MAS.S62:

Ocean IoT

Technologies, Industries, Sustainability

Lecturer

Fadel Adib (fadel@mit.edu)

TA

Sayed Saad Afzal (afzals@mit.edu)

Website

http://www.mit.edu/~fadel/courses/MAS.S62/index.html

Sign up on Slack for announcements

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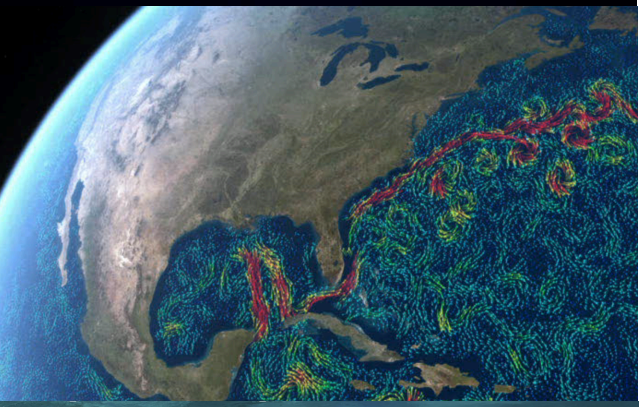


Let's start with some trivia

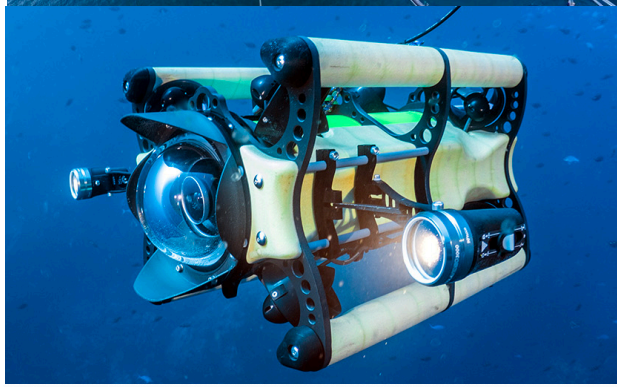
1. How percentage of the ocean floor has never been observed?

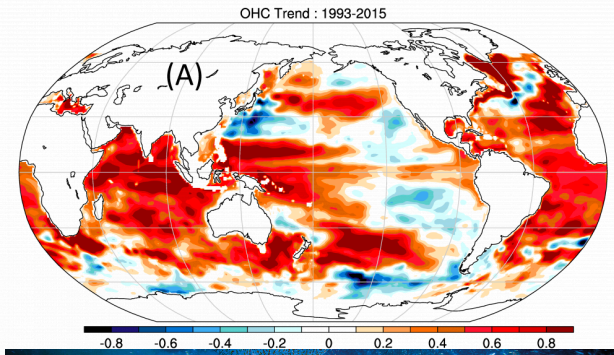
2. Out of every 10 marine organisms, how many have never been discovered?

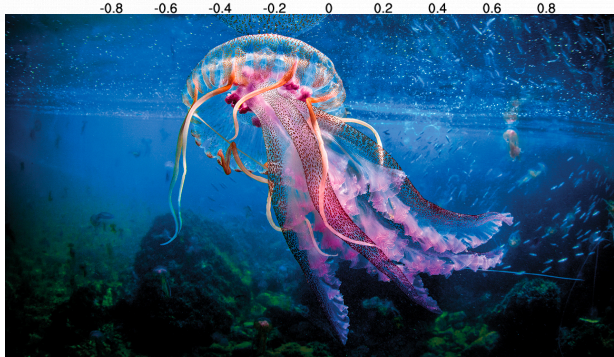
3. What is the world's fastest-growing food sector?

4. What has more heat content: the ocean or the atmosphere?

5. Which decade did the UN declare *"Decade of Ocean Science for Sustainable Development"*?







Internet-of-Things

Convergence of micro-sensing, computation, and communication that allows us to:

- *Acquire* (*sense*) data from the environment
- *Pre-process* data locally
- *Deliver* data to servers
- *Draw inferences* and *provide insights* about the world from the data using computational techniques
  - Sensor fusion, data integration
  - Signal processing
  - Machine learning
- *Control* actions in the environment

Example: GPS

Focus of class: Ocean IoT technologies

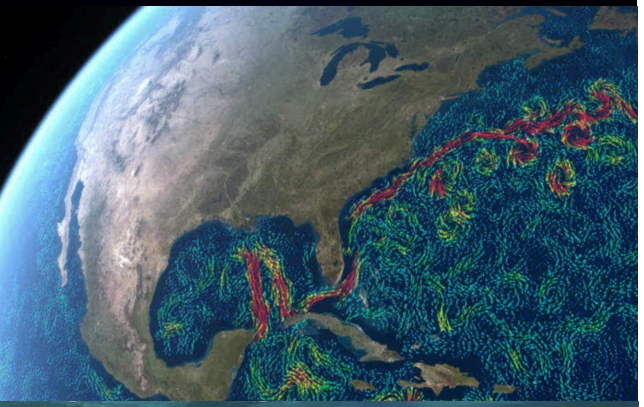
Taking the Internet of Things to the Ocean World

30 bn

IoT Devices

Less than 1 in a million of IoT is in the ocean, even it they covers >70% of the planet and has significant needs for food, climate, etc.

IoT Sensors → **Data** → **Decision Making & Prediction**



How Can IoT help?

1. How percentage of the ocean floor has never been observed?

2. Out of every 10 marine organisms, how many have never been discovered?

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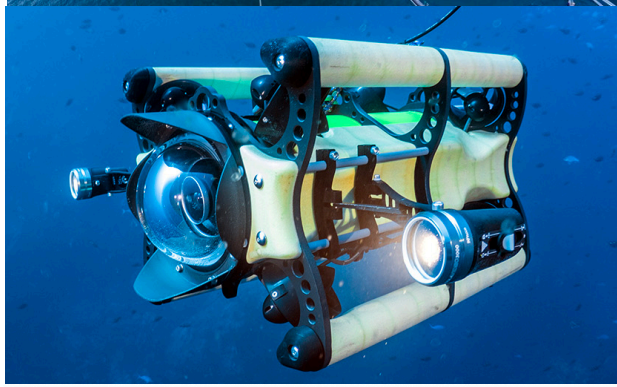
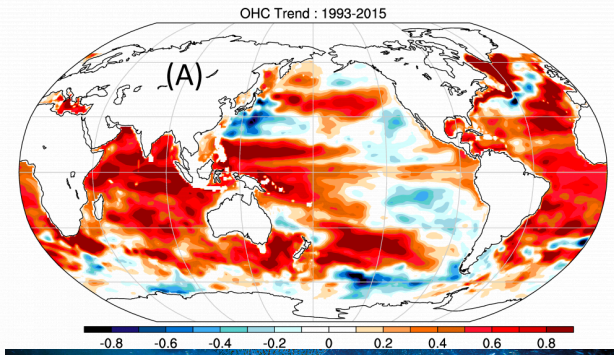
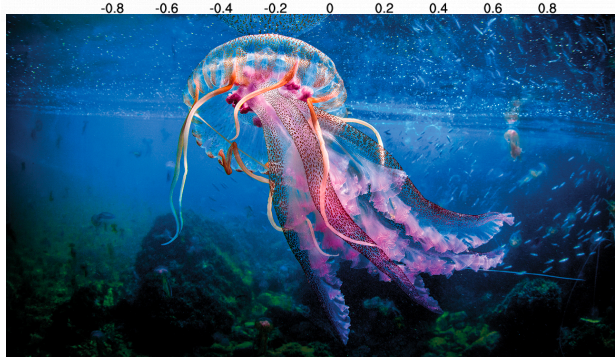


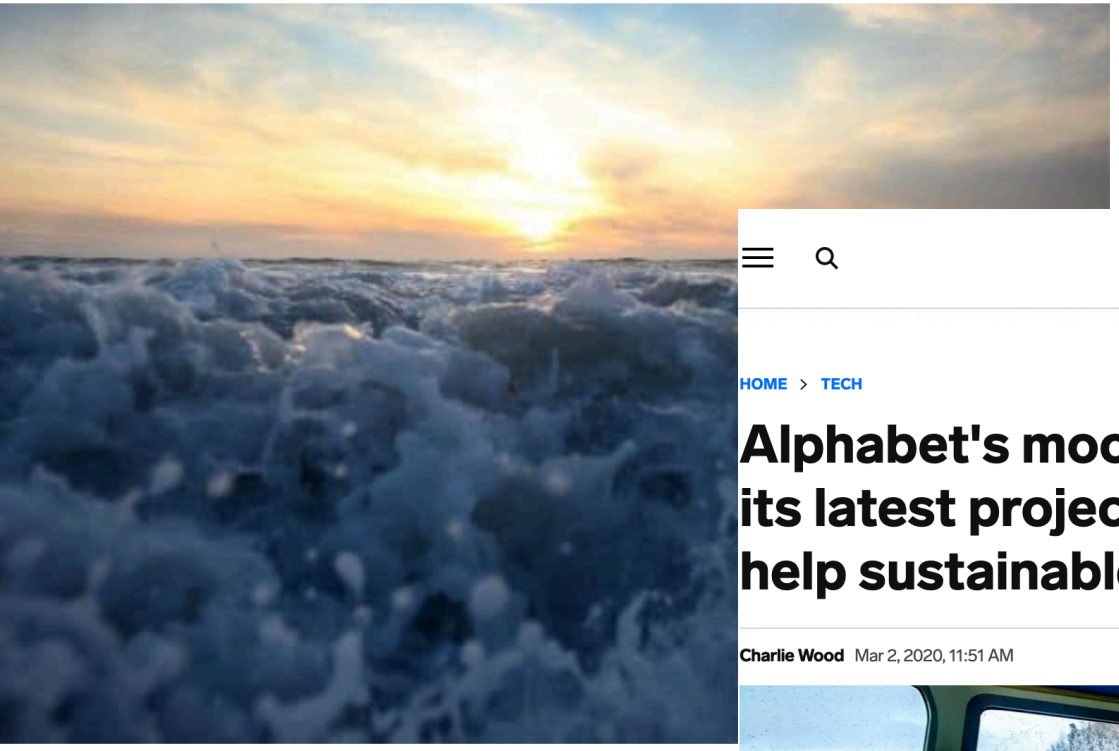




The Washington Post
Democracy Dies in Darkness

Energy • Analysis

To Save Earth's Climate, Map the Oceans



What lies beneath? (Photographer: David McNew/Getty Images)

By Dawn Wright | Bloomberg

August 17, 2021 at 2:45 p.m. EDT

Seabed 2030 aims to map the ocean floor by 2030

Forbes

DARPA Progress With 'Ocean Of Things' All-Seeing Eye On The High

David Hambling Contributor

Aerospace & Defense

I'm a South London-based technology journalist, consultant and author

INSIDER

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HOME > TECH

Alphabet's moonshot division unveils its latest project Tidal, which aims to help sustainable fishing

Charlie Wood Mar 2, 2020, 11:51 AM

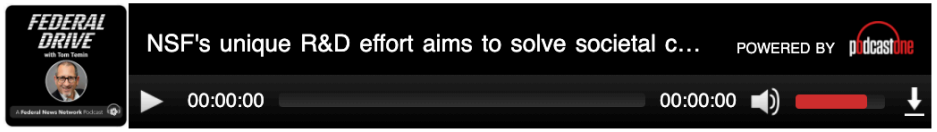
FEDERAL NEWS NETWORK

TECHNOLOGY DEFENSE WORKFORCE/MANAGEMENT

NSF's unique R&D effort aims to solve societal challenges

Jason Miller | @jmillerWFED

May 7, 2021 5:28 pm 6 min read



To help solve the challenges around climate change affecting the oceans and around the cybersecurity of communications

Why is bringing IoT to the ocean (esp. underwater) hard?

- **Communication:**
  - Can’t use radio (WiFi, bluetooth)
  - Direct underwater-to-air comms remains challenging
- **Power:**
  - No power outlet (access); hard to replace batteries
- **Sensing:**
  - Can’t use GPS (radio signals) for localization
  - Imaging is challenging (light interferes, refracts, etc.)

Main Components of IoT Systems

Axis #1:
Power/Energy

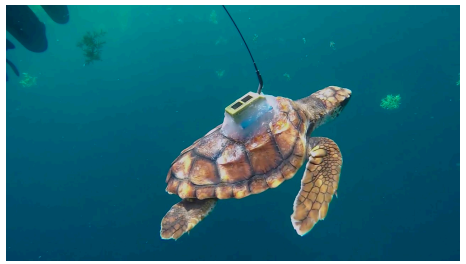
Axis #3:
High-level Task
(Sensing, Actuation)

Axis #2:
Connectivity

Axis #3: High-Level Task (Sensing, Actuation)

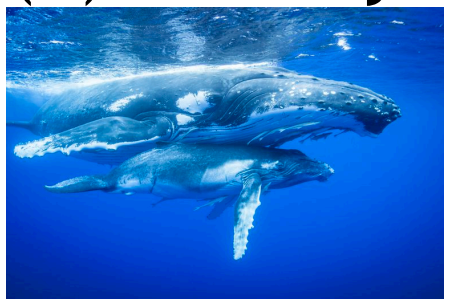
WHAT?

(1) Locations

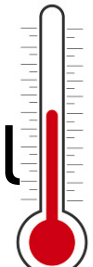


(2) Health

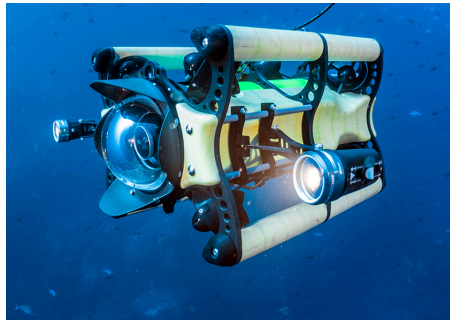
(3) Activity



(4) Environmental



(5) Autonomous

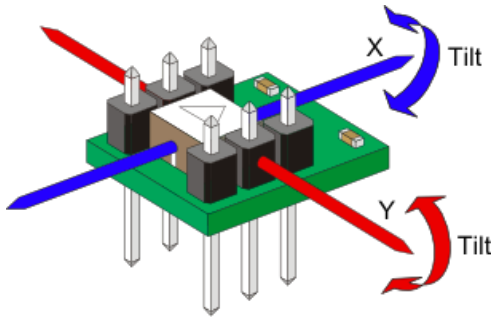


HOW?

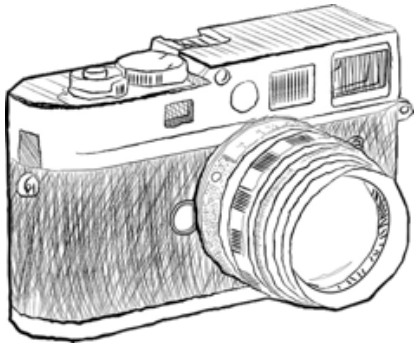
(1) Radio

(2) Acoustic/ Ultrasonic

(3) Inertial



(4) Visual



Axis #2: Computation & Connectivity

HOW do we obtain and process information?

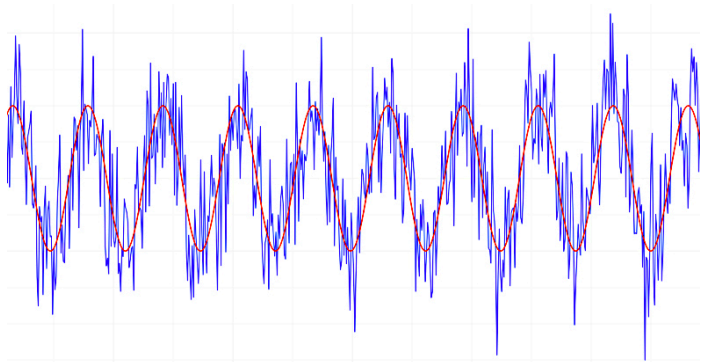
(1) Networking

- Connectivity
- Communication

(2) Data Management

- Storage
- Queries

(3) Signal Processing & Inference



- Digitization
- Inference & Machine Learning

(4) Security

- Digital, Analog
- Trust, Privacy

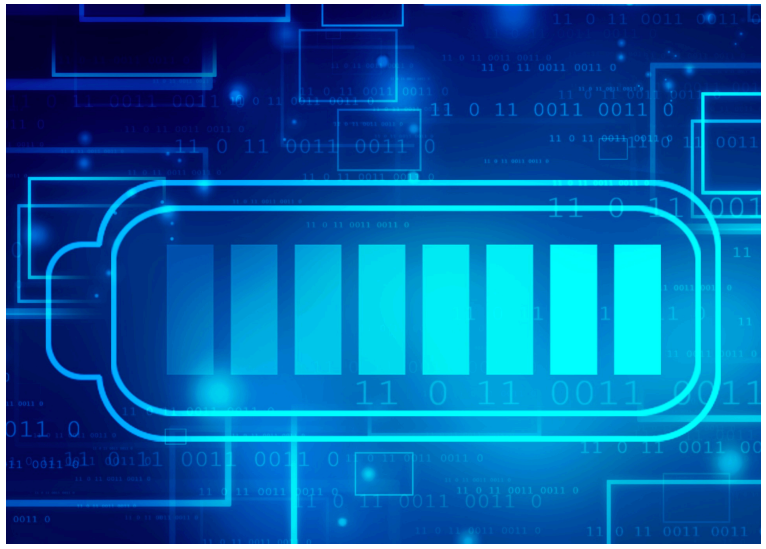
Axis #1: Power/Energy

HOW will we power up the nodes?

(1) Infrastructure

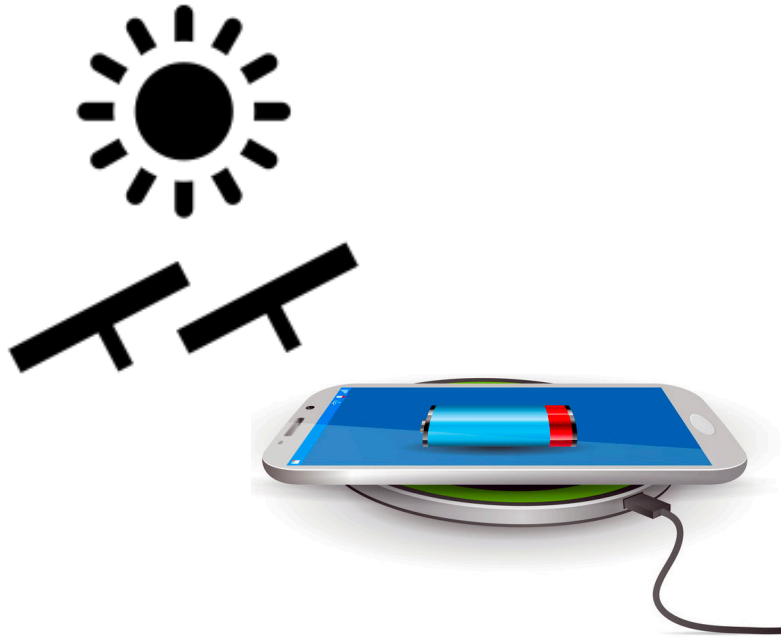
- Electricity, Network

(2) Battery



- Rechargeable/Non

(3) Energy Harvesting



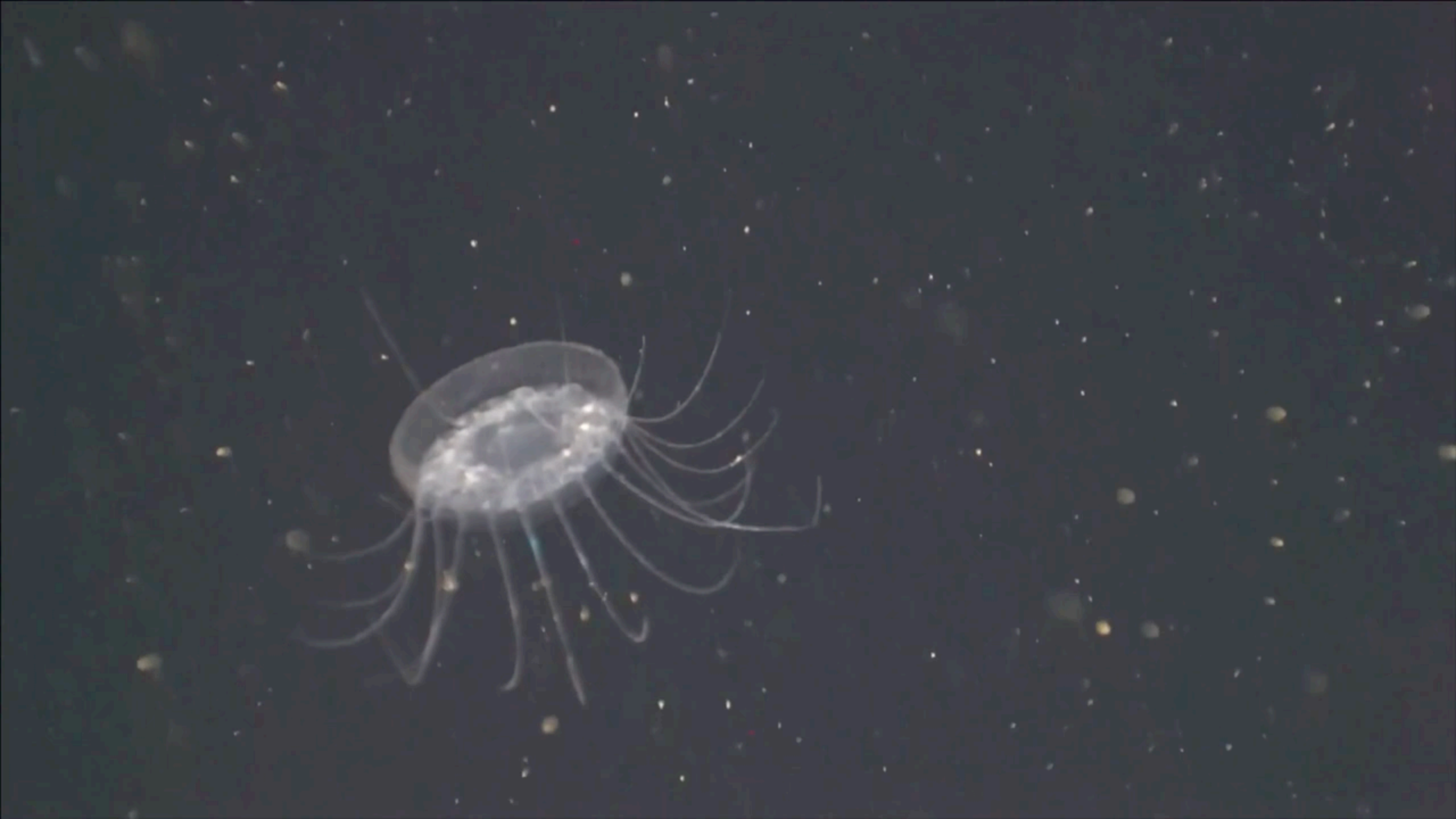
- Ambient, Wireless power
- Solar, Waves, Human Activity, RF

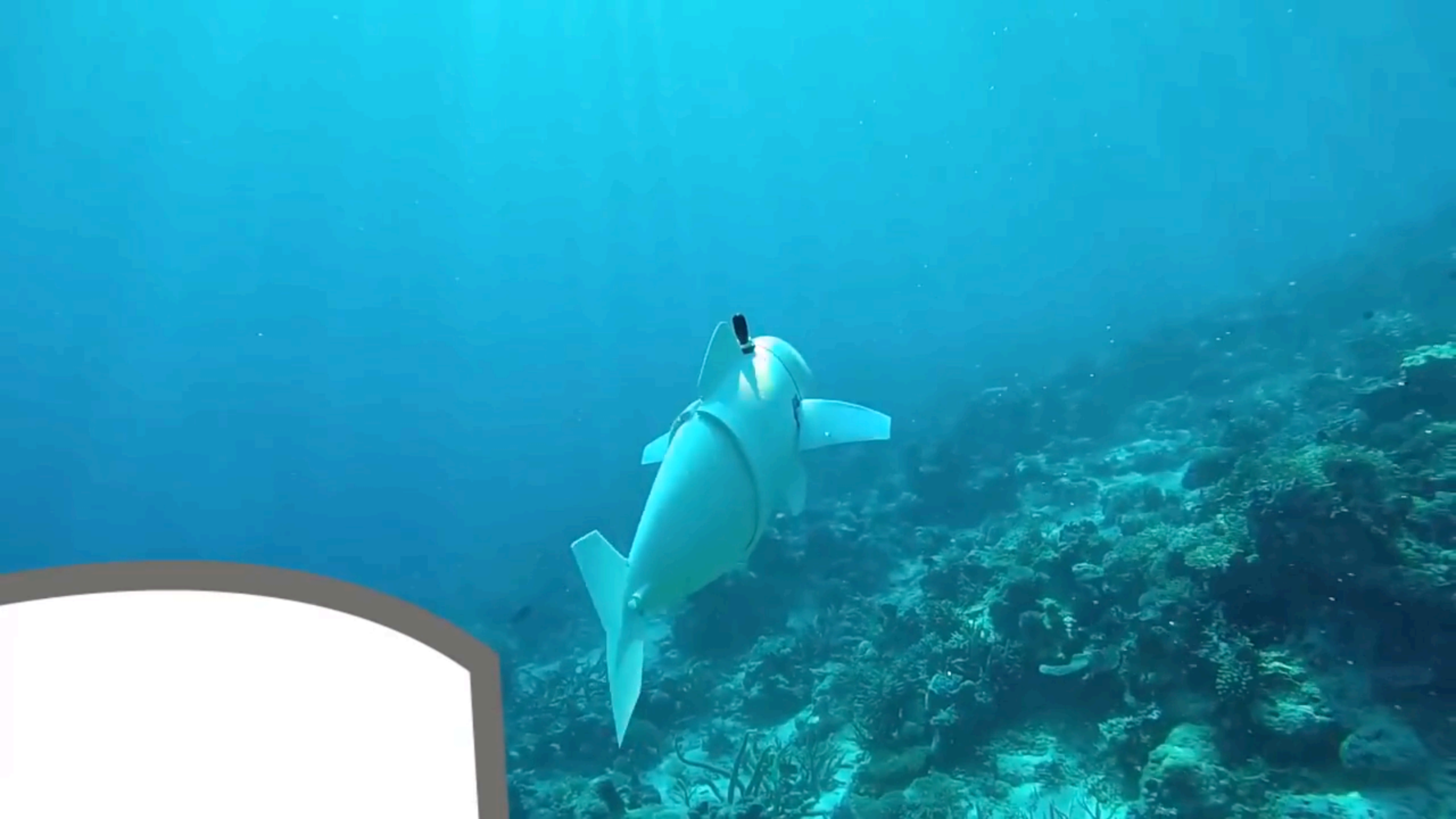
IoT System Architecture

Axis #3: High-Level Tasks	**What**		**How**	
	Location, Dynamics, Properties		Radio, Sound, Inertial, Visual	
Axis #3: Computation & Connectivity	(1) Networking	(2) Data Management	(3) Signal Processing & Inference	(4) Security
Axis #1: Power/ Energy	(1) Infrastructure	(2) Battery	(3) Energy Harvesting	

Example Ocean Connectivity, Sensing, & Power Technologies

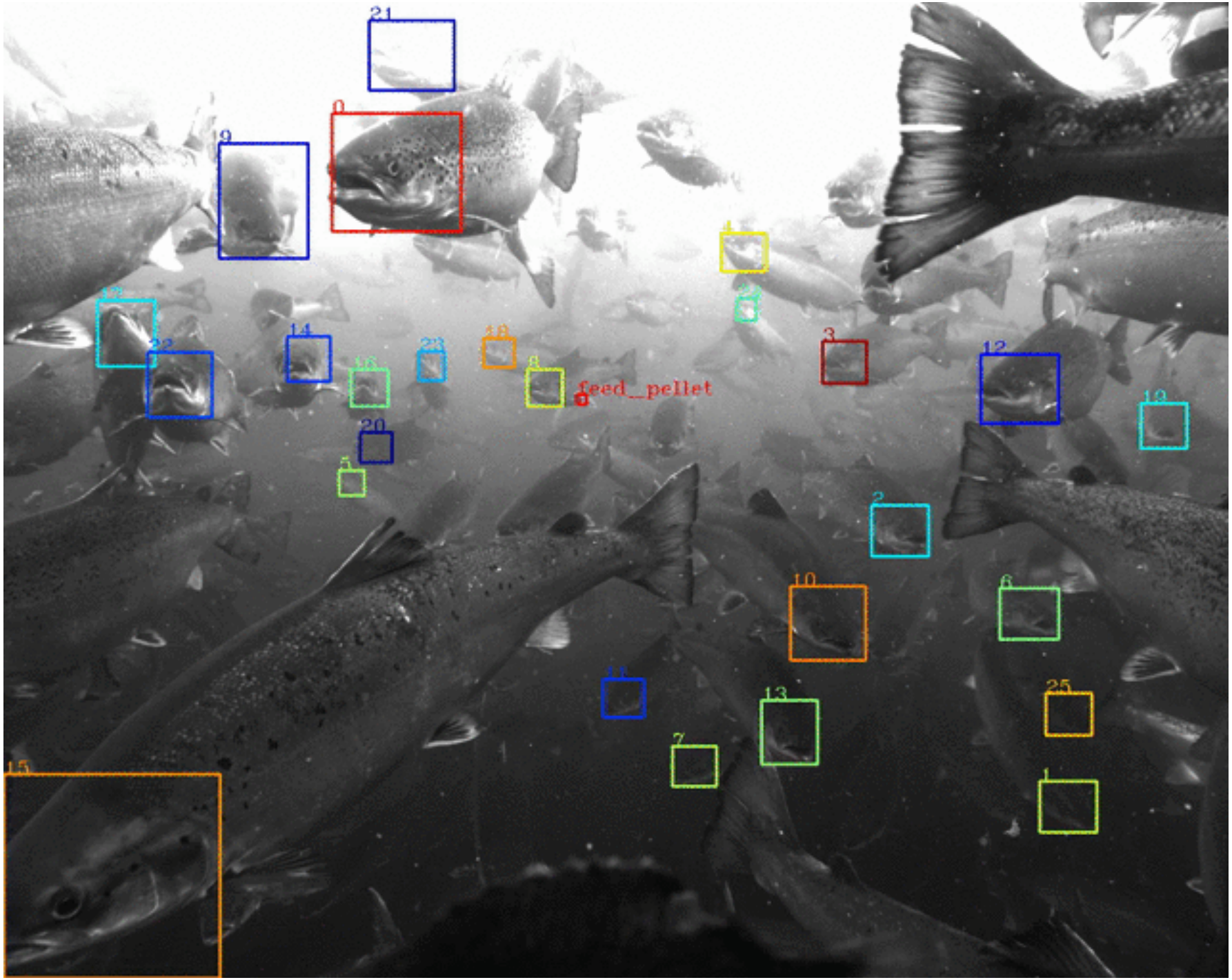

ARGO
PROGRAM
BUREAU OF METEOROLOGY





What did you notice about the “communications element”?

Did you know that a submerged submarine cannot wirelessly communicate with an airplane?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Goal of This Class

- Learn about the Motivation for Ocean IoT: problems, industries, sustainability, technological challenges
- Learn the **fundamentals** of ocean IoT technologies: communication, sensing, power, imaging, localization, robotics
- Learn from invited speakers about **emerging technologies**, solutions, and deployments
- Design and build your own Ocean IoT project (1K/team)

Class Format

- **Building the Foundations**
  - Communications: Acoustic, RF, Optical
  - Power: Energy Harvesting and Backscatter
  - Sensing: Localization & Imaging

- **Seminar Series**
  - New Imaging Methods
  - Opportunistic Sensing with Fishing Gear
  - Subsea Observations with SMART Cables
  - Marine Robotics
  - Low-Cost instrumentation
  - Bioacoustics
  - Remote Sensing & Imaging

MIT IoT Seminar Series

Dr. Jules Jaffe
UCSD Scripps
Underwater Imaging

Dr. Julie Jakoboski
MetOcean
Mobile Fishing Gear

Prof. Bruce Howe
University of Hawaii
Smart Cables

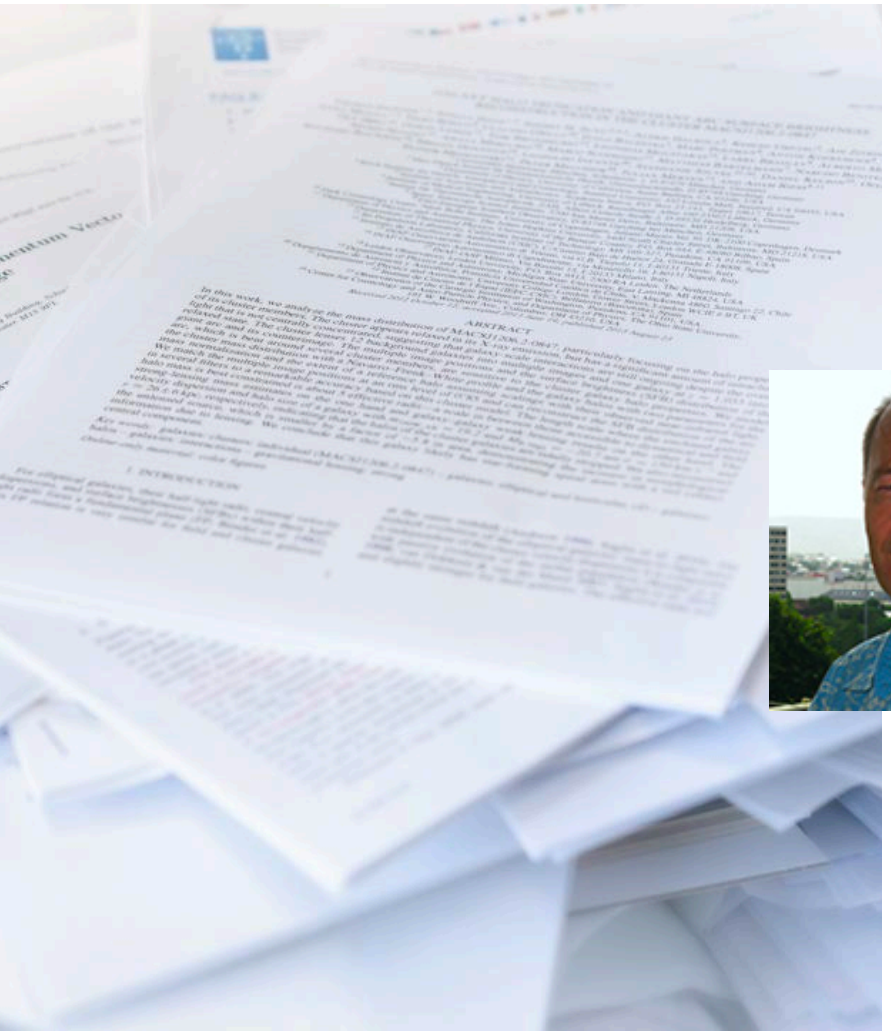
Prof. Matt Johnson-Roberson
University of Michigan
Marine Robotics

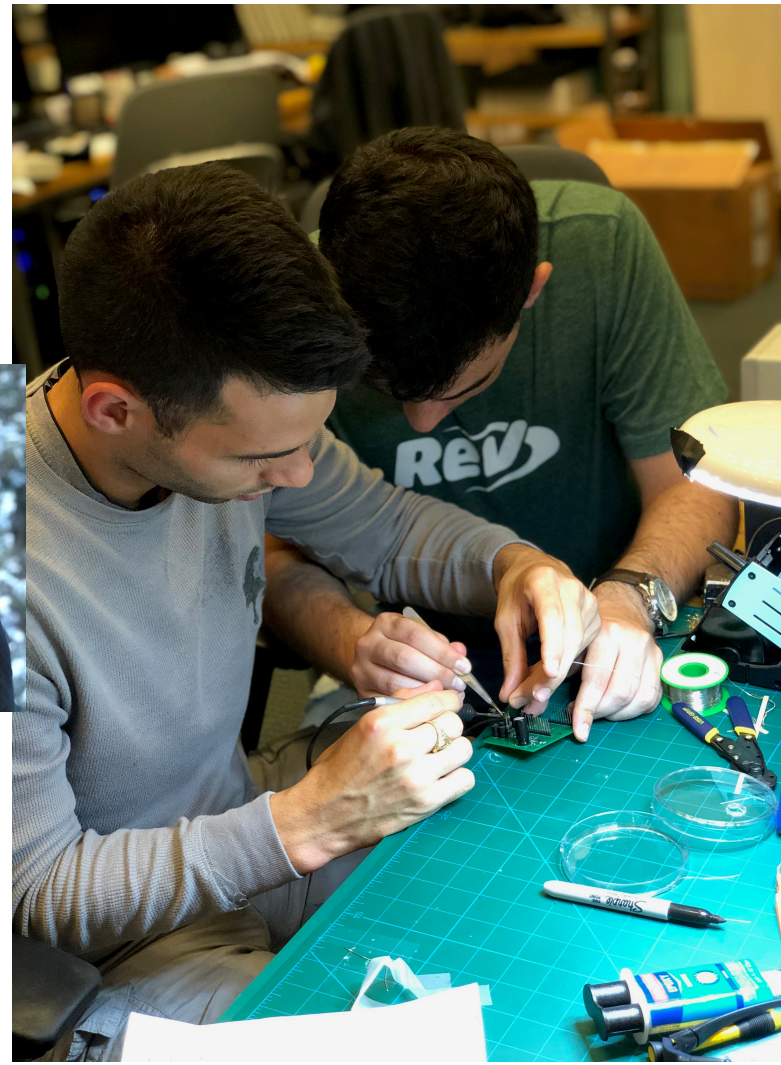
Prof. Melissa Omand
University of Rhode Island
Low-cost carbon pump sensing

Dr. Julien Bonnel
WHOI
Bioacoustics

Aiden Fitzpatrick
Stanford University
Remote Sensing

Course Organization





Reading & Reviewing Papers

Seminar Series + Discussions to Unpacking Tech & Societal Implications

Class Project

Logistics

Grading:

- 1 Course Project (60%)
  - Proposal (10%); Progress Report 1 (5%); Progress Report 2 (5%); Presentation (20%); Final Report (20%)
- Paper presentation: 10%
- Reading Questions & Participation (30%)
  - Includes submitting reviews before every lecture (15%)
  - Participation via Attendance+Interaction (15%)
  - May skip one review without affecting grade

Website: http://www.mit.edu/~fadel/courses/MAS.S62/

Paper presentation sign-up link

Slack sign-up link: Announcements; ask questions about lectures; project teams; etc.

Fadel & Saad office hours will be posted soon

Readings

We will read 1-3 papers/references per class:

- Everyone is expected to read the papers in advance
- Submit a short review of the required readings by midnight the night before the class
- Say something that is not in the paper

Submit Reviews here:

- http://www.mit.edu/~fadel/courses/MAS.S62/reviews.html

Projects

- All projects involve system implementation
- Work in groups of two (ideally)
- Will suggest project ideas; students can choose their own projects
- Can be (very) related to your research (come talk to me)

Timeline:

- Proposal (1-2 pages): October 15
- Progress Report 1: October 29
- Progress Report 2: November 9
- Final Presentation: December 6
- Final Report (6-8 pages): December 7

We will discuss project updates in class (on schedule/website)

Introductions

- Name
- Position (undergrad year, grad year, postdoc, industry)
- Major
- Why are you interested in this class?

How to Read a Paper

First Pass:

- Title, Abstract
- Figures (illustrations? important results?)
- skim intro & conclusions
- References

Second Pass

- Intro in details
- Overview, related work, or background sections
- Figures in details

Third pass:

- Read in detail
- Mark references for future read

How to Review a System Paper

How to think when reviewing a paper?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation
Is this an important problem?

- New problem? → Worthwhile or artificial?
- Existing problem? (i.e., have others worked on it) → Does it improve over prior work?

2) Related Work

- Does it really outperform prior work?
- Does it accurately represent prior work?
- Do you know past work? If not, search Google Scholar to get a sense of past work

3) Techniques

- Are they novel? intellectually interesting?
- Are they technically sound? Is there a key technical flaw?

How to Review a System Paper

How to think when reviewing a paper?

4) Implementation

- Significant effort?
- Matches the motivation?
- Simulation or real-world prototype?

5) Evaluation

- Comprehensive? Convincing?
- Does the system deliver what it promises?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation

2) Related Work

3) Techniques

4) Implementation

5) Evaluation

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstract"

Rough structure:

This paper presents XXX, a system that does YYY. **The goal is to** XXX. The **main challenge** the authors try to address is YYY.

The key idea is to do XXX. The authors do this by introducing/proposing ZZZ

The authors implement (or simulate) their system and **demonstrated** (results) that it outperforms the baseline?

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstracT"

2) Strengths & Weaknesses

- Use your answers to the questions of "How to think when reviewing"
- List 2-4 pros/cons
- Each should be a direct statement about the paper

<u>Rough structure:</u>

Pros:
+ Statement 1
+ Statement 2

Cons:
-
-
-

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

- Detailed comments to authors
- Elaborate on your pros/cons, areas for improvement, key concerns
- Ask questions about techniques, figures, results, etc.
- Based on the 5 points from how to think as well as technical details

Examples:

- If you listed a weaknesses small delta over prior work, specify in details why with references
- If experimental details are missing, state exactly what is missing and why it is problematic
- Include typos/grammar mistakes, potential suggestions to correct

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comm… to authors

- Detailed c… …c…
- Elabor… …r pro…
- …s about t…
- …the 5 points…

Examples:

- If you liste… …mall delta o…
- If exper… …ng, state…
- Inclu… …amma… …, potent…

For the sake of this class, we will drop "comments to authors".

Instead, you should add a paragraph on "suggestions for improvement".

- If you could improve this paper, how would you do it?
- How do you envision your proposed technique will improve the work

How to Review a System Paper

How to write a review? (for this class)

1) Summary

2) Strengths & Weaknesses

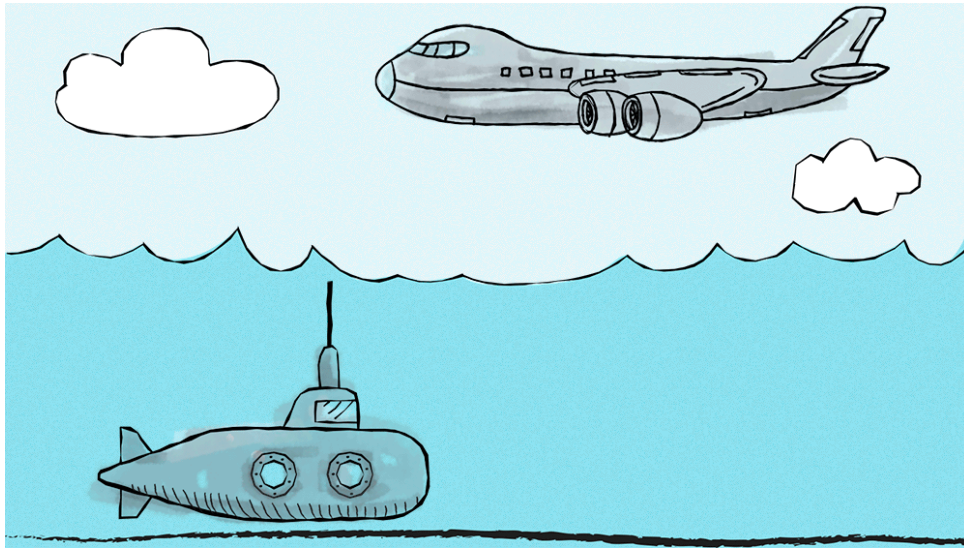
3) Suggestions for Improvement

Next Class (Communications)

1) Required (Reviews)

Underwater to Air Communications:

- via Acoustic+Radio, SIGCOMM 2018
- via Lasers, NSDI 2019



2) Optional Readings

- Chapter 2 - Fundamentals of Wireless Communications book