The Anthropic Odyssey

Macro-Imagineering Waterworlds

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Abstract: This macro-imagineering essay discusses the concept of settling small productive colonies on oceanic planets like Earth in dimensions and relative positions with respect to their primary stars, and particularly endowed with hydrogen-rich atmospheres. The primary objective is to indicate that, under certain terrestrial and hydrologic circumstances, no terraforming would be necessary for the establishment of anthropic habitats, because the main resources necessary for survival can be obtained from the available liquid water. From a thermodynamic perspective, colonies could be maintained by deriving energy transferred from the oceans through the different transient processes highlighted in this study, combined with energy received directly from the primaries. The conjecture posited here presupposes an advanced stage of scientific and technological development capable of effective interstellar navigation in a solar neighborhood of at least 50/100 light years distant.

Key words: Macro-imagineering, Waterworlds, Transient technology, Liquid water.

Resumo: Este ensaio de macro-imagineering discute a ideia do assentamento de pequenas colônias produtivas em planetas oceânicos semelhantes à Terra em dimensões e posições relativas com respeito às estrelas primárias, e particularmente dotados de atmosferas ricas em hidrogênio. O principal objetivo é mostrar que, nestas circunstâncias, nenhuma terraformação é necessária para implantação dos habitats antrópicos, uma vez que a partir da água líquida disponível é possível obter os principais recursos necessários à sobrevivência. Numa visão termodinâmica, as colônias são mantidas com a energia transferida dos oceanos por meio dos diferentes processos transientes apontados no estudo, combinada à energia recebida diretamente das primárias. A conjectura pressupõe, evidentemente, um estágio de desenvolvimento científico e tecnológico capaz de navegação interestelar efetiva em uma vizinhança solar de pelo menos 50/100 anos-luz.

Palavras-chave: Macro-imagineering, Mundos oceânicos, Tecnologia transiente, Água líquida.

1. Introduction

Terraforming has been a theme much more akin of science fiction than of futuristic realism based on known science and limitations imposed by laws of nature [1]. Terraforming an alien world can be an aspiring action of macro-imagineering as part of humanity's dream of greatness. Such a noble notion conveys almost unlimited power of exploration and pioneering spirit when it is associated with a less dreamy technology of interstellar travel by allowing space journeys that are consumable in a few decades, or even in a few years. Browsing the web shows many articles that deal with near-light-speed travel theories. But, as the Nobel laureate physicist Kip Thorne has pointed out, “it will take many centuries for humans to make any of those ideas real” [2]. In actuality it is not credible that humans will achieve such feats in one or two centuries. The travel distances to be overcome are unimaginable and the challenges of biological adaptation are colossal, to say the least, and some appear to be insurmountable. However, it is human nature to want to go further. If the same "luck" persists that brought together all the fortuitous factors that culminated in the formation of the Earth and its singularly giant moon, and established the auspicious conditions for the emergence of life and, later, including the human species, one might logically conjecture a remote future where humans will tend to seek survival under the starlight of alien suns, after consuming all the resources available in this solar system. Everything seems to suggests that, if humans outlive their own vices, at some point in anthropogenic civilization may dominate a small portion of deep space with a few colonies spread across a 50/100 light year radius from our primary star. This perspective focuses on educated guesses while remembering Arthur Clarke’s visionary spirit and many speculations. What is interesting about these fun conjectures is the fact that, except for the exotic technology required for interstellar travel, the establishment of clean energy colonies in other star systems with ocean worlds is based on common, non-exotic technologies.

Because water is an essential ingredient for life as we know it, planets with large masses of liquid water are the central attention of astrobiology, although there is the caveat where an overabundance of water — whether fresh, brackish or salty — points in the opposite direction of life sustainability. This assumption is conditioned by water-rich planets with H_2-rich atmospheres that are referred to as Hycean worlds [3], which include large ocean worlds with habitable conditions underneath H_2-rich atmospheres. The presence of large water volumes is inferred from the combination of mass, density, and planet physical diameter. For instance, the low density of the twin planets **Kepler-138 c** and **Kepler-138 d** (both located in Lyra constellation at 218 light-years away, twice Earth's mass and about half of Earth's density) indicates that they must be composed mainly of water. It cannot be assumed that there oceans are similar to those on Earth because it is possible that they may be a water phase occurring at high pressures, the so-called supercritical fluid (Figure 1). Additionally, earth-sized planets orbiting the very cool red dwarf **TRAPPIST-1** (Figure 2), around 40 light-years from Earth, could be watery [4]. But, our approach does not concern the plausibility of the existence of life, a subject that has already been widely discussed by Serpa [5], Serpa & Cathcart [6] and Serpa [7], but rather focuses on the plausibility of the establishment of specific colonies in aquatic worlds that one might term “aquawelts”[1].

This essay extends macro-imagineering beyond terrestrial borders and ventures into extra-solar domains in an effort to project an alternative remote future, should humanity survive itself. While we remain far from such achievements, it is hoped that this work will motivate more projects and investments in simple and clean energy transformation technologies, exploring the technical potential of the different ocean energy processes that shall vary accordingly to further developments.

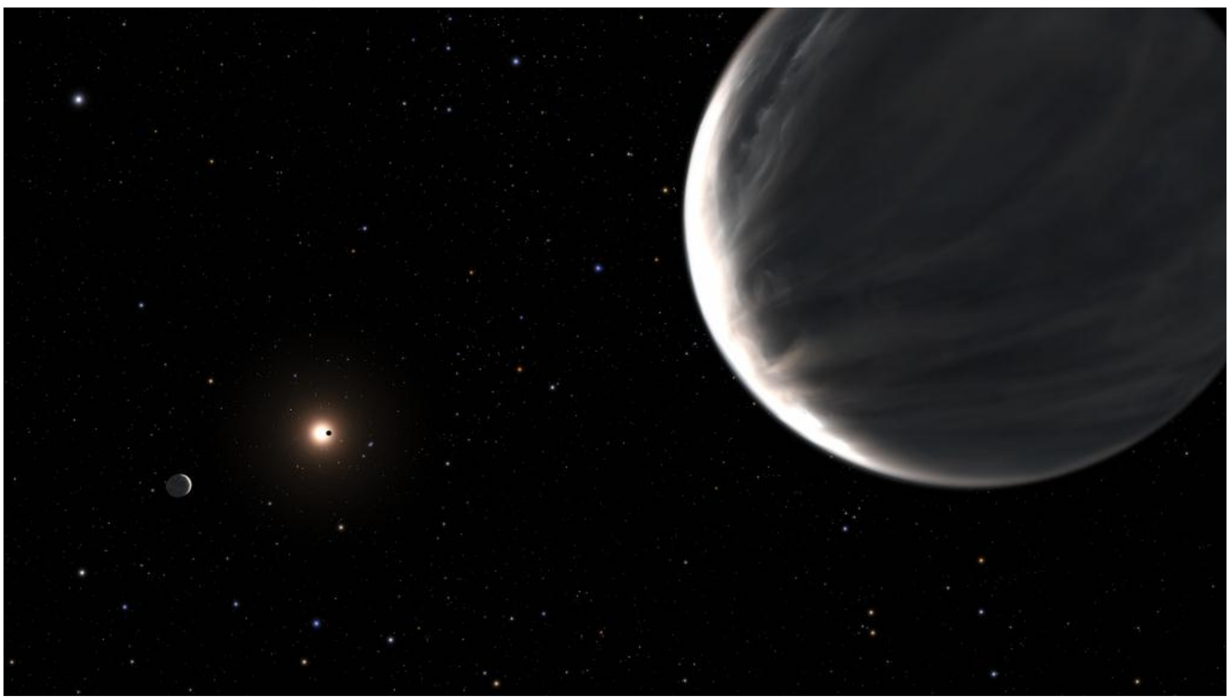

Fig 1. An artistic illustration of Kepler 138 d with Kepler-138 c at left, and Kepler 138 b transiting its parent star (credits to NASA, ESA, and Leah Hustak (STScI)).

[1] A combination of ‘*aqua*' for water and ‘*welt*' from the German for world.

Fig 2. An artistic vision of the TRAPPIST-1 system (credits to NASA, Jet Propulsion Laboratory).

2. The search for Waterworlds (Aquawelts)

The discovery of thousands of exoplanets has triggered all types of important researches and simulations to support the detection of atmospheres and the determination of the surface characteristics of the orbs. Overcoming uncertainties in this field, however, remains a challenging mission, despite the recognized progress of recent years.

Particularly, the detection of global liquid water surfaces, involving more than the combination of mass, density, and planet physical diameter, necessitates the establishment of other critical parameters in order to draw consistent and reliable conclusions because these observations involve some indirect assertive routes. An interesting and straightforward approach helping to identify exo-oceans was based on simulations of flux and/or polarization measurements of the light from the parent star reflected by exoplanet surfaces at wavelengths from 350 to 865 nm. This assumption supposes an ocean surface with waves composed of Fresnel reflecting wave facets and whitecaps [8]. Scattering within the water body is included. Their investigation started from a light column vector defined by

$$\mathbf{F} = \begin{bmatrix} F \\ Q \\ U \\ V \end{bmatrix}, \qquad (1)$$

where F is the total flux, Q and U are the linearly polarized fluxes, and V is the circularly polarized flux. The researchers assumed that incident starlight on the planets was unidirectional and unpolarized. The reflected starlight is polarized when scattered by gases, aerosol, or cloud particles through the planetary atmospheres and/or by reflection off the surfaces [8]. The degree of polarization of the reflected starlight was defined as

$$P = \frac{\sqrt{Q^2 + U^2}}{F}, \qquad (2)$$

where V is ignored because it is expected to be very small. The researchers performed the simulations covering the planetary disk by a grid of pixels, summing the fluxes reflected by each of the N pixels that are illuminated by the parent star. Influences of the ocean color, clouds and wind speed were considered. Detailed descriptions of the math are available and easily understandable in reference [8].

Those computer simulations provide an overview of what can be expected from the observations according to the theoretical background developed. Increasingly sophisticated orbital telescopes like the James Webb promise observations whose accuracy will take us closer to the reality of the neighboring worlds that intrigue us and instigate our macro-imagineering.

3. A realistic approach to exocolonies

Oceanic planets dimensionally similar to Earth and relative orbital position are particularly attractive for the settlement of small scientific colonies, strategic support star bases, and technological development centers. This type of situation is especially attractive if planets are comprised by an underlying rocky core. This kind of situation obtains precisely because the energetic foundation of anthropic activities in such worlds is easily discovered in observable hydro-dynamics of the ocean, this subject is well known in its connections with solar energy, which has provided a physical basis for the rise of clean technologies that are simple to implement. More than that, hydrogen processing and the direct use of thermal energy provided by the primary star are essential complements to battery charging system. Nothing exotic is required. It is not necessary to terraform a waterworld (aquawelt) for such endeavors. All that is required in environmental terms is a suitable star, oxygen, and hydrogen, where daylight and whatever kind of water is present. These colonies could form networks of laboratories, accommodations, and various facilities, forming small floating cities, processing water desalination, hydrogen, and other atmospheric components for various purposes (Figure 3).

Fig 3. The network of a small floating power city (credits to https://www.freepik.com).

Fig 4. Power plant with mechanical arms to convert wave kinetic energy (credits to https://www.freepik.com).

Based on what is known from experience with Earth's Ocean, in a typical Earthly waterworld (aquawelt), without obstructing landmasses, there are five different main oceanic sources that can be used to implement transient technologies to perform useful work:

1) Waves on the upper surface of the oceans created by transfer of wind kinetic energy to water (Figures 4 and 5);
2) Ocean Thermal Energy Conversion (OTEC), which has been detailed by Serpa [9], based on temperature differences between stellar thermal energy stored in upper ocean layers and the coldest layers around 1,000 m below. In order to operate an OTEC power plant, a minimum temperature difference of 20°C (Figures 6 and 7) is needed;
3) Ocean currents driven by wind (Figure 6) and associated with inertial effects (Coriolis forces);
4) Tidal rise-and-fall derived from the gravitational interactions within the planet-star system, or, planet-moon(s)-star system if that is the case (also Figure 6).

Although there is substantial uncertainty in ocean energy's technical potential, to take an idea of the energetic power of the ocean motion, Krewitt *et al*. [10] reported (for 2050) a global technical potential of 331 EJ/yr that is predominantly derived from OTEC (300 EJ/yr) and wave energy (20 EJ/yr). This is questionable, of course, but based on literature searches, it appears to be the most realistic approach in the context of current technological development.

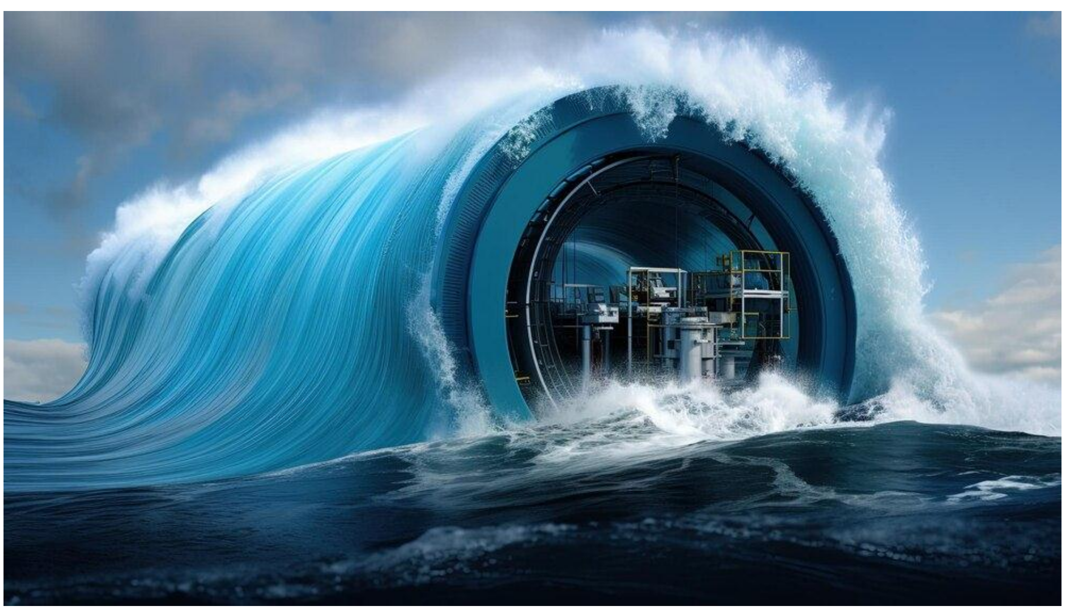

Fig 5. Ocean energy system for wave power generation (credits to https://www.freepik.com).

Fig 6. Transient towers to use both kinetic energy sea currents and OTEC operation (credits to https://www.freepik.com).

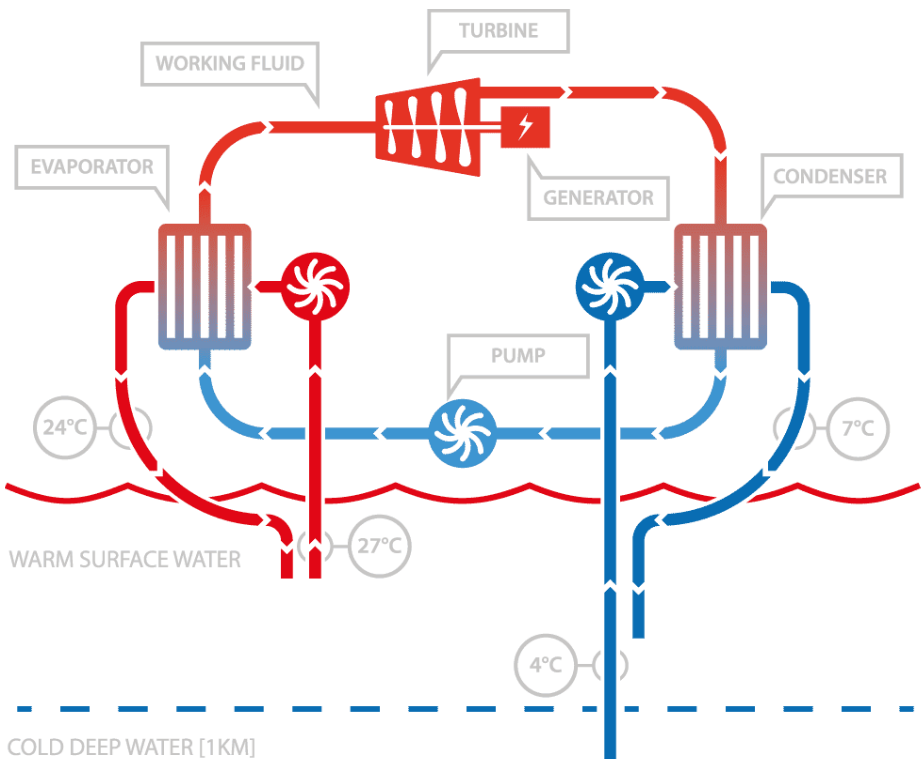

Fig 7. Basic scheme of an OTEC system (credits to https://globalotec.co/what-is-otec/).

Thermodynamics is the physical science of economy and efficiency par excellence. For this reason, the cost-effective supply of clean energy provided by OTEC systems is extremely attractive both for its obvious advantages in ecological and environmental savings and for its easy-to-apply operating principles based on the availability of energy originating from the primary star (most of the time a red dwarf is expected). Requiring less land than other renewable energy technologies, OTEC plants present immense potential for generating useful energy, perhaps even greater than that of other renewable sources. They can even be implemented on floating vessels or platforms (Figure 8).

Aswad *et al.* [16] summarized and applied the approach of Uehara and Ikegami [17] to simulate and calculate the power generated from the turbine in an OTEC system in Bali Sea accordingly two fundamental equations:

$$P_G = m_{WF}\eta_T\eta_G\left(h_1 - h_2\right), \qquad (3)$$

the turbine power equation, where P_G is the generator power (MW), m_{WF} is the mass flow rate of the working fluid (kg/s), η_T is the turbine efficiency = 0.85, η_G is the generator efficiency, and $h_1 - h_2$ is the decrease in adiabatic heat between the evaporator and the condenser shown in Figure 7;

$$P_N = P_G - \left(P_{WS} + P_{CS} + P_{WF}\right), \qquad (4)$$

the corresponding net electrical power equation, where P_N is the clean electric power (MW), P_{WS} is the warm sea flow pump power, P_{CS} is the cold sea water pump power, and P_{WF} is the working fluid pump power (see Figure 7).

Substantial attention is given in this essay to the OTEC system for obvious reasons of practicality and economy, not precluding the combined use of the other forms of clean energy production listed above. As can be concluded, using temperature gradients between the sea and the deep sea in the tropics of an earthly oceanic planet, the production of electrical energy on a large scale is perfectly plausible, as is furthermore proven by the simplicity of the principles involved and the extensive literature known on the subject.

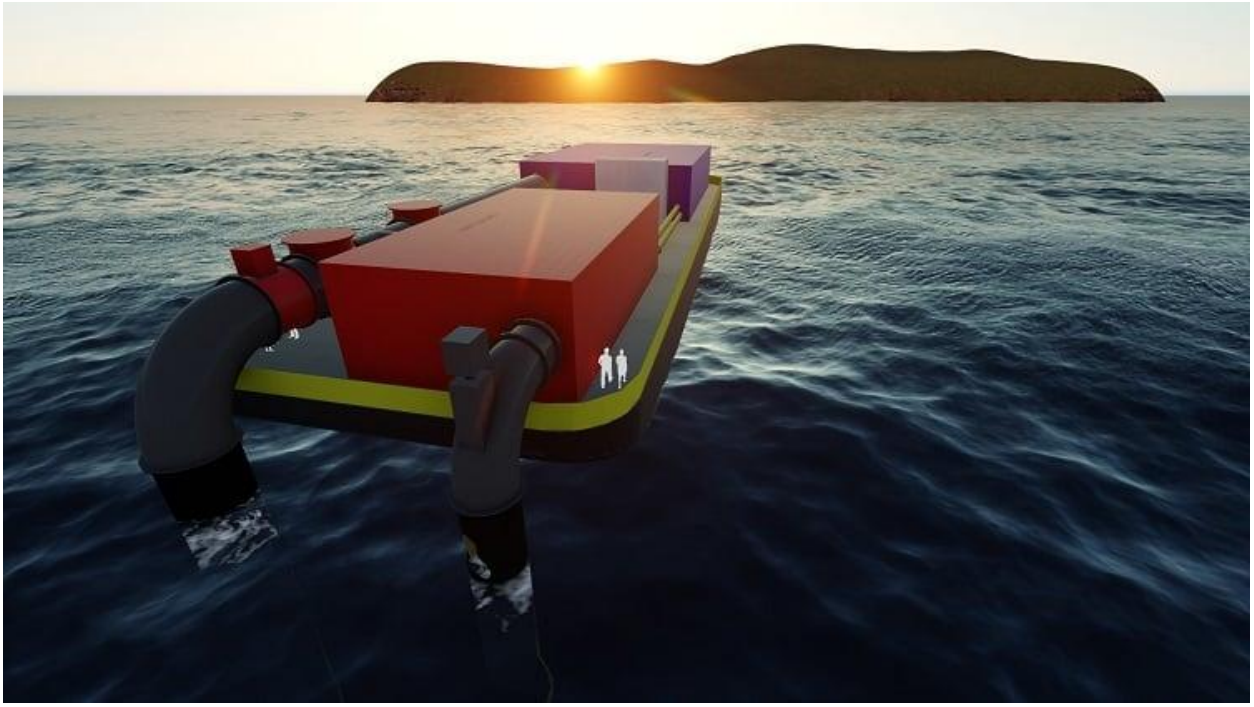

Fig 8. An OTEC system housed on a floating vessel (credits to https://maritime-executive.com/).

4. The Earth Example

Macro-imagineering's many published proposals for large-scale geographical technical interventions on the Earth have ignited modern-day considered thoughts about potential implications for global governance. However, it was the masterful geoscientist Rhodes W. Fairbridge (1914-2006) who vigorously promoted the concept that the solar system regulates Earth's basic climate regimes [11]. Governance, always an iffy and unceasing attempted effort, will soon be made more effective by the inauguration of a digital twin of planet Earth's Ocean [12]. Earth's tidal forces, an incessant flux of motionful seawater, are connected to solar and lunar rhythms that inexorably shift millions of metric tons of seawater and materials–at high speeds. Geoscience experiments led by Macro-imagineering may be the intellectual discipline that venerates real-world Earth and far-distant similar Earth observation most seriously [13].

While in limited circumstances technology's development can seemingly decouple society's economic growth from some oceanic impacts, but such is not usually the case. Since 2017, the SEABED 2030 mapping effort has been undertaken to chart the entirety of the world-ocean's floor. It has so far achieved about a ~25% mapping outcome. (Importantly, that is the equivalent of being fully aware of just ¼ of your home's multiple rooms!) Nevertheless, as Andrew Goudie indicated in his 2023 book *Landscapes of the Anthropocene with Google Earth*, the opaque and deep world-ocean is becoming more clearly defined and intensely studied by experts desiring to learn its factual elements with increasing accuracy. So, it is obvious that some near-term future author will need to pen *Seascapes of the Anthropocene with Google Trappist-1*.

Earth-orbiting satellites, remote imagers, have already shown how geographically extensive is humankind's industrial actions on the world-ocean [14]. Extending that view, others have described the many potential intrusions on and in the world-ocean that are technically possible in the future near-term [15]. As arm-chair spectators and speculators, we cannot add much to these two documents except to say that caution must always be exercised to all interference with the circulation of the Earth's world-ocean, its living and inorganic contents, as well as its outstanding beauty!

5. Conclusions

This essay can be seen as a natural consequence of the macro-imagineering that has been widely discussed in several editions of *CALIBRE*, something that has already become a mark of boldness and modernity of the thinking minds dedicated to the topic. Despite the focus on a distant hypothetical future, the technologies discussed are classic expressions of anthropogenic activity upon the laws of Nature with practical purposes, configuring highly feasible technical suggestions for present-day energy conversion and cleaner production here on our suffering homeland planet, and, in prospective centuries, on the aquawelts that we colonize. In current global circumstances, it is unwise to make predictions for the next centuries, or even for the next fifty years. Devastation is accelerating and profit interests are rampant. In the escalation of environmental destruction, the voices of positive transformation are often drowned out by the fanfare of pathetic consumerist ideologies and technological futility. The future of humanity is unknown, but we can reduce the spectrum of possible negative outcomes if we focus our efforts on concrete objectives for the survival and good of the species *Homo sapiens sapiens*, not on futile and immediate lucrative goals that could result in planetary ecocide.

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