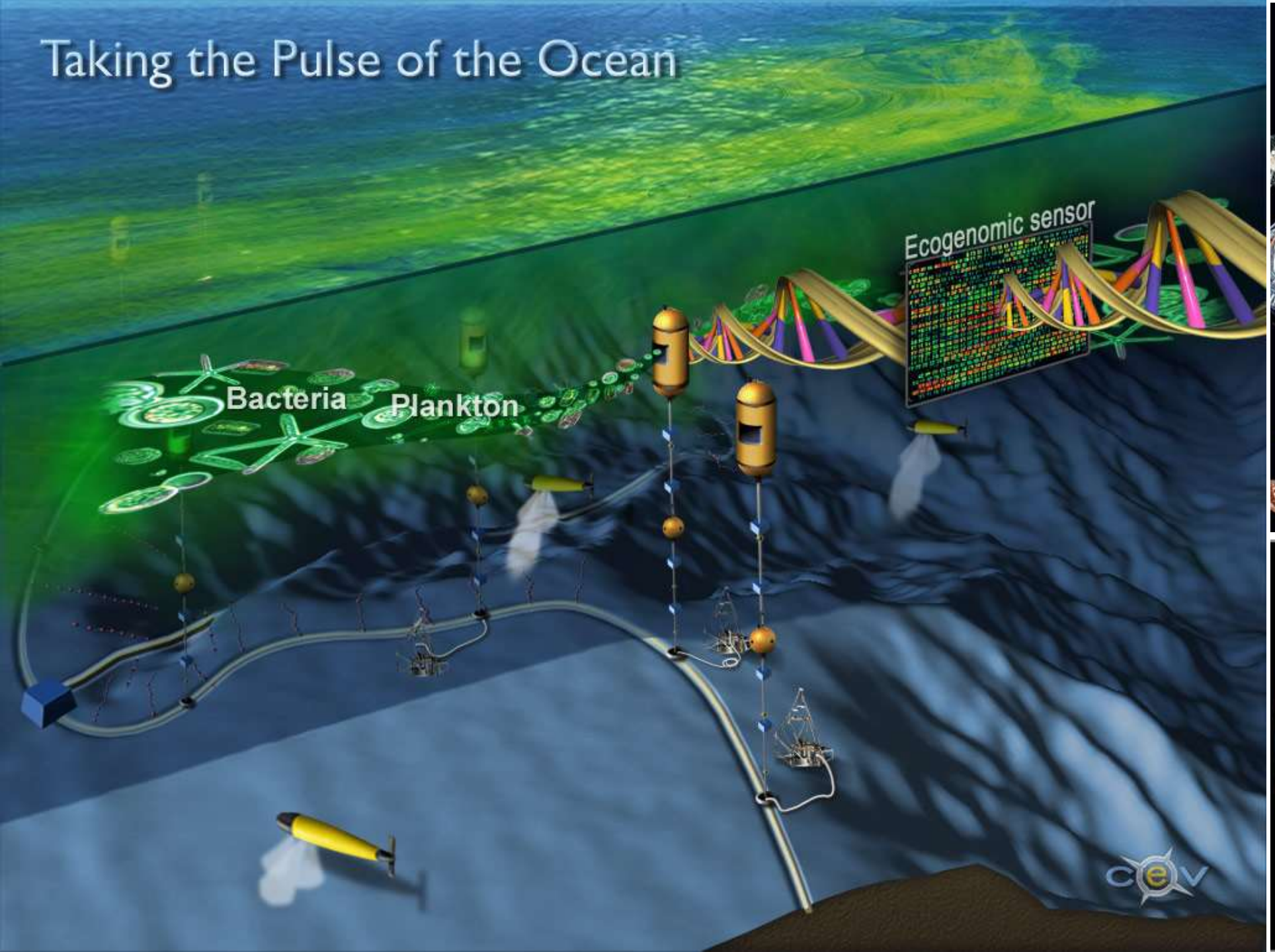
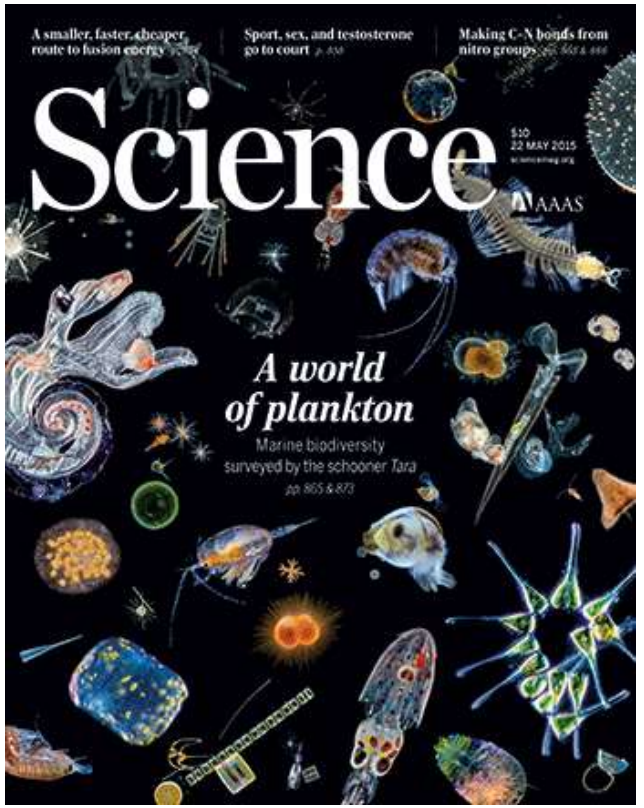
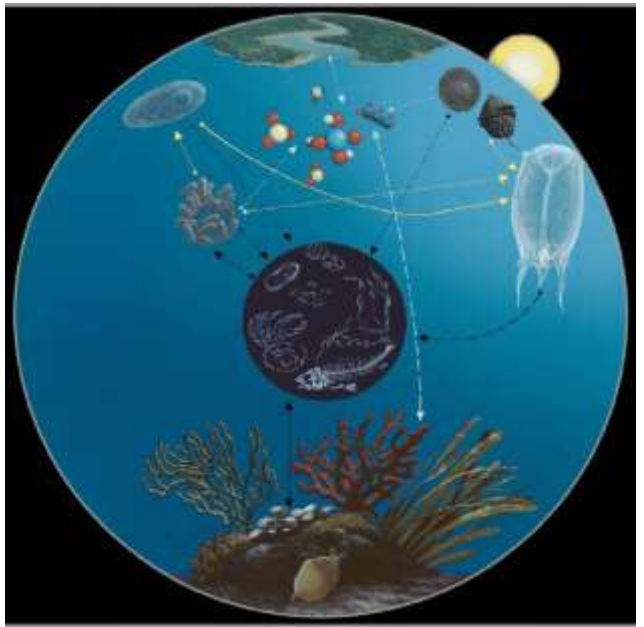
# Autonomous underwater instruments for in situ analysis and underway sampling: Taking the Pulse of the Ocean


**Dr. Leo Chan**

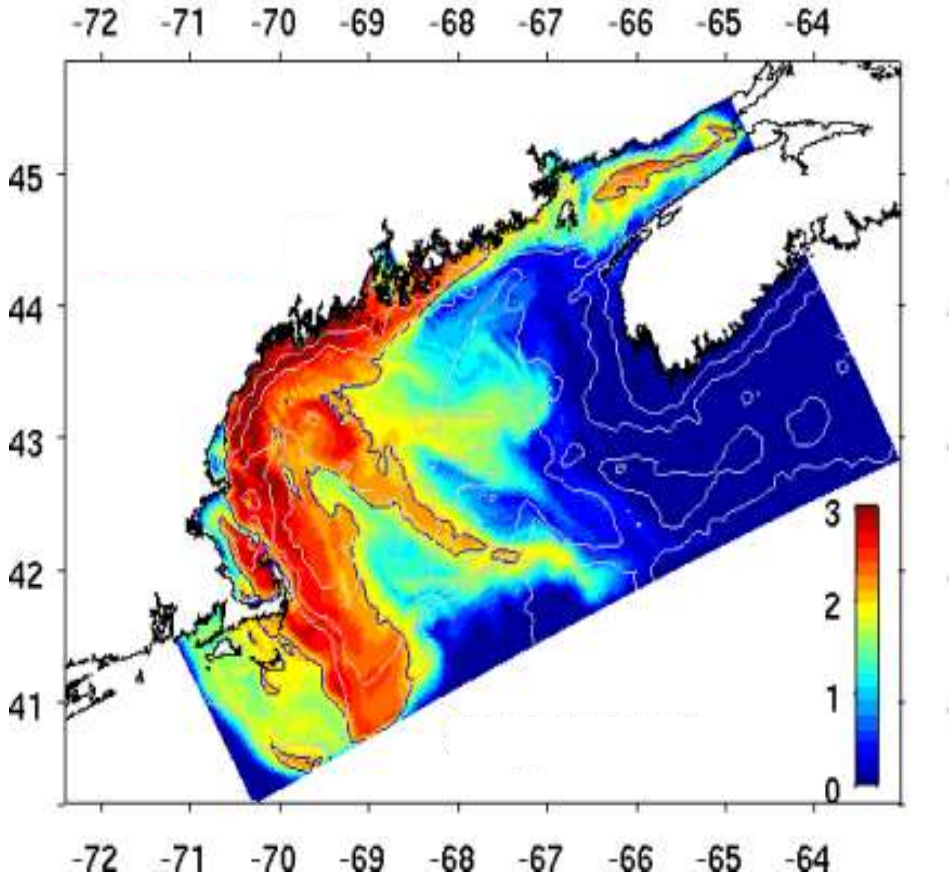
State Key Laboratory in Marine Pollution
Shenzhen Key Laboratory for the Sustainable Use of Marine Biodiversity
Department of Biomedical Sciences
City University of Hong Kong


Taking the Pulse of the Ocean
Ecogenomic sensor
Bacteria
Plankton


A smaller, faster, cheaper route to fusion energy
Sport, sex, and testosterone go to court
Making C–N bonds from nitro groups
Science
$10
22 MAY 2015
AAAS
A world of plankton
Marine biodiversity surveyed by the schooner Tara
pp. 865 & 873



# New Applications of Two *in situ* Autonomous Biosensors in Harmful Algal Bloom and Biotoxin Research and Monitoring



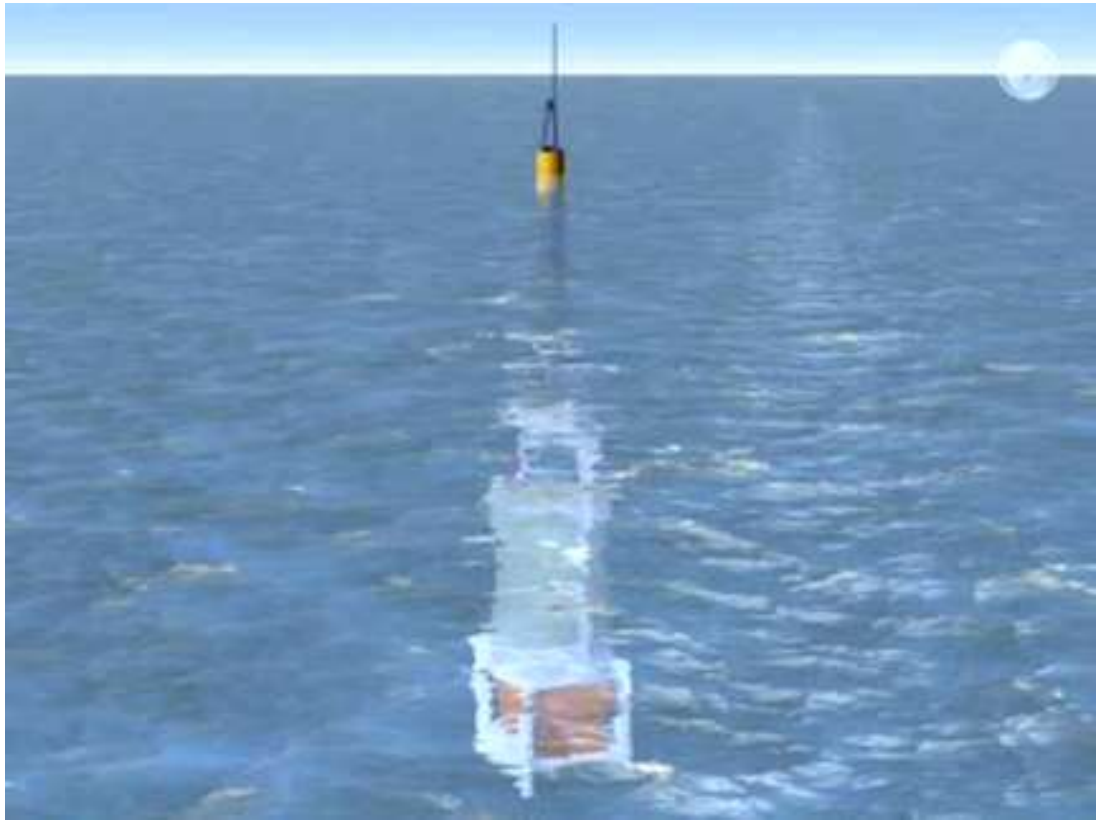

**Environmental Sample Processor (ESP)**

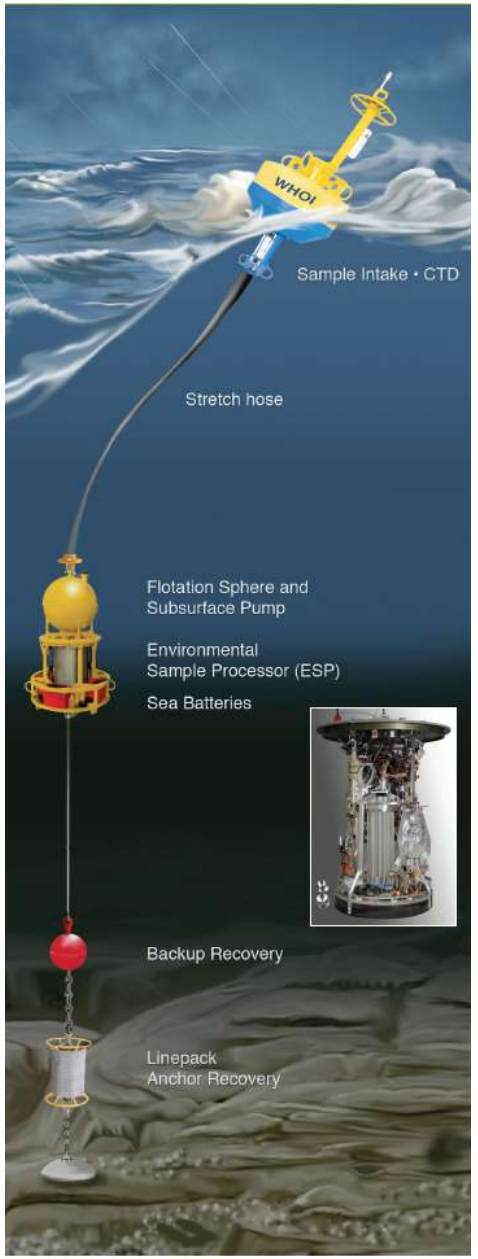
**Credits: Donald Anderson, WHOI**

**Imaging FlowCytobot (IFCB)**

# The Environmental Sample Processor (ESP)

**Robotic instrument capable of *in situ* water collection and DNA-probe-based cell identification and enumeration as well as antibody-based toxin detection**






**Credits: Donald Anderson, WHOI**

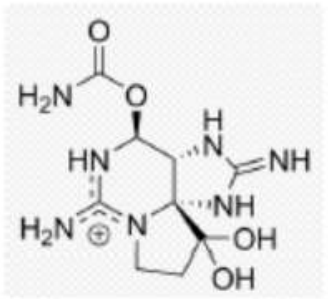
# The ESP can detect a wide range of targets

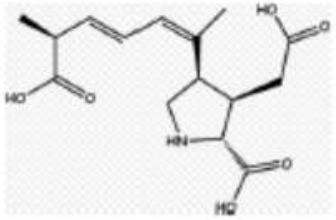
Microbes

Harmful Algae


Invertebrate Larvae

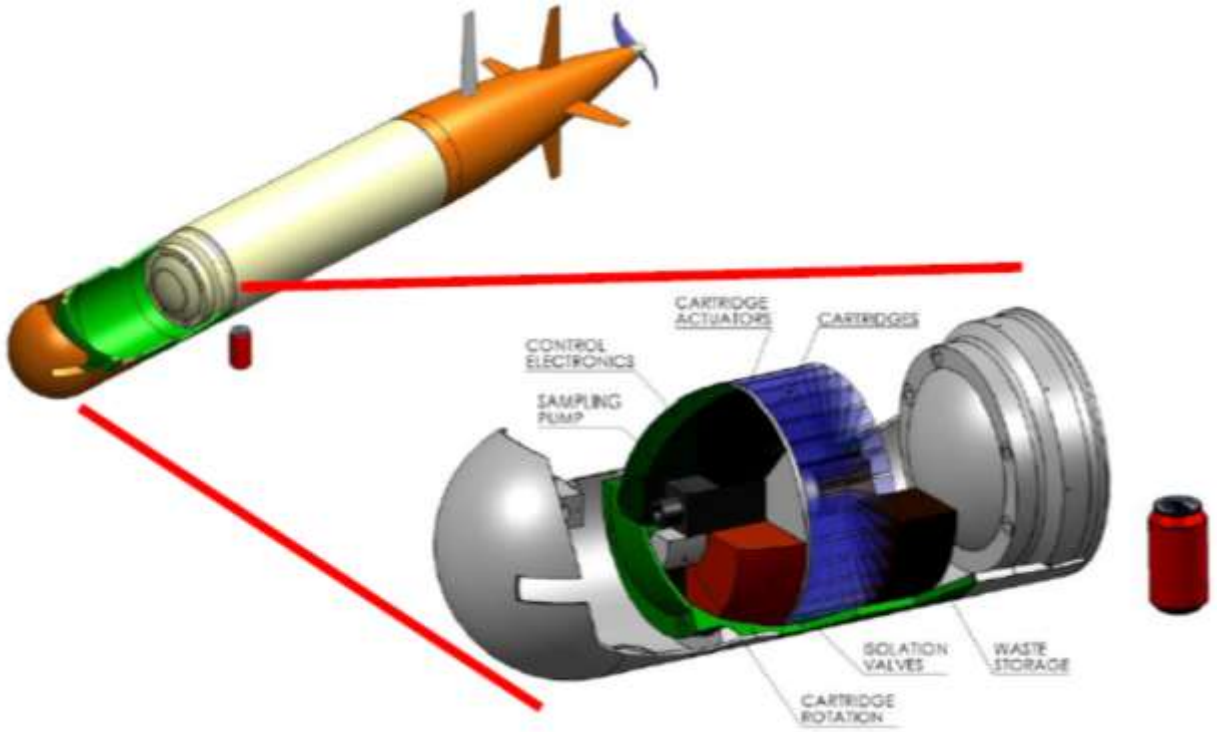

Toxins



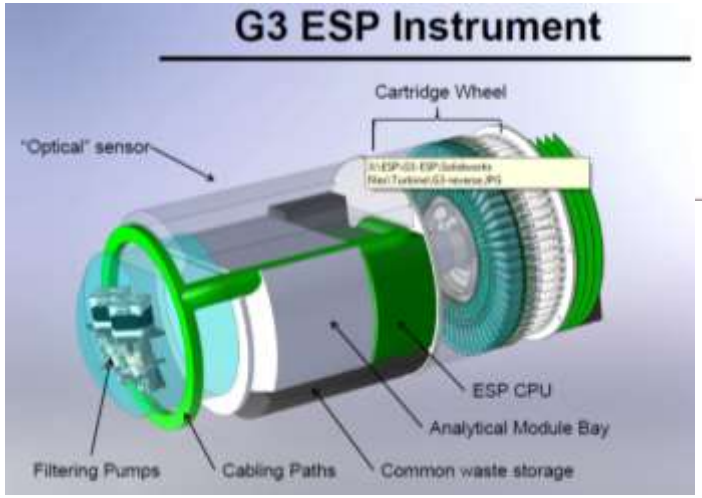


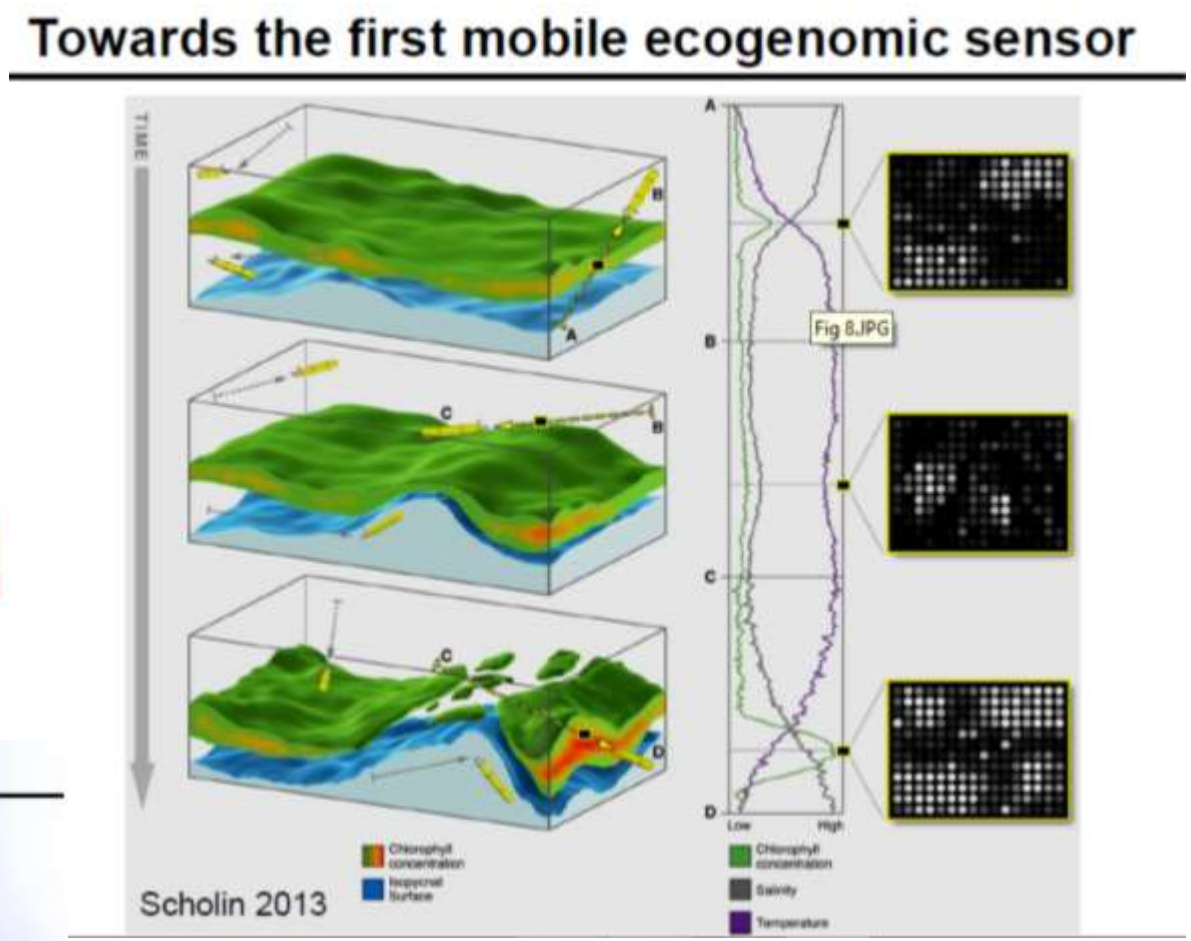
Credits: Chris Scholin, MBARI

# The Environmental Sample Processor (ESP)



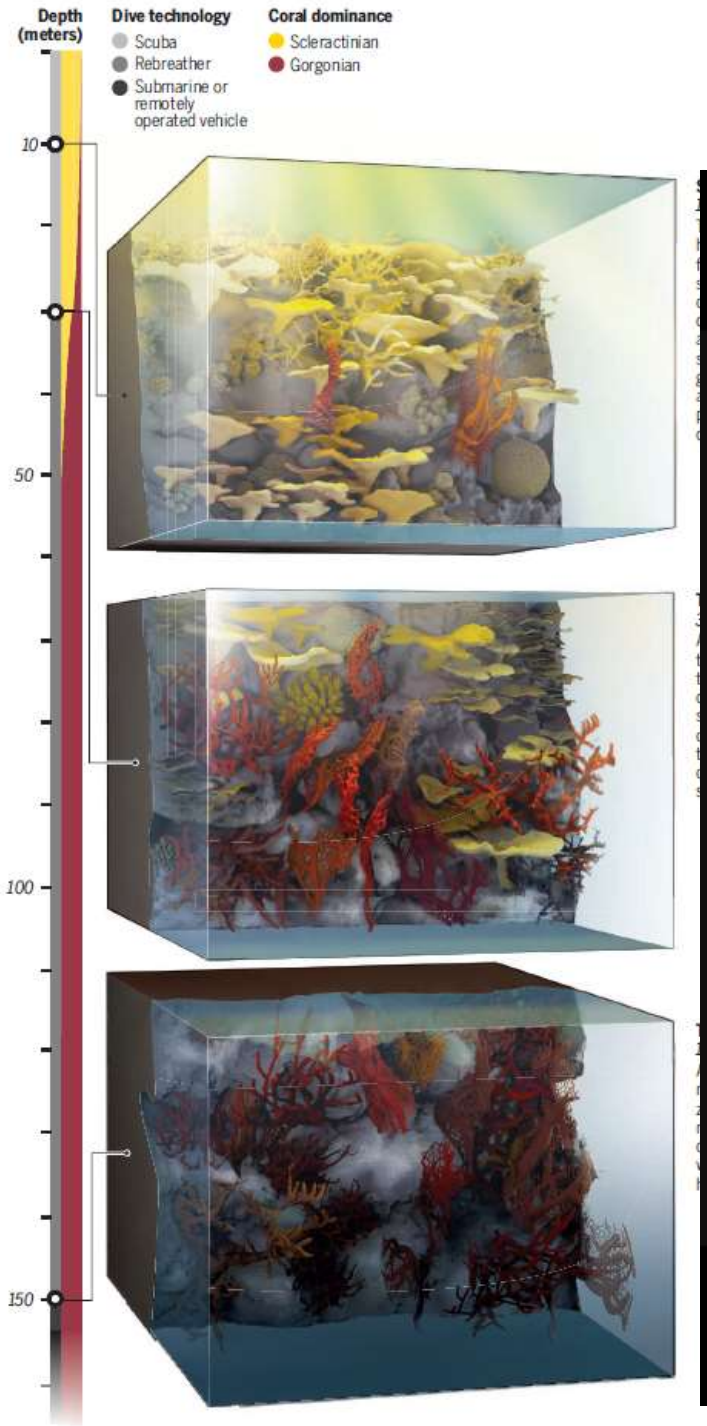




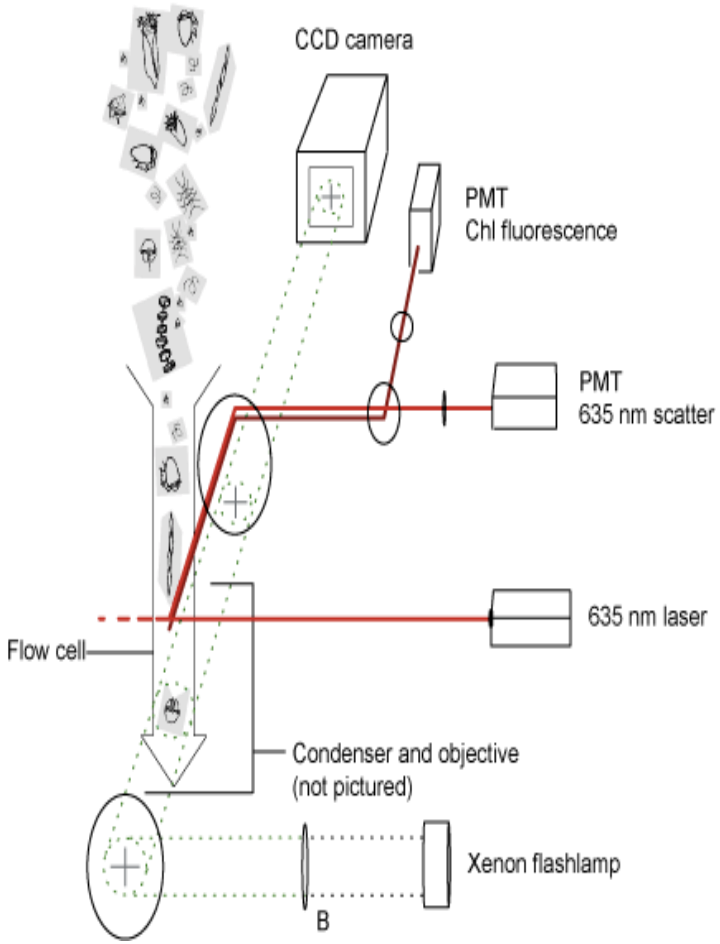




**Credits: Chris Scholin, MBARI**

# Marine Genetic Resources Discovery from Mesophotic Environments



# Imaging FlowCytobot (IFCB): a submersible, imaging flow cytometer



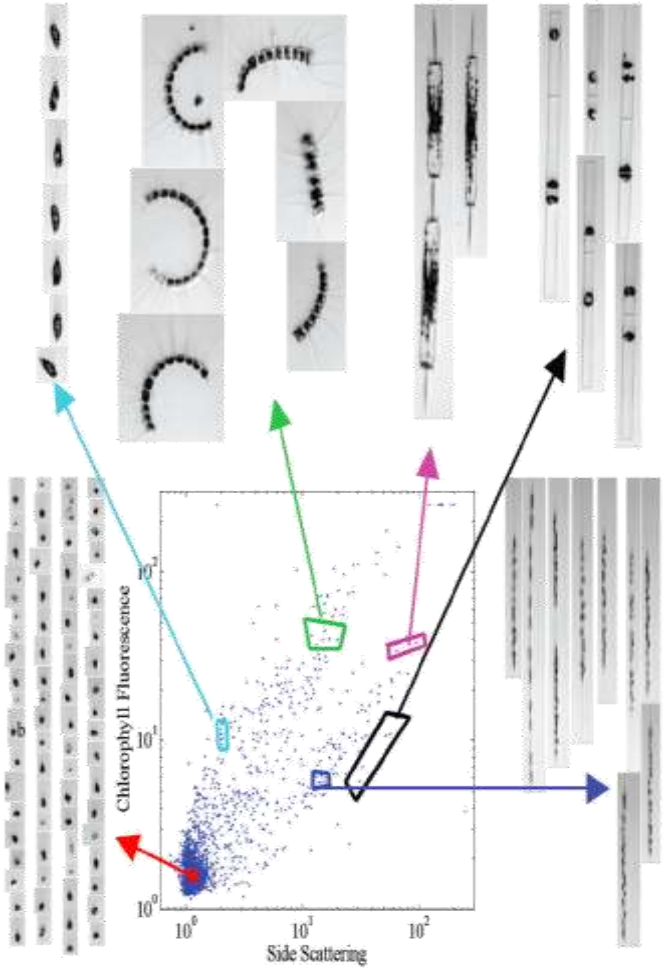
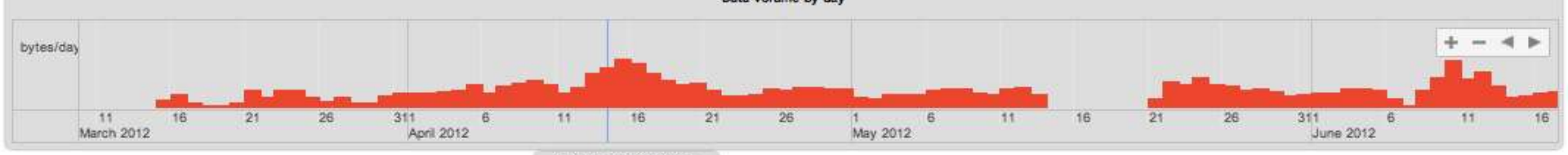




**Image processing**
**Supervised machine learning algorithm**
**Statistical error correction**
**88% overall accuracy**

Sosik and Olson 2007

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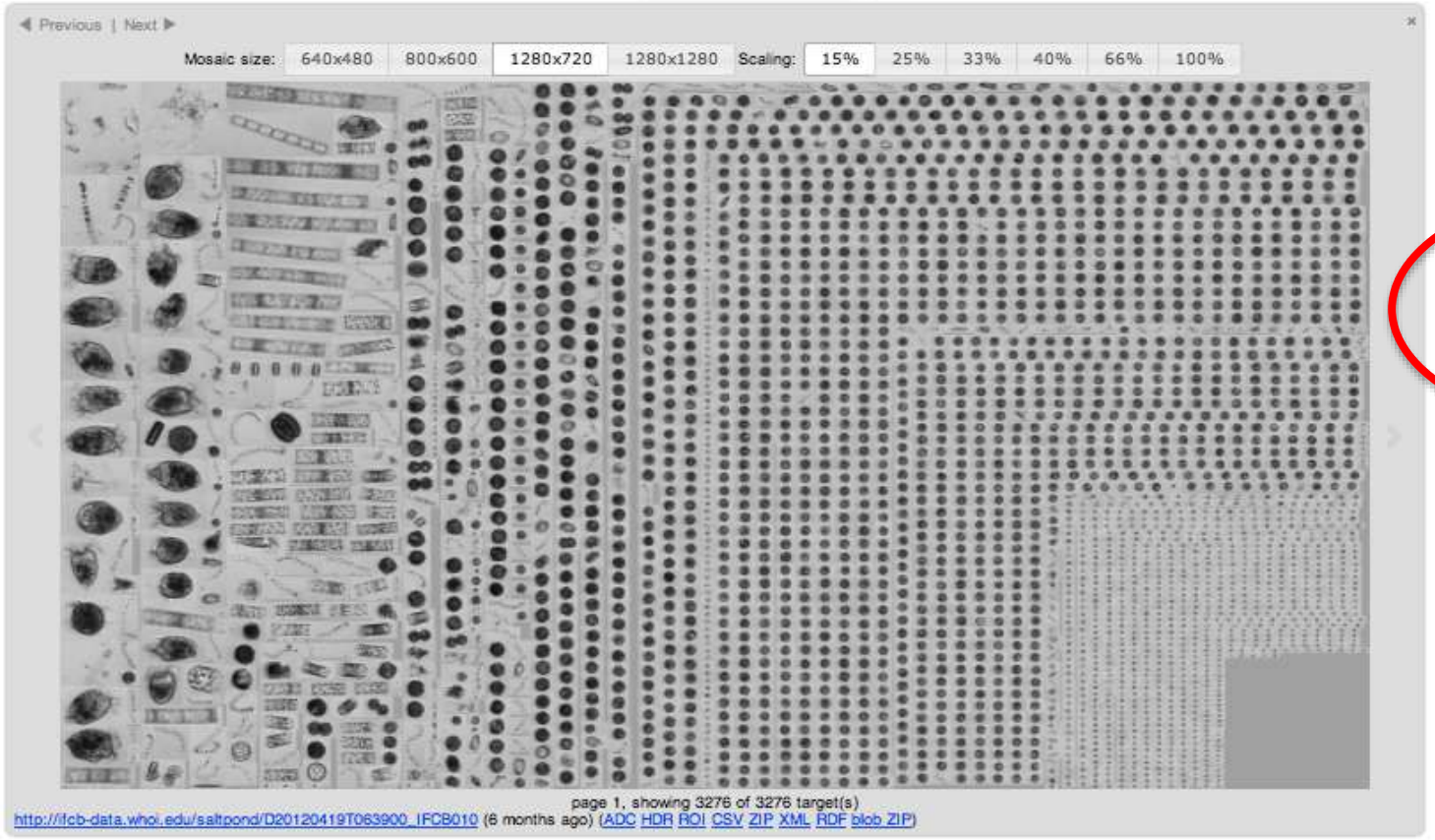



**200,000 images per day; 16M images per bloom**

**Automated classification is essential**

http://ifcb-data.whoi.edu/saltpond/dashboard/pid/http://ifcb-data.whoi.edu/saltpond/D20120416T101102_IFCB010

Heidi Sosik, Robert Olson, Joe Futrelle @ Woods Hole Oceanographic Institution
Version 2.0.3 - October 2012 - About User guide API

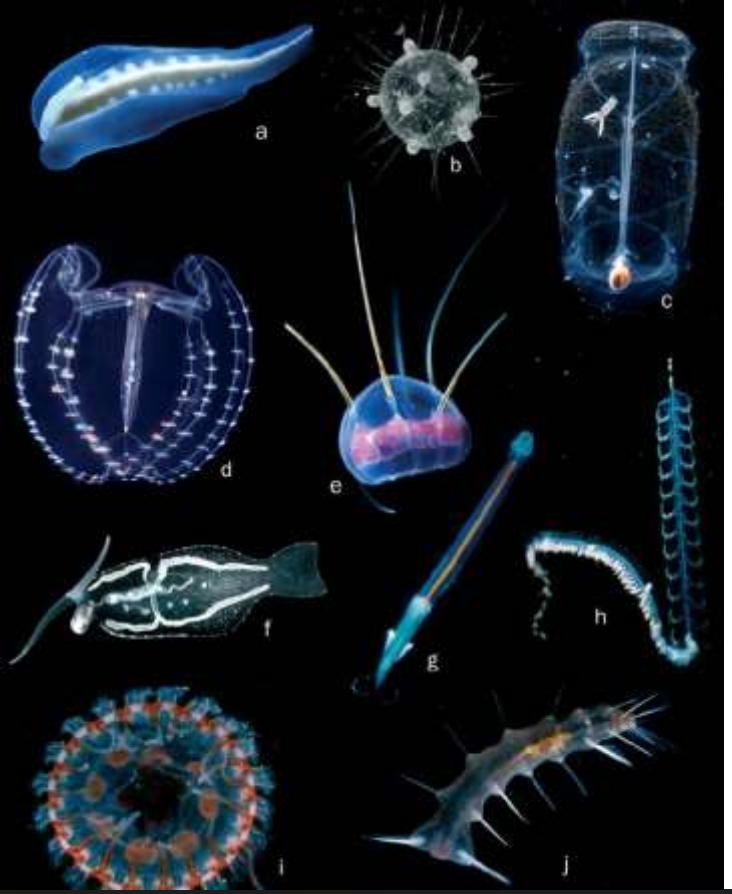
**Credits: Donald Anderson, WHOI**

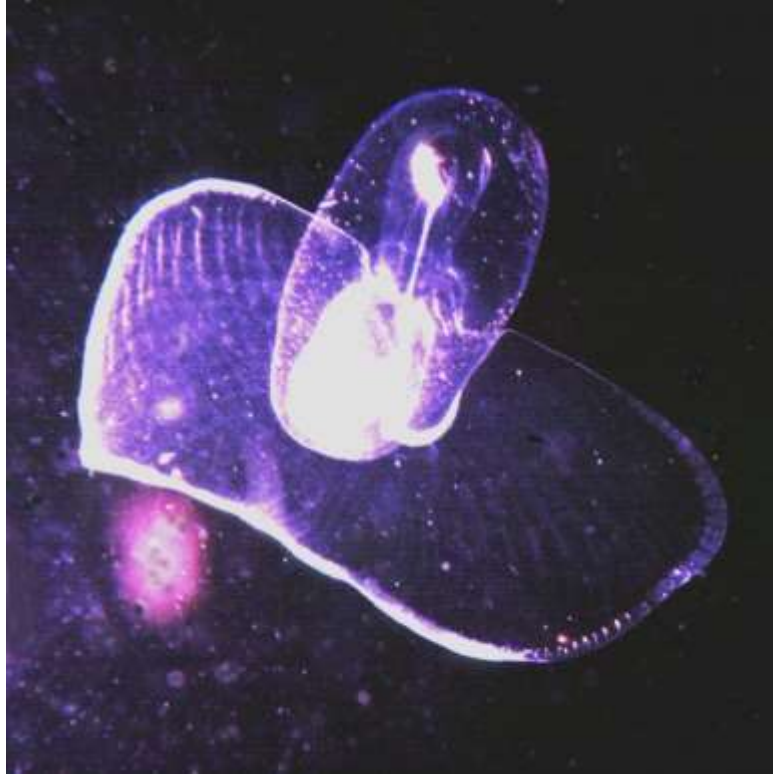
# The Imaging FlowCytobot (IFCB)

## Instrument Overview

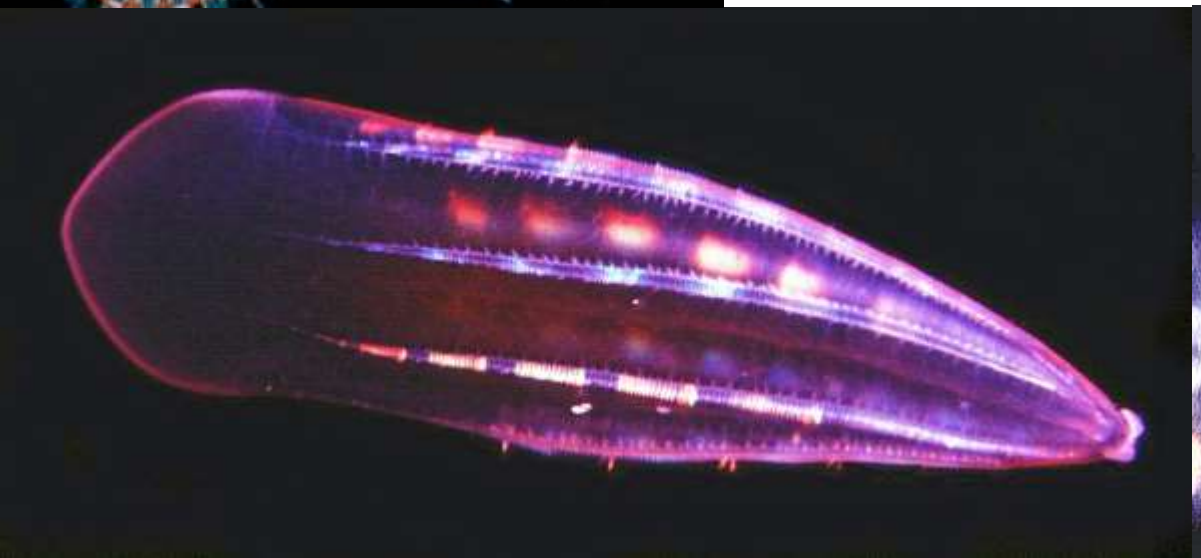

McLANE®
RESEARCH LABORATORIES, INC.

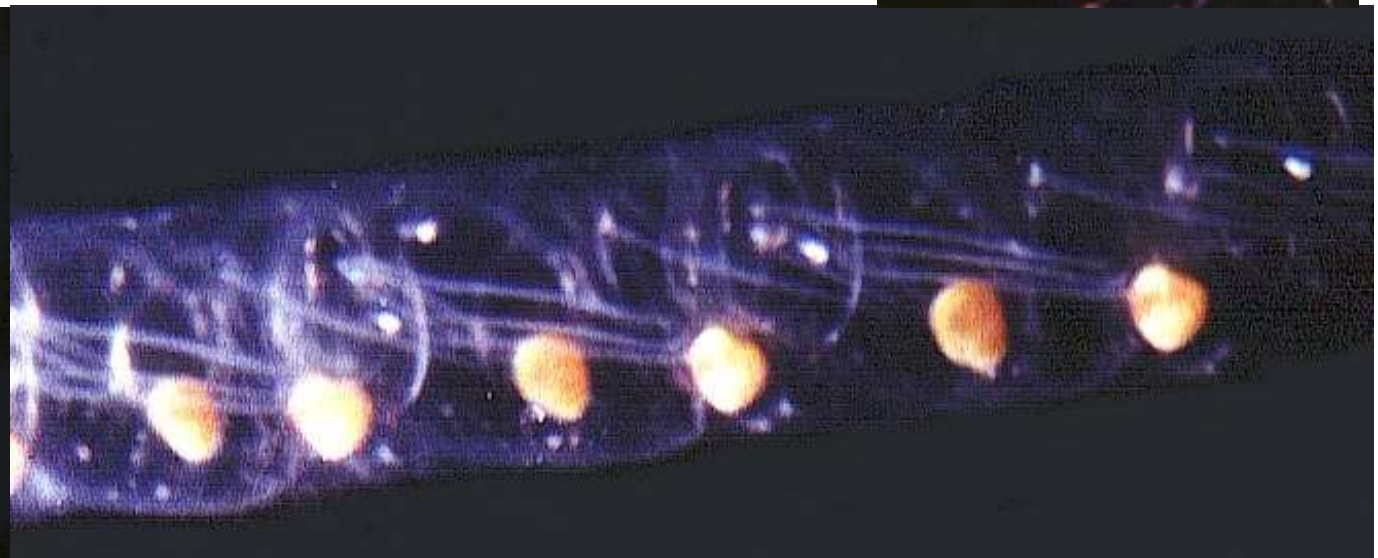
# IFCB deployment on Jetyak or Wave Glider



# Gelatinous Zooplankton





# Transatlantic Abundance of the $N_2$-Fixing Colonial Cyanobacterium *Trichodesmium*

Cabell S. Davis[1]* and Dennis J. McGillicuddy Jr.[2]

Colonial diazotrophic cyanobacteria of the genus *Trichodesmium* are thought to play a significant role in the input of new nitrogen to upper layers of the tropical and subtropical oceanic ecosystems that cover nearly half of Earth's surface. Here we describe results of a transatlantic survey in which a noninvasive underwater digital microscope (the video plankton recorder), was towed across the North Atlantic at 6 meters per second while undulating between the surface and 130 meters. Colony abundance had a basin-scale trend, a clear association with anticyclonic eddies, and was not affected by hurricane-forced mixing. Subsurface abundance was higher than previously reported, which has important implications for the global ocean nitrogen cycle.

limitation thought to play a major role (*17*). *Trichodesmium* abundance has been difficult to quantify using traditional net sampling, because the colonies are easily damaged or destroyed during collection, which results in underestimation (*18*, *19*). Sampling with bottles (e.g., 10-liter Niskin) has provided quantitative estimates of vertical abundance over broad areas of the tropical Atlantic (*18*), whereas current estimates of abundance in the Sargasso Sea are based largely on net tows.

We used an in situ digital microscope to quantify the abundance of *Trichodesmium* noninvasively across the Sargasso Sea during August and September 2003. We towed the video plankton recorder (VPR) (*20*–*23*) from the Azores toward Bermuda, continuing across the Gulf Stream to the Slope Water south of Cape



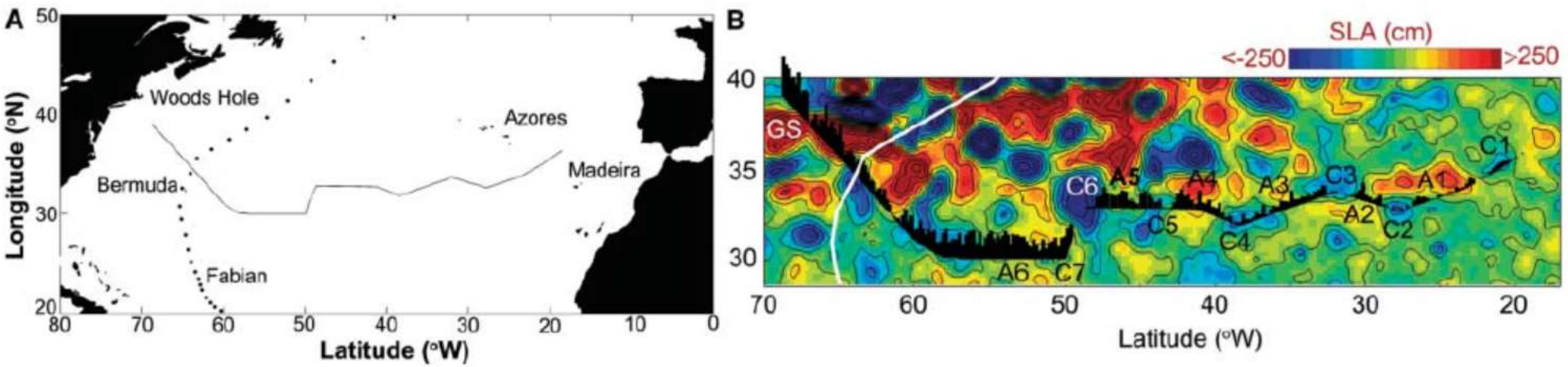
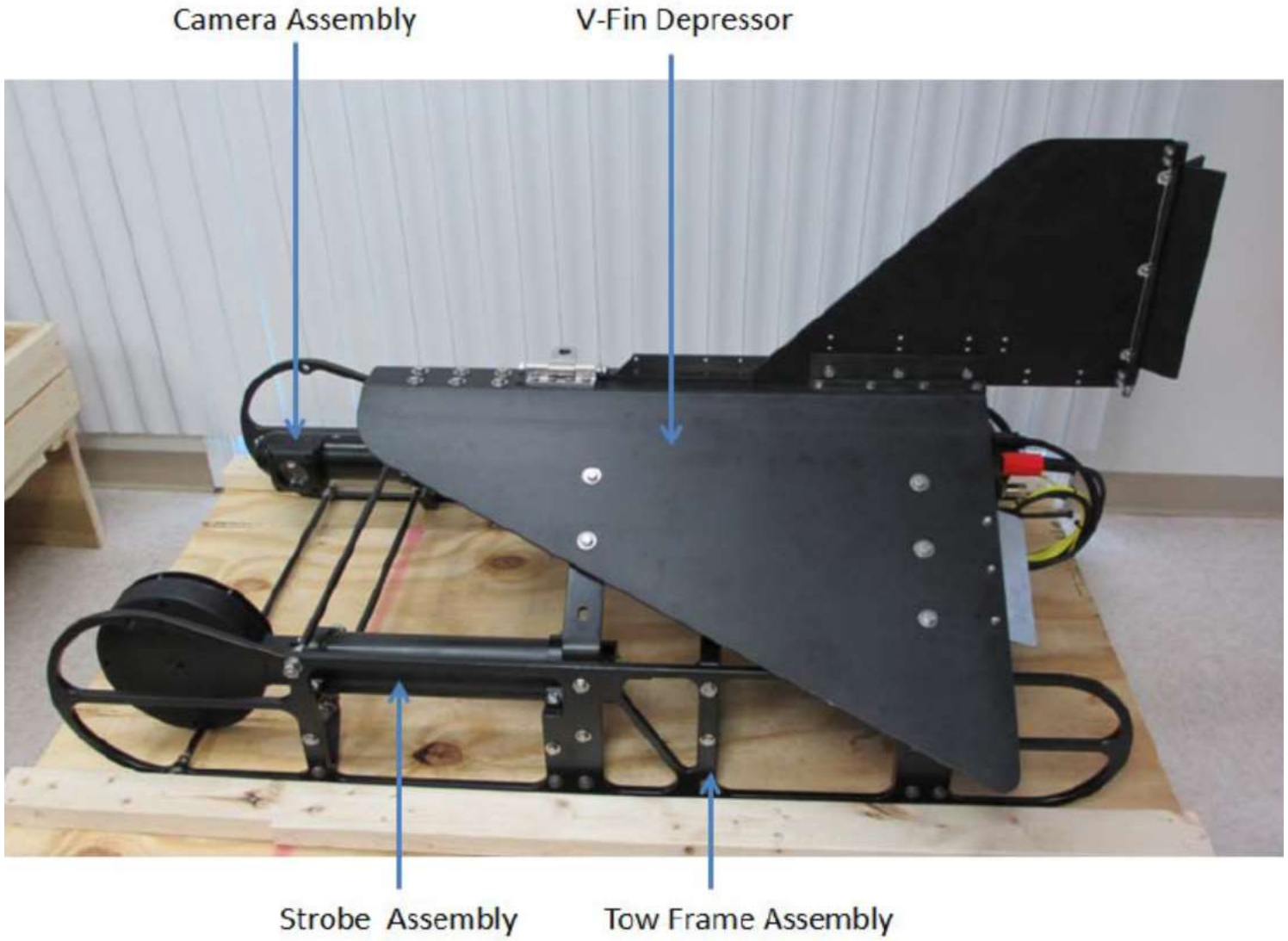
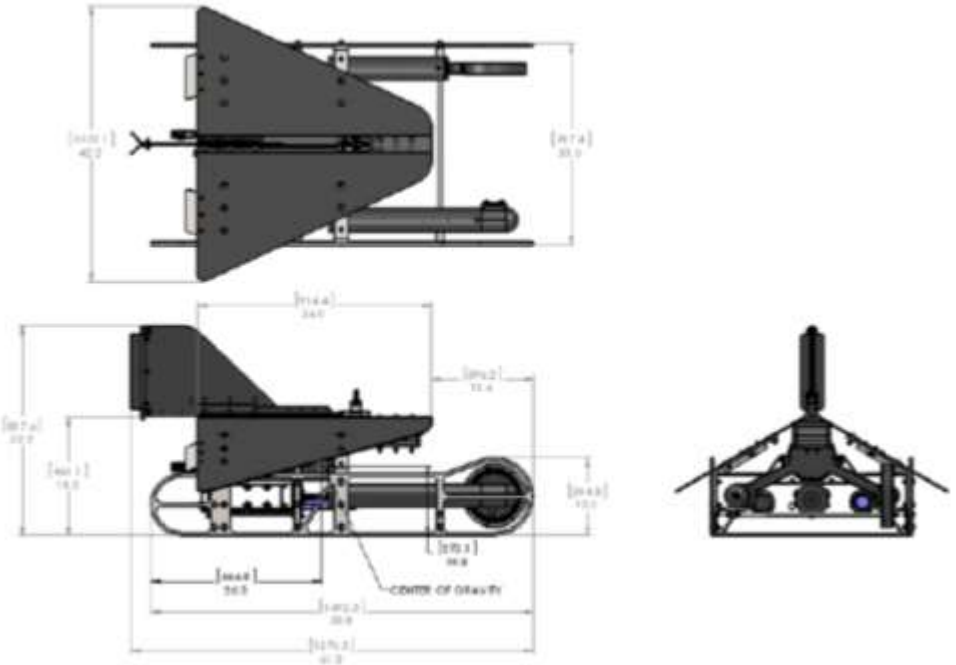



**Fig. 1.** (**A**) Cruise track of the R/V *Knorr* across the North Atlantic from the Azores to the Slope Water south of Woods Hole, Mass. (28 August to 8 September 2003). Dots show 3-hour positions of hurricane Fabian. (**B**) Along-track histogram of hourly *Trichodesmium* abundance (number/$m^3$) (puffs) (Fig. 2A top panel) overlaid on a contour plot of sea surface height (sea level anomaly, SLA) from satellite altimetry data on 3 September 2003. Highs and lows in the SLA data are labeled to show positions of seven cyclonic (C) and six anticyclonic (A) eddies as well as the Gulf Stream (GS). Note lower *Trichodesmium* abundance in cyclonic eddies on the eastern half of transect. White line is path of hurricane Fabian.

# Digital Autonomous Video Plankton Recorder (DAVPR)



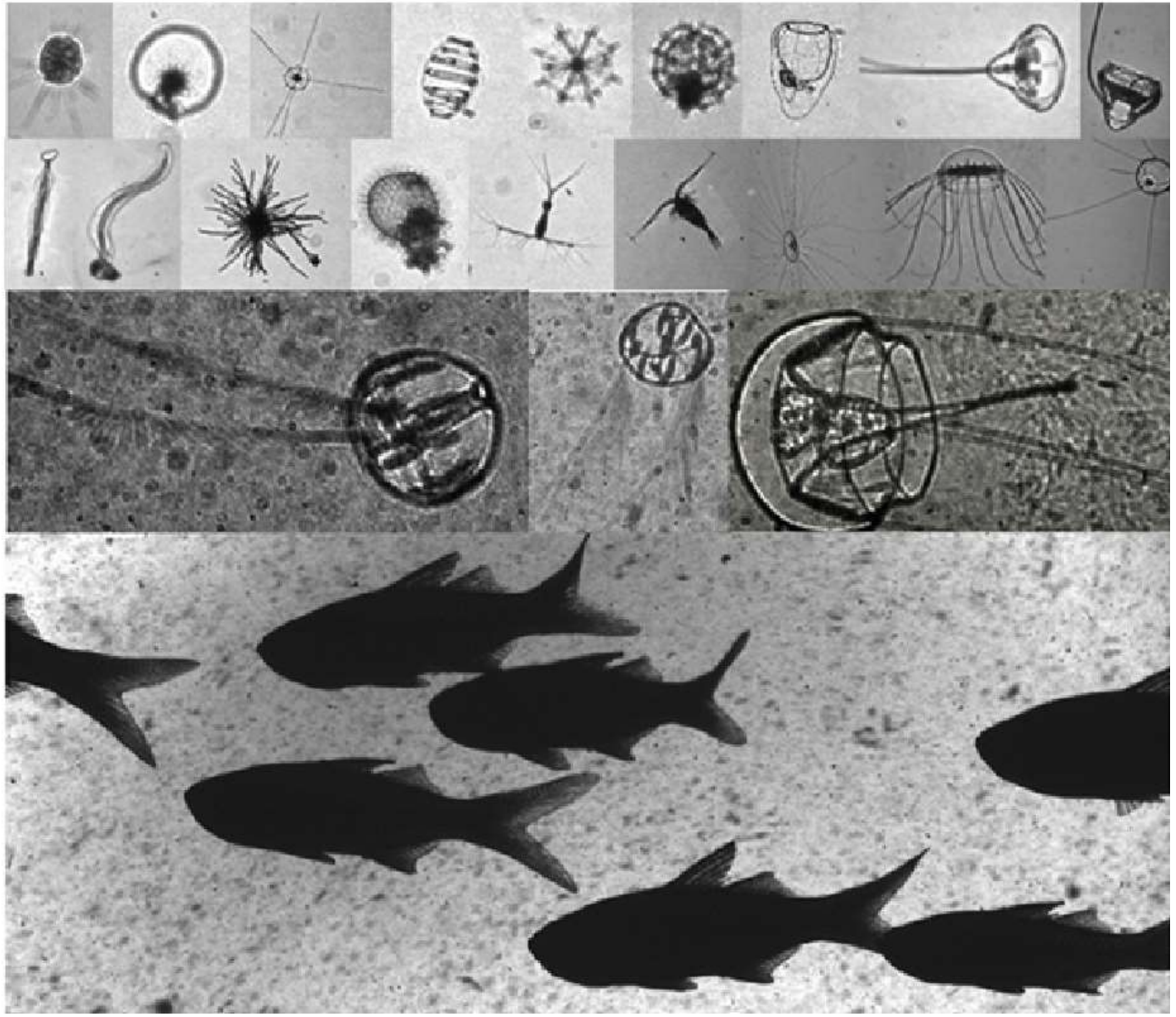
# Planktonscope

1. **Self contained, battery powered, CCD camera**
   i. **Does not require cable and could be easily deployed off small boast**
   ii. **Relatively small size and operation is relatively easy**
2. **Red light for turbid waters and reducing disturbance**
3. **Each image sample 1.2 – 2.4 Liter water**
4. **Pixel resolution 25 – 30 µm, from phytoplankton to larval fish**

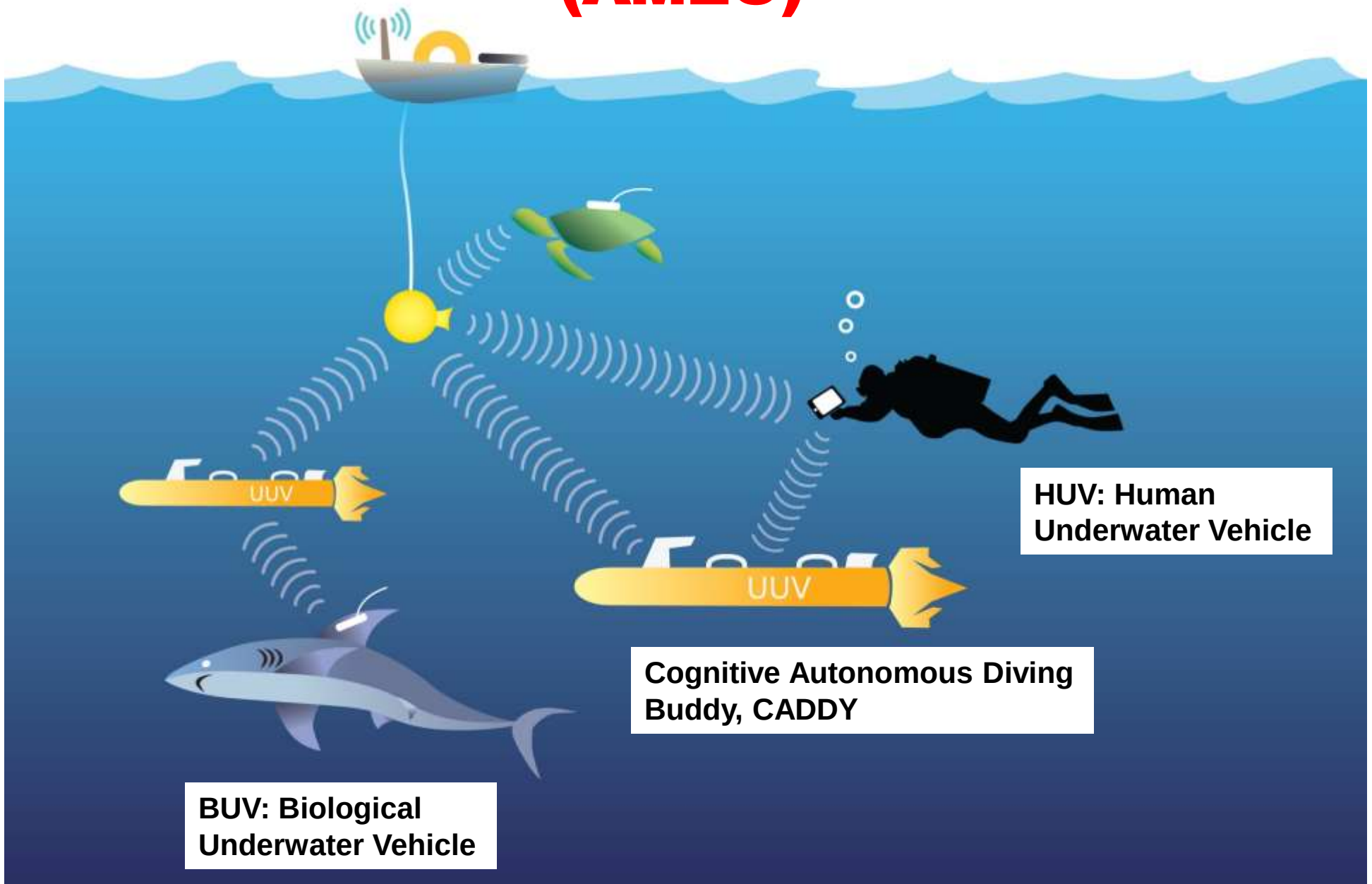
**Three different models:**

- **Planktonscope – underway system: sampling surface water while boat is underway**
- **Planktonscope – Mooring system: on buoys or piers**
- **Planktonscope – Towing system: sampling throughout the water column**

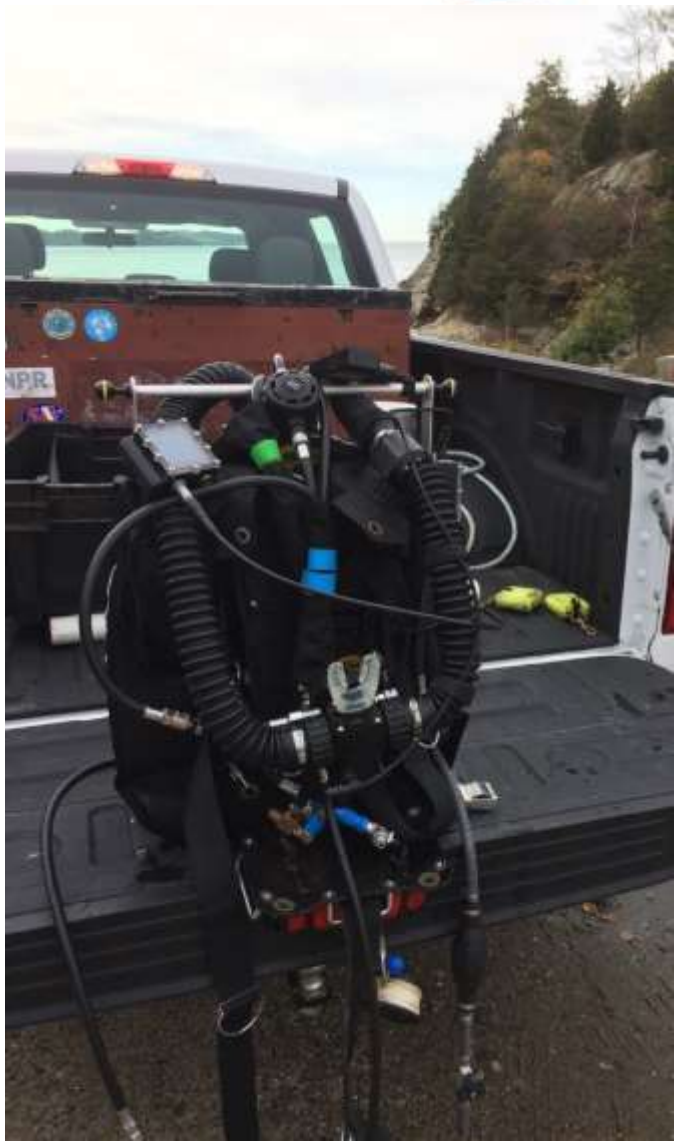
# Planktonscope Towing



# Autonomous Marine Environmental Observatory (AMEO)



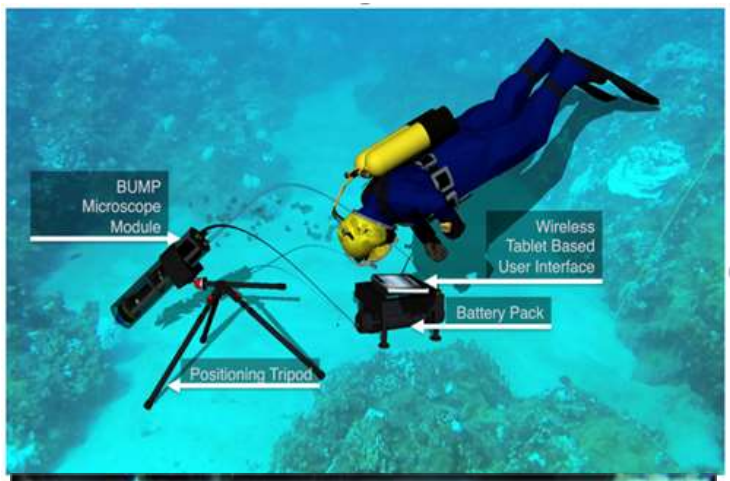
# Exploring the mesophotic zone: My rebreather



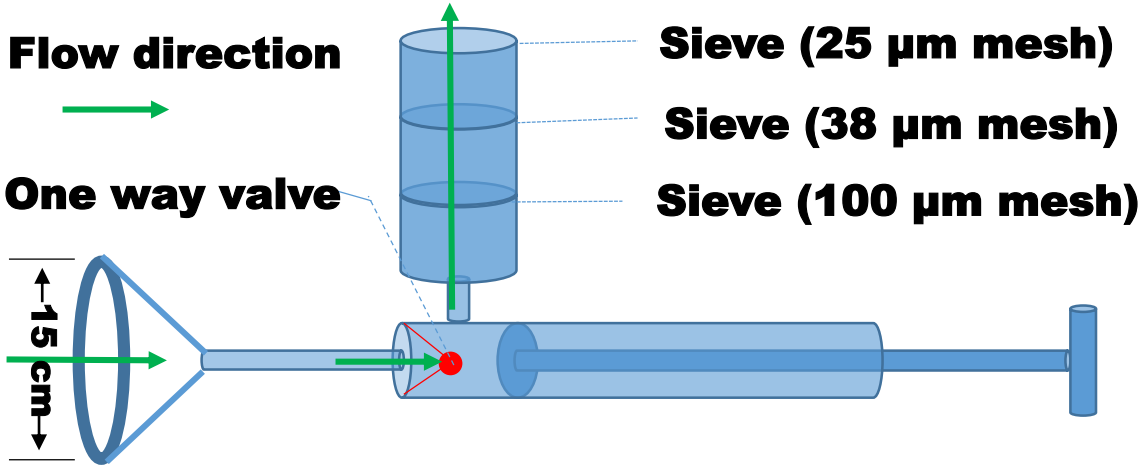
# How to collect benthic dinoflagellates ?

## Benthic underwater microscopy (BUM) for *in situ* studies of benthic ecosystems

https://youtu.be/Gf-cxm-KeK8




**The BUM is an imaging system that provides the first *in situ* underwater observations of benthic environments at nearly micrometer resolution (up to 2.2 um)**





*Nature Communications* 7, Article number: 12093 (2016) doi:10.1038/ncomms12093

# Benthic underwater microscopy (BUM) for *in situ* studies of benthic ecosystems

# BUM - Benthic Underwater Microscope

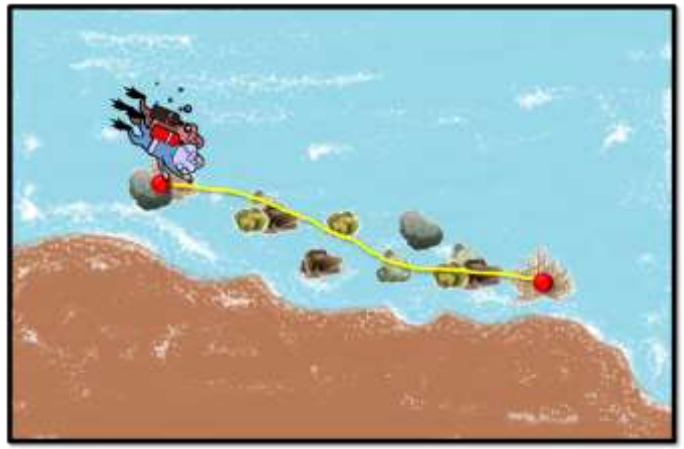
## for *in situ* studies of benthic communities

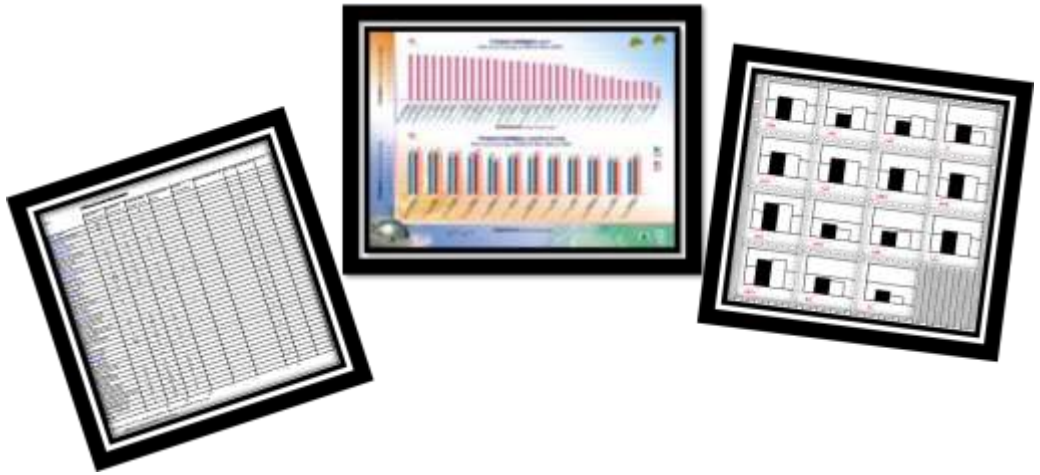
**Jules Jaffe Laboratory for Underwater Imaging, SCRIPPS Institution of Oceanography, University of California San Diego, USA**

- **Temporal and spatial analysis of BETA and their potential impacts on coral communities;**
- **Observing the natural processes at microscopic scale in natural environments.**

# How to assess the health conditions of Coral Communities?

- Survey methods can indicate where and how much coral coverage and loss;
- Coral bleaching was the cause of coral death because we saw them bleach taken place;
- How about the physiological conditions of surviving corals: whether they are physiologically healthy or in declining health? We don't know!
- Thus, there is value in having an easy way to measure and assess the physiological conditions of reef corals.

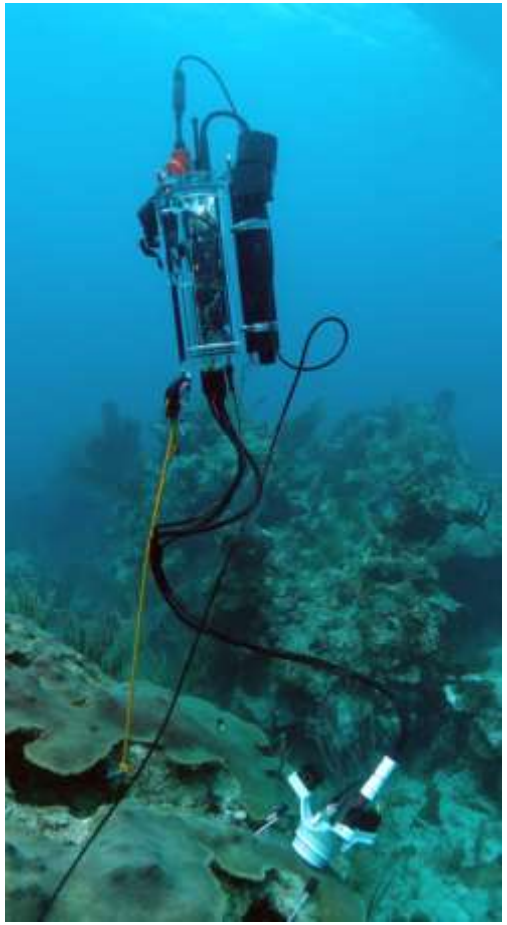


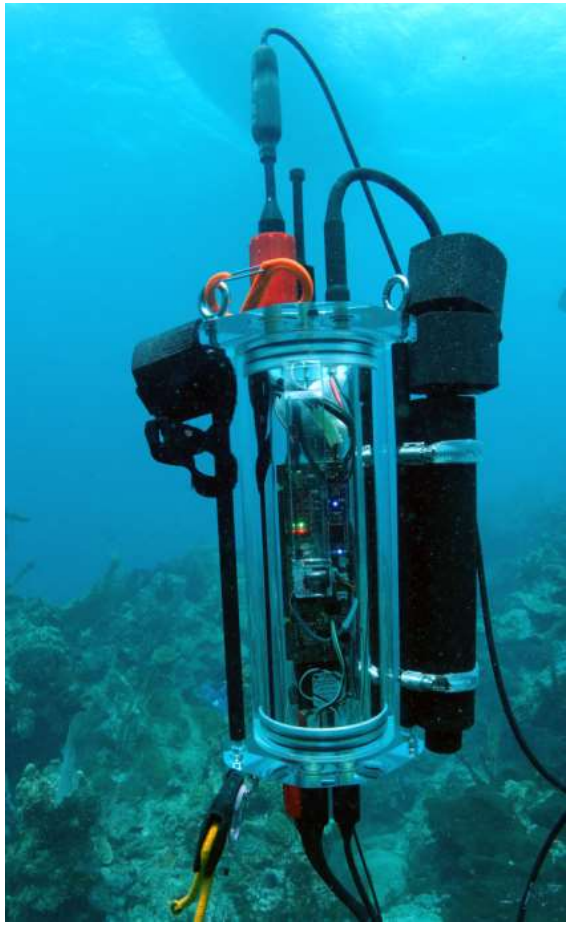


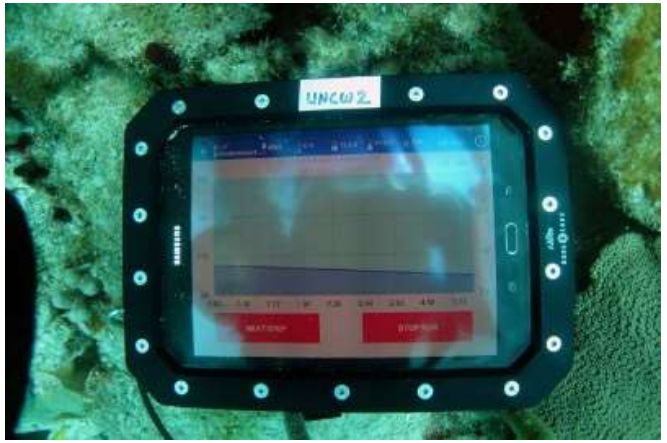
# CISME Coral In Situ Metabolism

## (pronounced “Kiss Me”: not harmful to the corals)

Dr. Alina M. Szmant and Dr. Robert F. Whitehead
University of North Carolina Wilmington, USA








# CISME – Coral *In Situ* MEtabolism

CISME™

**WHAT IS IT?**

**Diver deployed *in situ* respirometer for non-destructive measurements of reef coral Respiration, Photosynthesis and Calcification.**

**WHAT IS USED FOR?**

**Measures the metabolic rates of benthic organisms or substrates types:**

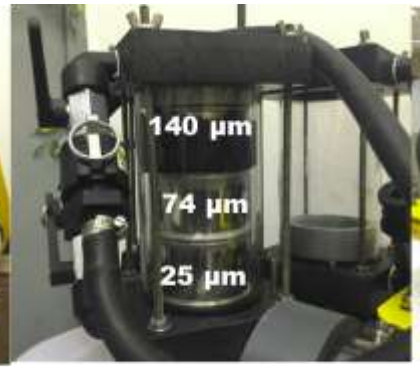
- **Corals and benthic algae;**
- **microbial films and sediments;**
- **sponges, other invertebrates;**
- **numerous other uses.**

**APPLICATIONS?**

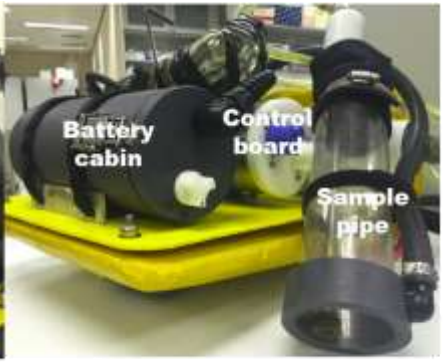
- **Physiological-ecological research;**
- **Environmental monitoring;**
- **Conservation work/Management.**

# Portable Underwater Laboratory/Observatory

Complete sampler system

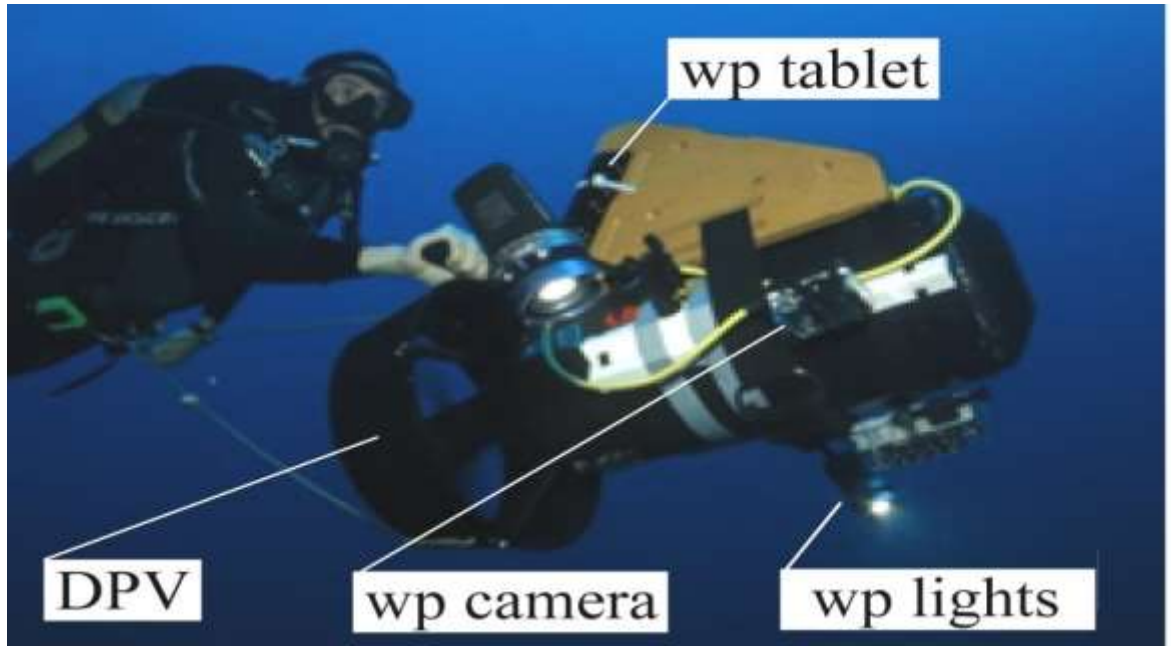



Fractionator




Battery and control panel

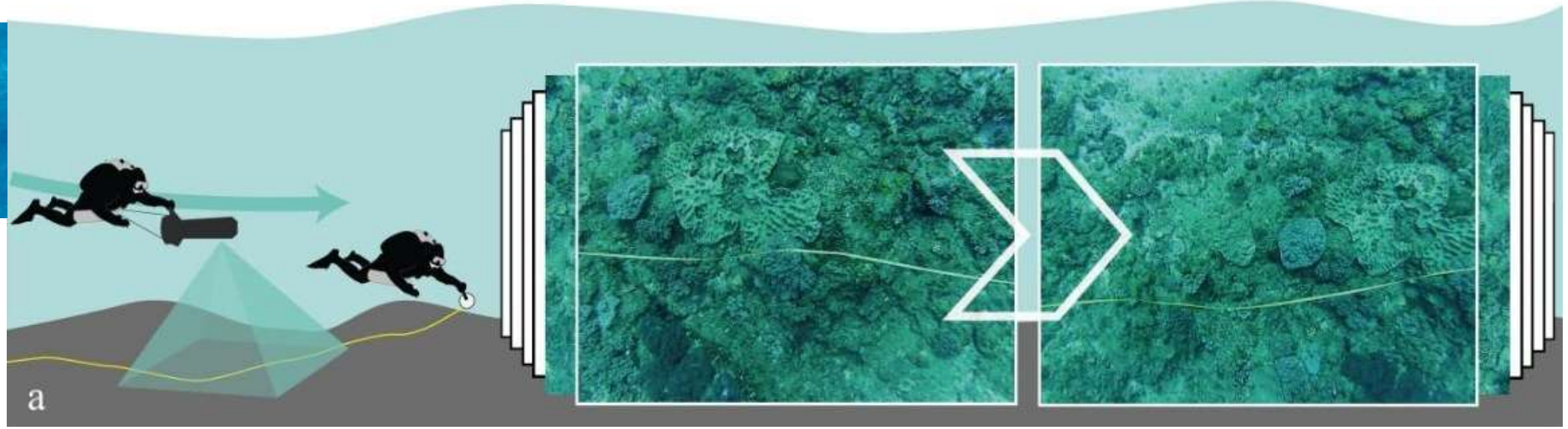
# Exploring the mesophotic zone: My ocean space habitat




**Diver Propulsion Vehicle (DPV) equipped with camera, the waterproof tablet and the lights**

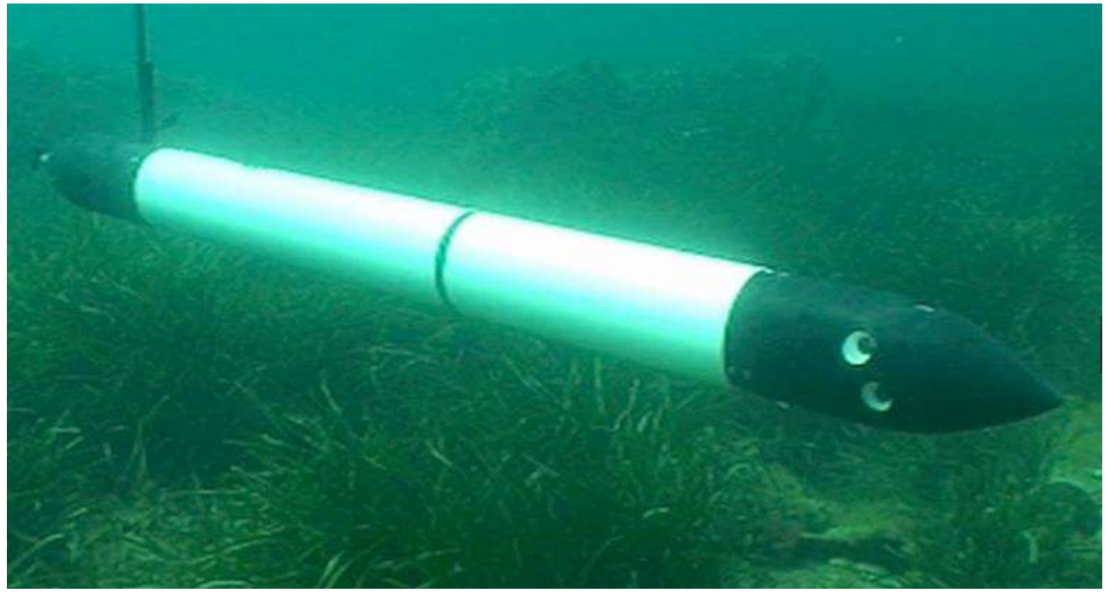
# Third-generation underwater mosaics approach [1]

**which relies on underwater scooters, micro-cameras, inertial navigation sensors and GPS buoys.**



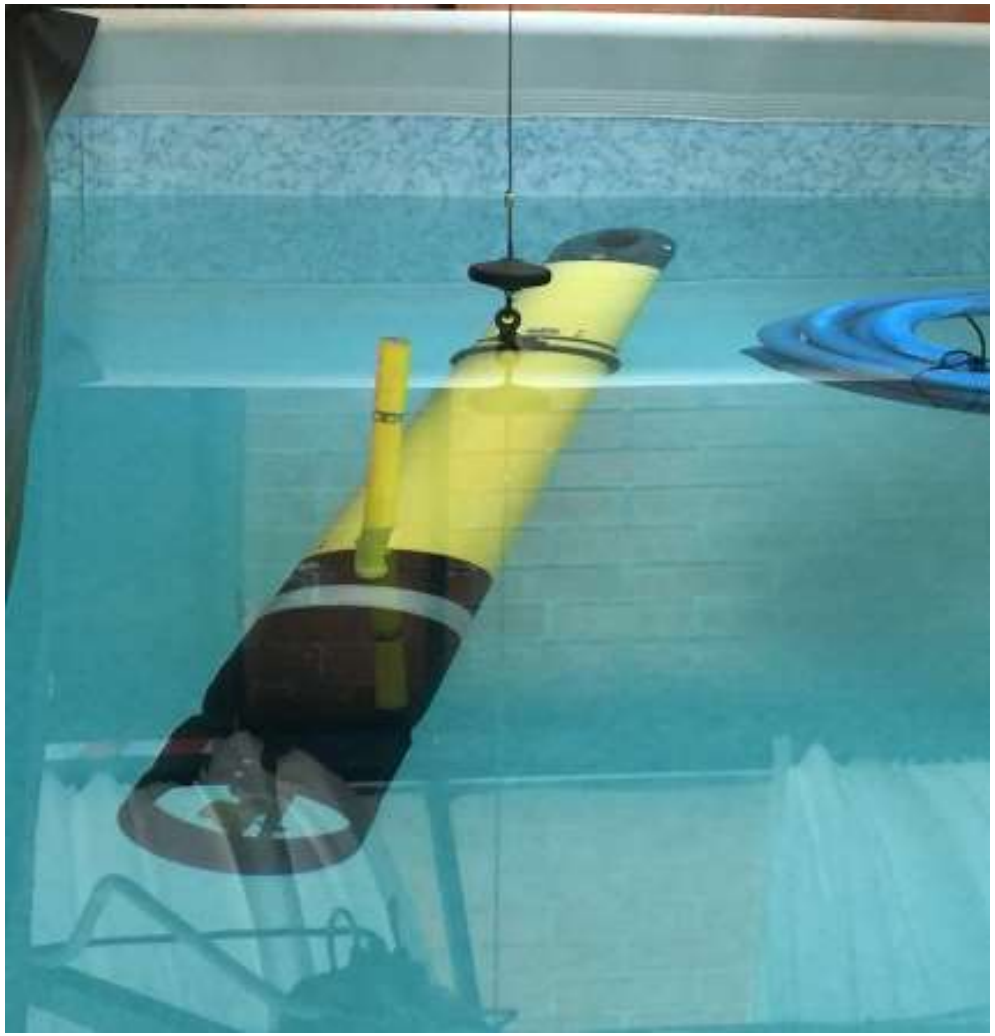

**Transect deployment and image collection (left) and detailed example of the collected imagery (right)**

# Deployment of an autonomous underwater vehicle to conduct Benthic Habitat Mapping for Marine Park in Hong Kong



**eFolaga is the newest version of Folaga, a class of torpedo-shaped Autonomous Underwater Vehicles (AUV) designed for carrying different kinds of underwater instruments, e.g. cameras for collecting images, a multiparameter probe for collecting environmental data, an altimeter, a surface buoy equipped with GPS and WiFi.**

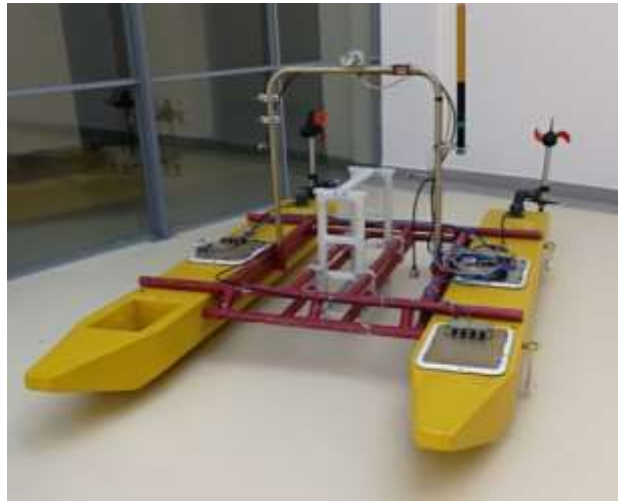
# Custom-made Autonomous Underwater Vehicle (AUV) for Marine Environmental Monitoring



**YSI EXO2 Multi-parameter water quality monitoring sonde**

**Hydrophone**

# Intelligent Marine Robotic System, iMRS



## In Collaboration with Institute of Marine Technology Problems of Russian Academy of Sciences & Harbin Engineering University

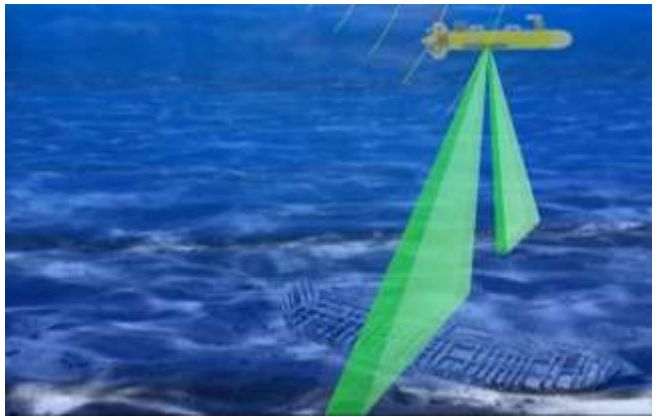
IMTP FEB RAS

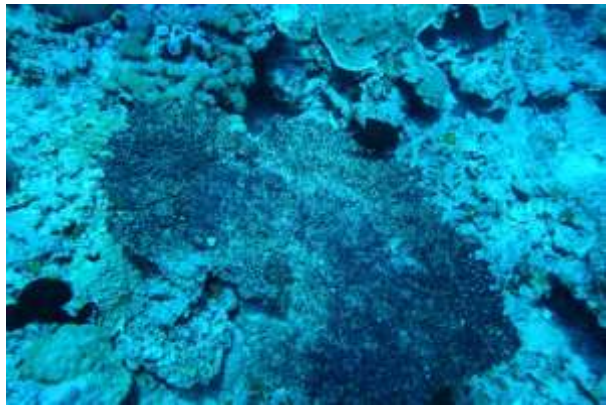
哈尔滨航士科技发展有限公司（筹）
Harbin Flagship Science and Technology Development Co.,Ltd

# Intelligent Marine Robotic System, iMRS

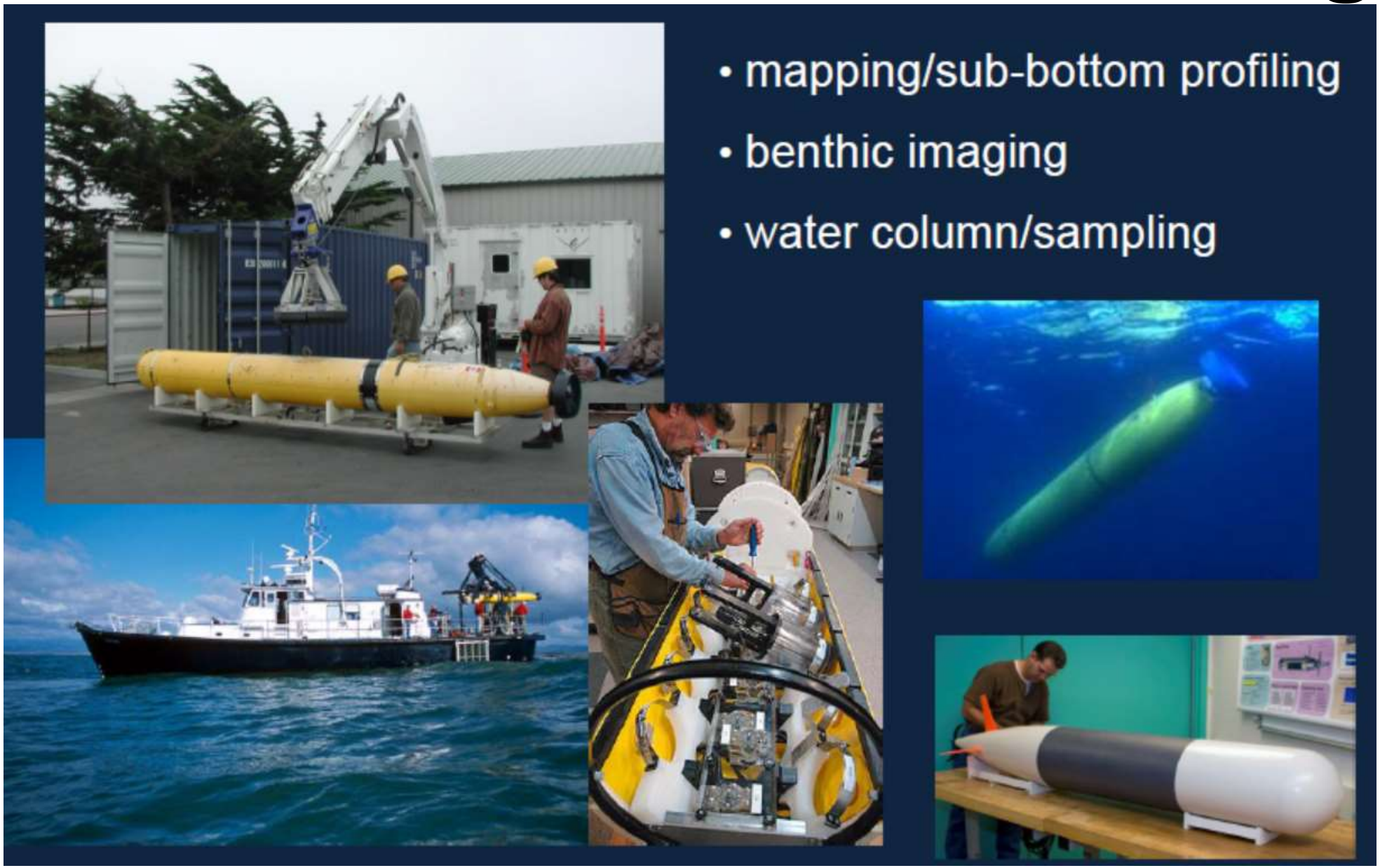
香港城市大學
City University of Hong Kong

- **Estimation of biological diversity and ecological conditions in coral communities;**
- **Bottom habitat density estimation and mapping;**
- **Fish diversity survey**
- **Images Mosaicing.**

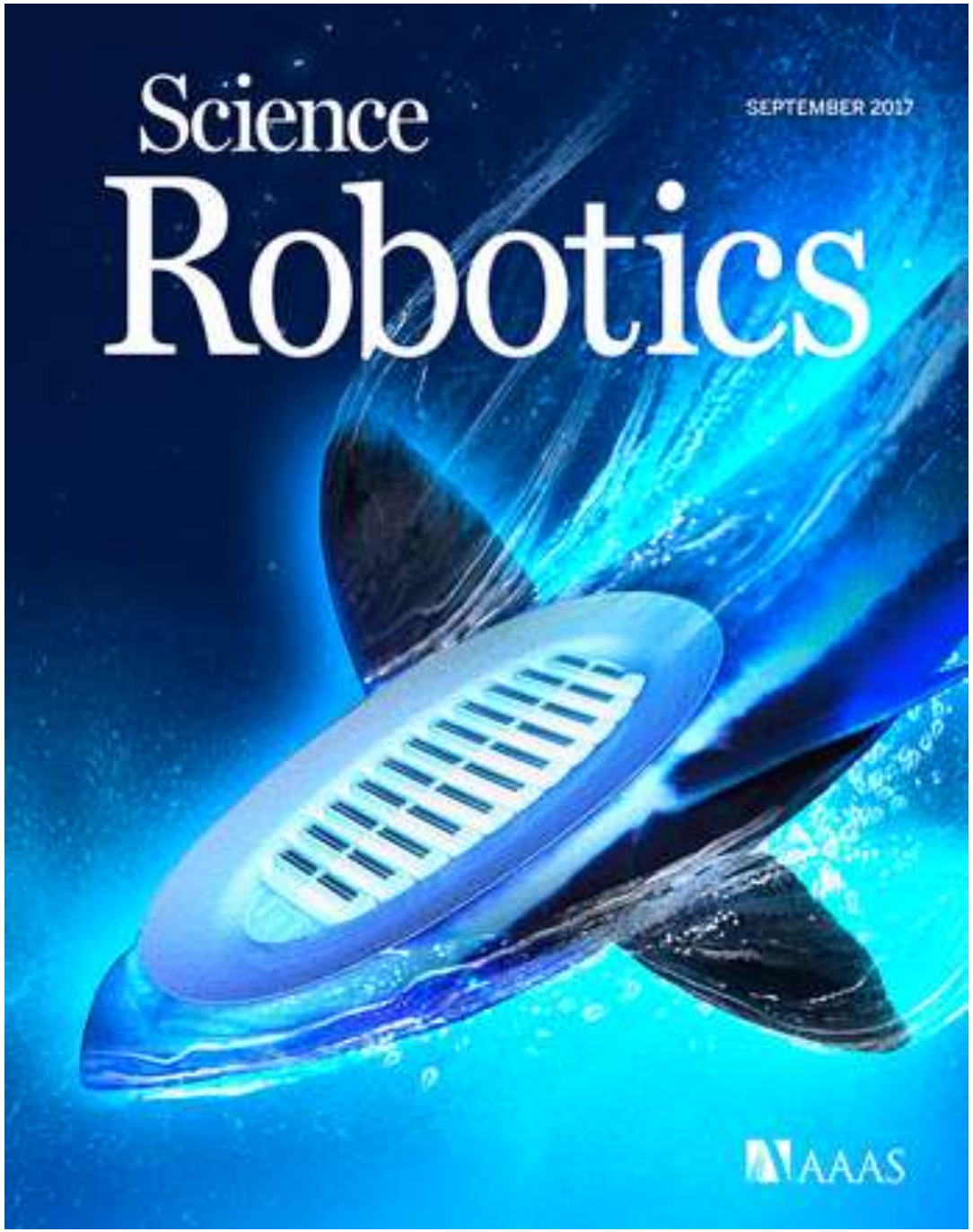




# AUVs have come of Age

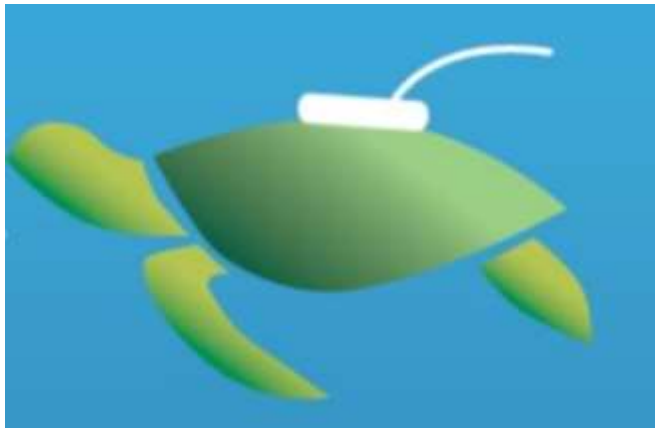


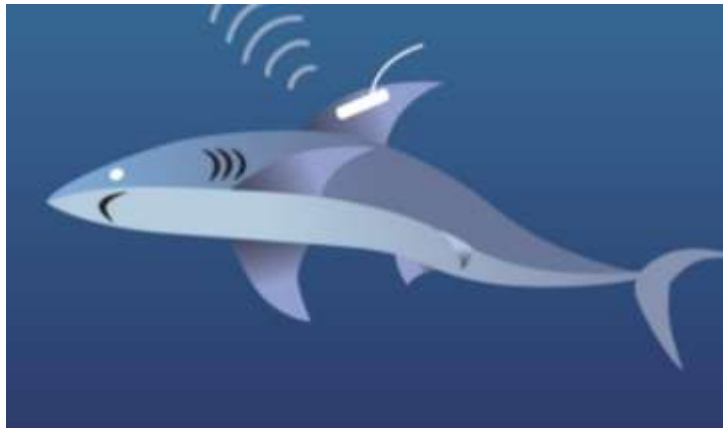

**Credits:**
**James Bellingham, WHOI**




# BUV: Biological Underwater Vehicle

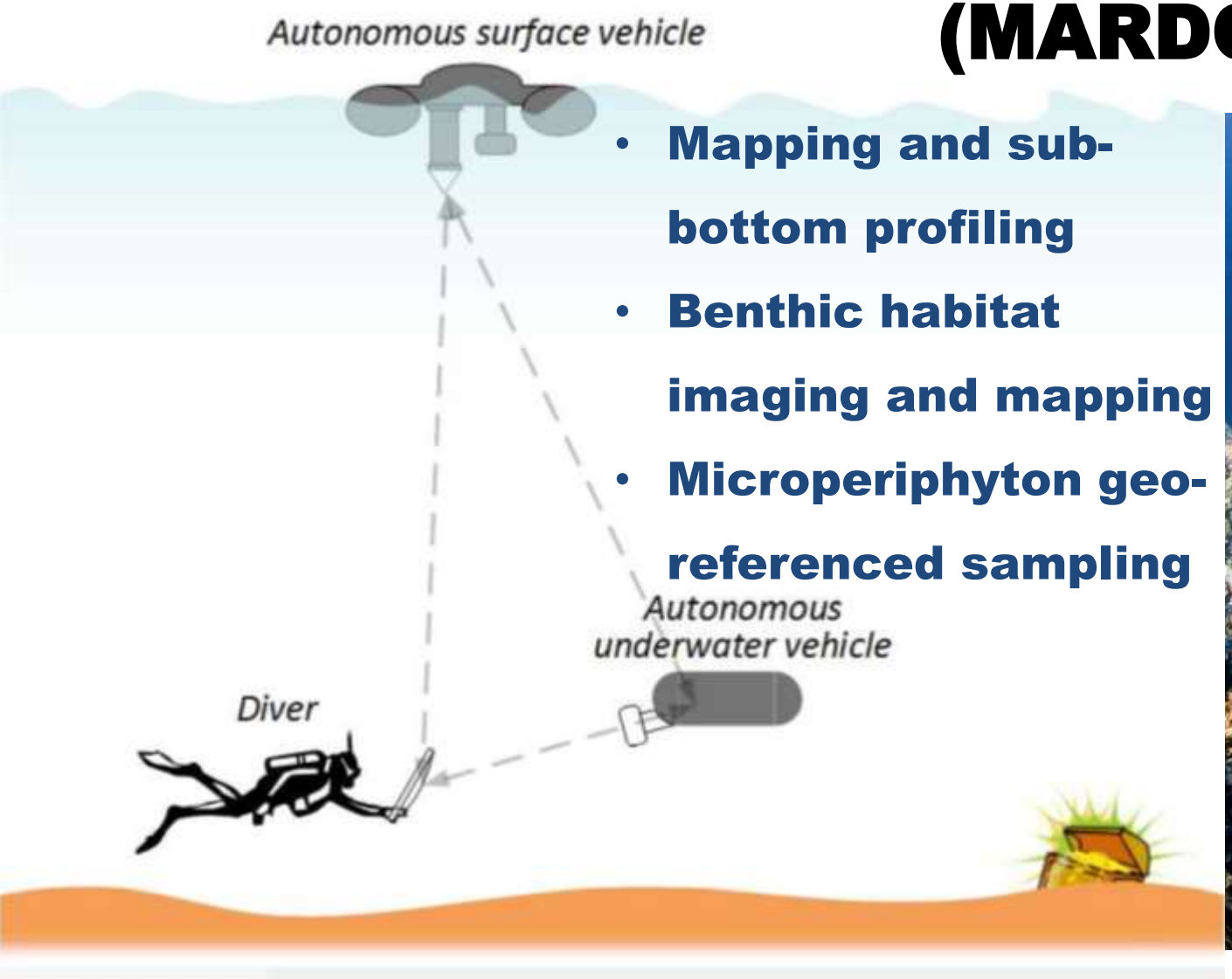
**ONLINE COVER** Biological Remora with the Bioinspired Robotic Disc. Remoras attach to a diverse array of marine animals using a highly modified dorsal fin that forms an adhesive disc. Wang *et al*. developed a multimaterial biomimetic disc that enables robust attachment and underwater hitchhiking to a variety of surfaces. This bioinspired adhesive technology may reduce transport and movement costs, increase mission durations for autonomous underwater vehicles, and enable underwater gripping applications. [CREDIT: LI WEN, YUEPING WANG, AND KLAUS STIEFEL]





## For Veterinary Medical Research for Marine Mammals

# Exploring the mesophotic zone: Marine Autonomous Robotic and Divers Complex (MARDC)




- Mapping and sub-bottom profiling
- Benthic habitat imaging and mapping
- Microperiphyton geo-referenced sampling

China Autonomous Diving Buddy (CADDY)

香港城市大學
City University of Hong Kong
專業 創新 胸懷全球
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# Joint Research & Development Centre for Advanced Ocean Observation and Innovation Technologies

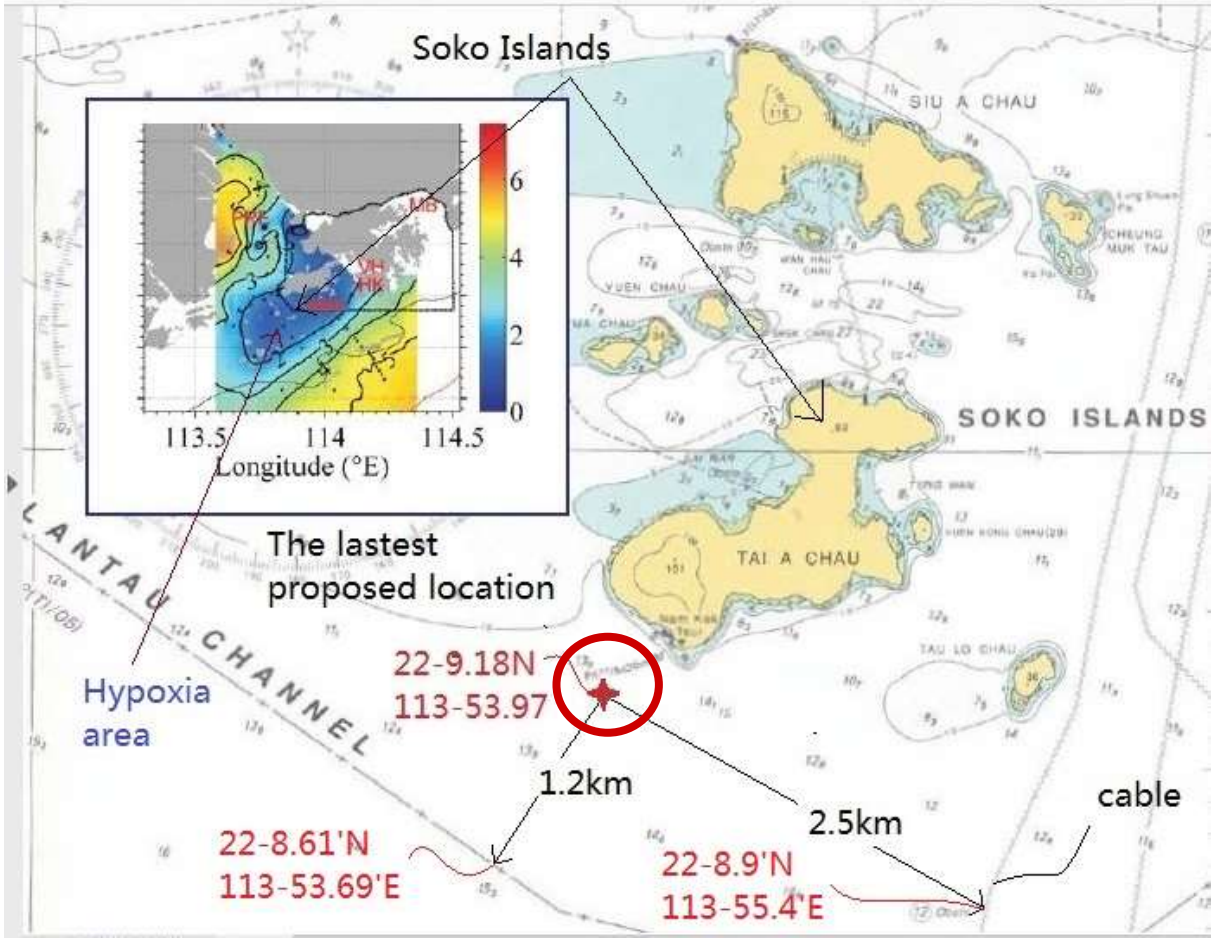
# Objectives

- ✓To develop this Joint Centre into an international high-level nurturing platform ;
- ✓To pursue exploration of the complexity of the natural ocean systems in innovative ways;
- ✓To catalyst the development of marine innovation technology and marine-related industries;
- ✓To stimulate the formulation and development of the research activities in marine science and ocean observation in China and Hong Kong.

# Research Scopes

1. Underwater Intelligent Observation technology development and application
2. “The 21st Century Maritime Silk Road” Coral Reef Ecosystem Monitoring
3. The 21st Century Maritime Silk Road” Coral Reef and Paleoclimate Study

# Integrating fixed-point buoys and mobile platforms to form an underwater intelligent observation network


Scientific Buoy Location in Hong Kong

# Scientific Buoy Design

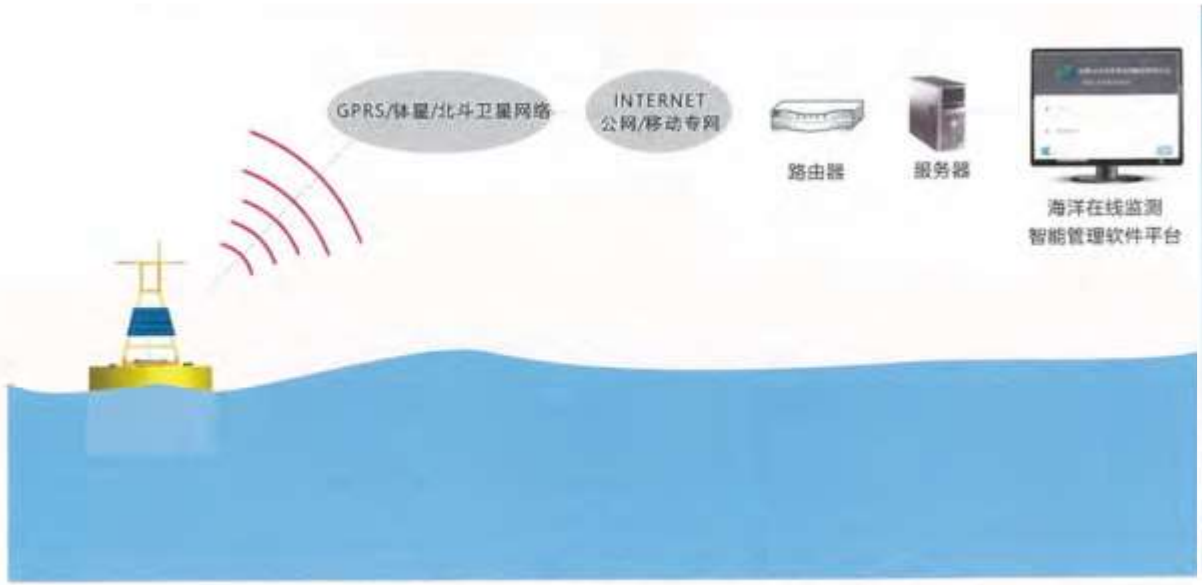



圖 浮標式海洋在線監控自動站運行拓撲圖

圖 定点垂直剖面掛載式監測浮標結構設計示意圖

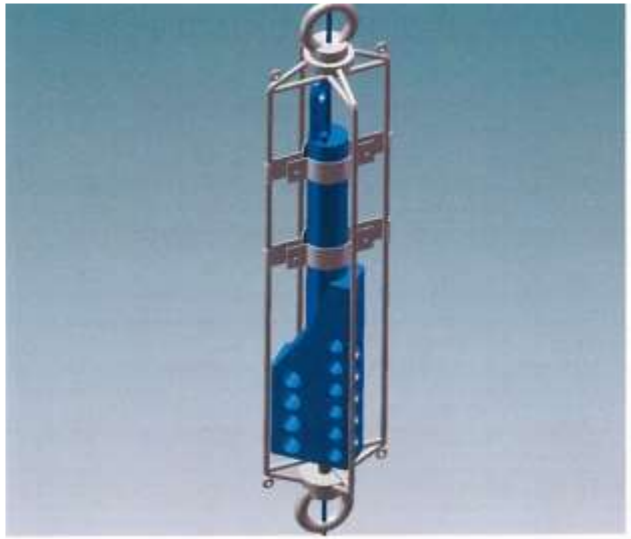


圖 剖面掛載鏈（中部）

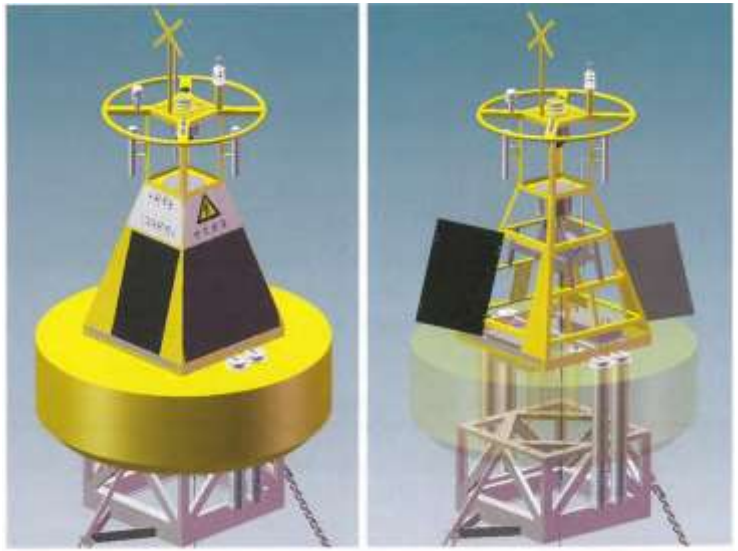


圖 浮標體整體結構實圖（左）與透視圖（右）

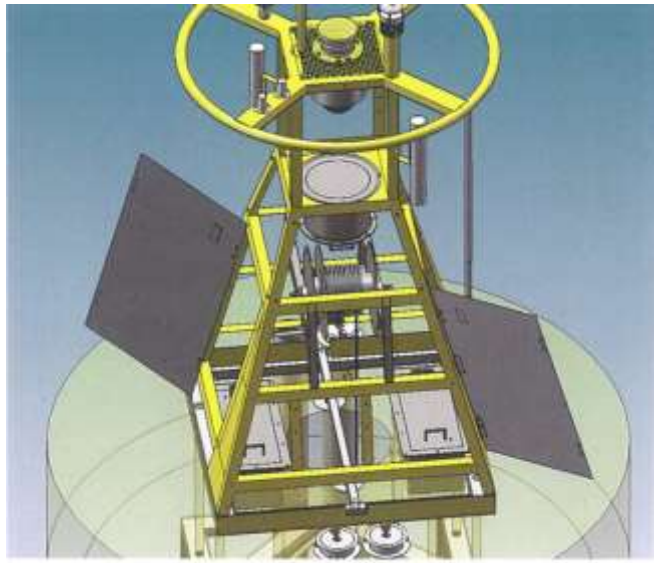


圖 浮標電子艙內部結構示意圖

圖 剖面掛載鏈（底部）

# Physicochemical parameters

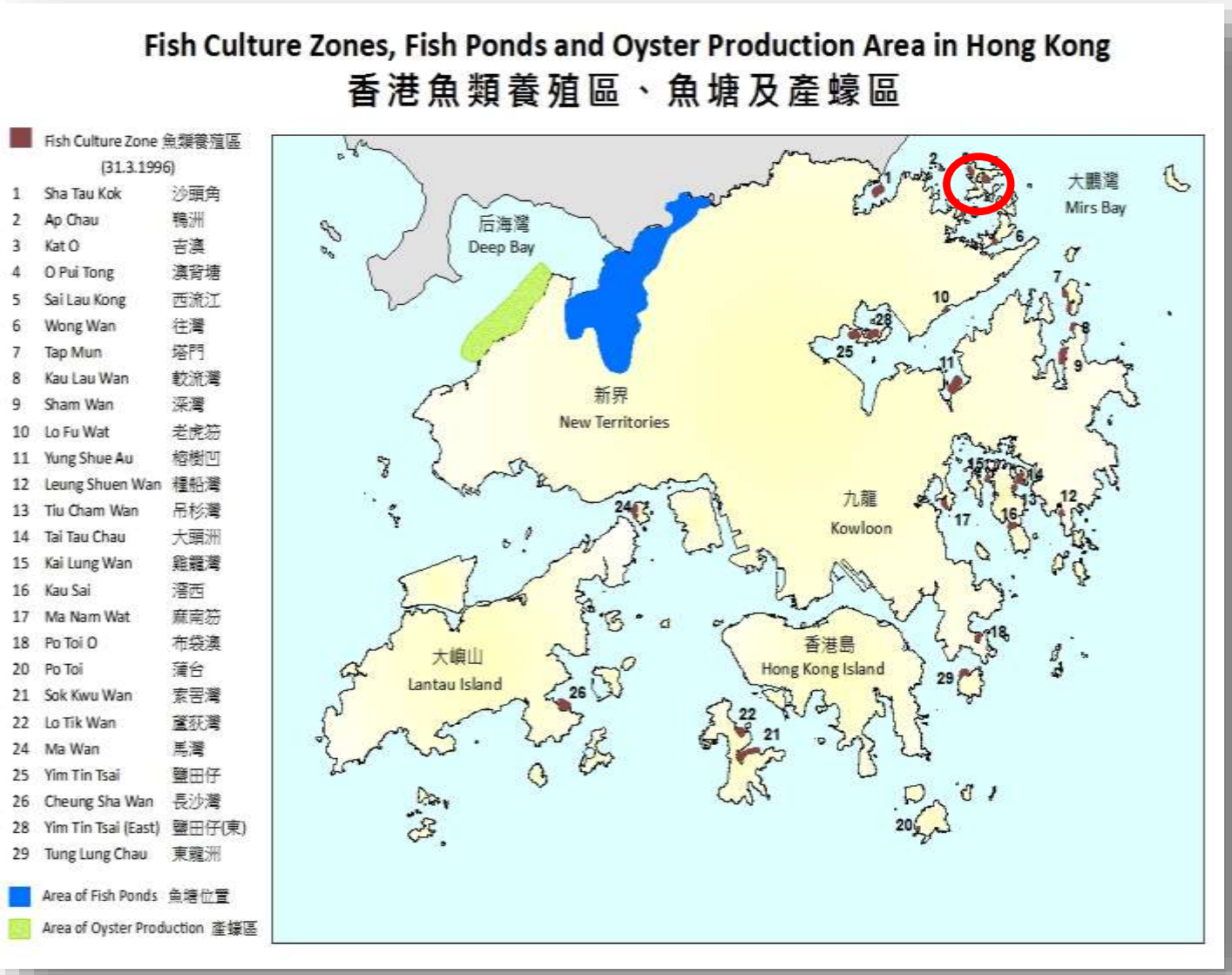
**Seabird HydroCAT-EP**

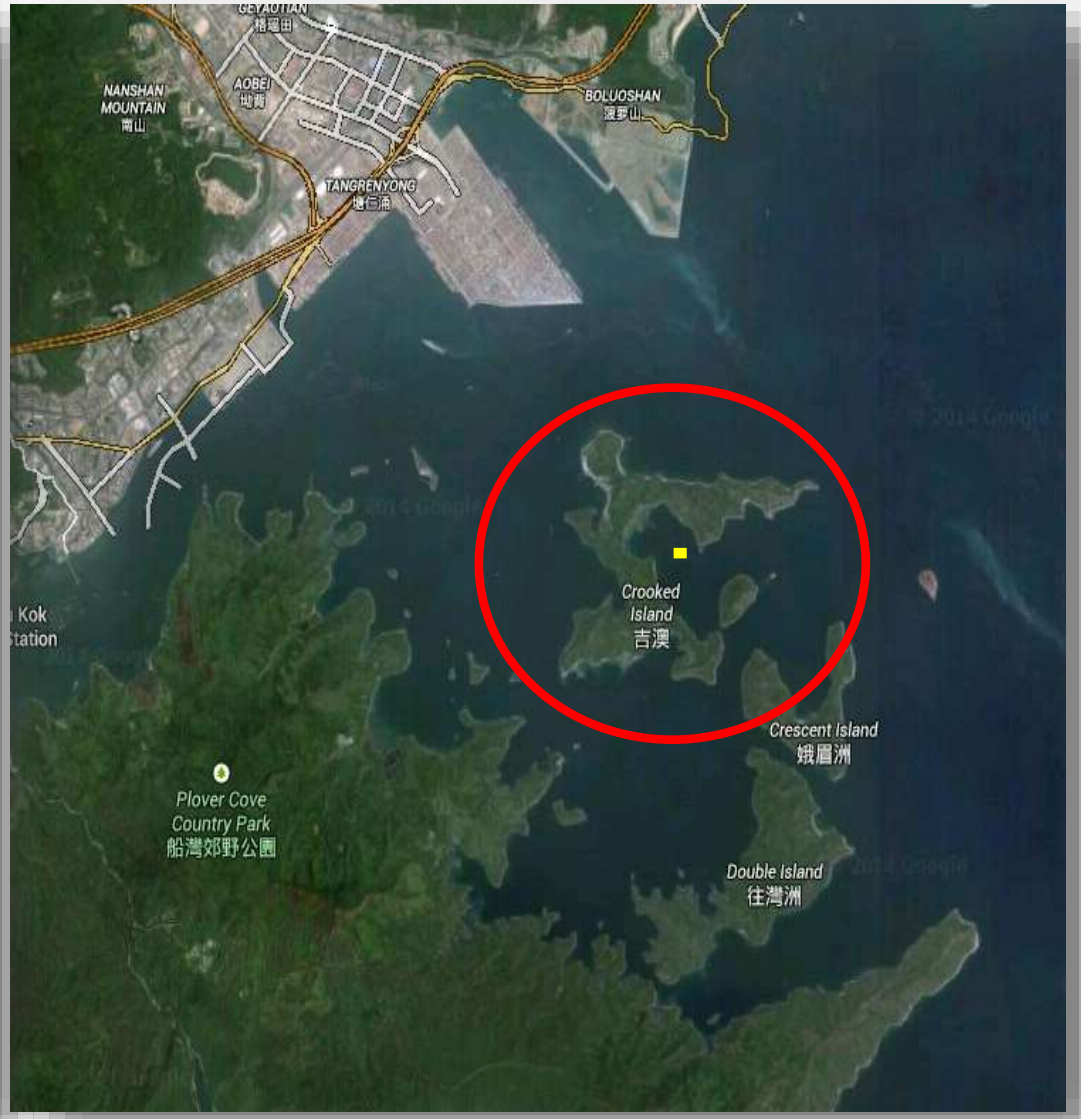
- **Conductivity**
- **Water Pressure**
- **pH**
- **Seawater temperature**
- **Dissolved oxygen**
- **Chlorophyll a**

**NorTeK ADCP (Current profiler)**


**Real time surveillance camers**

# Proposed Location of Joint Centre: Kat O Island or Crooked Island



# Existing Facility in Kat O



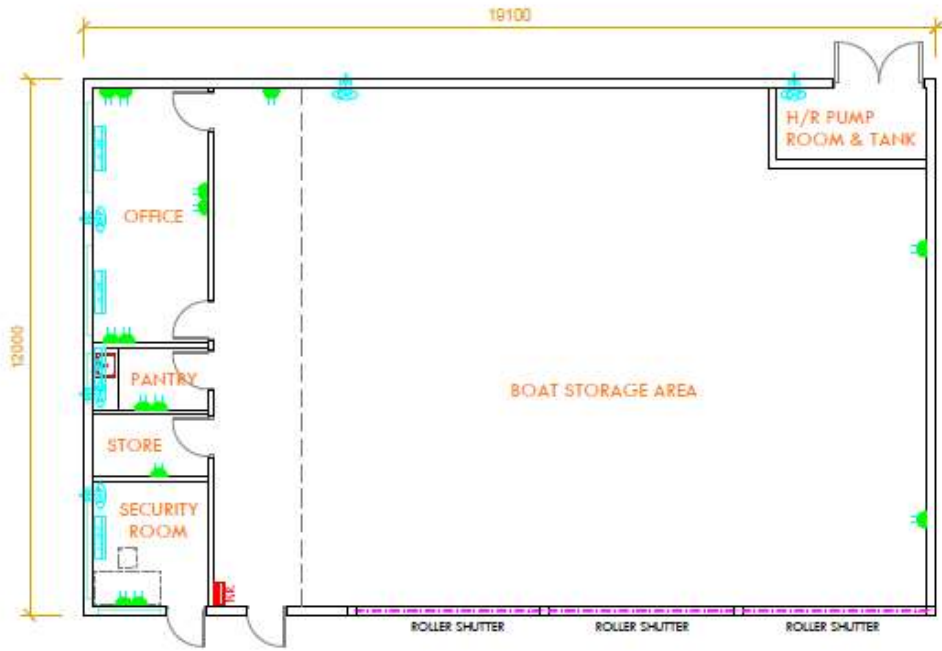
**Kat O island is a 300 years old village with limited access by public**

# Kat O Public School


**Proposed research facilities:**

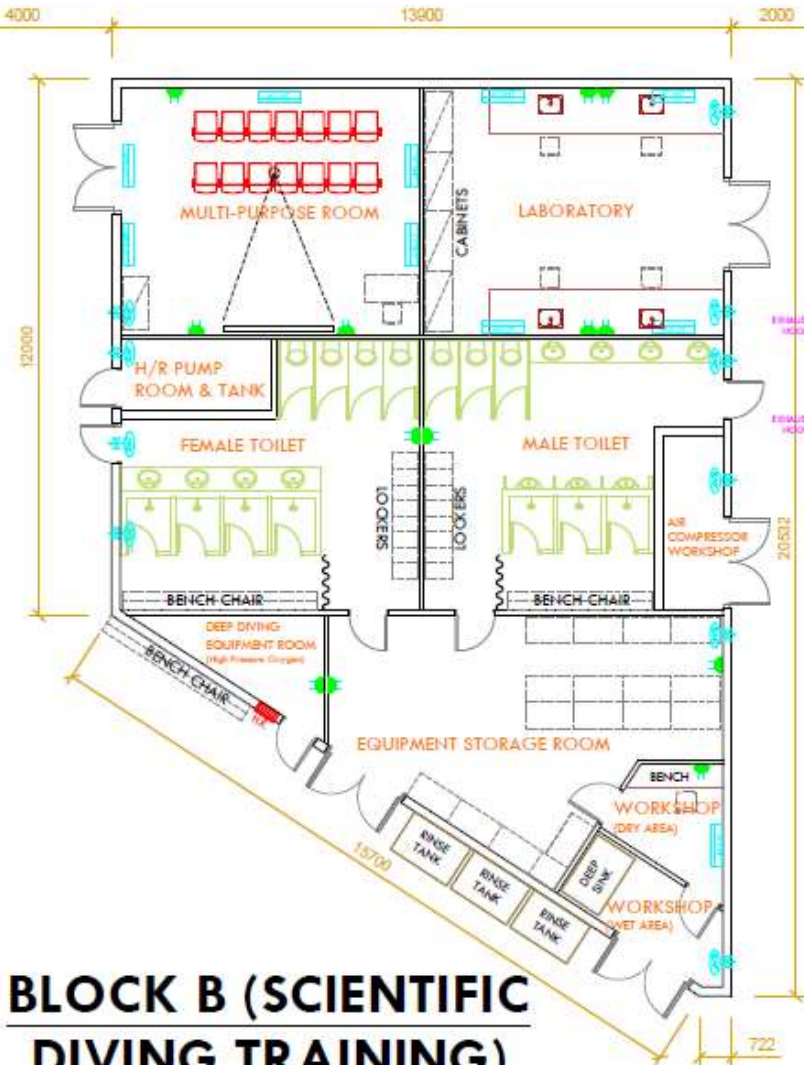
- **One dry laboratory to process samples with freezer and fridge storage space;**
- **One storage and maintenance room for dive gear as a base for diving and underwater activities;**
- **One storage area for water sports equipment for sport education.**

# Kat O Education and Underwater Research Centre




## BLOCK A (BOAT STORAGE AREA)

(AREA:230 SQM ; HEADROOM: 3.5M)




## BLOCK B (SCIENTIFIC DIVING TRAINING)

(AREA:230 SQM ; HEADROOM: 2.8M)


## BLOCK C (LABORATORY)

(AREA:230 SQM ; HEADROOM: 2.8M)

# O Pui Tong AFCD Station

## Advantages

- Freshwater supply
- Seawater supply
- Power supply

## Proposed research facilities

- Marine environmental monitoring station
- State of the art teaching and research laboratories
- Engineering and electronics workshops
- Advanced diving facility
- Marine bacteria and microalgal Culture Collection
- University diving and boating facilities able to conduct underwater research

# Acknowledgements


香港城市大學
City University of Hong Kong
專業 創新 胸懷全球
Professional · Creative
For The World

大學教育資助委員會
University Grants Committee

Croucher Foundation
裘槎基金會

National Natural Science Foundation of China
國家自然科學基金委員會

Shenzhen Science and technology Innovation Committee
深圳市科技創新委員會

SEA DWELLER UNION
潛者聯盟

**SKLMP Advanced Scientific Diving Team**


***We might not have it altogether, but together we have it all.***


Thank you for your attention !