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

## The Idea

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 ~~along what is now called the ``Urban Sea''~~. 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 ~~of Urban Seas~~ 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).

**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 (SmallSats) constellation, in-situ air, surface and underwater vehicles with software to control and visualize the information gathered. The use of SmallSats and smart robotic technologies

reduces deployment time to provide opportune solutions and

consequently, leverages the latest techniques in AI, Robotics and

software engineering.

**PROCOPIO** will provide information for water quality measurements suitable for

lay persons who can obtain and interpret near real-time (hours) data

visualized at spatial and temporal scales to provide actionable

information to deal with coastal pollution, erosion, toxic waters and

sediment laden plumes.

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.

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. **PROCOPIO** will allow citizens

to develop a critical understanding of the rapid change taking place

in their coastal environment and to ‘connect the dots’ between human activity

and the effect on the ecosystem around them. Citizen scientists will

be engaged in generating new observations and new knowledge. 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.

With its integrative open-source framework connecting robots, services and users in a seamless manner, **PROCOPIO** will serve as a replicable blueprint for ocean

observation in targeting integration, synthesis, cost-effectiveness

and scalability. It for needed for 21st century decision making.

## 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 and also society in general.

Although we estimate the total project cost to be ~$63.5 Million

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

operational deployment), as milestones are met in the first two years, **PROCOPIO** is likely to attract funding from public and corporate sources.

**Milestones**

* Architectural design of the system with a focus on software integration and use of existing remote sensing data products (Years **1–2**)
* Demonstration of the integrative software system using existing aerial, surface and underwater vehicles from the Univ. of Porto and targeting use-cases such as aquaculture to monetize the work (Year 3)
* Outreach to the European Union and/or other European funding schemes to fund 2--3 SmallSats to demonstrate the full capabilities in a coastal ecosystem (Years **3–5**)

We will also 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. In doing

so, the startup needs could be substantially reduced; we estimate then

the need for about ~$5--$10 Million over the 3-year development period.

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 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.

## 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.