**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 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 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.

Natural events such as storm surges, tsunamis and upwelled waters

impact such mega-city coastal communities in addition. Turbulence in

the upper water-column with potential injection of nutrients, either

from the benthic or open ocean waters, can often result in sudden

outgrowth of harmful algal blooms, or stirring up human-induced

pollution in such coastal areas.

In both human and nature induced events, the resulting mix can make it

unsafe for any form of human activity often with no obvious and

expected visible sign of near and present danger to local communities.

However, the consequences can reverberate with mass scale die-off of

marine life, poisoned shellfish and coastal wildlife and as well as

causing neurological damage or fatalities to the human population on

consuming seafood or using beaches for recreation.

Current forms of monitoring are based on sensors (if present) spaced

well apart, periodic human-made measurements that can be impacted by

harsh weather and which typically sub-sample such dynamic coastal

environments.

**PROCOPIO** 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 information derived

from these assets. 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. Coordinated perspectives across different

synoptic spatial and temporal scales in turn will provide a

hyper-realistic situational assessment to stakeholders including those

who drive policy making for human health.

In the report, “Global Marine Trends 2030”, Lloyds Register predicts

that by 2030, the coastal ocean will be “almost unrecognizable”. As we

enter the United Nations “Decade of the Ocean”, **PROCOPIO** will broaden and

deepen knowledge that will aid and augment global ocean sustainability

and stewardship, and the management of our Urban Seas.

## Why Now?

The oceans cover more than 70% of the earth's surface. The base of

the human food-chain starts with tiny phytoplankton which generate the

oxygen for every other breath we take. With the onset of a climate

crisis, the oceans are changing rapidly in ways we do not

understand. 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, including poor water quality, tainted fish stocks and

intensifying coastal erosion, 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.

By leveraging rapid advances in technology, **PROCOPIO** will field an

innovative system of small satellites and robust autonomous in-situ

platforms for obtaining unprecedented views of coastal oceans and

atmospheric and land interfaces. It will aid in the understanding and

monitoring of coastal waters so that they can be explored and utilized

in a sustainable and informed manner.

**PROCOPIO** will leap-frog the traditional incremental and siloed methods in

ocean observation by leveraging modern computational methods in data

science, autonomous robotics and smart sensors. 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.

## 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

for 21st century decision making.

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 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 new

knowledge. Scientists will be able to pose (and answer) new questions

that could not have been asked before. 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. **PROCOPIO** will serve as a replicable blueprint for Ocean

observation in targeting integration, synthesis, cost-effectiveness

and scalability.

While some coastal ocean observatories use a limited number of robotic

assets or remote sensing data, **PROCOPIO** is unique in the range and

diversity of how these sensors are deployed, how data is integrated

and synthesized, and how citizen engagement is used to improve the

value of the output. Additionally **PROCOPIO** provides an integrative

open-source framework to connect robots, services and users in a

seamless manner that is both scalable and replicable, providing a

blueprint for other initiatives worldwide. It leap-frogs current

methods by delivering 21st century predictive modeling, learning and

analytical capabilities, which are supported by AI and visualization

techniques that are non-existent in other interventions.

## 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.

* 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)
* Go after 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 need.

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.

## 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.