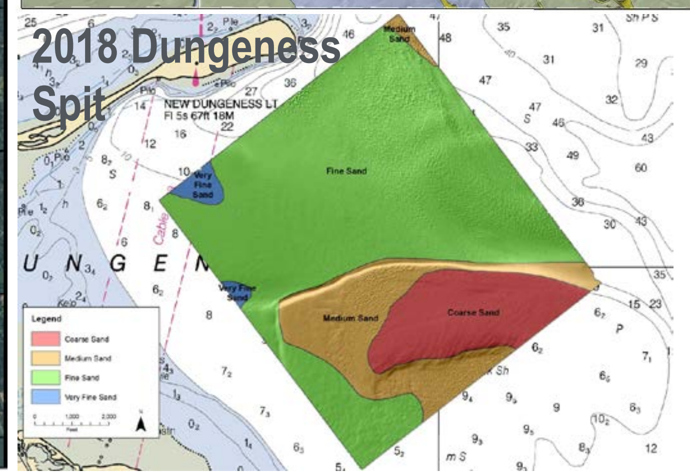

Technical Accomplishments (continued)

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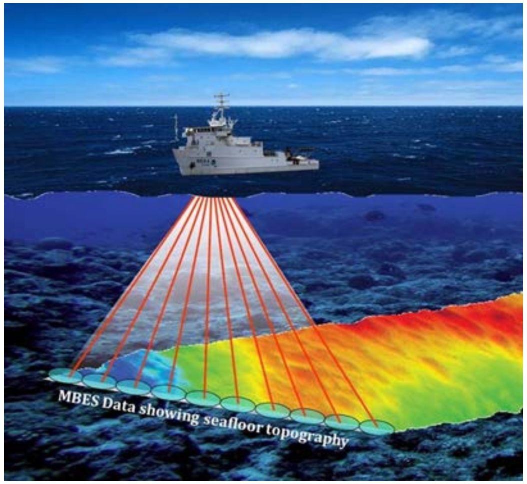

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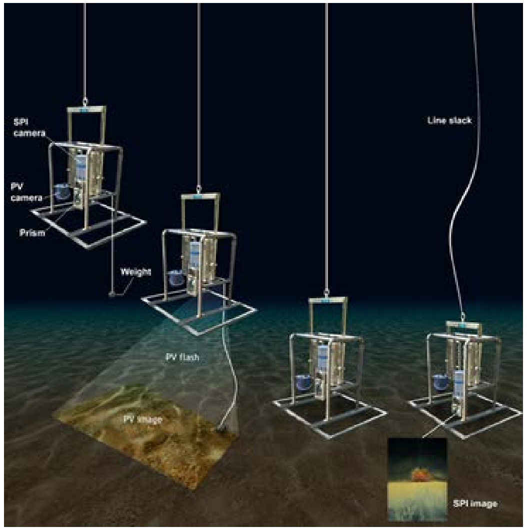

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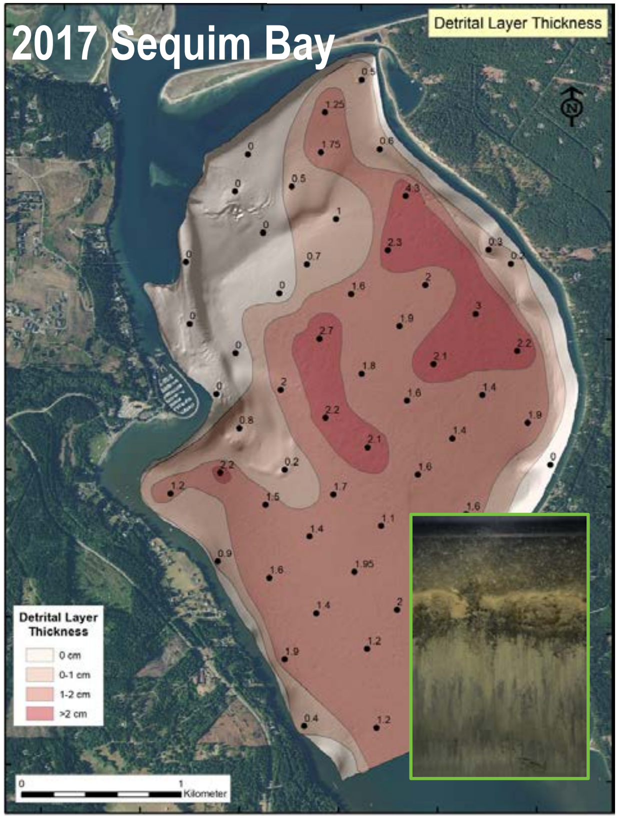
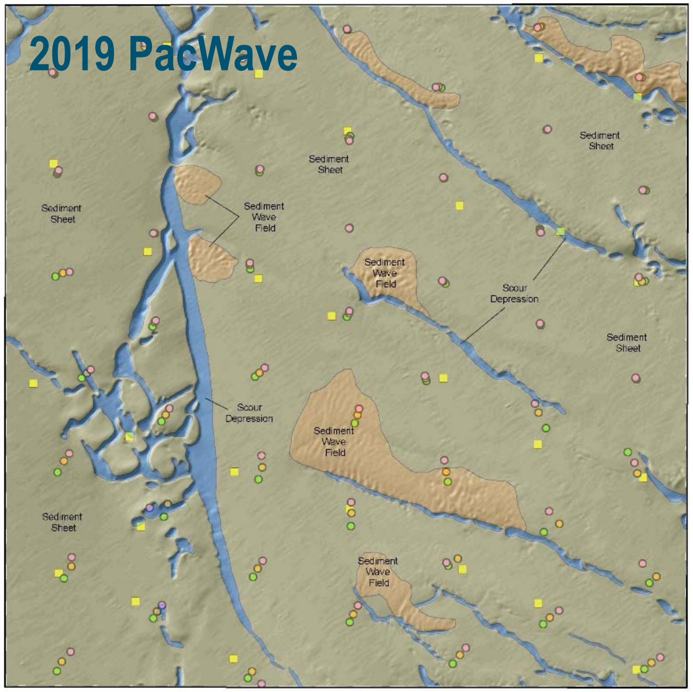
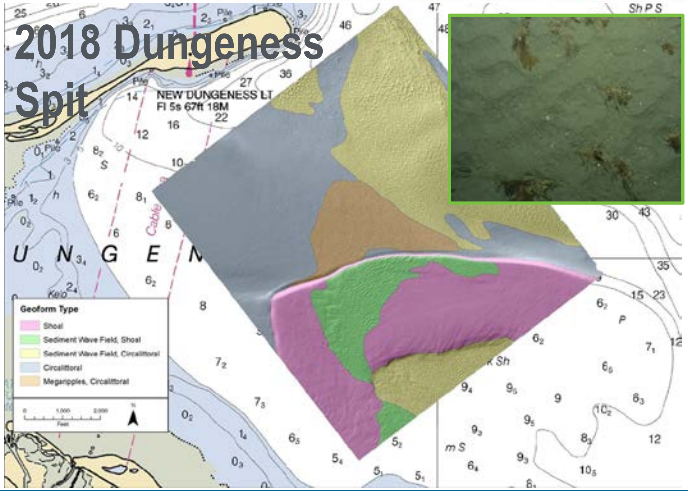
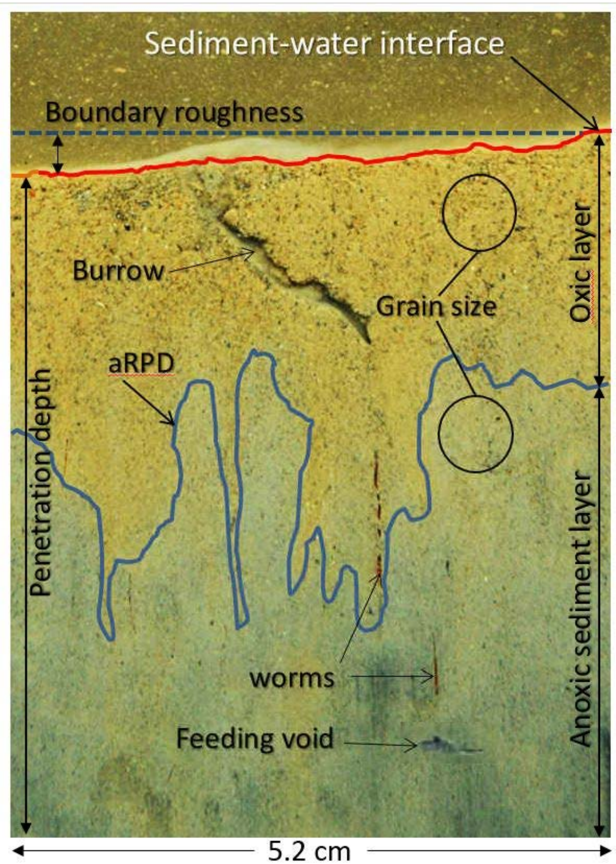
CMECS
Geomorph
Maps



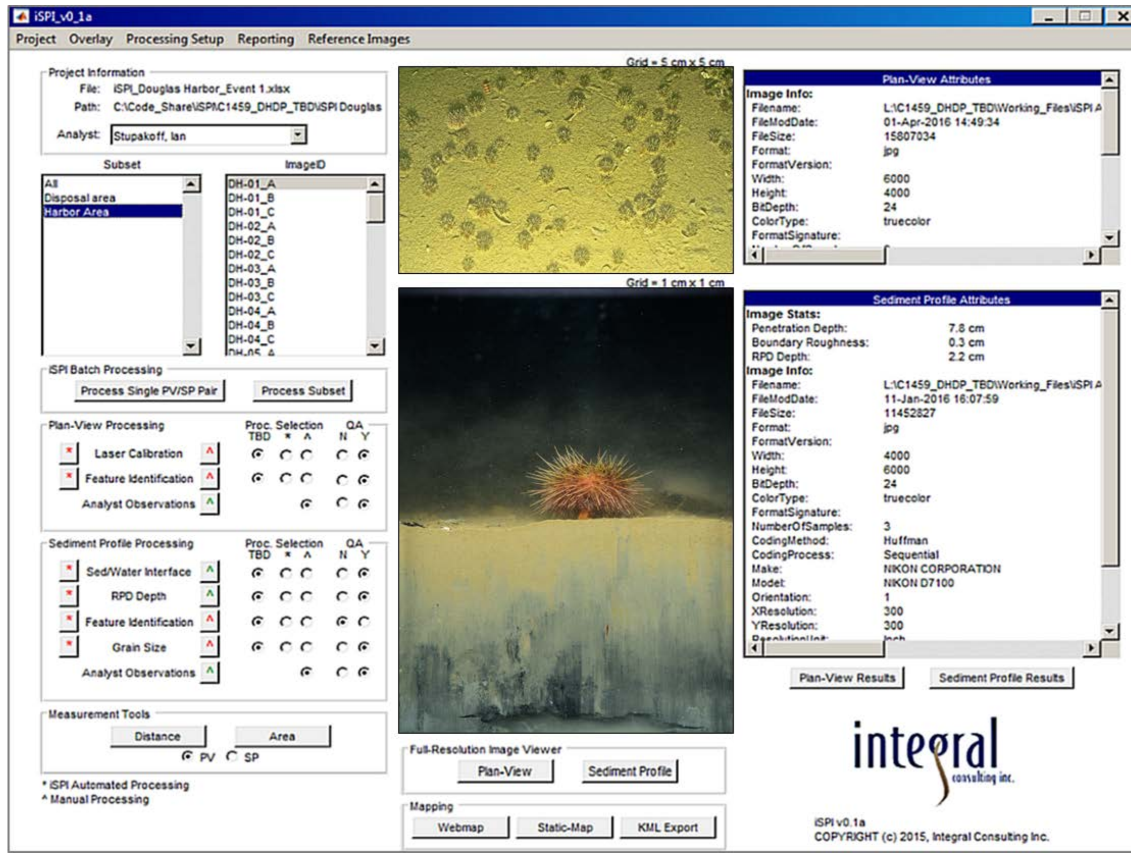




SPI/PV Image Automated Data Extraction and Management



SPI Features Measured



iSPI Automated Image Analysis Platform

Technical Accomplishments (continued)

Technical Accomplishments (continued)

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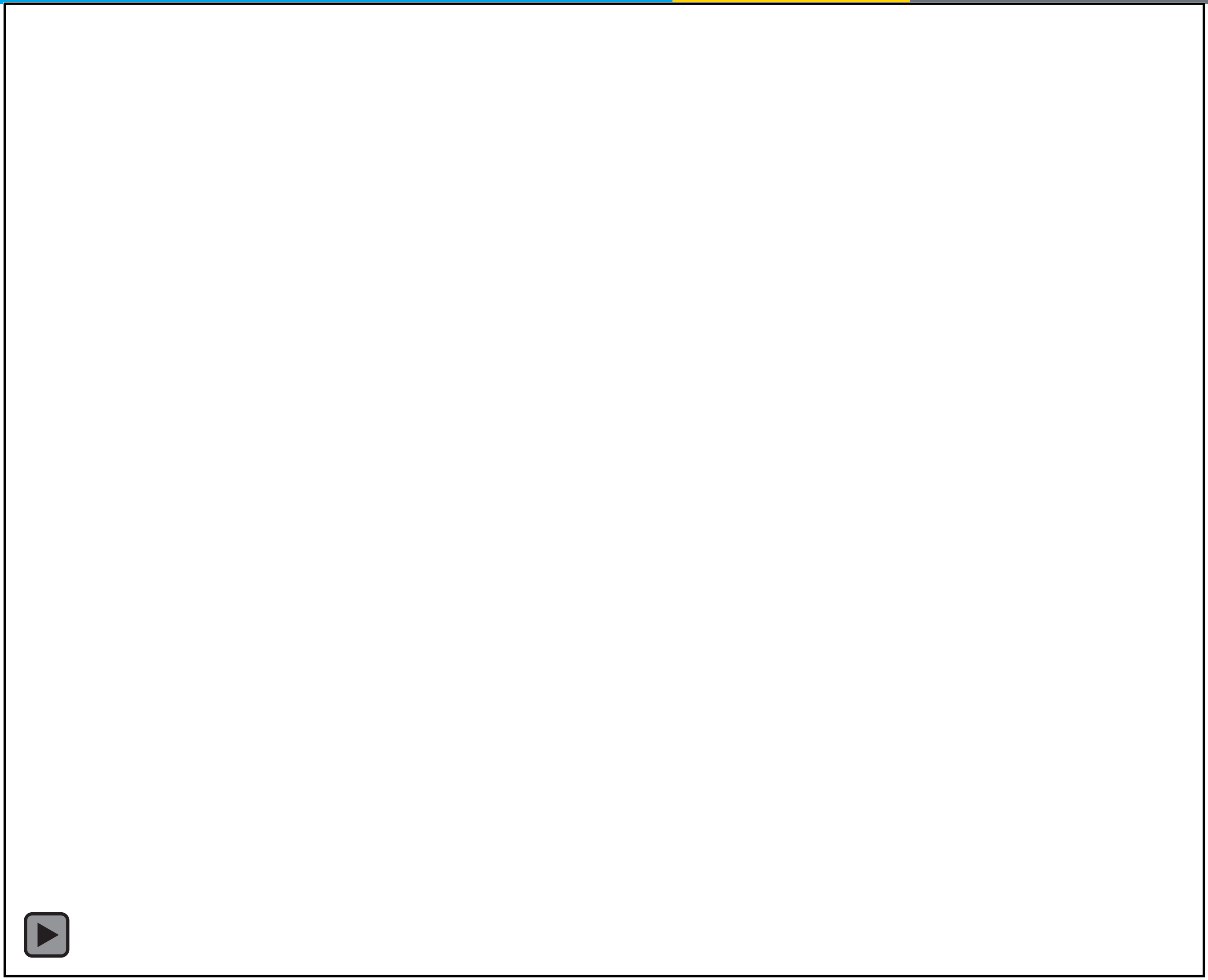


Summary of Computer Automated Image Analysis

SPI Images

- Grain size (major mode in phi units) throughout image: fully automated (meet performance criteria ±1 phi unit)
- Sediment-water interface/penetration depth: fully automated (meet performance criteria ±0.5 cm)
- aRPD depth: supervised automation (meet performance criteria ±0.5 cm)
- Identification of biological features: in progress

Plan View Images

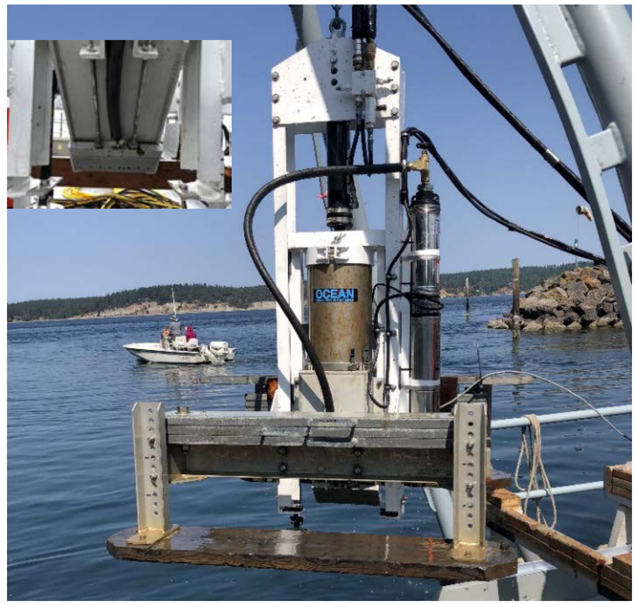
- Laser calibration/field of view: (meet performance criteria ±20%)
- Identification of biological features: automation to be explored

Technical Accomplishments (continued)

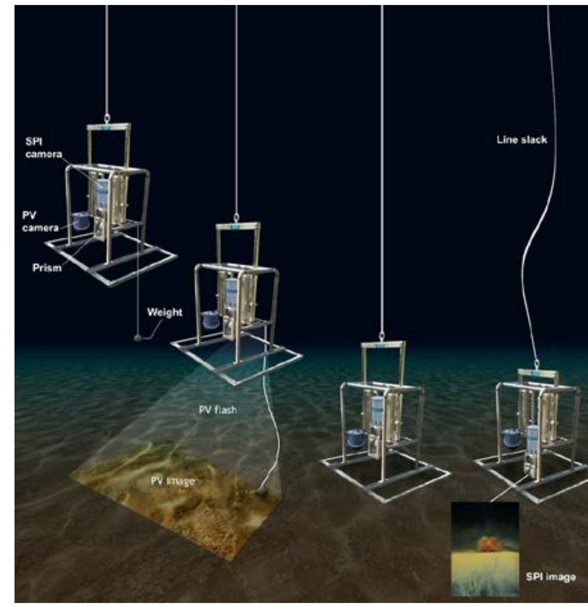
Replaced passive piston with hydraulic piston for forceful insertion into seabed

Added pump/water injection system near bottom and on back of prism to fluidize bed during penetration

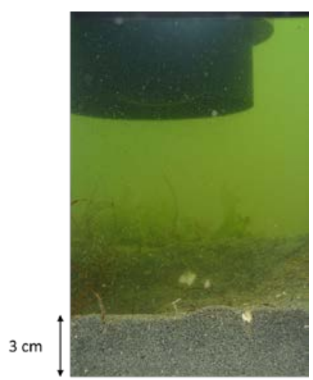
Power SPI Design



Passive SPI Design



Passive SPI system



Piston only, 16 cm penetration

Water injection, 20+ cm penetration

Progress since Project Summary Submittal

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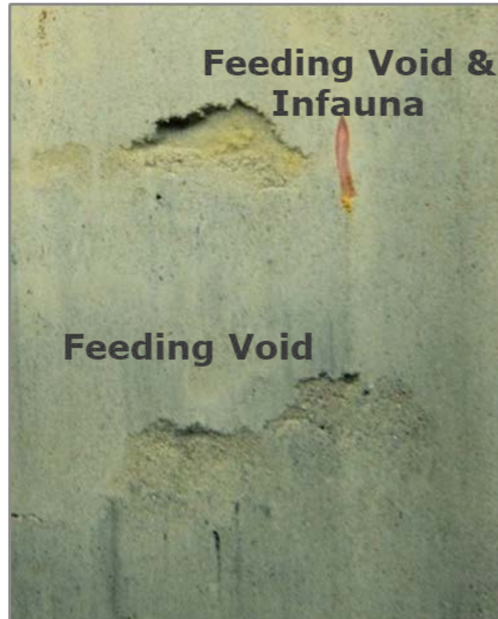
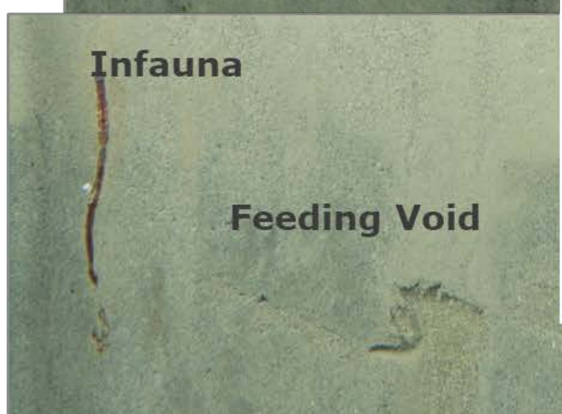
Algorithms for the Identification of Biological Features

- Computer Vision & Deep Learning: Convolutional Neural Networks (CNNs)
- Generate curated sets of thumbnails from existing SPI/PV image library that can be used to train automated image classifiers

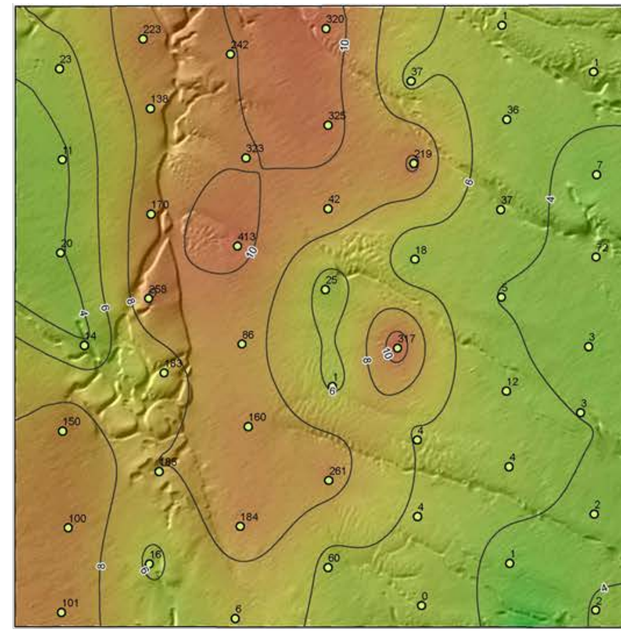


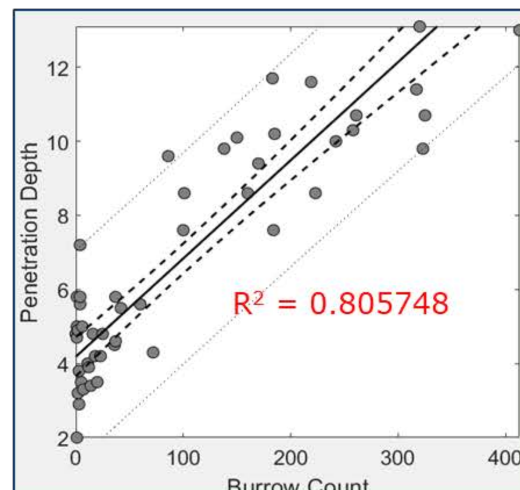


Progress since Project Summary Submittal

PacWave Mapping: Biota and Substrate Characteristics





Questions/Comments