Fondation Jacques Rougerie

Cesar HARADA, Protei Director

PROTEI: Open-Source, Shape-Shifting Sailing Robot to sense and clean the oceans.

The problems Protei is addressing.

Open-H20 is a growing international community of artists, engineers, marine biologists, naval architects, and academics, developing open-source technologies to explore, study and preserve the ocean. Since 2010, the Open-H20 team has collaborated to evolve Protei drones into sustainable vessels capable of collecting data in various marine environments and effectively cleaning the ocean.

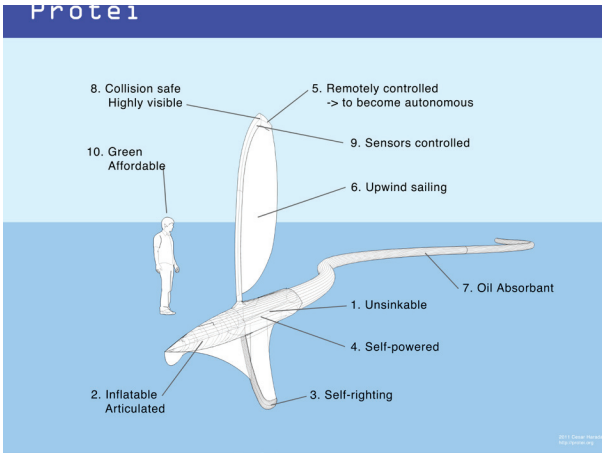

Fig. 1. Protei Technology Vision

Recent local environmental catastrophes, from the Fukushima Daiichi nuclear disaster to the Deepwater Horizon oil spill, underscore the need for multiple solutions to counteract the global consequences of theses disasters.

Oil Spills: The current use of skimmer ships, bacteria and fire to remove oil from marine environments highlights the necessity of advancing oil collection technology. These techniques are not effective enough to efficiently tackle the complexity of today's oil spills. Estimates show that the skimmer ships, often repurposed fishing vessels deployed by the US Coast Guard for the cleanup of the Deepwater Horizon oil spill, collected only 3% of surface oil. Skimmer ships are the most commonly used technology in oil spill cleanup, which demonstrates that there is a need for alternative technologies.

Plastic Debris: The Great Pacific Garbage Patch, a mass of plastic debris in the Pacific Ocean two times the size of Hawaii, is a consummate embodiment of anthropogenic pollution. Research on the photodegradation of the trash has found increasing levels of toxics throughout ecosystems and food chains, highlighting the importance of removing this detritus. Collecting this debris poses many challenges as often it is spread unevenly across large areas and mixed amongst marine life.

Radioactivity: The environmental impacts of the Fukushima Daiichi nuclear disaster continue to have global effects as radioactive pollution spreads across land and marine environments. The disparity in the results of the data provided by the Japanese government and TEPCO (Tokyo Electric Power Company) and that of local residents points to the demand for an independent agency to monitor radiation levels.

General Oceanography and Natural Reserve Monitoring: The lack of available surface marine data limits oceanographic studies. The most popular general oceanographic and climate-monitoring device is the ARGO, a network of about 3500 free-drifting profiling floats that provide mainly underwater data on the temperature and salinity of the ocean. However, ARGO gathers mostly subsurface data, and their location is uncontrollable, as passively drifting vessels. Collecting surface data

in a controlled manner would allow for greater insight into the long term effects that industries such as fishing and farming have on the health of marine ecosystems, as well as the causes behind phenomena like algal blooms and coral reef bleaching.

What Protei is

Protei is a seafaring surface vessel, constructed to carry research instruments and environmental clean-up equipment autonomously over long distances on the ocean via wind power. The project was conceived in response to inefficiencies in oil spill relief efforts, and frustration with the unsustainable research and design costs of current robotic oceanic drones. Protei's mission is to provide a locally accessible, economically efficient platform for the development of ocean-cleaning data collecting robotic drones. Our goal is to harness human innovation, technological ingenuity, and creative design to preserve the integrity of our natural resources.

One of the biggest obstacles to effective disaster prevention and clean oceans is the lack of international coordination and collaboration, as the diversity of methods for aquatic disaster relief is vast. Open_H2O wants to create effective remediation techniques through a collaboration platform to determine common evaluation criteria and foster relief efforts. In this way, Open-H2O and Protei will have a global impact.

Oil Spills: Protei drones are being designed to sense oil in water through infrared technology, detect leaks in oil drilling sites, autonomously coordinate clean-up efforts, and drag oil sorbent booms to absorb contaminants.

Plastic Debris: Through partnerships with interest groups such as Kaisei, a non-profit that leads ocean-cleaning expeditions, Protei aims to sustainably collect and discard the plastic debris contaminating oceans. By leveraging wind power, Protei can transport collection nets to and from remote ocean treatment plants, minimizing the environmental impact of ocean cleaning.

Radioactivity: Protei drones aim to facilitate real time offshore measurements of radiation levels, map the path of its spread, detect its activity along coastlines, and pinpoint hotspots of hazardous levels.

General Oceanography and Natural Reserve Monitoring: Protei's design allows the drones to be self-righting, unsinkable, collision-safe and hurricane-ready. The unique shape-shifting hull provides superior mechanical control and steering efficiency, maintaining momentum while making tight turns to tack back and forth across the wind. The ability of the drones to navigate rough waters in a variety of weather conditions while not disturbing natural environments allows Protei to provide reliable data.

Market Opportunity

Interest groups around the world are working to protect coral reefs, preserve sea life, and clean the coastlines. Unmanned vessels for cleaning contaminants on the water reduce health hazards to workers and allow boats to be operated during a storm. There is already a market for unmanned ocean cleaning solutions in the private and governmental sectors, which have developed devices such as the Liquid Robotics Wave Glider used by the Scripps Institute, the UC Santa Barbara's Groovy Drum Skimmer, and Ocean Therapy Solution's V-20 oil-water separating machines. However, these projects are cost prohibitive and inaccessible to local communities and grass-root initiatives.

In 2010, while helping with the oil spill relief efforts in the Gulf of Mexico, Protei founder Cesar Harada found that the general public is looking for better solutions to preserve the ocean. Local residents wanted to get involved in the cleanup efforts, but did not know how. Harada conceived of a fleet of

robotic oil collecting sailboats as a remediation tactic that would enable local communities to take a hands-on approach to marine disaster relief efforts.

Through Kickstarter, a website used by authors, film-makers and artists in search of project funding, Harada was able to raise $34,000 from 300 backers, exceeding his goal by 24%. This exemplifies the market viability and investor interest in Protei. With the backing, Harada assembled a team of engineers and built a large-scale prototype of the ocean-cleaning robot, which is evolving into a six meter industry ready vessel.

A 2011 research initiative through Stanford University's course in Global Entrepreneurial Marketing (GEM) determined there is a substantial market for Protei. A web survey administered to a random sample of global participants, and interviews with industry experts, including the head of the Stanford Oceanic Group, found that more than half want to use Open-H20 for research and education purposes.

Protei's fundraising success and market research confirms the need for an ocean-cleaning technology available in the public sector that is financially viable and globally scalable. Our technology fulfills this market need for a locally funded tool for hobbyists, scientists, and even kids, as an educational and informative platform, to raise awareness of the impact of oil and other man-made ocean disasters.

2010 - 2011: Crowd-funded - 300+ individuals and organizations have "backed" us on KickStarter
2011 - 2012 : Philanthropy - supporters (V2_ Institute for the Unstable Media, DNV)
2012 - 2013 : Sponsorship - individual sponsors, media exposure
2013 - 2014 : Grants - Scientific partners and universities
2014 - 2015 : Sales - customers and users
2015 - 2016 : Operations, data-collection, clean-up - local residents, companies, non-governmental organizations

Fig. 3. Sources of funding

Viability of solution and competitive advantages

As previously mentioned, there are a number of organizations developing oil-spill cleanup and oceanographic data collection technologies, a majority of which are proprietary organizations or governmentally funded ventures. However, these products are not as affordable, adaptable, or replicable as Protei. This makes the product much more economically accessible, and thus gives us a competitive edge as we enter the marketplace (*Fig. 2*).

As captured by the Stanford GEM research, the market landscape includes technologists, enthusiasts, students, research institutions, and sponsors. We have developed a number of strategies to build out our customer base, including social marketing campaigns, conference and symposia presentations, and strategic partnerships. Due to the open-source nature of this project, we have been able to develop relationships with other programs developing new technologies for do-it-yourself (DIY) fabrication of sophisticated hardware. Through sharing knowledge with organizations such as OpenROV, a low-cost telerobotic submarine that can be built with mostly off-the-shelf parts, and DIY Drones, the world's largest amateur unmanned aerial vehicle (UAV) community, Protei and Open-H20 have been able to build a strong business model using insight from these companies.

Protei's unique market position is due to the sailing vessels' shape-shifting hull. Its structure and locomotion is inspired by a deep understanding of the physiology and mechanics of how fish and birds use long tails to stabilize their bodies in the water and

air respectively. Our research and testing has shown that a flexible hull provides superior mechanical control and steering efficiency for a sailing robot. The innovation behind Protei's shape-shifting technology allows for efficient maneuverability while dragging a long and heavy payload such as an oil absorbing tail or garbage collecting net. This allows Protei to maintain stability at both low and high speeds, which traditional designs with rigid hulls and rear rudders are not able to do.

Project Timetable demonstrating product or technology's feasibility

Open-H2O is developing two sizes of drones. Protei_010, a one meter long boat that is scheduled for manufacturing in the fourth quarter of 2012, is ideal for sensing remote marine data. A six meter long boat, based on the structure of Protei_006, will be able to drag several hundred liters of oil or trash. We plan to manufacture the six meter autonomous ocean-cleaning boat by 2015.

The following timeline outlines the proposed research, prototype, and manufacturing plans for the above vessels:

September 2012: Protei_010 ready for manufacturing
December 2012: Protei_010 released as beta product
February 2013: Protei_010 ready for wide-release
June 2013: 6 meter manned prototype
June 2014: 6 meter manned beta product
October 2014: 6 meter autonomous prototype
October 2015: 6 meter autonomous product

Commercial Viability of Protei

The Stanford GEM marketing research project found ample enthusiasm for Open-H20's initiatives. Nearly all participants expressed interest in collaborating in some way with Open-H20 or participating in a workshop on the topic.

Additionally, Protei and Open-H20 will economically and technologically benefit from the increased concern for oceanic preservation, the Internet's capacity to facilitate the formation of connections, the momentum of the Open Source Hardware movement, the emergence of Citizen Science groups, and the rise in popularity of at-home, DIY fabrication with desktop 3-D printers.

Protei 1m	**Liquid Robotic Wave Glider**	**Repurposed fishing vessel**
Low cost ($100-500)	High cost ($200,000)	Super high cost ($350,000)
Open-source	Proprietary design	Proprietary design
Made from accessible materials	Made from expensive materials	Made from expensive materials
Uses renewable energy	Uses renewable energy	Not sustainable, environmentally destructive
Unmanned, operable during a storm	Unmanned	Cannot be operated during rough weather conditions

Fig. 2. Comparison of Protei to other products on the market

Our indexes of Success

Open-H2O has developed criteria to evaluate performance, design attributes, environmental-cleaning goals, and engineering targets for Protei. We use four thematic criteria to measure progress and success.

Environmental: Protei quantifies the number of tons-of-oil absorbed or plastic trash collected as well as the amount of usable and significant environmental data collected to determine the environmental impact of products.

Social: Social success is measured on the happiness of each project's crew and the community it serves. The greater social impact of Protei can be seen through improvement of social connections and increases in joint efforts towards environmental preservation.

Technological: Success is defined by the pace of evolution and the ability of new technology to maintain Protei's high quality and low cost objectives.

Profit

As Protei is classified as a B-Corp, success is determined by revenue generated and Protei's ability to maximize a positive environmental impact using those profits.

The progress and success of Protei drones are evaluated using the following technical criteria:

Environmental impact and efficiency; safety and limitation of potential hazards; unsinkability; self-righting capabilities and healing momentum; power sustainability; maneuverability; speed at different points of sail; operability in different water and current conditions; radius of tacking and jibing; Bollard Pull (pulling power); environmental noise reduction; resistance, turbulence, flow analysis (velocity prediction); material resistance to corrosion, fouling and mechanical stress; cost of production; ease of replicability and distribution; the ability to surpass barriers of local regulations, taxes, insurability; Open Source Software and Hardware standards; and quality of documentation and interoperability.

Additionally, scale and reach of Protei is measured by media mentions, prizes, exhibitions, academic partnerships, and fellowships for staff members. Our successful prototypes have gained international

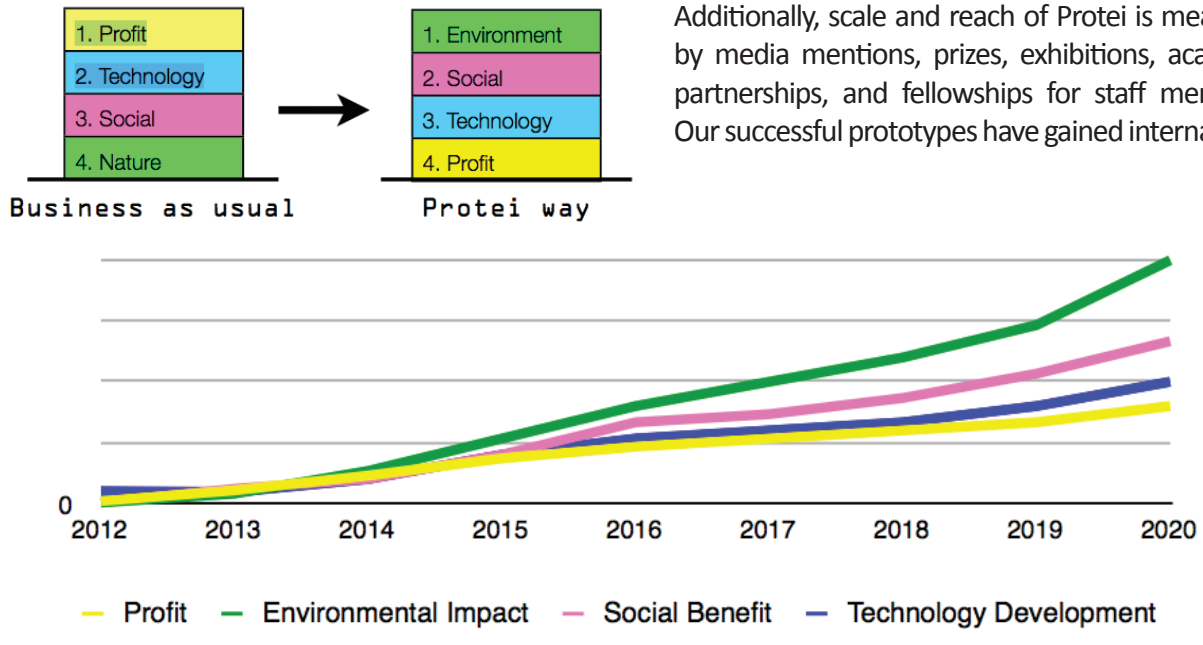

Fig. 4. Protei's business agenda

recognition for innovation, open-source design, and pluripotentiality to various fields of oceanographic research, waste reduction, and pollutant mitigation.

***Media mentions*:** TED, CNN, Huffington Post, Wired, The Guardian, Scientific American, Vogue, VICE, Motherboard, New Scientist, Good.is, FastCompany, Innovation Daily, Nature.com, Physorg, Hackaday, Zeilen, Bateaux, Treehugger.

***Prizes*:** ARS Electronica Hybrid Art Honorary Mention (2012); VIDA Awards for Artificial Intelligence and biomimicry; Fundacion Telefonia (Spain).

***Exhibitions*:** Protei has been featured in numerous exhibitions around the world (USA, Netherlands, Brasil, Berlin, UK, Ireland, Japan, Korea, Czech Republic, Turkey) at museums, art fairs, festivals, science centers, maritime exhibitions, and Maker Faires.

***Academic Partnerships*:** Protei has built strong academic partnerships with renowned universities, including Stanford University, MIT, ITP at NYU, TU/e Eindhoven, Syddansk University, Hongik University, Seoul, Goldsmiths University of London, and Southampton University.

***Fellowships*:** Cesar Harada became a Senior TED Fellow while developing Protei in New Orleans. He has presented Protei around the world at TEDx events.

Global Scalability

Open-H20's mission is to build a worldwide community of engaged participants that can take immediate action to solve local and global environmental issues. In joining the Open-H20 community, participants build, buy and deploy the products. Current marketing initiatives focus on word-of-mouth endorsements and Protei's ability to garner media coverage through community outreach programs, strategic partnerships and participation at industry summits. Print and online distribution of the Protei Handbook, which details the conceptual design and history of Protei as well as instructions for how to build Protei_006, aims to grow awareness for the drones in the marketplace.

Protei's emphasis on hands-on techniques and low cost production allows Protei to service the general public's demand for an affordable technology that is user friendly.

Open-H2O's commitment to Open-Source Hardware ensures that Protei's technology costs will remain minimal. Protei's business model is structured on the premise that members of the Open-H20 community will reproduce, improve, and deploy the technology. This community-driven momentum facilitates the production of drones, which would typically require tens of millions of dollars and many years of development, to be built at a fraction of the price at an accelerated rate. This ensures that they are affordable and can be easily reproduced, allowing Protei to grow the global community market share.

SOURCES CITED:

[1] Richard A. Kerr (13 August 2010). "*A Lot of Oil on the Loose, Not So Much to Be Found*". Science 329 (5993): 734–5.doi:10.1126/science.329.5993.734. PMID 20705818.

[2] "Deepwater Horizon Oil Spill." Wikipedia. Wikimedia Foundation, 06 Sept. 2012. Web. 10 June 2012. <http://en.wikipedia.org/wiki/Deepwater_Horizon_oil_spill>.

[3] Fountain, Henry. "*Since Exxon Valdez, Little Has Changed in Cleaning Oil Spills*." The New York Times. The New York Times, 25 June 2010. Web. 10 June 2012. <http://www.nytimes.com/2010/06/25/us/25clean.html?pagewanted=all>.

[4] E. Gernez, C.M. Harada, R. Bootsman, G. Levine, P. Keen. (2012, June) *Protei Open Source Sailing Drones: A platform for Education in Ocean Exploration and Conservation.* International Conference on Information Technology (ITHET) 2012.

[5] "NOAA - National Oceanic and Atmospheric Administration." NOAA - National Oceanic and Atmospheric Administration. N.p., n.d. Web. 10 June 2012. <http://www.noaa.gov/>.

The Protei Team

Open H2O

Protei