Clear Blue Sea

Cleansing the Oceans of Plastic Pollution

WHITE PAPER

Analysis of Potential Marine Instruments for Implementation on Clear Blue Sea's Floating Robot for Eliminating Debris (FRED)

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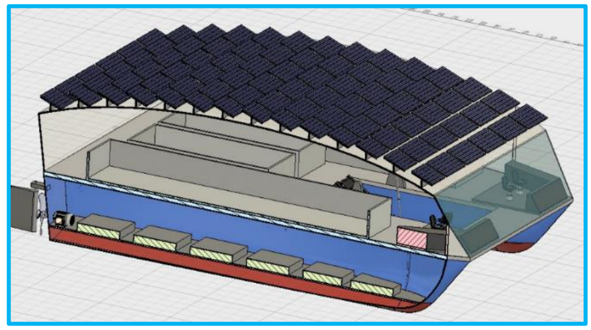
Abstract. Clear Blue Sea's optimal architecture for its Floating Robot for Eliminating Debris (the ideal FRED) requires multiple oceanographic and navigation instruments for their marine robot to be semi-autonomous in performing plastic debris cleanup in the ocean gyres. The gyres are where massive areas of floating plastic pollution, often referred to as "garbage patches" or "plastic soup" have accumulated over the decades. This White Paper identifies and assesses ocean conservation organizations and their innovations to learn how they have approached the challenge of semi-autonomous operations far at sea. Six specific marine instruments are evaluated for their function and effectiveness, providing engineering guidance to Clear Blue Sea in its design, build, and operation of their FRED innovation for cleansing the oceans of plastic pollution.

The Problem. The earth has five major ocean gyres, meaning gigantic circular oceanic surface currents that have high concentrations of plastic pollution. These garbage patches are a human-made problem generated by the ever-increasing production of plastic and society's improper disposal and low level of recycling of plastics. These gyres contain plastic litter ranging in size from miles-long fishing nets to trillions of microplastic particles. The largest is the Great Pacific Garbage Patch which is estimated to be the size of Texas. This extensive amount of marine debris in all our oceans substantially affects the ecosystem, whether by injuring marine mammals which encounter its mass or my killing marine animals which ingest this plastic when mistaken for food.

NOAA Map of Pacific Garbage Patches

The Opportunity. Clear Blue Sea (CBSea) is a startup nonprofit company created in response to the global crisis of ocean plastics. CBSea's goal is to operate a fleet unmanned, solar-powered, semi-autonomous marine robots named the Floating Robot for Eliminating Debris (FRED) as shown to the right. These marine robots will cruise at slow speed to optimize collection of floating ocean debris, enabled by booms guiding plastic litter onto a conveyor belt and into a storage bin. FRED is powered solely by the sun to avoid further damage to the marine environment, with onboard batteries for energy storage. CBSea is currently prototyping FRED for test off the San Diego coast, followed by a Pilot Program in Hawaii, leading to full operations in the Pacific gyres.



The Challenge. Fleets of FREDs will operate on a 365/7/24 basis on their own until issues such as severe weather dictate that FREDs be remotely controlled by Clear Blue Sea staff stationed at a Mission Control Center in Hawaii. To perform their cleanup function, FREDs must have embedded instrumentation that is highly effective and reliable. Clear Blue Sea requested this White Paper to gain greater knowledge of existing instruments which are most relevant to FRED's mission of ocean plastic cleanup.

Methodology. Two companies were researched based on their innovations in autonomous vessels having instrumentation relevant to Clear Blue Sea's requirements for FRED. Liquid Robotics deploys a surfboard-like robot (Energy Harvesting Ocean Robot) that converts wave motion into propulsion and uses solar energy as its power source. This vessel does not require an onboard pilot, but does require remote control by a human operator. Hydroid deploys a submarine robot (REMUS Marine Robot Submarine) that identifies underwater objects and notifies operations via satellite of the object's geographical coordinates. Similar to Liquid Robotics' innovation, there is no onboard pilot and the vessel is remote-controlled using advance software. This submarine has embedded instruments to enable vessel autonomy and to collect data on submarine performance and its environmental conditions.

Tony de Paolo, Senior Engineer at Scripps Institute of Oceanography, was contacted for advice on further research and analysis. He suggested specific instruments relevant to FRED's mission, and a review of Woods Hole Institute's website for additional information resources.

Findings. Six specific instruments were identified as essential for FRED to accomplish its mission of ocean cleanup:

- Weather Transmitter
- Miniature Wave Buoy
- Acoustic Doppler Current Profiler (ADCP (
- Conductivity, Temperature, and Depth (CTD)
- Inertial Measurement Unit (IMU)
- Low-resolution Camera

Weather Transmitter. This is an all-in-one weather instrument that monitors six of the most important weather parameters: air pressure, temperature, humidity, rainfall, wind speed, and wind direction. Vaisala is a representative company that makes this instrument at a cost-effective price of $3,000, given the price range of S500 to $5000. Weather transmitters would provide FRED and Clear Blue Sea's Mission Control Center staff with real-time data for six different weather factors needed to navigate the seas.

Miniature Wave Buoys (MWB). This oceanography instrument records the axis for North, East, and Down; Global Positioning System (GPS) velocities; GPS latitude and longitude; GPS course and speed over ground; and sea surface temperature. From this data, derived calculations include mean period, peak direction, significant wave height, directional wave spectrum, peak period, and 9-band wave energy and direction. MWB data is transmitted via a satellite network and made available through the MWB website, which provides authorized users with a graphical display of the fielded buoy's observations. The buoy's GPS enables vessels to be located via satellite as frequently as each half-hour. The wave "buoy" does not need to be submerged from the outside of the vessel, but can be embedded inside the vessel and perform just as effectively. Historical MVB data can be analyzed to predict patterns associated with storms to present how weather affects wave direction and periodicity.

Acoustic Doppler Current Profiler (ADCP). This instrument tracks the strength of ocean currents to measure how quickly water moves across the water column. The ADCP transmits "pings" into the ocean at a constant frequency. Due to the Doppler effect, sound waves bouncing back from an object moving away from the ADCP have lower frequency than sound waves returning to the instrument. This difference of wave frequencies is the Doppler shift, which is applied to calculate the speed of the identified objects and the water around it.

ADCPs that are mounted on a vessel require power, a shipboard computer to receive the data, and a GPS navigation system so the vessel's own movements can be compared to the ocean currents. ADCP capabilities to detect ocean areas with abnormally high currents would enable FRED to avoid travelling in gyre areas with high currents.

Conductivity, Temperature, and Depth (CTD). This instrumentation provides precise charting of the distribution and variation of water temperature, salinity, and density to better understand how the ocean environment affects the life residing within it. This instrument can readily be embedded on FRED to support science research of the physical properties of the water column at specified depths, location, and time. CTDs require frequent calibration and would be a standard part of FRED's preventative maintenance procedures.

Inertial Measurement Unit (IMU). This instrument can track a vessel's specific force, angular rate, and magnetic field using accelerometers and gyroscopes to detect changes in pitch, roll, and yaw. This instrument's functions are essential for guidance and control of unmanned systems, although they can suffer from accumulated error leading to vessel drift, being the variance of reported versus actual location.

Low-resolution Video Camera. This capability can enable FRED to send videos or photos via satellite to Clear Blue Sea's Mission Control Center and Website. With video, Clear Blue Sea can scan FRED's locale for visible plastic debris density, including sighting of ghost nets which FRED is designed to avoid given their risk of entanglement. Low-resolution video can also serve scientific research by more fully documenting plastic pollution in the gyres. Low-resolution cameras require far less power than high-resolution ones, important since FRED is solely solar-powered.

Recommendations. Based on a comparative assessment of alternative suppliers, recommended instrumentation for FRED embedding include the following:

- Vaisala's Weather Transmitter
- Scripps Institute of Oceanography's Miniature Wave Buoy (which includes an IMU)
- Teledyne Marine's or Sontek's ADCP
- Fondriest Environmental's or Valeport's CTD
- Go Pro's Low-Resolution Video Camera

In addition to the above commercially-available proven technologies, there is an additional not-yet-invented instrument that would critical to FRED success in performing ocean plastic cleanup. Since FRED will be navigating through thousands of miles of plastic to complete its duty, a crucial instrument would be one that measures plastic particles in the ocean. Although instruments exist to measure water turbidity, including amounts of dissolved clay, algae, and other microscopic organisms, there is no commercial instrument that measures clarity of water in terms of density of plastic particles.

An instrument with this functionality would enable FRED to capture scientific data on plastics in the ocean gyres, as well as sense how dense is the presence of plastic in its navigational path. An instrument that could measure the clarity of water, per plastics, would enable scientist to more accurately map out high-density areas of plastic within the Gyre so that FRED could focus on these locations for ocean cleanup.

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