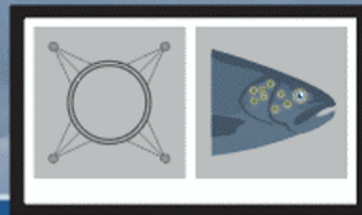




SINTEF



# Digitalization and Robotics in Aquaculture

Eleni Kelasidi, Senior Scientist, Aquaculture Robotics and -Automation, SINTEF Ocean FFU, Stavanger, 26.01.2023

# Background and Motivation

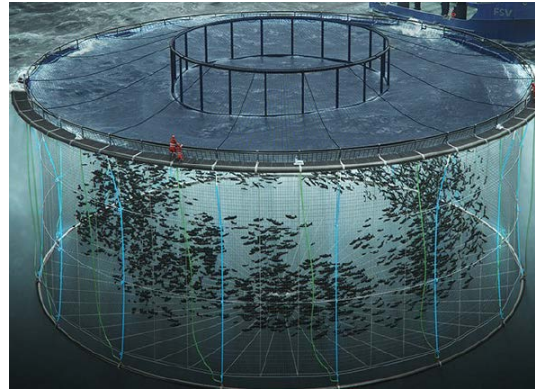


# Aquaculture Industry – Need for Automation and Robotic solutions



Photo: Adresseavisen

Starting point



Current industry standards



Salmar AS

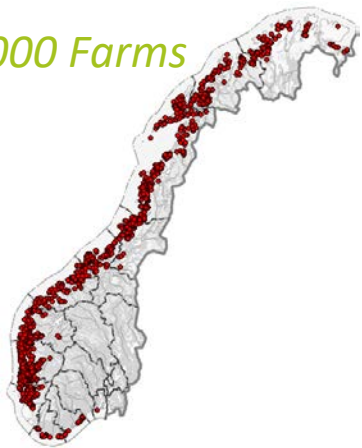
Ocean Farming

**Trend:** increasing the volume and fish population – What about technology use and precision?

New Concepts

New Challenges

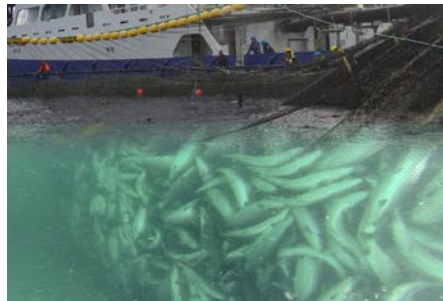
1000 Farms



Manual and high-risk operations



Fish Welfare



Structure Health



**Need for:** Robust, safe and efficient autonomous Inspection, Maintenance and Repair (IMR) operations



HAUGE AQUA

New concepts – New challenges

Photo by Marius Dahle Olsen

# Robust, safe and efficient autonomous IMR operations



- Limitations due to manual operations
- The number of fish farms are increasing
- More exposed sites for fish farming
- Optimization of precision and production
- Increase of fish welfare conditions
- Reduction of cost in fish farm operations

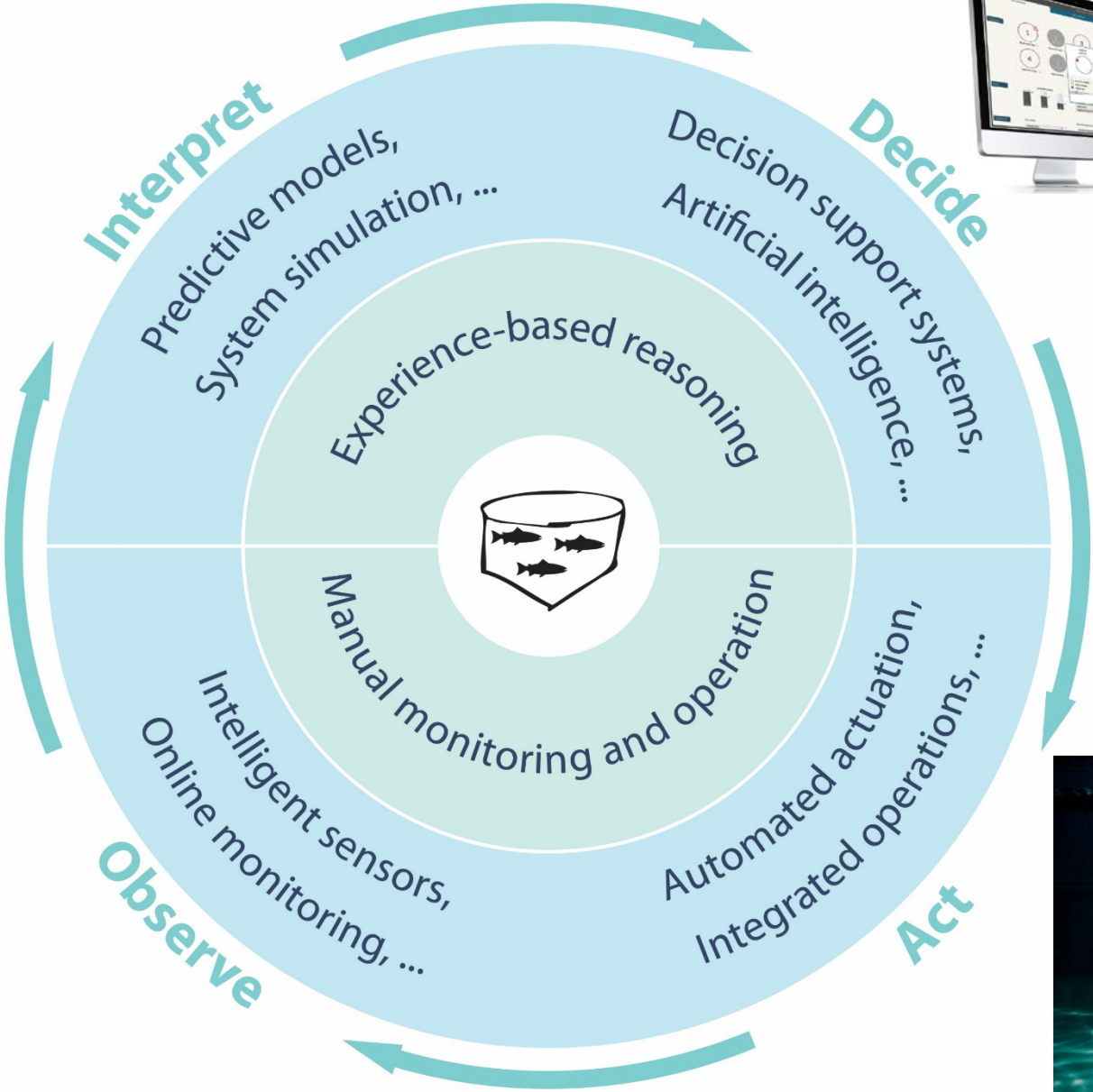
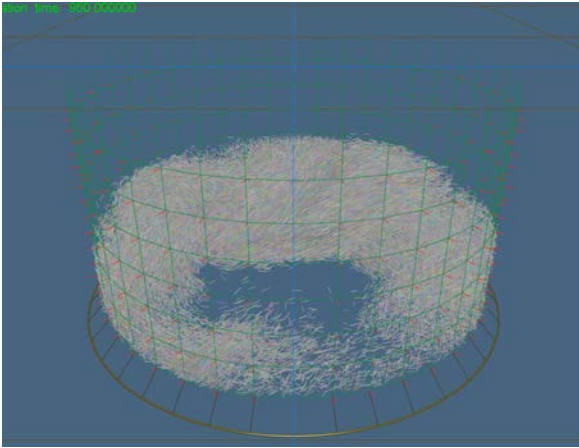


# Intelligent Farms...

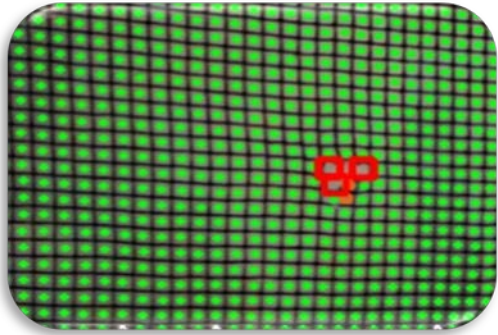
An aerial photograph of a large, circular fish farm structure in the middle of a dark blue sea. The structure is composed of a metal frame with blue netting. A white boat is docked at the bottom edge of the circle. Several white cables or lines extend from the bottom left corner towards the structure. A yellow buoy is visible in the bottom right corner.

Precision Fish Farming

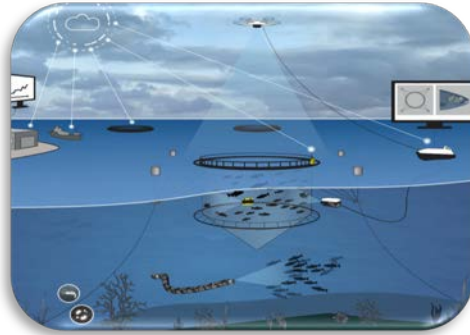
# Precision Fish Farming - PFF



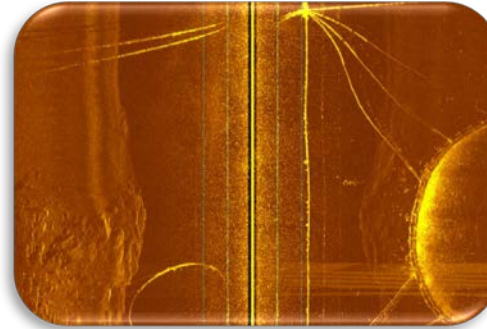
# Increase Precision during Operations in Fish Farms



Net Inspection



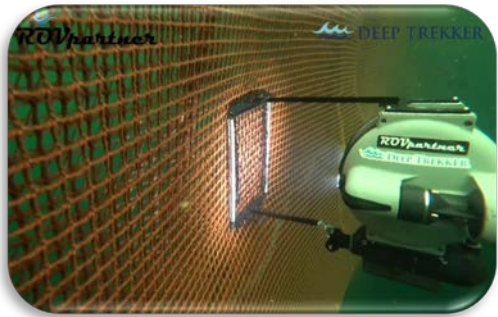
Environment Monitoring



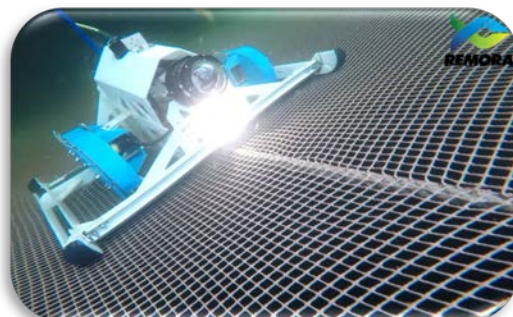
Mooring Line Inspection



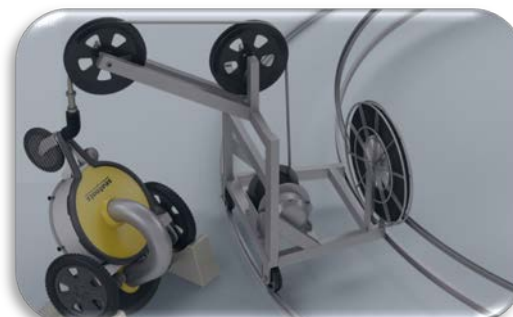
Fish Monitoring



Net Repair



Net Cleaning



Dead Fish Removal



Equipment Installation

Cleaning of collars and sinker tubes, Maintenance on collar and railings, Inspection of technical equipment within the pens, Inspections of cage structures, Assistance/support during well boat operations; deliveries, delousing, crowding, Disinfection and cleaning of equipment and sensors, Assistance during Net Installation, Cage Maintenance, Maintenance of camera equipment, Sealice counting – non intensive methods based on sensors, Wrasse shelter placement and cleaning, Feeding tupe connections and maintenance



# Motivation for using UUVs

1. Limitations due to manual operations
2. Fish farming precision and production optimization
3. Reduce risks



Foto: Aqualine

23% perform heavy lifting often or very often



27% have to lift with their upper body twisted or bent often or very often

26% perform repetitive and monotonous work often or very often

Illustration by Noëlie Delesse - 2019

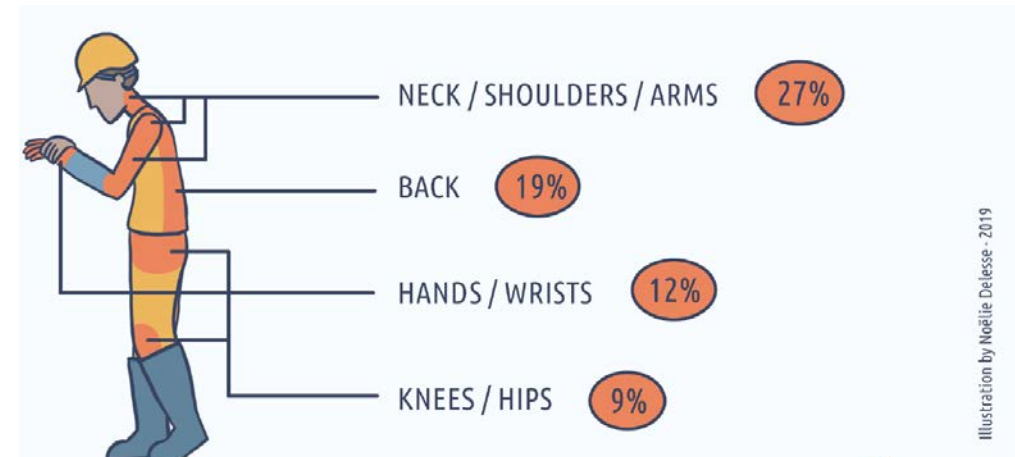
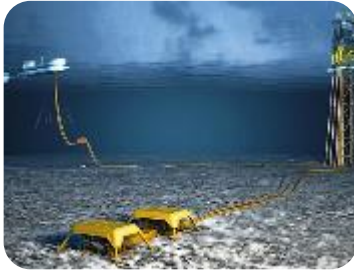


Illustration by Noëlie Delesse - 2019



SINTEF

# Underwater Robotic Solutions for Subsea Applications



Resource Extraction



Science



National Defence



Aquaculture



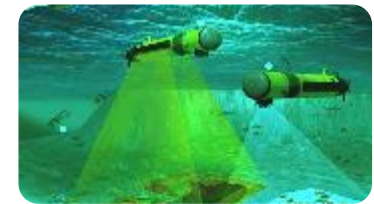
Telecommunications



Construction, Inspection  
and Maintenance



Archeology



Search and Recovery

Dirty

Dangerous

Distant

Dull

Dear



SINTEF

## Aquaculture Robotics and Autonomous Solutions

### Challenges and Motivation



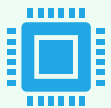
Harsh and Complex Environment –  
Wave zone operations, Exposed  
locations



Flexible Structures and  
Deformations – Operations in  
dynamic environment



Large Amount of Biomass to  
account for – up to 200.000 fish in  
each cage



Manual/Risky/Costly Operations –  
Far from Autonomy & Industry 4.0



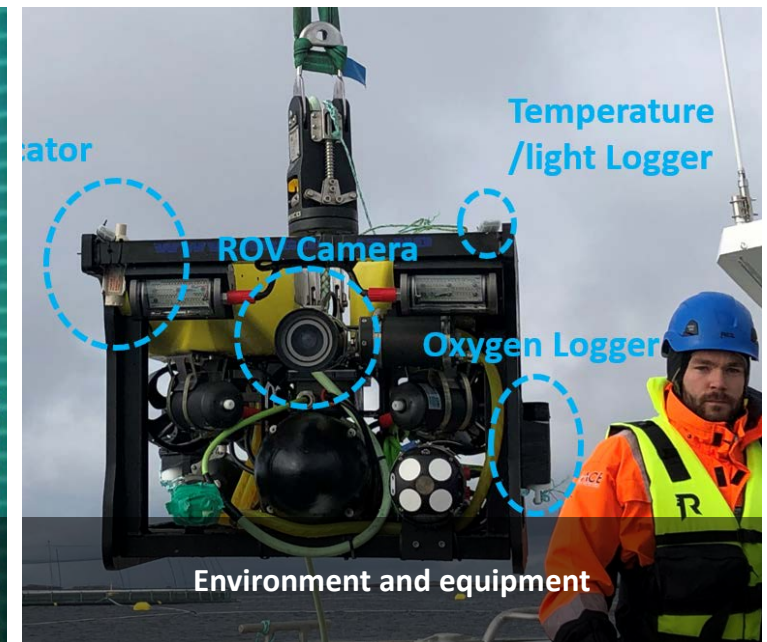
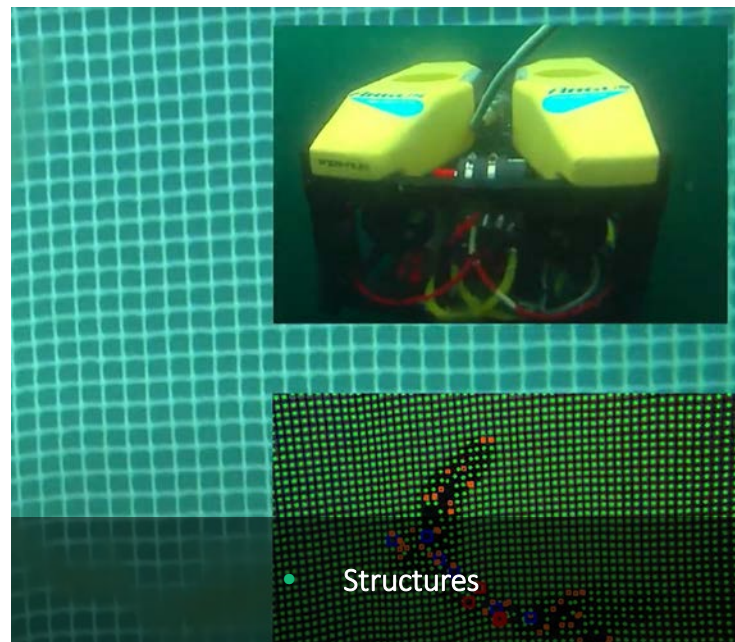
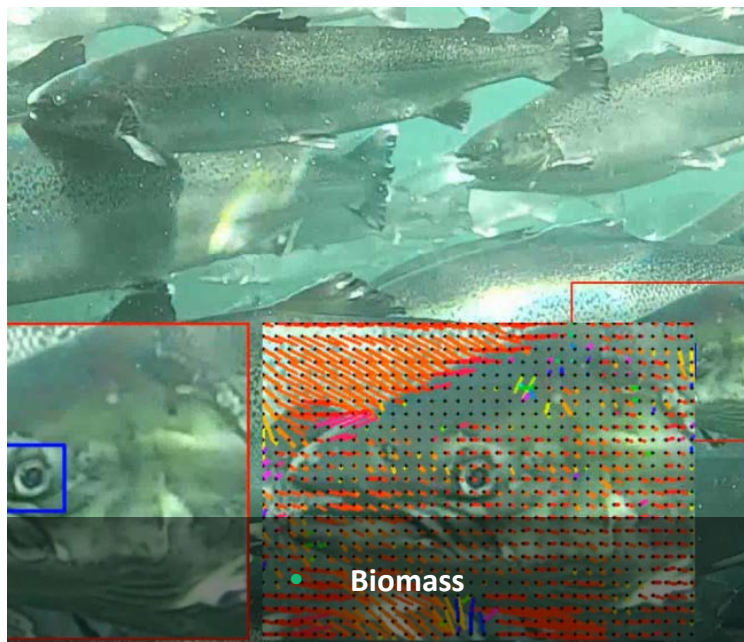


SINTEF

# Aquaculture Industry

## Aquaculture Robotics and Autonomous Solutions

Novel research and innovative solutions for robust, safe and efficient autonomous *Monitoring, Inspection* and *Intervention* operations in fish farms to reduce costs and risks, increase objectivity and production, and contribute to better fish welfare.



*Operations in Dull, Dirty, Dangerous, Difficult and Dear environment – 5Ds of Robotization*



# IMR Operations





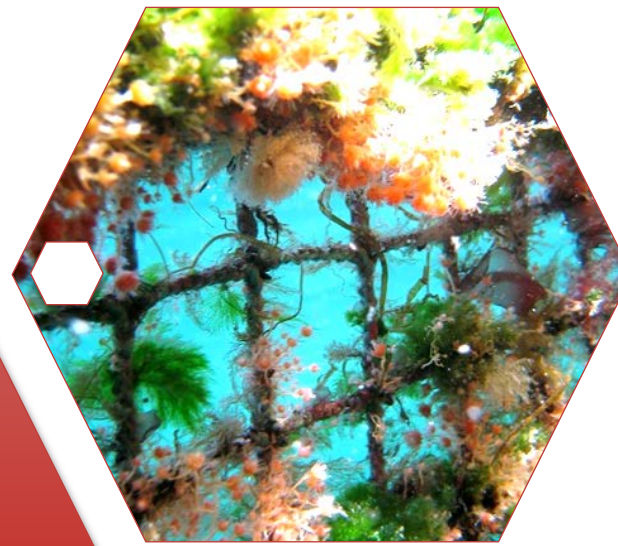
SINTEF

# Autonomous Monitoring and Inspection UUV Operations

CageReporter  
Merdrov  
Exposed  
NetClean 24/7

## Environment

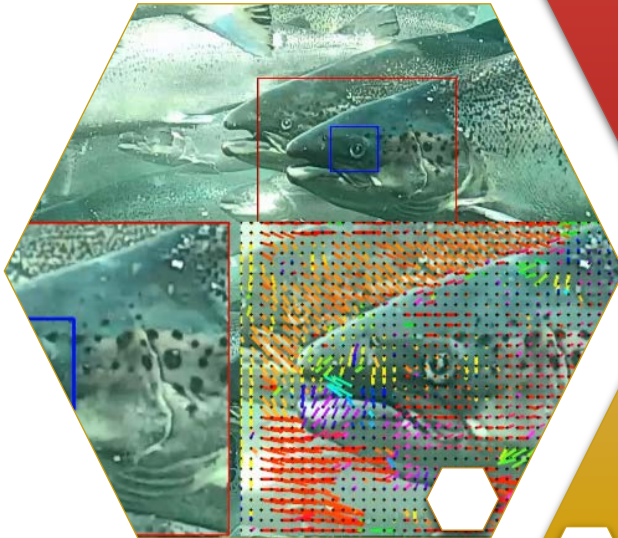
- Temperature, oxygen, salinity, current, waves
- Light conditions
- Feed waste and pollution
- Fish escapes



CageReporter  
Merdrov  
Artifex  
Exposed  
ResiFarm  
CHANGE

## Structures

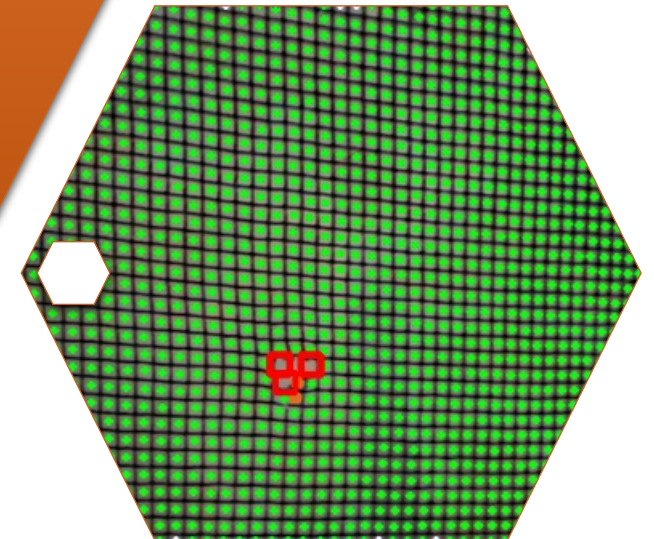
- Hole detection
- Mooring lines
- Biofouling conditions
- Structure deformations and irregularities
- Equipment



## Biomass

- Fish conditions
- Fish behaviour and stress level
- Stocking density
- Physical injuries and wounds
- Parasite detection, e.g., sea lice
- Fish feeding and feed waste

CageReporter  
RACE Fish  
Machine  
Interaction



# Autonomous Intervention Operations with UUVs

- **Biomass**

- Dead fish removal
- Assistance during well boat operations

- **Structures**

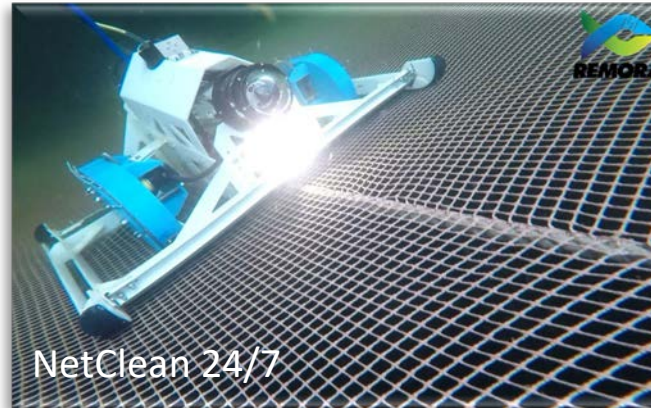
- Net cleaning
- Net repair
- Assistance during net installation
- Maintenance on collars and sinker tubes

- **Equipment**

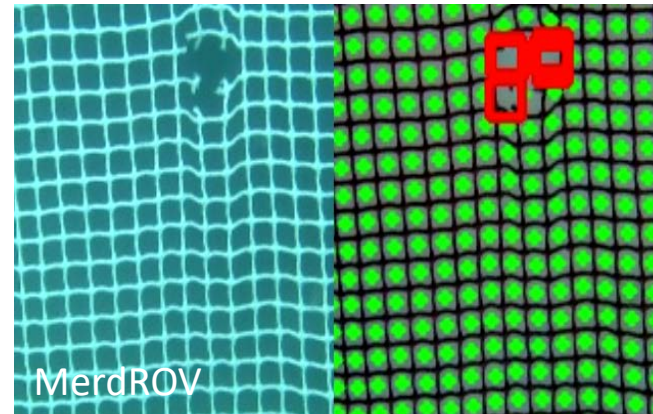
- Equipment removal
- Equipment installation
- Equipment disinfection and cleaning

- **Autonomous feeding**

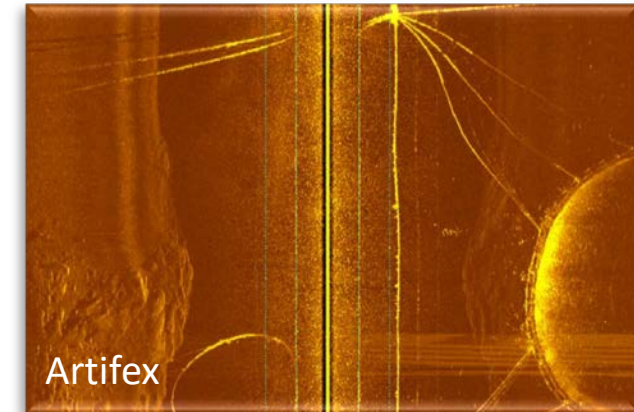
- Net Cleaning



- Net repair



- Mooring line inspection



- Assistance during crowding



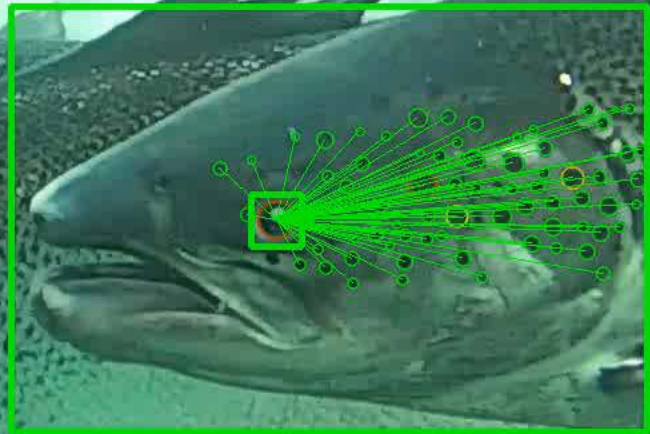


# Monitoring Operations

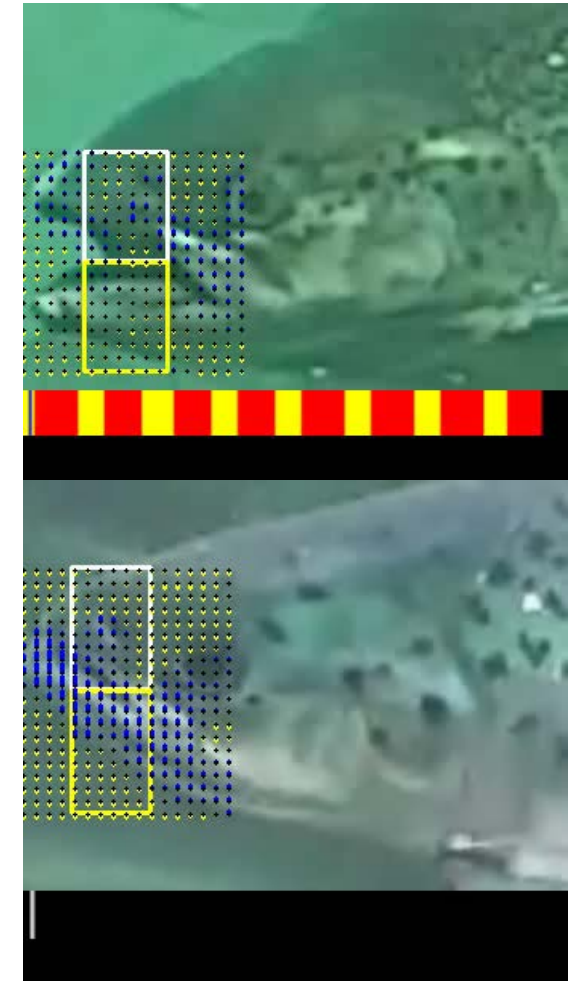
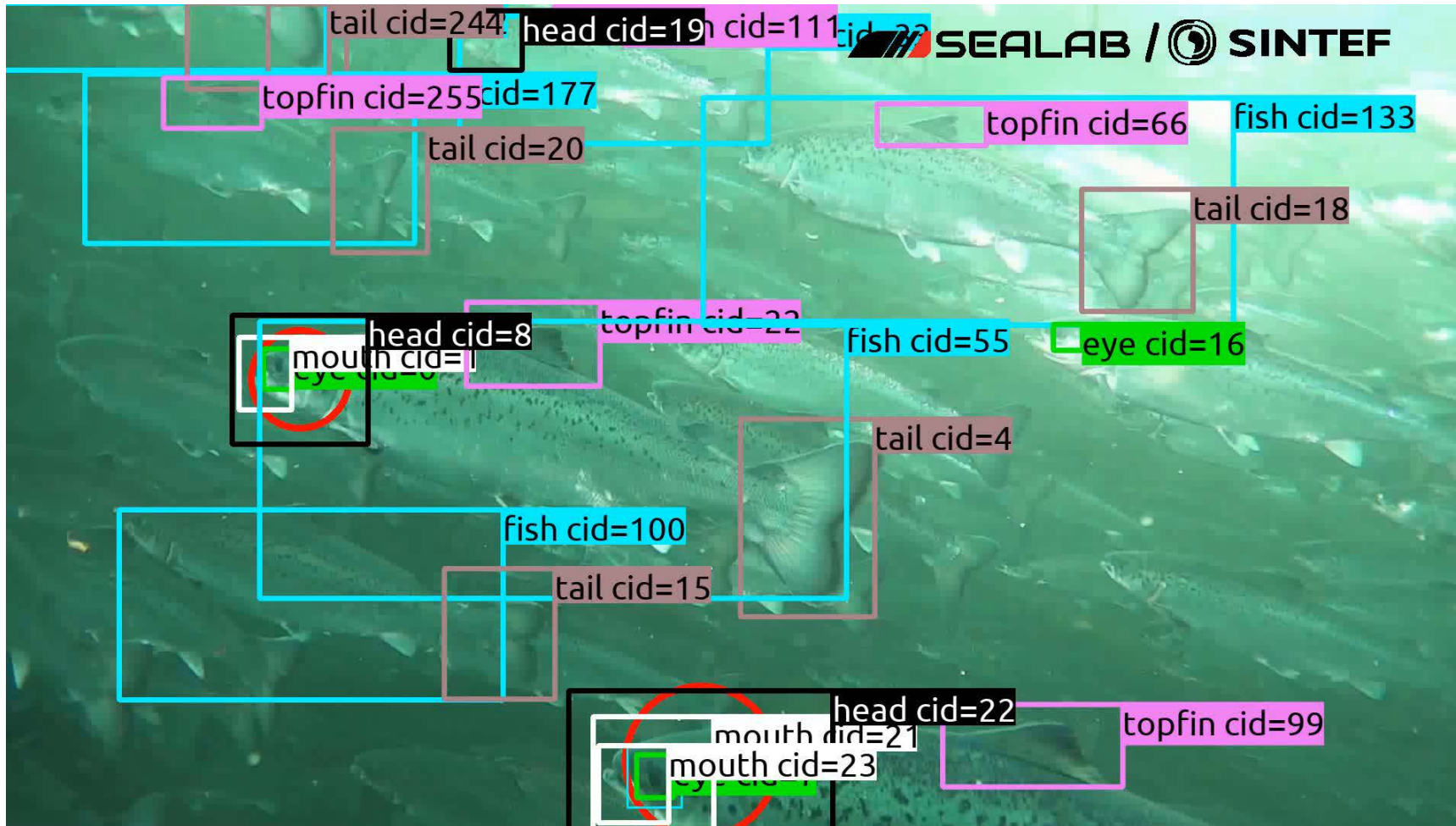




solmon\_015 solmon\_016



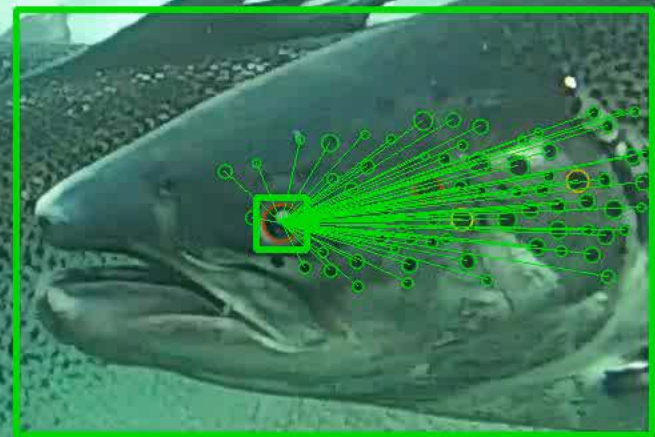
# Robustness in salmon detection + mouth opening/closing



solmon\_015 solmon\_016



# Know your fish and its health status

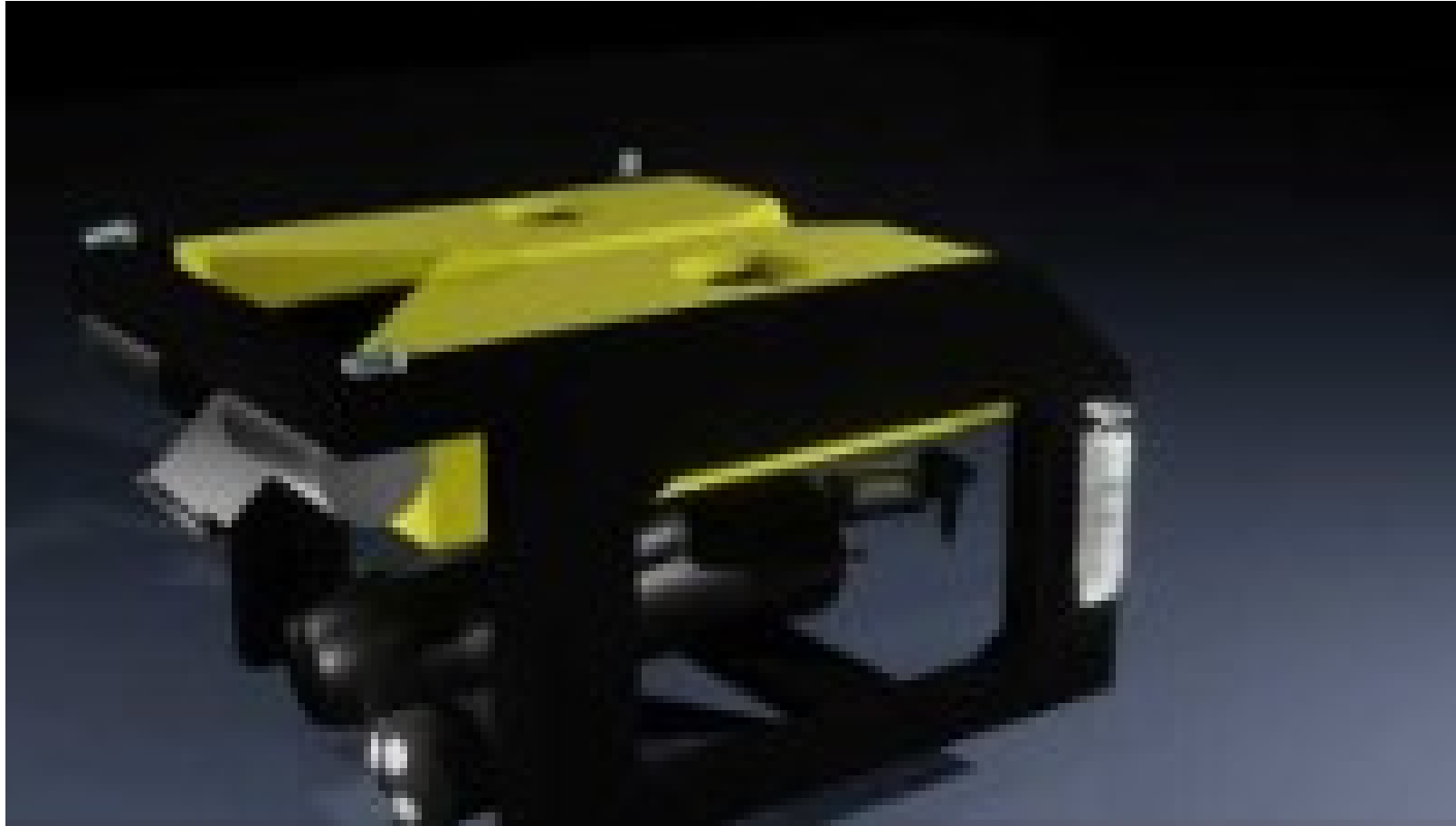


- Counting of observed fish
- Parasite detection, e.g. sea lice
- Detection of physical injuries and wounds
- Monitoring of fish feeding and feed waste
- Biomass and average weight estimation
- Behavioural indicators

Reduce risk and stress...better welfare

- **CageReporter**

Resident (24/7), autonomous, non-tethered vehicle (AUV) for high quality data acquisition



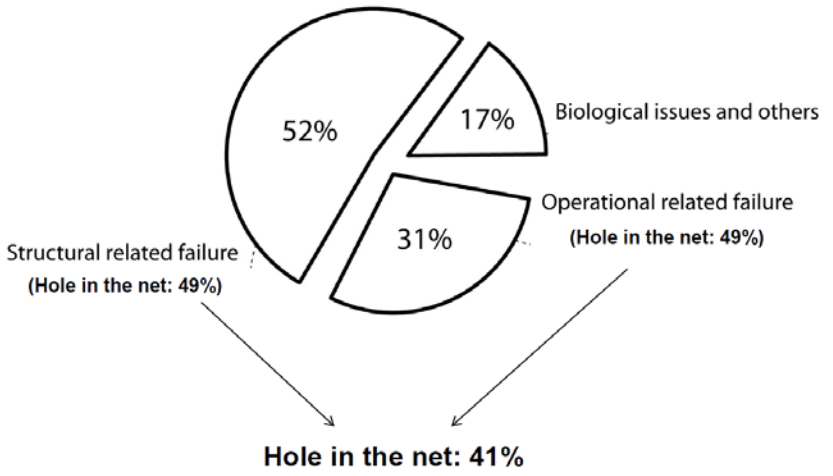
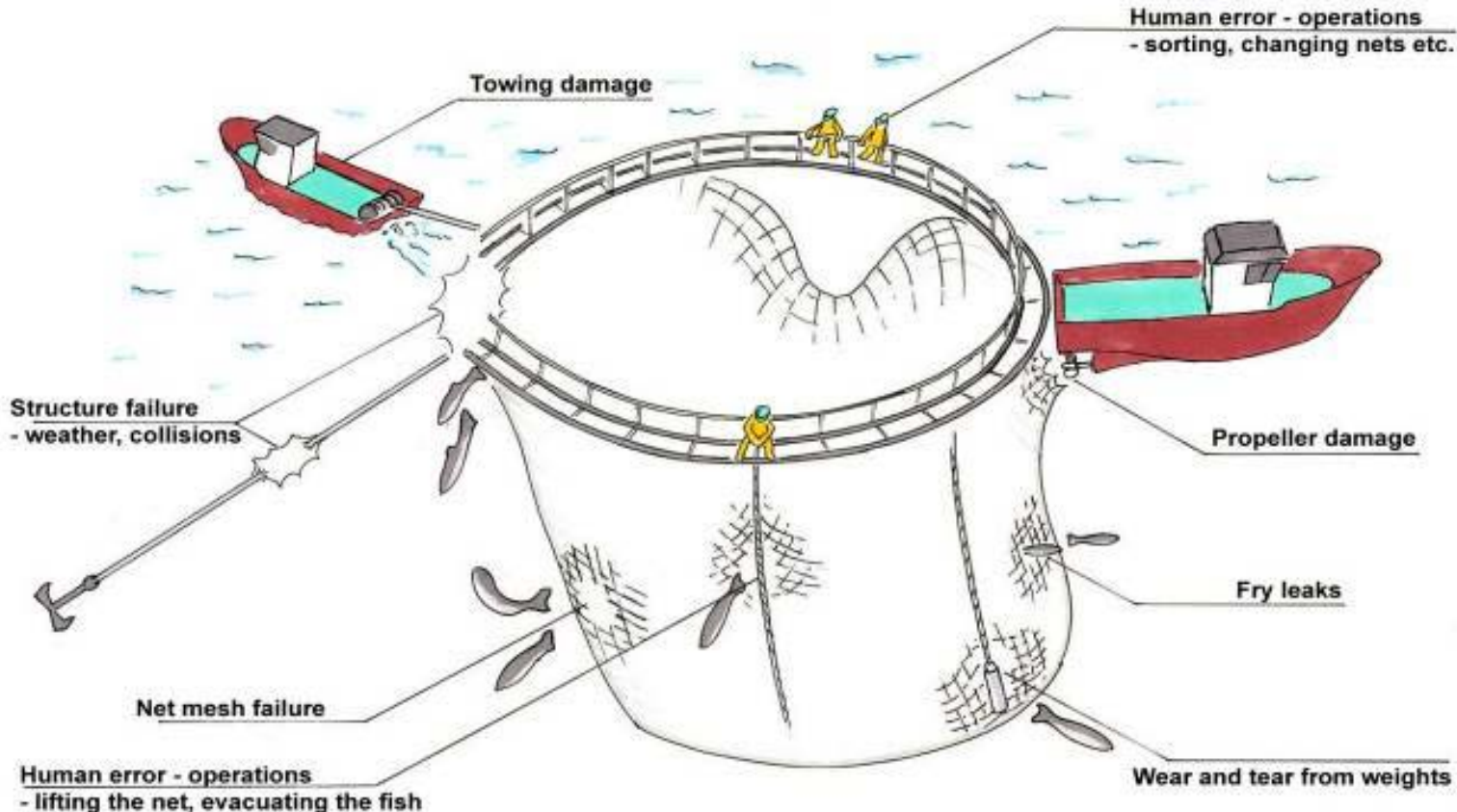
**Partners:** Water Linked, Sealab, Norsk Havservice, SINTEF Ocean, NTNU, HES-SO



# Inspection Operations



# Fish Escapes – Need for better control

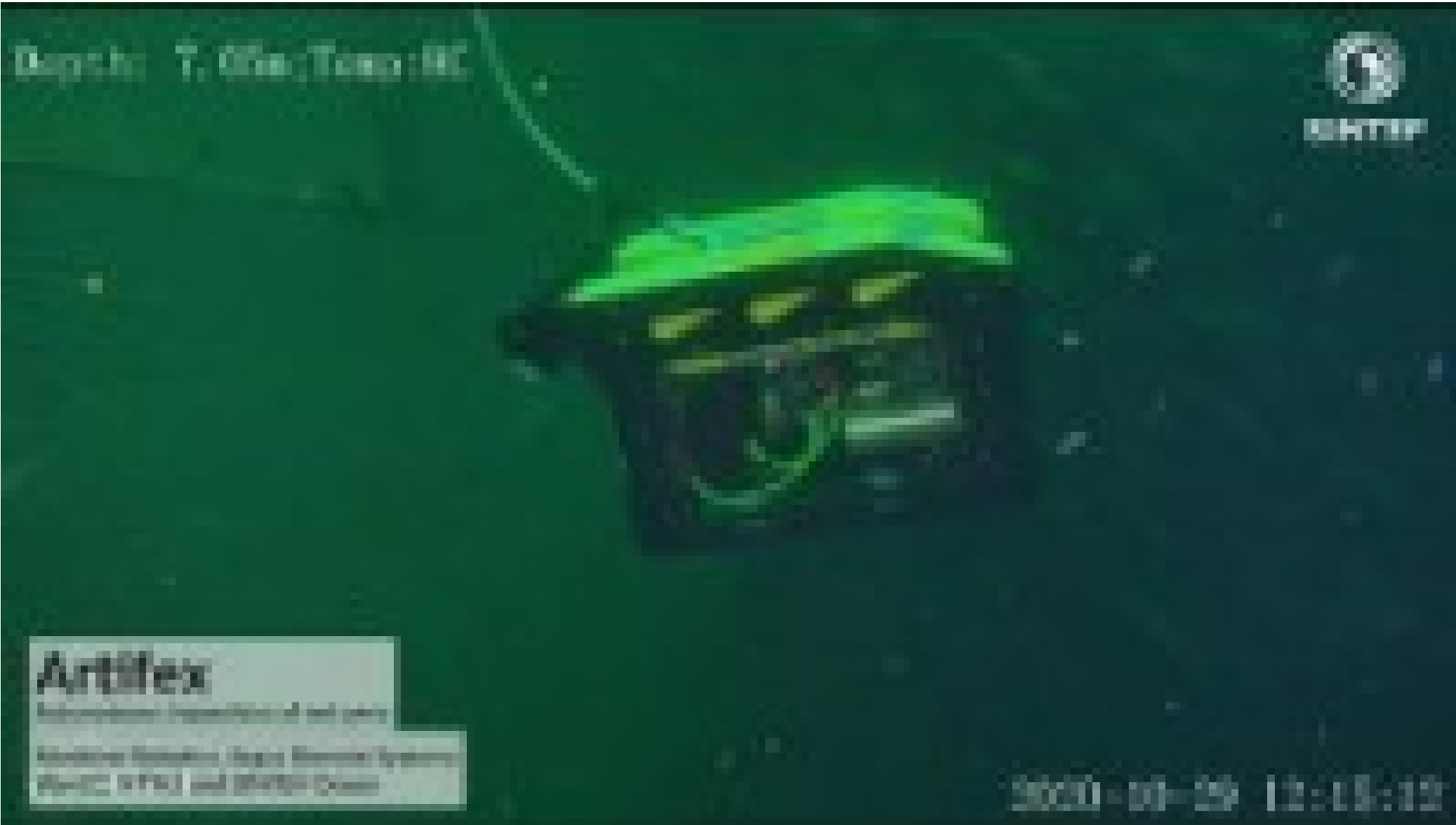


Depth: 8.14m;Temp:8C



FIFISH

2020-10-29 12:22:12





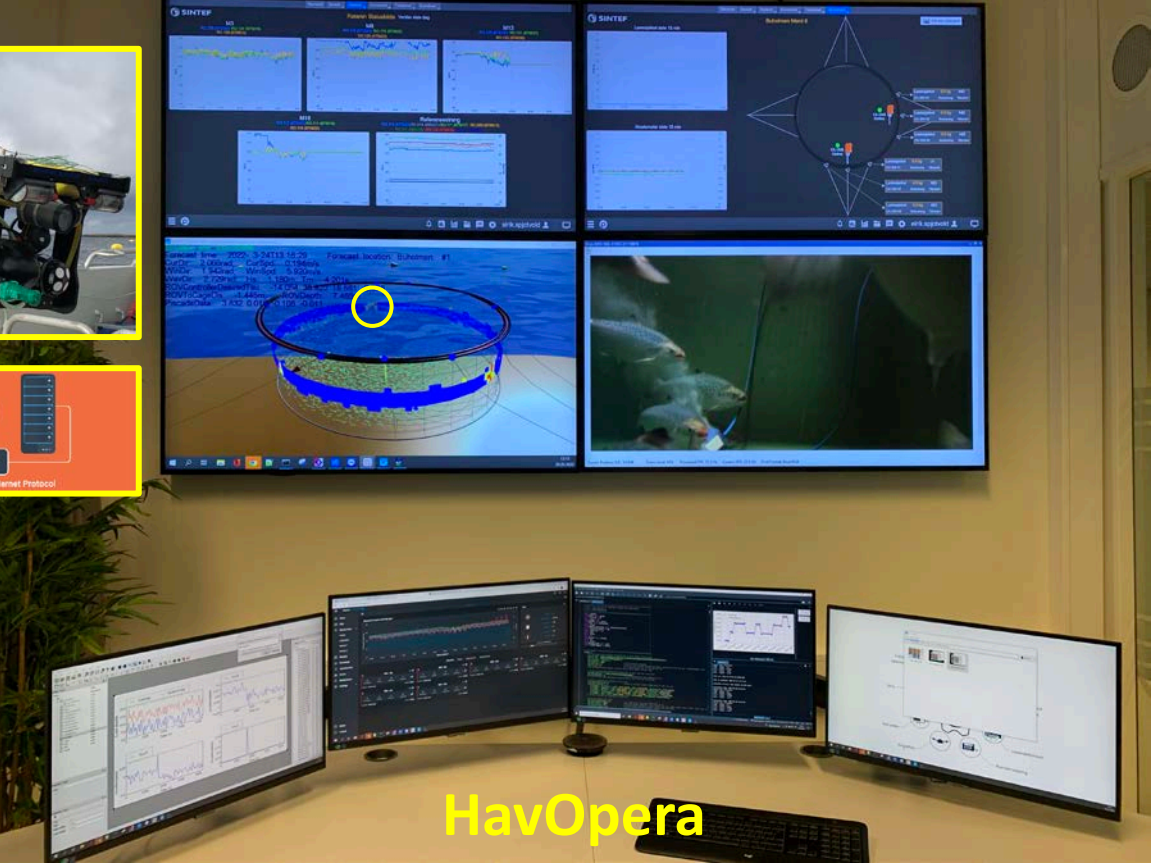


# Remote Operations



# Remote operations for net inspection with ROV

- Real-time monitoring and documentation of net inspection with ROV



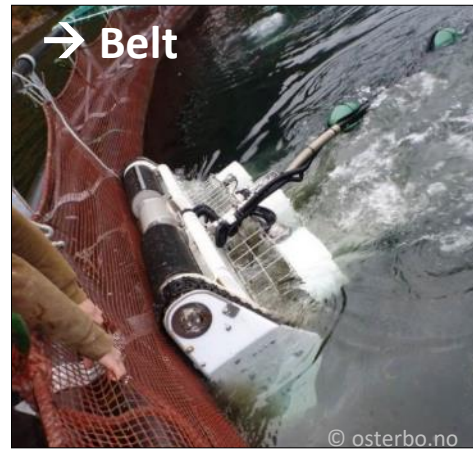


# Intervention Operations



# Today's cleaning equipment

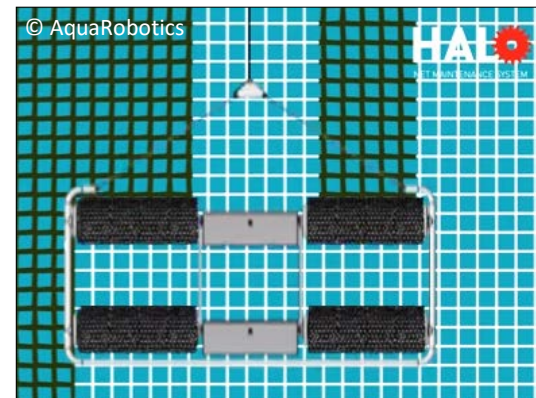
## Pressure cleaning (50 – 350 bar)



## Include suction



## Autonomous brushing





SINTEF

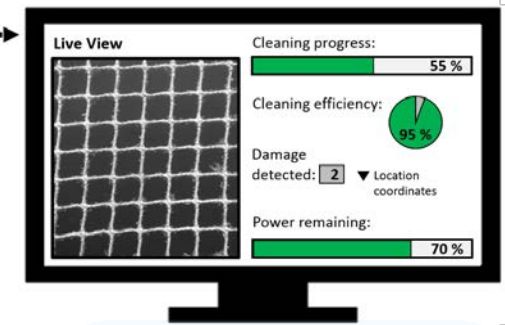
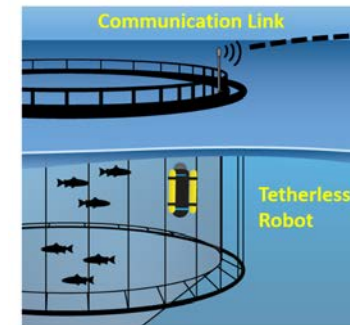
# NetClean 24/7

## Tetherless robot for biofouling prevention and inspection in salmon farming

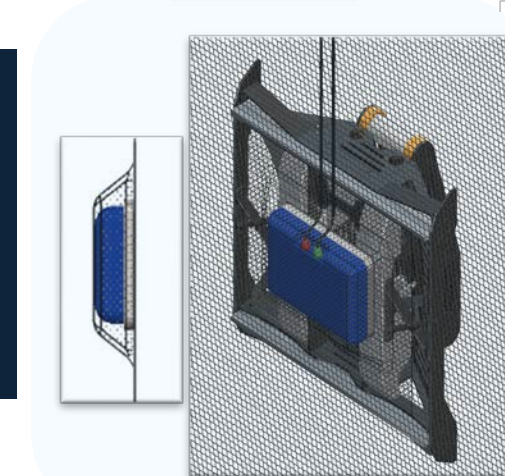
- Develop **novel technology** – build an advanced self-actuated robot
- Introduce a **new management strategy for biofouling prevention**
- **Autonomous cleaning and inspection operations**

### Main goal:

1. Improve farming control and productivity
2. Reduce costs and risks
3. Have positive effects on fish health and welfare



Remora Robotics AS



Concept design of docking station



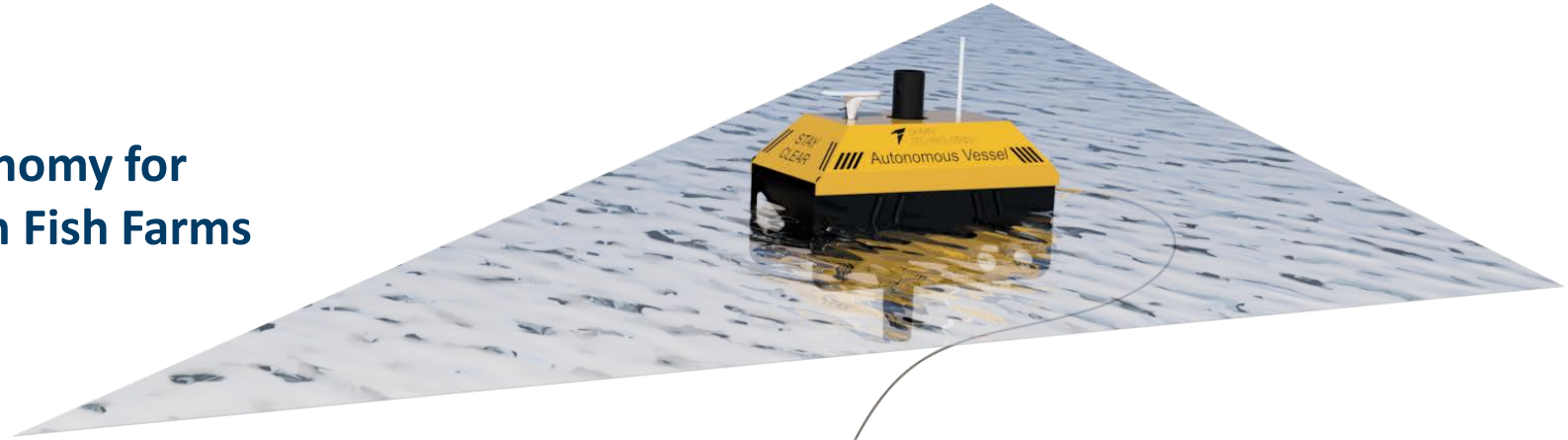


# ResiFarm project



# ResiFarm

## Resilient Robotic Autonomy for Underwater Operations in Fish Farms



Reshape the underwater operations in dynamic, complex and perceptually-degraded environments through developing resilient solutions for autonomous robots.



# Robotic solutions – Different Layers of Interest



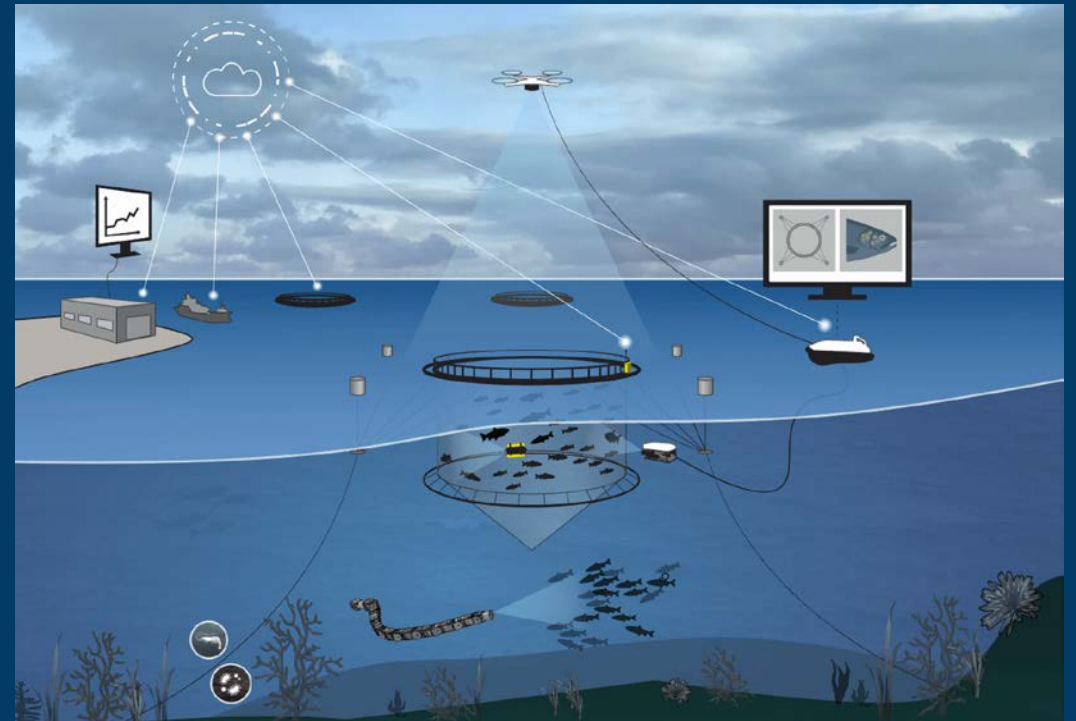




Vision...



# Autonomous Operations in Fish Farms





SINTEF

# Enabling technologies

A system able to perform a set of complex operations without human assistance and the ability to compensate for system failures or environment uncertainties.



Communication (subsea and in air)



Robot launch and recovery systems and/or docking systems



Motion Planning and Navigation



Sensors and computer vision systems



Intervention tools (robotic arms)



Autonomy and artificial intelligence



# SINTEF ACE-RoboticLab...

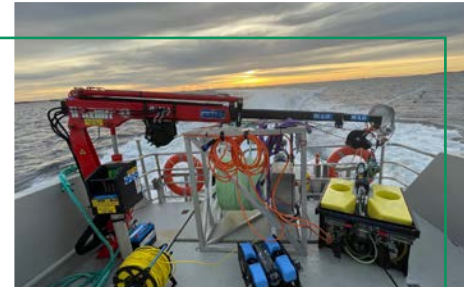
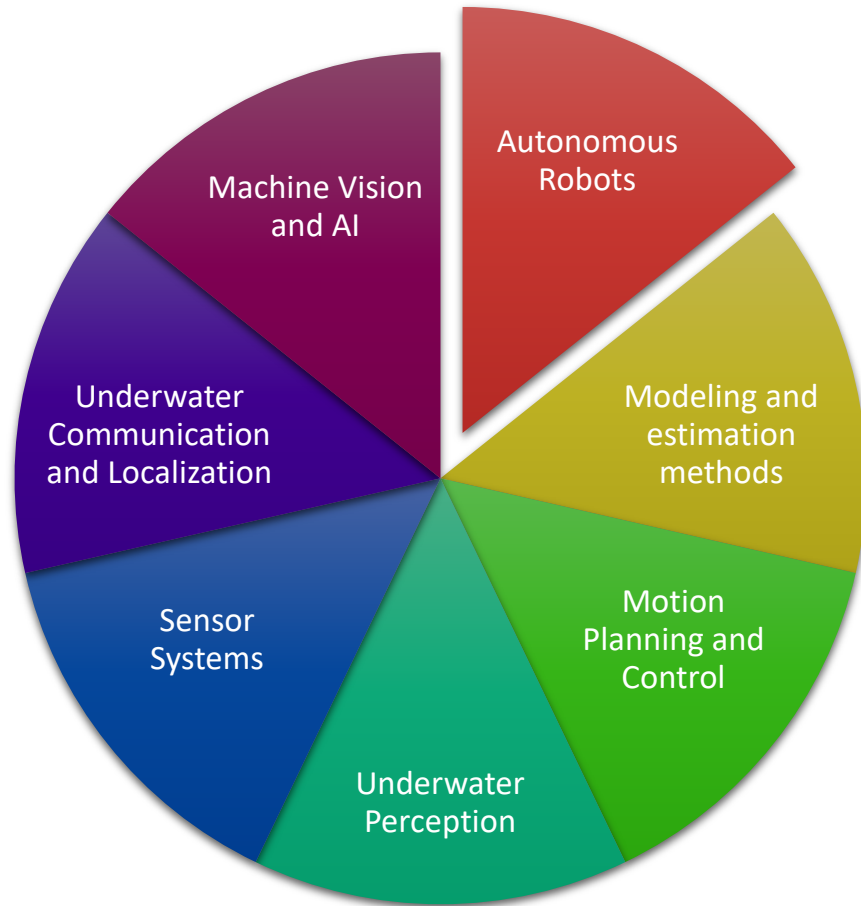
First aquaculture related robotic lab



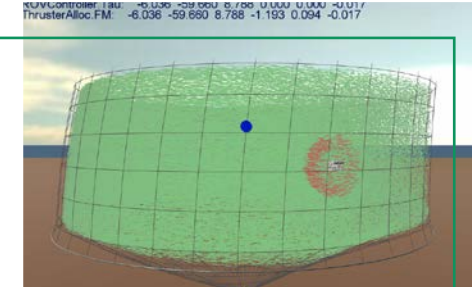
to drive up efficiency and minimize risks

# Biology and Technology Interaction

## R&D in SINTEF ACE-RoboticLab



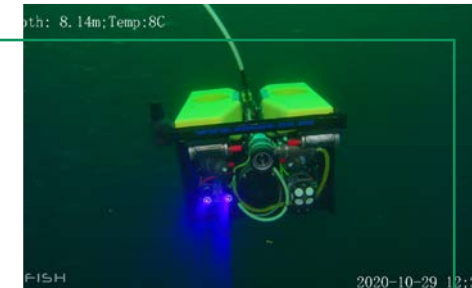
SINTEF ACE-RobotLab



FhSim



USV



UUVs



RPAS



Sensors



# SINTEF ACE – Aquacultural Engineering

- **The world's one and only full-scale facility**
- 4 Experimental locations in central Norway
- Expertise in the interaction between biology and technology
- Verifier for future technology





SINTEF

# Unmanned Underwater Vehicles



## ROVs

CageReporter,  
ResiFarm EXPOSED

Partner: Argus, Skarv  
Technologies



## AUVs

ResiFarm project

Partner: Eelume



## USVs

Artifex Project

Partner: Maritime  
Robotics

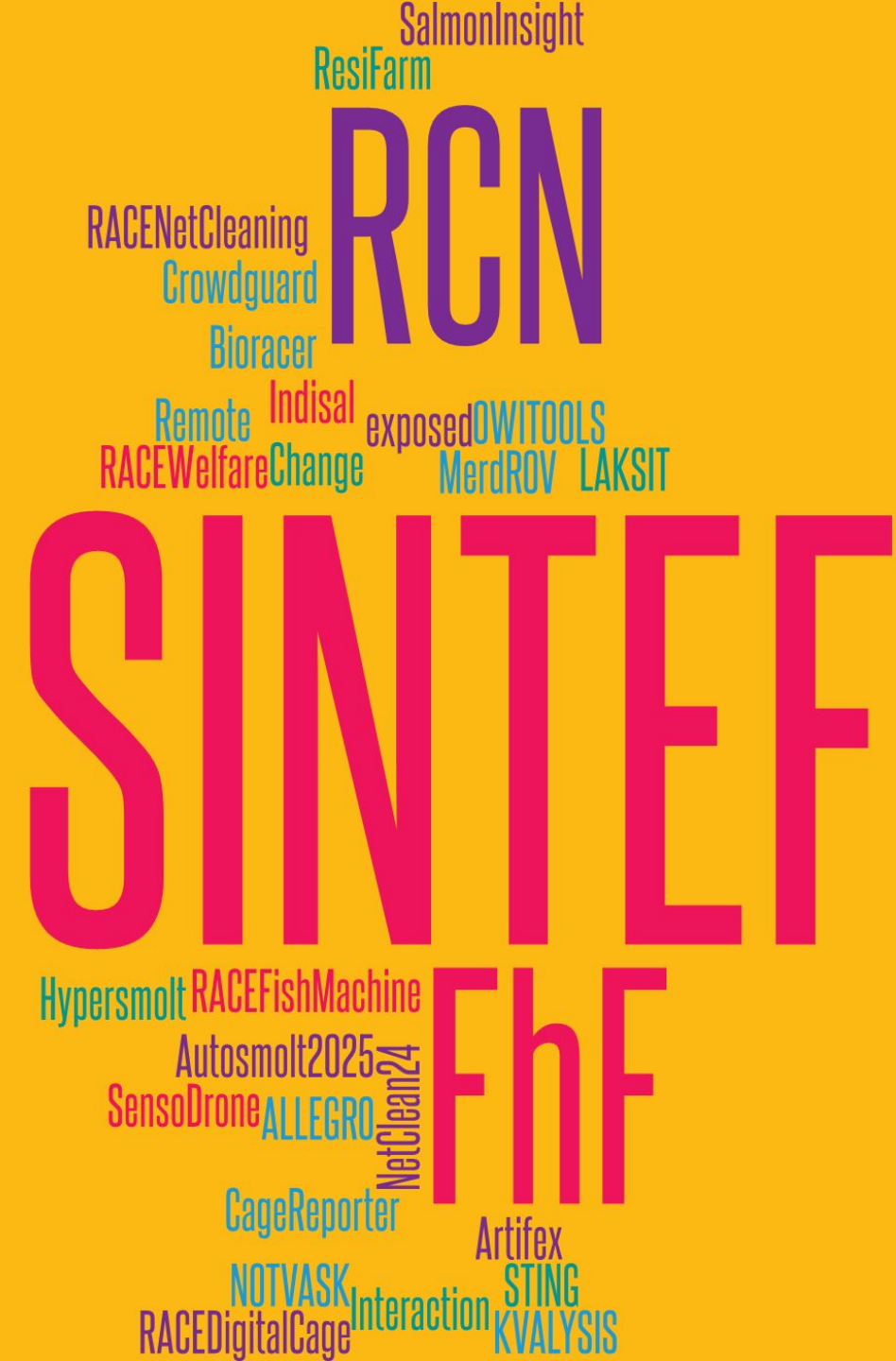
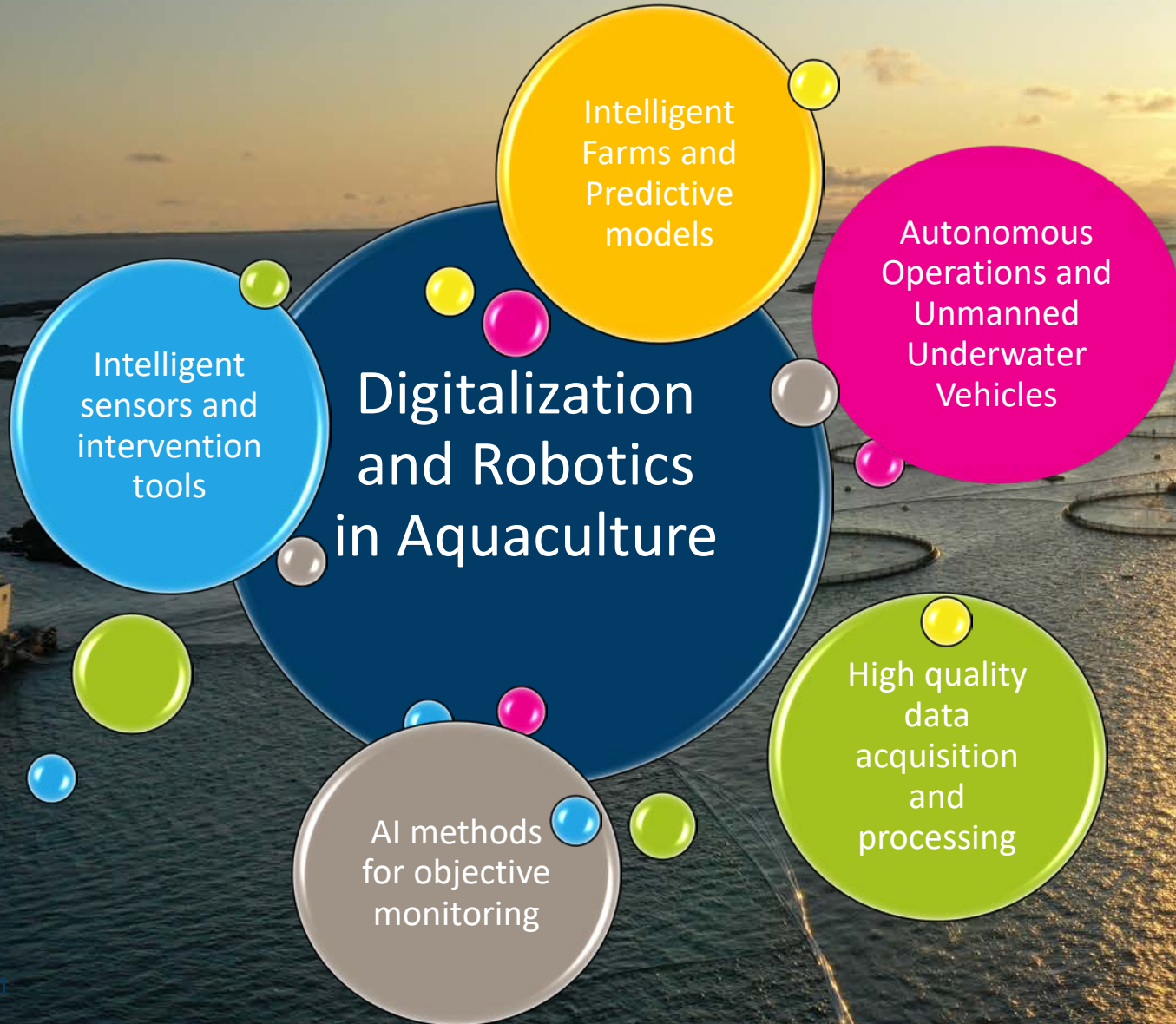


## UAVs

Artifex Project

Maritime Robotics

# Biology and Technology Interaction







Thank you...

# Contact - Information

---

## Eleni Kelasidi

---

Senior Research Scientist



[+47 45 18 57 96](tel:+4745185796)

[eleni.kelasidi@sintef.no](mailto:eleni.kelasidi@sintef.no)

Unit: [SINTEF Ocean AS](#)

Department: [Aquaculture](#)

Office: Trondheim



SINTEF

Technology for a  
better society