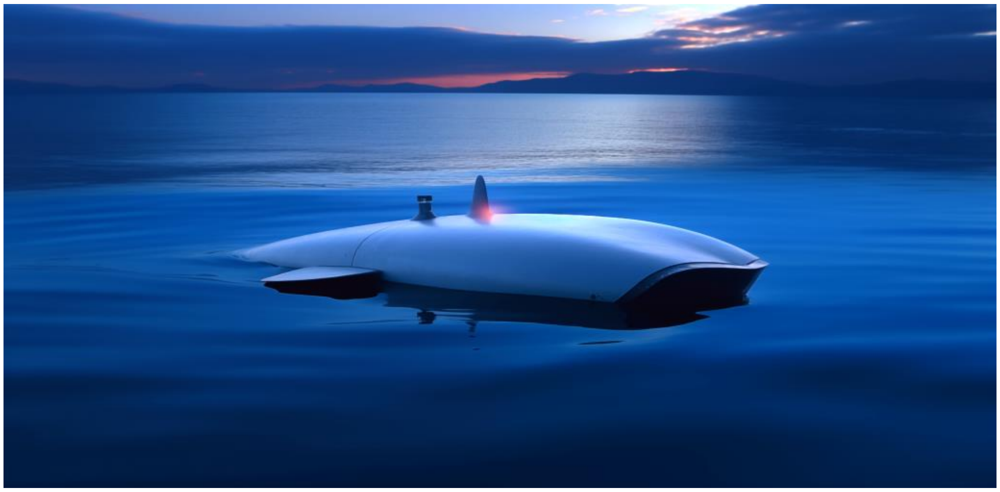

O.R.C.A

observe release capture analyze

Team7 – Newton

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Executive Summary

In a world threatened by the silent invasion of microplastics in our oceans, we introduce O.R.C.A, which stands for Observe. Release. Capture. Analyze, a groundbreaking, revolutionary solution designed for researchers, scientists, and academics who are dedicated to unraveling the true extent of the microplastic invasion. Existing sampling methods prove to be inadequate in delivering standardized data essential for combating ocean pollution. O.R.C.A comprises of a mothership, MARLIN, serving as a hub and control center, facilitating seamless data transmission and wireless energy transfer. Complementing MARLIN are the baby fish, BEAMOs, efficiently collect microplastic samples and vital environmental data. Our solution empowers researchers to gather data consistently and comprehensively on a larger scale, expediting the identification and mitigation of unknown and threatful microplastics in areas facing significant environmental damage.

Introduction

The Challenge-Based Innovation (CBI) program, an initiative conceived by CERN, epitomizes the intersection of cutting-edge science and technology with the imperative challenges facing society. It serves as a testament to CERN's unwavering commitment to applying open science, pioneering technology, and profound expertise to yield tangible societal benefits.

In the academic year of 2023-24, the CBI program strategically aligns itself with specific Sustainable Development Goals (SDGs), enhancing its impact by addressing critical global issues. This strategic alignment encompasses SDG 3.9, focusing on the reduction of illnesses and deaths caused by hazardous chemicals and pollution; SDG 11.6, with a focus on minimizing the environmental footprint of cities; and SDGs 14.1 and 14.3, concentrating on mitigating marine pollution and countering ocean acidification.

This year's CBI agenda is powered by four groundbreaking technologies under the EU-ATTRACT program. These transformative technologies are:

- **H3D VISIOnAI3 -** Augmented reality (AR) headgear to help surgeons to attain reliable high resolution visual discrimination of anatomical structures in real-time
- **PiPe 4.0 -** A system for in-situ monitoring of gas parameters in the distribution of network of biogas, biomethane and hydrogen-enriched natural gas
- **SNIFFER DRONE -** Drone-based odor monitoring system based on the state of the art IR chemical sensors
- **IALL -** A tunable thin lens based on liquid crystals

This project report explores the synergies between CBI programs and these cutting-edge technologies and their potential to make a significant contribution to the achievement of the SDGs. Through a research and design thinking approach, this project will seek to find a sweet spot where pioneering science and technology meets with societal goals integrate.

Understanding the Problem & HMW

In addressing the pervasive issue of microplastic pollution in our oceans, our research journey commenced with a comprehensive exploration guided by critical stakeholders such as oceanography specialists, water filtration experts, microbiologists, and sustainability executives. This collaborative effort unveiled critical insights into microplastic detection challenges, emphasizing the need for a paradigm shift in our data collection and analysis approach. The research questions, deeply rooted in the complexities of microplastic pollution, provided a structured framework for our exploration and addressed prevention strategies, the latest research findings, emerging technologies, education campaigns, global challenges addressing pollution, and potential "magic wand" fixes. These questions thoroughly examined diverse facets and guided our exploration toward innovative and practical solutions.

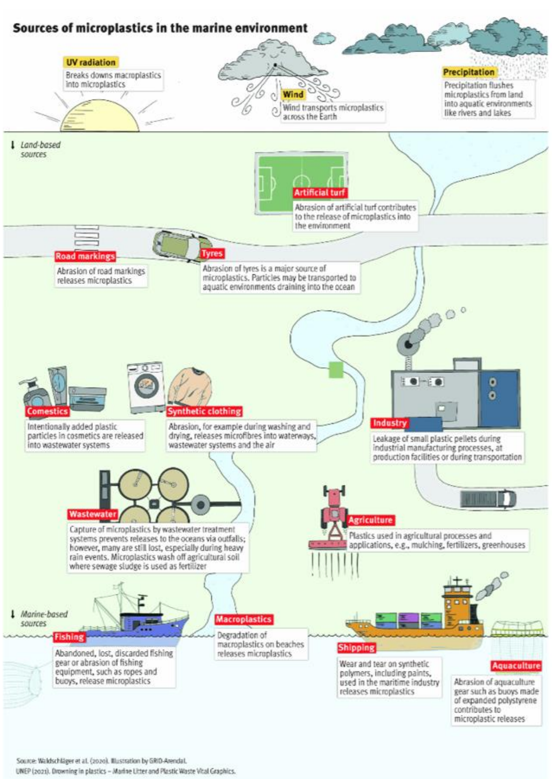

Fig 1: Sources of MPs in the marine environment

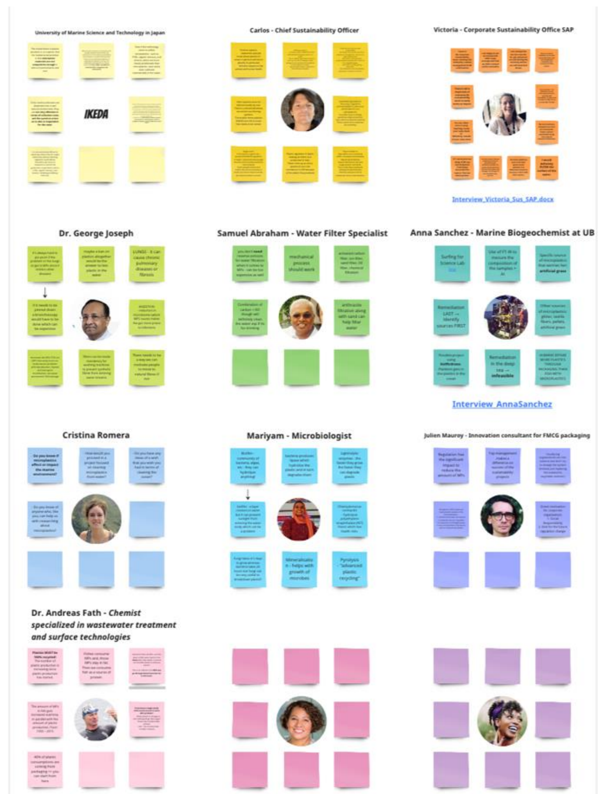

Fig 2: Interviewees

Microplastics, measuring less than five millimeters, stemmed from the breakdown of more oversized plastic items and industrial processes. Their extensive distribution in water columns, sediments, and marine organisms posed ecological risks, with documented cases of marine life ingestion raising concerns about environmental consequences. The urgency of this issue required practical understanding, mitigation, and action. Our investigation delved into the sources of microplastics, revealing their presence in tap water, seafood, personal care products, domestic dust, and natural plastic waste. Bottled water, a commonly consumed resource, was identified as a contributor, with 93% of sampled bottles containing microplastics.

In our pursuit of addressing the pervasive issue of microplastic pollution, our research revealed critical insights that advocated a paradigm shift in plastic usage, accelerated regulatory frameworks, and the deployment of cutting-edge technologies. Our investigation also showed the urgency of collaborative efforts across multiple domains, outlining a roadmap for holistic action. Some of our key insights highlighted the need to revolutionize plastic usage, prevent plastic entry into oceans, and expedite regulatory measures for sustainable practices. We found that current detection methods needed enhancement for identifying large concentrations, categorizing microplastic types, and improving traceability. We explored existing innovative solutions, such as the Snifferdrone, which could leverage plankton reactions, to monitor and mitigate microplastic pollution, as well as household filters, community awareness initiatives, underwater mapping, surface detection, and microplastic attraction strategies. Our team aimed to address core areas of prevention, regulation, detection, user behavior, and technology-specific interventions.

Technologies

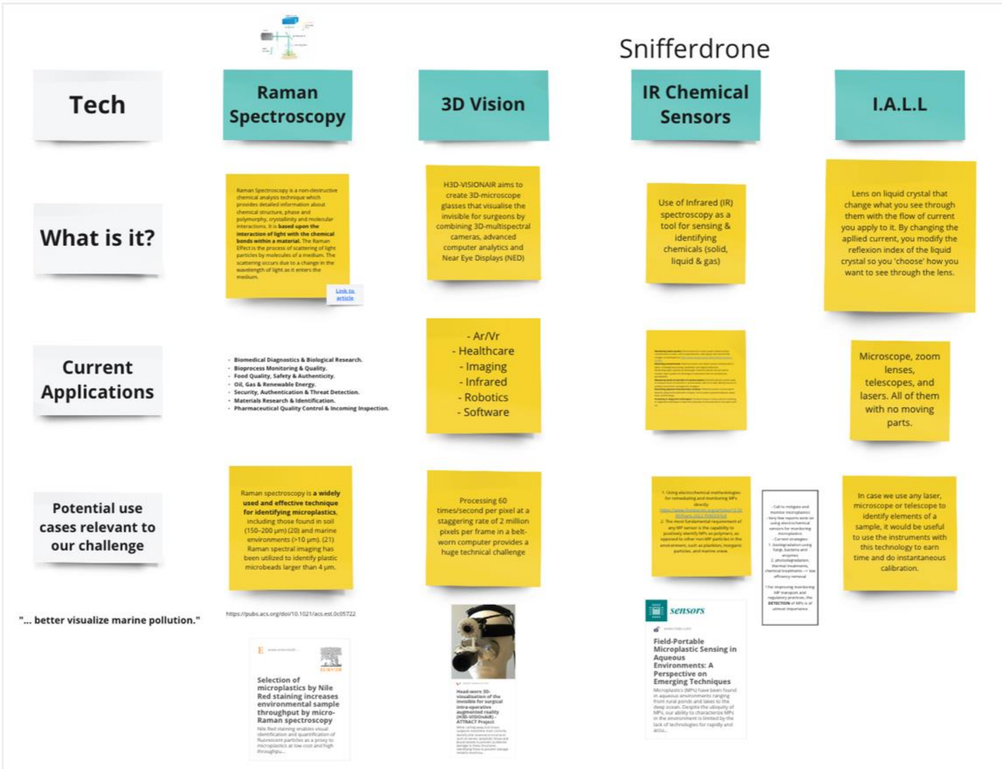

Fig 3: Leveraging ATTRACT 4.0 technologies

This comprehensive approach emphasized the importance of real-time data, visualization techniques, and collaborative endeavors to combat the complex challenges posed by microplastic pollution, culminating in our ‘initial’ design challenge: "How might we improve data collection and visibility of microplastics to prevent their entry into the world's waterways, driving community awareness and action?" The stakeholders involved in this research journey included researchers, scientists, and academics, who faced significant hurdles due to inconsistent, outdated, and time-consuming methods. The insights from the research revealed that high annual costs limited large-scale studies, and the resulting disorderly information impeded comprehensive data synthesis. Additionally, traditional sampling methods, which were time-consuming, further hindered timely monitoring of microplastic pollution in marine environments. Our research proposed essential questions to address these challenges that guided exploring prevention strategies, technological advancements, and community engagement, and we examined emerging technologies such as Raman spectroscopy, 3D vision, I.R. chemical sensors, and I.A.L.L., envisioning a future where these cutting-edge tools could enhance microplastic detection and sampling in the ocean. Furthermore, our investigation explored various existing methods for removing microplastics, including trawling, ROVs and AUVs, sediment traps, and optical methods like infrared vision. Our research aimed to revolutionize data collection on microplastics, acknowledging the inadequacy of traditional methods and the critical need for a more sophisticated approach. Our stakeholder insights emphasized the importance of real-time data, visualization techniques, and collaborative efforts in addressing microplastic pollution in the ocean.

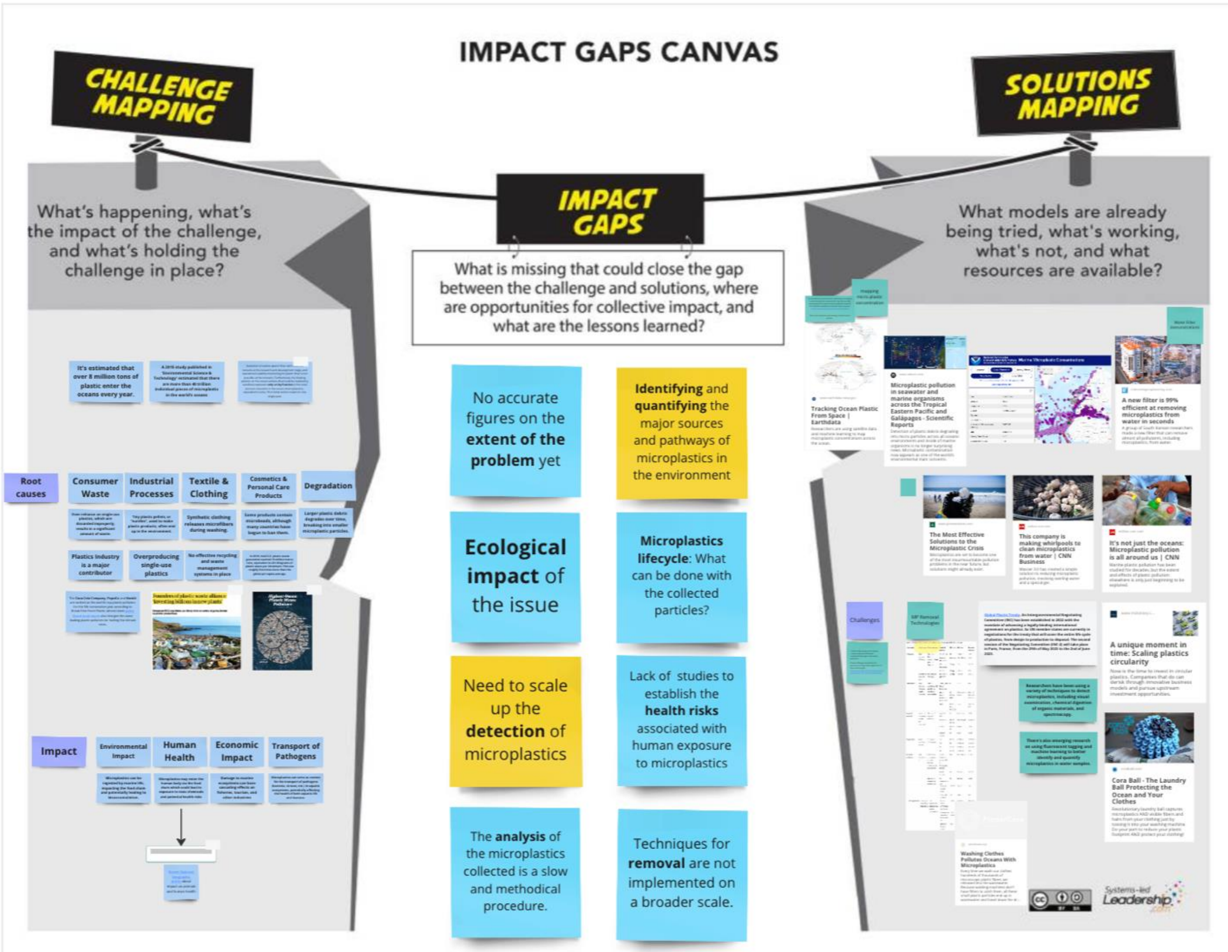

Fig 4: Impact Map

Our impact gap map painted a distressing picture, estimating that over 8 million tons of plastic found its way into the oceans annually, contributing to more than 40 trillion individual microplastic pieces in the world's oceans and causing extensive environmental, human health, and economic consequences. Our insights highlighted the necessity for a more holistic approach, encompassing prevention, regulation, detection, user behavior, and technological enhancement. The extensive research journey into ocean microplastic pollution revealed critical insights that underscored the pressing need for a paradigm shift in our approach to this global environmental challenge. Despite advancements in satellite monitoring, operational capabilities for plastic litter were still in the research and development stage, and the floating plastics on the ocean surface represented only a tiny fraction—1%—of what enters oceans each year. This realization highlighted significant impact gaps, including the need for accurate figures, identification of primary sources, and a comprehensive understanding of the ecological impact of microplastics. Another contributing factor that emerged as a root cause was consumer waste, fueled by over-reliance on single-use plastics. The plastics industry, industrial processes, textiles, and cosmetics contributed substantially to this environmental crisis, and, over time, the degradation of larger plastic debris exacerbated the issue, breaking into smaller microplastic particles. Notably, major industry players, including The Coca-Cola Company, PepsiCo, and Nestlé, persisted as the world's top plastic polluters, a position held for the fifth consecutive year, and the consequences of microplastics pollution were profound, affecting the environment, human health, and economic sectors. When ingested by marine life, microplastics disrupted the food chain and posed potential risks of bioaccumulation. Moreover, these minute particles may have entered the human body through the food chain, exposing individuals to toxic chemicals and health risks. The economic impact was evident in the damage to marine ecosystems, leading to cascading effects on fisheries, tourism, and various industries

Fig 5: How might we scenarios

The research also revealed that accurate figures on the problem's extent are lacking, emphasizing the need for comprehensive data. We also found that the ecological impact and lifecycle of microplastics, along with health risks and removal techniques, remain insufficiently explored. Accordingly, there's a need to scale up detection efforts, adopt efficient analysis methods, and implement broader detection strategies and addressing these gaps is essential for a more comprehensive and effective approach.

As an outcome of these discoveries, we developed several assumptions that we could explore to combat microplastic pollution. Suggestions ranged from changing plastic usage patterns to accelerating regulations, deploying innovative technologies, and detecting large concentrations of microplastics. The team also converged around the themes of enhancing traceability and accessibility of sustainable products for consumers and leveraging innovative solutions like Snifferdrones. However, the team recognized several critical impact gaps, including the need for more accurate figures, an understanding of the ecological impact, and the current slow pace of microplastic analysis. Moreover, techniques for removal should be implemented on a broader scale, revealing a significant need for innovation and systemic change.

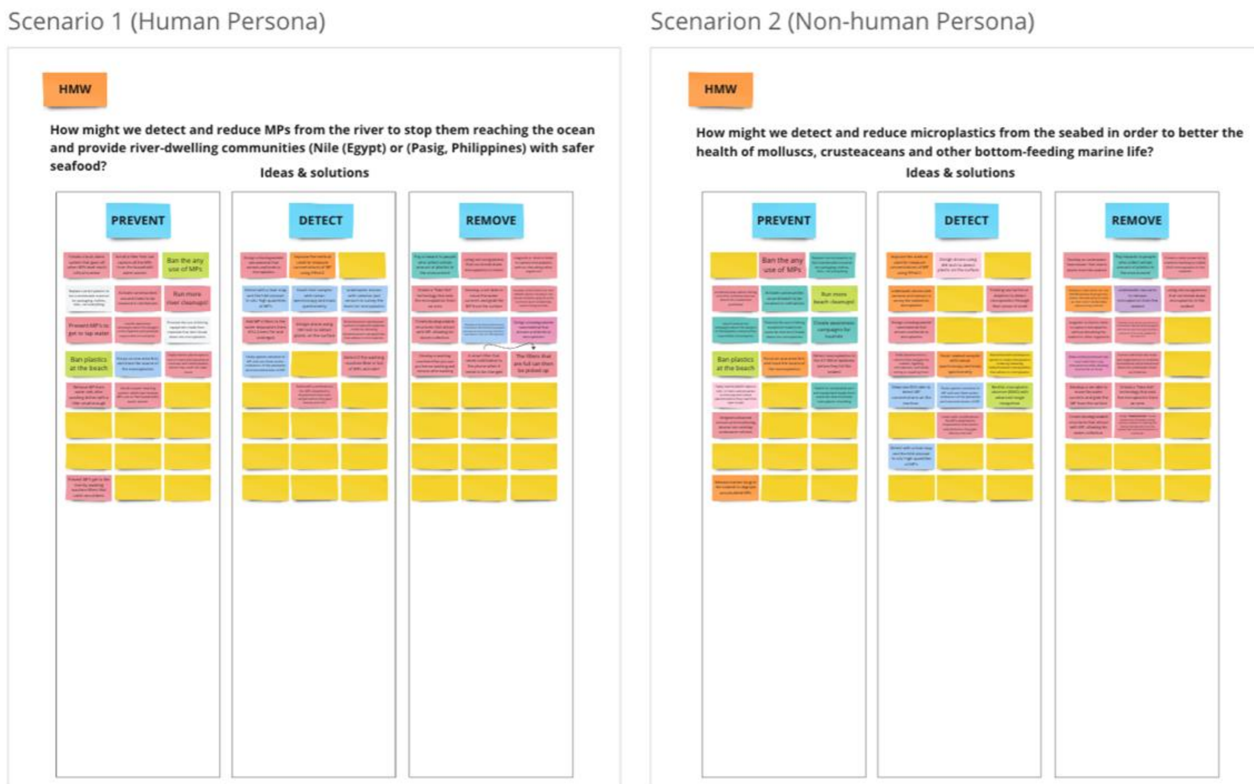

Fig 6: Exploring a new design direction

The 'new and improved' how might we questions we crafted helped guide our research focus and reflected our commitment to comprehensively understand microplastic pollution and its potential solutions. We divided our approach into three key areas: prevention, detection and removal and explored various solutions by leveraging two design approaches: How might we detect and reduce MPs from the river to stop them reaching the ocean and provide river-dwelling communities (Nile (Egypt) or (Pasig, Philippines) with safer seafood? And how might we detect and reduce microplastics from the seabed to better the health of mollusks, crustaceans, and other bottom-feeding marine life? As an outcome of this phase, we finally agreed that the final design challenge should focus on our ultimate aim: to aid scientists and researchers by improving data collection of microplastics via more efficient and accurate sampling and detection. This served as a crucial cornerstone for the entire research initiative.

In conclusion, our research journey revealed the multifaceted challenges posed by microplastic pollution and the insights gained highlighted the need for immediate and collaborative action. By addressing impact gaps, exploring innovative solutions, and framing comprehensive research questions, our O.R.C.A project seeks to lead the next wave in microplastic detection and sampling and catalyze real-world change in the fight against microplastic pollution. It is a call to action, emphasizing the urgent need for a collective, global effort to preserve our oceans' health and future generations' well-being.

Fig 7: Miro board

Solution Exploration

In order to arrive at our final solution, a comprehensive ideation process was undertaken following the Design Thinking methodology. Early on, our group identified the focal point of our investigation as microplastics, a choice influenced by a captivating presentation during the welcoming weeks of the course. Subsequently, we delved into an extensive exploration of the subject, seeking to discern existing gaps between the issue and implemented measures. Simultaneously, our team familiarized itself with various ATTRACT technologies available for incorporation into our project.

A systematic approach involved the mapping and analysis of systems, contemplating potential interventions for addressing the microplastics issue. An overarching question confronted us: should our efforts be directed towards mitigating the production of microplastics at their source or devising methods to eliminate them from water bodies? Seeking expert insights, we engaged with specialists including water filter experts, microbiologists, engineers, doctors, chemists, and marine biogeochemists. These consultations afforded us a better understanding of the issue, guiding our subsequent ideation.

We embarked on an ideation process where a multitude of ideas emerged. Employing tools such as the Impact-Effort Matrix, Impact Mapping, Iceberg Model, and others, we classified these ideas into three main categories: prevention, detection, and removal of microplastics. This classification helped shape an initial question—How might we—tailored to both human and non-human perspectives, laying the foundation for our creative thinking process.

Several innovative concepts surfaced during this phase, including a device using a Snifferdrone to detect microplastics attached to phytoplankton emitting dimethyl sulfide, a system to monitor the microplastic filter in washing machines and alert users, and a "Fake fish" technology designed to consume microplastics. Additionally, a proposal to develop a robot capable of identifying and retrieving macro plastics from ocean surfaces was considered. After a comprehensive assessment in comparison to existing solutions, we ultimately opted for the detection of phytoplankton as the preferred approach for mapping microplastic concentrations in the ocean. In considering this idea, it is essential to note that phytoplankton often attach to floating microplastics on the ocean's surface, subsequently causing them to sink. Furthermore, phytoplankton release dimethyl sulfide, an odor that attracts birds, leading to inadvertent ingestion of plastics. This insight influenced our decision-making process as we envisioned utilizing a drone to emulate the bird's role in this dynamic.

Acknowledging the laborious nature of current sampling and mapping processes, we shifted towards detection as our primary focus. In response to coaching session feedback, our solution evolved into a three-step process: surface detection of microplastics using the Snifferdrone, subsequent removal of detected plastics with a robot, and the utilization of a robotic "vacuum" for seabed clean-up. However, upon consultation with a marine biogeochemist, we recognized the absence of a correlation between phytoplankton and microplastic concentrations, prompting a re-evaluation of our chosen approach.

Contemplating alternative options and synthesizing insights from interviews, a key revelation surfaced—the primary challenge in the microplastics domain lay in the limited understanding of the issue's magnitude. The extended process of sample collection, transportation to laboratories, and individualized analysis prompted a strategic focus on this aspect. Our ultimate solution, named O.R.C.A (Observe Remove Capture Analyse), emerged from this realization—a device designed to detect and reduce microplastics in oceans, safeguarding underwater organisms' health and contributing valuable data to the research community.

The O.R.C.A project initially encompassed two distinct ideas: a surface device resembling an orca with cameras for visual input and a detachable drone for location sharing, alongside an underwater robotic fish for monitoring and analysing microplastics. The final solution seamlessly integrates both concepts into a cohesive and comprehensive approach.

Solution and Technology

Our solution to the challenge of microplastic pollution in the oceans is known as O.R.C.A, a pioneering system that integrates the MARLIN Surface Hub with a fleet of BEAMOs. This strategy represents a significant advancement in our understanding and management of ocean health.
MARLIN serves as a floating command center on the ocean's surface. It is pivotal in gathering data from the BEAMOs and transmitting it via satellite to research teams. Its mobility is a crucial feature, enabling it to relocate and facilitate continuous sampling across various ocean regions.

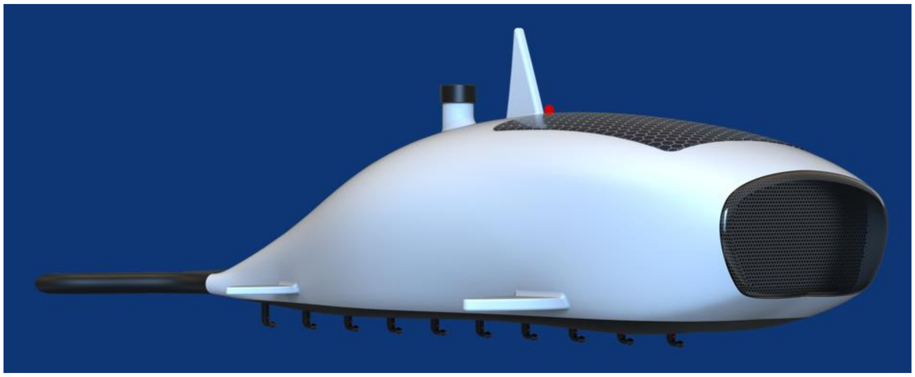

Fig 8: ORCA design

BEAMOs are at the forefront of quantifying microplastics. They have been designed to navigate water currents, filtering and capturing microplastics efficiently. BEAMOs are primarily designed to quantify microplastic levels in marine environments. By monitoring the water flow within and outside the system, they precisely estimate the fullness of the microplastic filter.

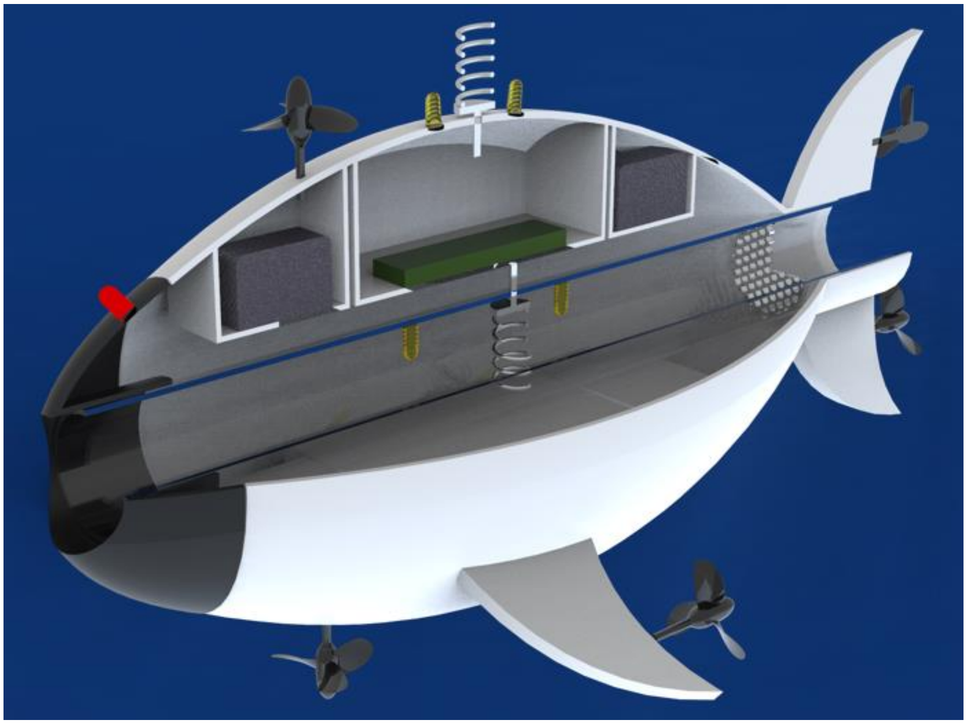

Fig 9: BEAMO design

The interaction between MARLIN and BEAMOs is central to the effectiveness of the system. MARLIN employs long-range ultrasound signals to guide BEAMOs, which use these signals for accurate navigation back to MARLIN. MARLIN and BEAMOs communicate and transfer energy through Wireless Power Transfer (WPT) when magnetically coupled. BEAMOs emit a 40Hz sound to keep fishes away, ensuring focused microplastic collection. Upon reconnection, MARLIN uses reverse suction to collect the microplastics from BEAMOs. These samples are then analyzed by PiPe4.0 technology, providing accurate data on microplastic concentrations.

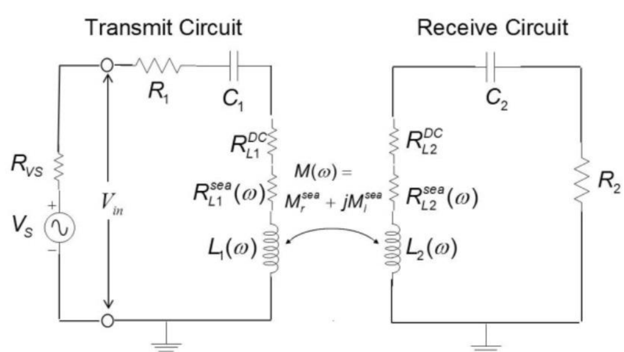

Fig 10: Underwater WPT model.

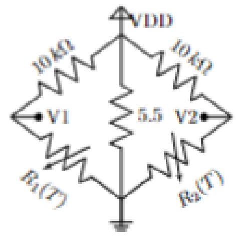

Fig 11: Flow sensor.

Each BEAMO has six motors, two for each direction. Its primary movement relies on ocean currents, using its motors only when necessary. Upon deployment, BEAMO has an assigned area. It uses its position calculation system to determine if its current location is correct and decides to either stay in the same current or switch to another based on this. The main goal is to minimize energy consumption. Initially, BEAMO operates in 30-minute sessions, but it can function up to 1 hour. The motors are designed to run a maximum of 40% of the total time. Each pair of motors consumes 20W to reach a maximum speed of 4m/s. Based on this consumption and its operation, BEAMO is equipped with an 8Wh battery.

On its part, MARLIN has a single motor, similar to a boat's, and is remotely controlled. Every 45 minutes, MARLIN changes its location, operating approximately 10 minutes for each move. To move at a speed of 5m/s, it consumes 4.3kW. To operate for 12 hours a day, it is estimated to need a 10kWh battery. Additionally, for extended autonomy, Marlin is equipped with 8m^2 of solar panels capable of generating an average of 11.2kWh per day, considering the conditions of the Mediterranean Sea.

Our solution is exceptional in its holistic and dynamic approach to studying microplastic pollution. By integrating advanced robotics with cutting-edge data analysis, we provide an unparalleled insight into pollution patterns. This information is essential for making informed decisions in environmental policy and cleanup initiatives.
In the short term, this system delivers critical data for immediate interventions in areas heavily impacted by pollution. In the long term, it contributes to a deeper understanding of environmental impacts, influencing global conservation strategies. The technological innovation of our system not only pushes the boundaries of environmental research but also demonstrates the potential for similar methodologies in other ecological studies. This solution represents a paradigm shift in addressing environmental challenges, particularly in enhancing ocean health.

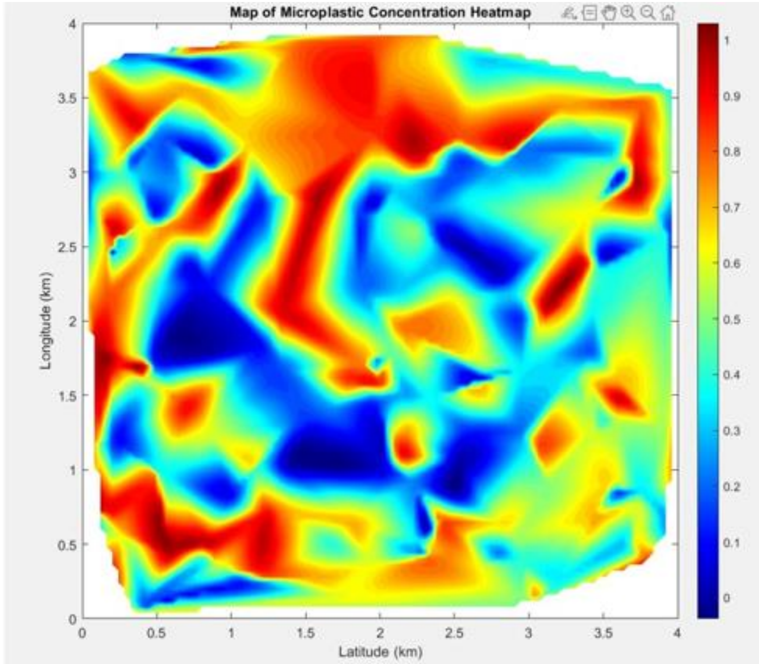

Fig 10: Heat map example

The final prototype is a robotic fish (BEAMO) with a tube inside it which is where the water flows through. At the end of the tube, we have added a net with holes smaller than 5 µm (the size of the microplastics), so when water gets out of the fish, the microplastics stay inside it, providing the tube with the function of microplastics filter. To calculate the filter capacity, that is, how full the tube is and how many microplastics it contains, we have implemented the following system: The system is based on 2 precise thermistors (sensor temperatures), and a heat source in the middle of them. All these elements will be in touch with water as BEAMO swims, but we have isolated the Electronics and the most delicate parts from water to keep them safe. The heat source is positioned and calibrated with the intention that when the water flows slower than expected due to an accumulation of microplastics at the end of the filter, this water will suffer a temperature increase that will only be detected by the second sensor. This is because when the water passes through the first sensor, it is still cold.

Thanks to this system, knowing the temperature difference between the 2 sensors, we can know the capacity of the filter in real time, giving us the possibility of drawing precise microplastics concentration maps in a short period of time, solving the current existing problem of taking a significant amount of time and effort to make an estimation and sampling of underwater microplastics. This approach helps identify the areas where they accumulate the most.

For the prototype, we used an Arduino Nano 33 Board. We put it inside the BEAMO and used its Wi-Fi module to simulate underwater communications, where Arduino sends the necessary data wirelessly. To receive the data, we programmed Python code for any laptop that needs to act as receiver. You cand find both codes in the References. The purpose of these codes is to visualize in your laptop a graph with the temperature difference between the two sensors inside the BEAMO, so when we feel an increase of this value, we can determine that we found a high microplastics concentration area at that precise moment. In the following image, you can find a real example of how that would be seen (the values of the image were taken at the final presentations under water conditions):

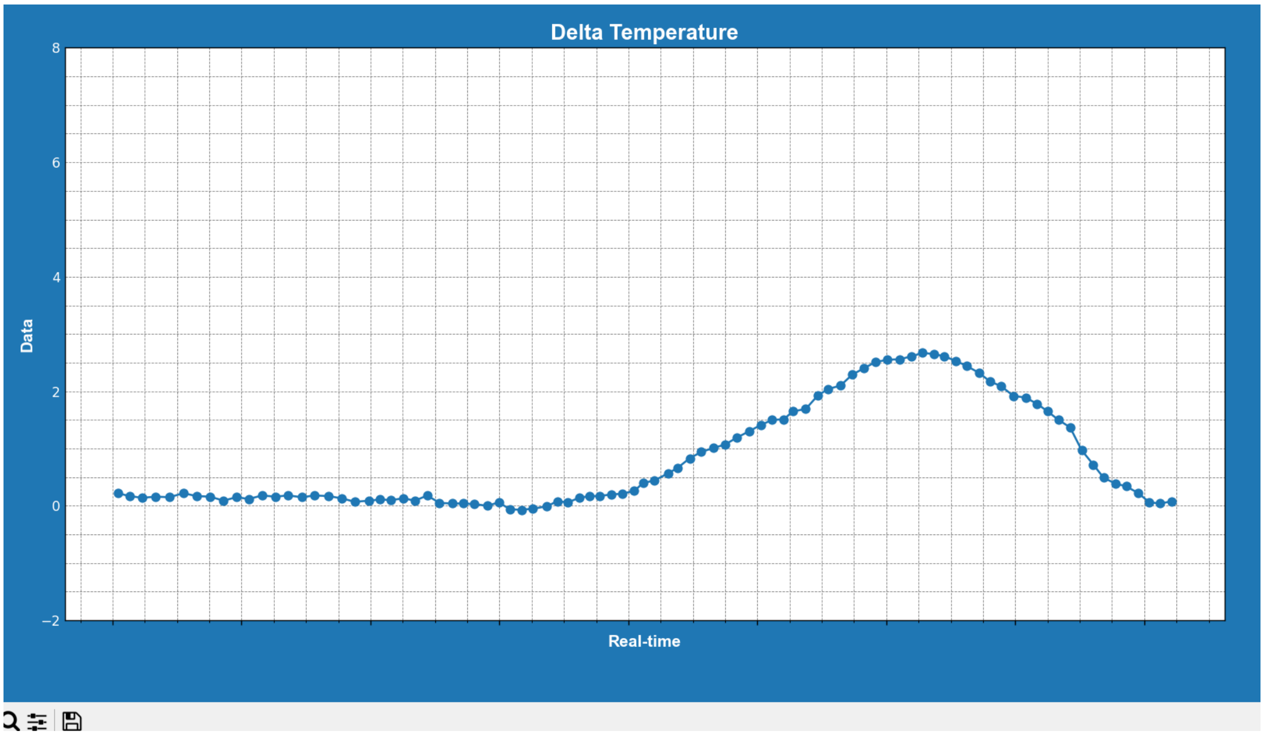

Fig 11: Plot of the real-time temperature difference between sensors

Social Impact & Next Step

O.R.C.A or Observe. Release. Capture. Analyze, is a groundbreaking solution to combat plastic pollution in the oceans. O.R.C.A's value proposition lies in its comprehensive approach. The system facilitates seamless communication between the central hub (MARLIN) and smaller autonomous devices (BEAMOs), ensuring accurate data collection and efficient transfer. The benefits are compelling—cleaner oceans, healthier marine life, and more informed decision-making. O.R.C.A's innovative approach to microplastic sampling and detection brings about a paradigm shift in environmental preservation. By adhering to standardized measurement practices, it ensures precision and accuracy in assessing microplastic concentrations, providing a reliable foundation for scientific research. The real-time data and insights generated by O.R.C.A not only contribute to immediate cleanup efforts but also play a pivotal role in the long-term establishment of a comprehensive oceanic dataset. This dual impact is crucial for effective environmental preservation, as faster and more accurate data collection directly translates to informed decision-making. The time and cost savings introduced by O.R.C.A amplify its significance in the fight against oceanic pollution. With its remote-controlled/autonomous capabilities and efficient data collection methods, O.R.C.A streamlines the process, reducing the time required for comprehensive microplastic sampling. This operational efficiency leads to cost savings, allowing resources to be allocated more effectively toward other crucial aspects of environmental conservation. Scalability and reliability form the backbone of O.R.C.A's contribution to safeguarding marine biodiversity and supporting ocean-dependent communities worldwide. Its scalability allows for the deployment of this cutting-edge technology in high-concentration areas, addressing specific environmental challenges with precision. The reliability of O.R.C.A's data ensures that decisions made for environmental preservation are grounded in accurate information, providing a vital tool for the sustained well-being of both marine life and communities dependent on the ocean. In tandem with these foundational benefits, O.R.C.A's focus on cleaner oceans, healthier marine life, and more informed decisions aligns with its overarching mission. As it strategically deploys in regions with high ecological sensitivity and microplastic concentrations, O.R.C.A maximizes its impact, contributing not only to immediate cleanup efforts but also to the scientific understanding of ocean pollution. With standardized measurement, real-time data and insights, time and cost savings, as well as scalability and reliability, O.R.C.A is poised to make a significant, positive impact on the health and sustainability of our oceans.

Our next steps involve forming impactful partnerships with esteemed research institutions, like the UN, NGOs, investors, and governments to secure essential funding and support. By collaborating with influential entities like UNEP, WHO, and EEA, we aim to build a strong financial foundation and benefit from their expertise. This strategic alliance enhances our scientific credibility, global reach, and advocacy for policy changes. And, by engaging with governments and investors, we ensure the continuous development and deployment of our innovative solutions. These partnerships will potentially lead us towards a future where we can effectively support a better understanding of microplastic pollution in our ocean and contribute to environmental conservation and sustainable practices.

Learning & Recommendation

As a team, we were recommended by many visitors and experts to collaborate with international organizations and governments to implement the O.R.C.A system on a large scale. We believe it has the potential to make a significant impact on global microplastic pollution detection, monitoring and analysis. Collaborating with international organizations and governments could help facilitate the deployment of the system in different parts of the world. Before we make it a large-scale project, we would need experts to pilot and validate O.R.C.A so it can be better designed as needed, to help make the difference required for the researchers and scientists. The O.R.C.A project has the potential to educate the public about the issues of microplastic pollution and encourage individuals to make changes in their daily lives to reduce their contribution to the problem.

The learning outcomes through this project have proven to be beneficial to everyone in their own way. Some of the combines learning outcomes worth mentioning would be:

1. The importance of sustainable development goals and how these global challenges can be addressed by students. The project allowed us to have a moment of self-introspection and change certain behaviors to more impactful ones.
2. The team, with its diversity in ethnicity, culture, etc., felt a sense of global citizenship and a commitment through this project, to contributing to a more sustainable future. Every individual was brough together by their passion for life underwater and through every phase of this project, it was a reminder of how everyone is responsible for their actions and is capable of change. Our project taught us the unseen negative impacts of microplastics in the ocean and helped us design a solution to help the research community without harming marine life.
3. We, as students, have gained hands-on experience with designing, developing, and prototyping our designs which have helped improve our skillsets and can further add to our career growth.
4. We've seen significant growth in skills like teamwork, people management, communication, presentation skills, empathy, time management, problem-solving, and collaboration from working with different students from different disciplines, namely, engineering, design, and business.
5. The cohort was introduced to the latest technologies that are being developed and it was helpful to see how each team used the different technologies for different solutions. Being able to witness the growth and the ideas of different teams was encouraging and impactful. It goes to show how one technology can be used in many ways to help promote a sustainable future.

6. We were able to educate ourselves and others on the harmful effects of microplastics and the macro impact it has on humans, marine life and the environment.

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Arduino Code:

```
#include <SPI.h>
#include <WiFiNINA.h>
#include <WiFiUdp.h>
#include <OneWire.h>
#include <DallasTemperature.h>

const int sensorPin = A6, sensorPin2 = A7;    // seleccionar la entrada para el sensor
const int numDatos = 20;  // Número de datos a promediar
float sensorValue, sensorValue2;     // variable que almacena el valor raw (0 a 1023)
float sensor1Values[numDatos];  // Arreglo para almacenar los valores del primer sensor
float sensor2Values[numDatos];  // Arreglo para almacenar los valores del segundo sensor
int indice = 0;                // Índice actual en los arreglos
float mediaSensor1;
float mediaSensor2;
int status = WL_IDLE_STATUS;
char ssid[] = "POCO_F5";        // your network SSID (name)
char pass[] = "Orca_Team7";
int keyIndex = 0;              // your network key Index number (needed only for WEP)
unsigned int localPort = 2390;      // local port to listen on
char packetBuffer[256]; //buffer to hold incoming packet
char  ReplyBuffer[] = "acknowledged";       // a string to send back
WiFiUDP Udp;
WiFiServer server(23);
boolean alreadyConnected = false;
void setup()
{
  Serial.begin(9600);
  if (WiFi.status() == WL_NO_MODULE) {
    Serial.println("Communication with WiFi module failed!");
    // don't continue
    while (true);
  }
  String fv = WiFi.firmwareVersion();
  if (fv < WIFI_FIRMWARE_LATEST_VERSION) {
    Serial.println("Please upgrade the firmware");
  }
  // attempt to connect to Wifi network:
  while (status != WL_CONNECTED) {
    Serial.print("Attempting to connect to SSID: ");
    Serial.println(ssid);
    // Connect to WPA/WPA2 network. Change this line if using open or WEP network:
    status = WiFi.begin(ssid, pass);
    // wait 10 seconds for connection:
    delay(5000);
  }
  Serial.println("Connected to wifi");
  printWifiStatus();
  Serial.println("\nStarting connection to server...");
  // if you get a connection, report back via serial:
  Udp.begin(localPort);
  server.begin();
}
```

```
void loop()
{
  WiFiClient client = server.available();
  if (client) {
    if (!alreadyConnected) {
      client.flush();
      Serial.println("We have a new client");
      client.println("Hello, client!");
      alreadyConnected = true;
    }
    if (client.available() > 0) {
      // read the bytes incoming from the client:
      char thisChar = client.read();
      // echo the bytes back to the client:
      server.write(thisChar);
      // echo the bytes to the server as well:
      Serial.write(thisChar);
    }
  }
  sensorValue = analogRead(sensorPin);   // realizar la lectura
  sensorValue2 = analogRead(sensorPin2);   // realizar la lectura
  //mandar mensaje a puerto serie en función del valor leido
  float Vo, Vo2, Rdt, Rdt2;
  Vo = (sensorValue*3.3)/1024;
  Vo2 = (sensorValue2*3.3)/1024;
  Rdt = ((3.3/Vo) - 1)*15000;
  Rdt2 = ((3.3/Vo2) - 1)*15000;

  float T, T2, T_inv, T_inv2;
  T_inv = (log(Rdt/10000)/3977)+(1/298.15);
  T = (1/T_inv) - 273.15;
  T_inv2 = (log(Rdt2/10000)/3977)+(1/298.15);
  T2 = (1/T_inv2) - 273.15;
  // Almacenar los valores en los arreglos
  sensor1Values[indice] = T;
  sensor2Values[indice] = T2;
  // Incrementar el índice y reiniciarlo si alcanza el número de datos
  indice = (indice + 1) % numDatos;
  // Calcular la media de los últimos 10 valores para cada sensor
  mediaSensor1 = calcularMedia(sensor1Values, numDatos);
  mediaSensor2 = calcularMedia(sensor2Values, numDatos);
  float res= mediaSensor2 - mediaSensor1;
  Udp.beginPacket("188.185.250.173", 2390); // Reemplaza con la dirección IP de tu máquina y el puerto que escucha el script de Python
  Serial.println(String(res));
  Udp.print(String(res));
  Udp.endPacket();
  server.print(String(res)+"X");
  delay(2000);
}

// Función para calcular la media de un arreglo de valores
float calcularMedia(float values[], int length) {
```

Python Code:

```python
from telnetlib import Telnet
import numpy as np
from datetime import datetime
import matplotlib.ticker as ticker
import matplotlib.dates as mdates
import matplotlib.animation as animation
import matplotlib.pyplot as plt

tn = Telnet('192.168.1.235', 23)
all = 0
v_data = []
v_time = []
fig, ax= plt.subplots()
line, = ax.plot([],[], '-o')

# Customize appearance
fig.set_edgecolor(line.get_color())
fig.patch.set_facecolor(line.get_color())  # Background color
ax.set_xlabel('Real-time', color='white', fontsize=12, fontweight='bold', fontname='Arial')  # X-axis label
ax.set_ylabel('Data', color='white', fontsize=12, fontweight='bold', fontname='Arial')  # Y-axis label
ax.set_title('Delta Temperature', color='white', fontsize=16, fontweight='bold', fontname='Arial')  # Title
ax.grid(True, linestyle='--', linewidth=0.5, color='gray', which='both')  # Add grid with gray dashed lines
ax.set_ylim(-2, 8)
ax.set_xticklabels([])
start_time = datetime.now()
ax.xaxis.set_minor_locator(ticker.AutoMinorLocator(4))
ax.yaxis.set_minor_locator(ticker.AutoMinorLocator(4))
ax.tick_params(axis='y', which='both', length=0, labelcolor='white')  # Hide tick marks and set label color
def update(frame):
    data = tn.read_eager().decode('utf-8')
    if data:
        # Filtra solo los caracteres que son números o puntos decimales, y solo guarda 3 decimales
        if data[0] != '.':
            # Tomar el primer carácter y, si es un '-', tomar uno adicional, para tener siempre 3 decimales
            filtered_data = data[0] + (data[1] if data[0] == '-' else '') + ''.join(c for c in data[1:5] if c.isdigit() or (c =
            # Verificar que solo haya un punto decimal en la cadena
            if filtered_data.count('.') <= 1:
                print(filtered_data)
            else:
                print("Error: La cadena contiene más de un punto decimal.")
        else:
            print("Error: El primer carácter no puede ser un punto.")
        if filtered_data:
            print("Data: "+filtered_data)
            #print("Data: "+float_numbers)
            if len(v_data) == 90:
                v_data.pop(0)
            data_value = float(filtered_data)
            # Append data to lists
            v_data.append(data_value)
            v_time.append(frame)
            # Ensure both vectors have the same length
            min_len = min(len(v_data), len(v_time))
            # Update the line data with the last min_len points
            line.set_data(v_time[:min_len], v_data[:min_len])
            # Update the line data with the last num_points
            # line.set_data(v_time, v_data)
            # Adjust the x-axis limits to keep a moving window
            ax.relim()
            ax.autoscale_view()
# Create an animation
ani = animation.FuncAnimation(fig, update, frames=range(1, 10000000), interval=100)  # Update every 1000 milliseconds (1 second
# Display the plot
plt.show()
```