**PROCOPIO**: A Portable Robotic Observatory for Diagnosing Coastal Ocean Health for Human Well Being

## Summary

Our oceans host enormous biodiversity, provide multiple ecosystem

services, sustain vibrant economies, and play a significant role in

climate regulation, but are threatened by human activity and climate

change. We need a **sustained**, **persistent**, and

**affordable** data gathering capability to help us understand

and monitor how key processes such as acidification, hypoxia, toxic

blooms, pollution and erosion (amongst others) are impacting global

ocean sustainability and stewardship. In coastal regions, this is

especially important, because these areas mediate most of the

interactions between a significant percentage of the world population

and the oceans.

Urban population growth has exacerbated the pressures on the coastal

ecosystem. For example, resultant toxic blooms and oxygen depletion

have had deleterious effects on fisheries and other critical resources

that coastal populations depend on, while also impacting human

health. Furthermore, extreme weather events induced by climate change

will only hasten the worsening of water quality in these areas because

of enhanced runoff, coastal erosion and storm surges. An integrative

sea management approach and the protection of natural capital and

marine ecosystem resources can only be achieved with the help of

coordinated observations from space, aerial, surface and underwater

robots guided by Artificial Intelligence (AI) while providing

continual and reliable oceanographic data.

Many large telescopes point toward the heavens, but no such

observational system exists for looking at and into our oceans. Our

mission is to build a portable, robotic observatory for observing and

managing the health of our endangered coastal waters which can be

rapidly deployed anywhere in the world (Fig. 1).

## The Idea

**PROCOPIO** (A Portable Robotic Observatory for Coordinated Oceanographic

Observations) will be a modular system with bespoke approaches related

to water quality in the world's coastal zones with mega-cities. It

will integrate state-of-the-art hardware including a small satellite

(SmallSat) constellation, in-situ air, surface and underwater vehicles

with software to control and visualize the information gathered. With

frequent revisit times over a region by a constellation of \smle's,

coupled with latest smart and adaptive AI techniques, robots can

provide opportune solutions in near real-time.

Stakeholders across governments, industry, science, nonprofits and

citizenry will make use of layered views ranging from basic visuals to

the complex queries needed for effective management of resources and

increased scientific knowledge.

## Why now?

With the onset of a climate crisis, the oceans are changing rapidly in

ways we do not understand. In the report, ``Global Marine Trends

2030'', Lloyds Register predicts that by 2030, the coastal ocean will

be ``almost unrecognizable''. There is an urgent need to develop and

deploy new smart observational methods to provide information at

scales that matter to the 600 million people living along the coast

within 10 meters of the sea level. Predicting change and providing

early warning of hazardous events is essential for the well-being of

an increasingly vulnerable coastal ecosystem. It is also in line with

the goals of the 2021-2030 UN Decade of Ocean Science for Sustainable

Development.

## What is the novelty?

**PROCOPIO** is different from traditional methods for observing the coastal

ocean, which are inefficient, not cost-effective, too sparse in space,

too sporadic in time or too localized. There is poor integration

between the various measurements, especially between those made

in-situ and those made by satellites to produce actionable knowledge.

**PROCOPIO** leap-frogs current methods by delivering predictive modeling,

learning and analytical capabilities, which are supported by AI and

visualization techniques that are non-existent in other interventions.

With **PROCOPIO**, the density and diversity of observations will change by an

order of magnitude, the temporal scales of coastal observations will

change from weeks (for traditional shipboard sampling) or days (for

existing satellite data) to *hours and minutes* with the

provision of real-time information. Techniques in AI will adapt the

information depending on the kind of user, from well-informed

scientists, to the lay person curious about how beach conditions might

impact her leisure.

In the process of providing actionable knowledge, **PROCOPIO** will enable new

modes of management and new understanding about coastal ocean

processes in ways simply not possible before. \pro will allow citizens

to develop critical understanding of the rapid change taking place in

their Urban Seas and to ‘connect the dots’ between human activity and

the effect on the environment around them. Citizen scientists will be

engaged in generating new observations and be able to derive new

knowledge about how ocean processes work. Scientists will be able to

pose (and answer) new questions that could not have been asked

before. And policy makers will have the tools to make informed

decisions in time scales that matter, while developing truly

integrative policies on ocean sustainability and

stewardship.

## Milestones and Deliverables

* Architectural design of the system with a focus on software integration, building hardware and design and testing of Machine Learning systems for ocean model prediction (Year 1)
* Use of existing remote sensing data products (e.g. ESA and NASA

data products), integration of ocean models and building of AI-based adaptive control systems for aerial, surface and underwater vehicles. (Years 1-2)

* Incremental at-sea testing of adaptations of robotic vehicles

and integration of control with ocean model predictions (Years 2-3)

* Demonstration of the integrative software system using existing

aerial, surface and underwater vehicles from the Univ. of Porto and

targeting a single extensive use-case (e.g. from aquaculture, oil &

gas, others) to monetize this effort (Year 3)

* Upscope demonstration to include larger data sources for

physical ocean properties, including from buoys and synthetic data

sources (e.g. surf forecasts). If SmallSat budget permits, begin design

and build of satellite elements including payload elements (Years 3-4)

* SmallSat launch and operation begins. Validation of satellite payloads and calibration of sensor performance (Years 4-5)
* Pursue European Union and other large funding schemes to fund a larger constellation of SmallSats to demonstrate the full capability in a coastal meso-scale (~ 50 Km2) ecosystem (Years 3-5)

## Resources Needed

The **PROCOPIO** team comes ready with the aerial, surface and underwater

vehicle platforms, together with the extensive suite of software to

provide coordinated observations in the coastal ocean. We will build

custom sensors keyed towards important ocean variables integrated into

a 'train' of SmallSat platforms. Such a system working closely with the

in-situ robots will provide a clear consistent set of data

products. This data will be integrated to provide actionable

information to policymakers on the ground as also society in general.

We estimate the total project cost to be about ~$63.5 Million

over a period of 5 years (3 years for development and 2 for

operational deployment). We can also envision the project to be built

up incrementally.

* an initial focus on the software build, integration and test with available robotic vehicles in small scale demonstrations ~$5-$10 Million for 2 years.
* acquisition of robotic vehicles, buoys, floats and a range of sensors as payloads for these in-situ vehicles, their integration, deployment and demonstration at increasingly larger spatial and temporal scales for ~$20$-$30 Million for 2 years.
* acquisition of funds for a suitable at-scale design, build, test, launch and operation of a SmallSat constellation with a range of scientific payloads for biological and physical oceanographic measurements for ~$25 Million for 2 years.

Incremental build and evaluation of this concept can allow us to

attract a wide range of public and private sponsors in the US and

Europe. Equally, we will consistently work with our collaborators in

the Portuguese government to leverage expensive ship time for testing,

and other potential in-kind contributions from Portuguese and Spanish

resources.

For long-term operation and viability of this system, multiple

outcomes can be envisioned. First, with the experience garnered in

testing and fielding the system, a commercial spin-off of all or parts

of the technology could be very possible. If parts of the technology

could be monetized and spun off to other companies, **PROCOPIO** can then hold

the IP while continuing to work on research outcomes after the 5 year

term. Second, the project can itself look for contracts from

mega-cities and governments or their agencies to provide a

software-as-a-service model and be able to subsist as a not-for-profit

enterprise with unique expertise. Should other private or public

funding sources be available, those would also be carefully evaluated

at this time. at this time.

## Governance

The governing board of **PROCOPIO** will consist of prominent strategic

advisors from the US, including stakeholders and funders. In addition,

the project principals will be aided and advised by a scientific

advisory board consisting of technologists, ocean going scientists,

ecologists and policy makers from the US, Europe and targeted coastal

states.

## The Team

**PROCOPIO**’s inter-disciplinary team of seasoned researchers (see bio's

below) from the universities of Columbia/US, Porto/Portugal and

Vigo/Spain have worked in all the major oceans, fielded tens of robots

at sea simultaneously, designed/built/flown and operated multiple

SmallSat’s and complex systems in the deep sea and deep space.