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"Green cables" – Development, opportunities and legal challenges: Part I

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ABSTRACT
Modern submarine cables, known for their applications in telecommunications and connectivity, are currently being explored for possible applications in marine environmental monitoring by virtue of advancements in the integrated sensors and repeaters that can be installed on these cables at a mere additional outlay of 5–10 per cent of the total system deployment cost. These submarine cables are thus providing a sweet alternative for use in marine scientific research and are referred to as 'telecom-marine data cables', 'SMART cables', or simply 'green cables'. However, a few obstacles exist in their usage, as the submarine telecommunication cables have been granted unique rights and freedom by UNCLOS while data gathering through marine scientific research is dependent on national restrictions and has been left undefined in UNCLOS. Since the on-going effort of using these cables for dual use is being progressed without addressing the associated legal-regulatory aspects, there exists a need to revisit the existing legal regime for these emerging green-cables. In this two-part article, while part I will deal with the opportunities for development of 'green cables' part II will deal with the associated legal challenges and possible efforts to address these challenges.

KEYWORDS
Telecom-marine data cables; SMART cables; green cables; Marine Scientific Research; UNCLOS

Introduction

Understanding the deep ocean is imperative in order to avoid natural calamities and forecast changes in climate, which in turn requires monitoring of the ocean. While it is possible to monitor the ocean surface using satellites and ships, and the ocean interior, (up to a limited depth), employing floats, Argo, gliders, drifters, and acoustics, there is limited technology available to monitor the seafloor and collect the requisite data for this part of the ocean. Today, it is an accepted fact that many of the Earth's most fundamental activities such as earthquakes, its magnetic field, and other ongoing geophysical processes often originate and occur beneath the ocean. However, deploying equipment on the seafloor to measure these fundamental and planet-shaping events is becoming difficult due to challenges such as the unavailability of research ships, associated costs and time

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for measuring data on the seafloor, and, the lack of sunlight or availability of a continuous supply of electricity to power the tools that might be involved in such research. This inability to map the seafloor continuously limits the measurement of long-term geophysical data from the seafloor forcing scientists to rely on snapshots of what is happening in the ocean. This is like trying to monitor the security of a huge compound with snapshots of only the main access gates taken at predefined time intervals.

To overcome these limitations, over the years, scientists, with the help of the technology available to them at the time, have designed *underwater observatories*[1], *seafloor observatories*[2] and the *ocean observatory initiatives.*[3] Despite the use of technological advancements such as communication, robotics, computers and sensor technology to collect seafloor data, these observatories have limited reach due to non-availability of electricity to power the equipment in excessive water depth, and, at times, due to their physical distance from any land mass. This resulted in a new generation of scientific *cabled ocean observatories,* conceived by delegates at a workshop organised jointly by the International Telecommunication Union (ITU), the World Meteorological Organisation (WMO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO in Rome in September 2011;[4] ignited by a letter to the journal Nature,[5] written by climatologist and oceanographer Yuzhu "John" You of the University of Sydney in 2010.[6]

These cabled ocean observatories either use *existing* submarine telecommunication cables provided with sensors to measure key variables such as water temperature, pressure and acceleration on the ocean floor; or, *new* submarine cables laid for the dual purpose of telecommunication and data gathering. Such submarine cables are often referred to as "telecom-marine data cables", "SMART (Scientific Monitoring and Reliable Telecommunications) cables",[7] or simply "green cables", where a green cable system is defined as a fibre-optic submarine cable system equipped with sensors at regular intervals along the entire length of the cable. The ability to measure environmental conditions in the deep ocean gives the system the name "green". The aim of developing a green system is to incorporate sensors in the repeater housing, so as to avoid the cost of building a dedicated cabled ocean observatory.[8]

Though some suppliers have shown interest in the manufacture and delivery of these dual-use cables,[9] there are obstacles that remain in putting them to use, the biggest of which is identifying an entity to fund these cables, and, allocating the rightful ownership of the data collected by these cables – the Coastal States, the Researching agency, or the telecommunication companies. Yet another obstacle, that is in no way smaller than the others, is the legal aspect of these cables. This issue arises from the fact that both, the United Nations Convention on the Law of the Sea (UNCLOS), and customary international law, do not explicitly classify the legalities of dual-purpose telecom-marine data cables.[10] While these undersea cables are permitted freedom and protection, Marine Scientific Research (MSR) is subject to varying levels of jurisdiction and regulation by Coastal States and there is little international agreement for treatment of undersea cables that combine these activities.

The focus of this article is to communicate the importance of these green cables for scientific data collection, with special emphasis on the legal considerations arising from such dual-purpose cables. In doing so, one needs to keep in mind that dual-usage of these cables is still at a nascent stage. The present article first discusses the motivation that has made the submarine cables green and then proceeds to delve into the development of "green cables" and their use for MSR. The legal aspects of both the MSR and submarine telecommunication cables as discussed in UNCLOS; and how and where these dual-purpose cables fit in this legal framework, along with the possible way ahead for these green cables will be addressed in the second part of this article.

Motivation for using dual-use cables

Man, by his very nature, has never been satisfied with the status quo. He has always tried to push the limit, be it of himself, or of the technology around him. In doing so, he has often resolved issues plaguing future development by creating the technological advancements we see today. Keeping this working philosophy in mind, the present section aims to address the motivation and circumstances behind the development of "green cables".

Submarine telecommunication cables

A plethora of articles and literature exists on submarine telecommunication cables, which today, have become the backbone of the telecommunication industry, internet, finance, commerce, entertainment and many more services.[11] However, these cables, which run on the seafloor, can easily be damaged due to earthquakes and submarine landslides, as was witnessed during the 1929 Grand Banks earthquake,[12] the 2003 Algerian earthquake,[13] the 2006 earthquake of Taiwan,[14] the 2011 Japanese earthquake,[15] and the earthquakes off Southeast Alaska in 2013 and 2014.[16] Similarly, a dragging anchor can damage submarine cables too.[17] While telecommunication cables are completely deaf, dumb and blind,[18] and power submarine cables are cable of monitoring the electric and optical power flowing through them,[19] both of these cannot detect, measure or mitigate the hazards that lead to their outage. An Asia-Pacific Economic Cooperation report of 2012[20] referred to the hazards to such cables stating:

> The overall minimum-approach should be to build up the capacities to monitor the situation, obtain as much information about the status as possible, and prevent undesirable developments as soon as possible. In addition, the provision of basic protection measures against the common, likely hazards on the one hand, and the less likely but especially devastating ones on the other must be made.

This necessarily means that some form of sensor information from these cables is needed to minimise the damage to them for which a 3-axis accelerometer is considered to be a basic minimum. The other sensors that can be added include pressure and temperature sensors to provide inputs on the environmental situation prior to and during the cable fault event.[21]

Marine scientific research

UNCLOS recognises three separate categories of marine data collection: marine scientific research; surveys; and exploration and exploitation of living and non-living resources.[22] All of these activities are dealt with separately in Part XIII, II, III, XI, and Annex III to the Convention, respectively, as well as in the agreement relating to the Implementation of Part XI of the UNCLOS and related instruments.[23]

Based on UNCLOS, Captain J. Ashley Roach classified the types of marine data collection based on the purpose of the activity and how the data was being collected.[24] Hence the following categories of marine data collection currently exist:

(a) Marine scientific research, which includes the collection of data from fisheries research, oceanography, scientific ocean drilling or coring, biological, geological and geophysical studies, and aims at the expansion of scientific knowledge of the marine environment and its processes.
(b) Marine surveys, which include hydrographic surveys and military surveys.
(c) Operational oceanography, which includes ocean state estimation, weather forecasting, and climate prediction, and is directly associated with the safety of shipping and the physical domain of the ocean.
(d) Exploration and exploitation of natural resources, shipwrecks, and other underwater cultural heritage.

Of the categories recognised above, this article is concerned with "Marine Scientific Research (MSR)". While the Law of the Sea Convention does not contain a formal definition of MSR, an informal negotiating text issued in 1976, as provided in its draft Part III, Article 48, mentions that: "[f]or the purpose of this Convention, 'marine scientific research' means any study or related experimental work designed to increase mankind's knowledge of the marine environment".[25] The most successful effort in providing a working definition of Marine Scientific Research in the context of UNCLOS is by Soons[26] in 1982, who defined MSR as "activities undertaken in the ocean and coastal waters to expand scientific knowledge of the marine environment and its processes", thus distinguishing it from hydrographic surveys, military activities (including military surveys), and from research prospecting and exploration, which are comprehensively dealt with in other parts of the Convention. To this day this is the definition that is widely used by analysts.

The task of MSR, which is usually conducted by researchers, national and international organisations, and private corporations, is to observe, explain, and eventually understand sufficiently well how to predict and explain changes in the marine world. In doing so, it helps in the safe and economic use of the oceans; preservation of its stocks and resources; prediction of climate and natural hazards, environmental threats and ocean state. It also provides inputs to policymakers in pursuing developmental options and for societal benefit within the realms of weather forecasting and the prevention of natural disasters, while activities such as military intelligence, weapon testing, or those not concerning the marine environment do not fall under the ambit of marine scientific research.[27] The MSR may be "pure or basic" when it adds to man's knowledge about the marine environment; or "applied" when the research is purpose specific and aims to implement the result of some basic research into an application.[28] However, disagreement over being able to distinguish between fundamental, pure or basic scientific research and commercially oriented or applied research disallowed UNCLOS to define MSR exhaustively.[29]

Evolution of data collection methodology

As discussed in the Introduction of this article, the Earth's most fundamental activities occur only beneath the ocean, and require the availability of continuous, high resolution, long-term data in order to enable us to understand these activities in a comprehensive manner. This need to monitor the ocean floor, led to the development of autonomous platforms and associated equipment and sensors with improved accuracy, increased duration of working, and the capability to work in extreme environmental conditions. Such autonomous platforms were either fixed or mobile, operating from within the ocean or through remote, manned or unmanned vessels, and powered varyingly by nature or by humans. These autonomous platforms such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) have provided us with glimpses of the continental margin, but have been unable to provide continuous biological, geological, and oceanographic data that are considered essential for reliable monitoring of changes in the Earth.

Spearheaded by Japan, Europe, Canada and the United States, this limitation propelled the development of multi-parametric cabled seafloor observatories using *retired submarine cables* for powering equipment in the ocean depths. Some of the well-known seafloor observatories using such retired submarine cables are the Dense Ocean-floor Network system for Earthquakes and Tsunamis (DONET), the Geophysical and Oceanographical Trans Ocean Cable (GEO-TOC), the Hawaii-2 observatory (H_2O) by Japan, the Monterey Accelerated Research System (MARS) by the US, and the Victoria Experimental Network Under the Sea (VENUS) by Canada (see Figure 1). Though these observatories are by various countries and are spread across the globe, their basic architecture remains the same. The most reliable architecture uses one or more junction boxes, (similar to a power strip), which are wire connected to land for power and communication. Multiple pieces of scientific equipment (seismometers, deep water pressure gauges, magnetometers, sediment traps, digital cameras etc.) are connected to this junction box and move around to distances that are governed by their respective umbilical cords. The greatest limitation

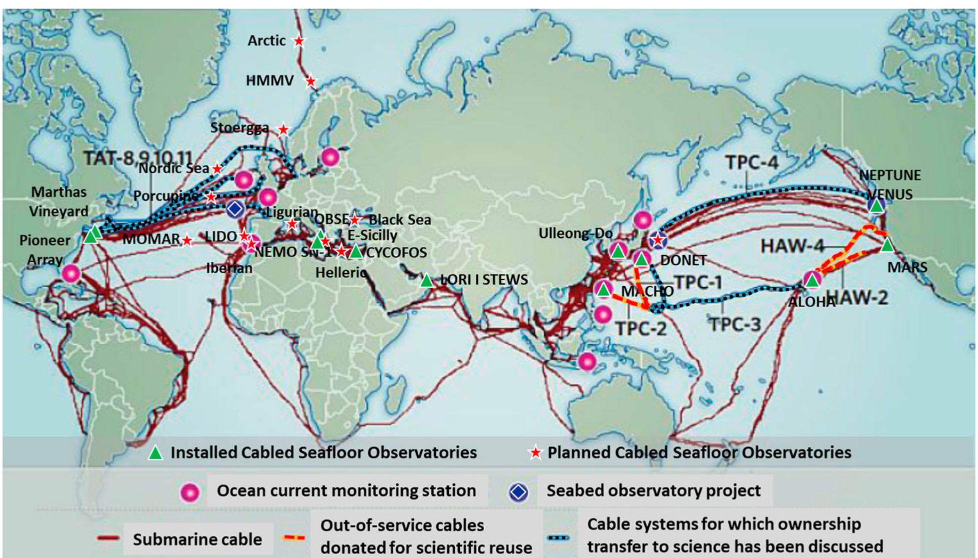

Figure 1. Global Network of seafloor cables.

Source: Modified from Y. You, "Harnessing Telecoms Cables for Science," *Nature* 466, no. 5 (2010): 690–1; Deborah S. Kelley, John R. Delaney, and S. Kim Juniper, "Establishing a New Era of Submarine Volcanic Observatories: Cabling Axial Seamount and the Endeavour Segment of the Juan de Fuca Ridge," *Marine Geology* 352 (2014): 426–50.

of these observatories is that they are anchored to regions close to the shoreline and neither they, nor their equipment, can access distances far away from the power providing shore. These observatories are powered by either an end to end straight line cable (as in the case of H_2O), or like a power grid (as in the case of NEPTUNE). More than 100 KW of power (sufficient to power 50 to 100 homes) flows in the system for power grid systems.[30] The data so collected from these observatories is huge, but is also area specific, due to limitations of the reach of the scientific equipment.

"Green" cables

As discussed in the Motivation for using dual-use cables, the increasing demand for long-term, real-time data from the deep, along with a need to provide eyes and ears to submarine telecommunication cables, supported by developing sensor technology, gave birth to the possibility of *green cables* as suggested by climatologist and oceanographer Yuzhu "John" You of the University of Sydney in 2010. Here, we will discuss the various types of submarine cables rendering them green, instead of deaf, dumb and blind.

Background

Based on the letter of Yuzhu You, the delegates of the 2011 ITU workshop conceived an opportunity of using submarine cables for ocean and climate monitoring and disaster warning.[31] Based on this thought the ITU, UNESCO/IOC, and the WMO established a Joint Task Force (JTF) in late 2012,[32] which was tasked to develop a strategy and roadmap that could lead to enabling the availability of modified "green" submarine cable systems for climate monitoring and disaster risk reduction by installing sensors on cables. While doing so the JTF was to address two main issues:

(a) *the need for sustained climate-quality data from the sparsely observed deep oceans, and,*
(b) *to increase the reliability and integrity of the global tsunami warning networks.*

If successful, with adequate support from industry and regulatory bodies, a wide network of mini-observatories would be established across the world's ocean floors to measure real-time climate data.[33]

It is essential to mention here that the installation of sensors on cables is not a new feature. Distributed Temperature Sensors (DTS) have been used in power cables on land since the 1980s and application of this technology with dynamic strain mapping has been used for subsea power cables successfully and is presently used in most undersea power networks.[34] Similarly, long before 2011, Japan had already installed earthquake and tsunami seismometers on NEC's analogue co-axial submarine cables installed off Omaezaki at 10 locations in 1979, which were subsequently upgraded to 125 sensors, (with repeaters), 30 km apart after 2011.[35] This work, called the "Tohoku cable system", presently uses 5,000 km of cable at a cost of US$ 500 M. Efforts are underway to increase this spread for improved coverage and accuracy.

Some pioneering work has already proven the concept of using sensors on submarine cables, thus launching ambitious initiatives in small regions of the deep ocean.[36] These initiatives use integrated sensors and repeaters installed at every 50-70 km to amplify the optical signals without disrupting the data being collected.

At a mere 5–10% increase of the total cost of the system deployment,[37] they are proving to be a viable option to the equipment intensive, costly, and localised provisions for Marine Scientific Research being presently used. Once implemented, these cables would additionally make a signific ant contribution toward meeting United Nations Sustainable Development Goal 13[38] and Goal 14.[39]

Scientific reuse of retired submarine cables

The period from 1960 to 1988 saw the use of analogue coaxial submarine cables for telecommunication purposes that provided less than 1,000 voice channels. Development of optical fibre technology in the 1980s[40] that could provide a large number of channels for voice and data (up to 2 Tbps per cable[41]), buoyed by a huge demand from international information exchanges, allowed replacement of the analogue coaxial submarine cables with optical fibre ones. The first Japan-USA optical fibre submarine cable system, TPC-8 (Trans Pacific Cable-8), which came into service in 1988, ensured termination of commercial services of the TPC-1 in 1990 and the TPC-2 in 1994, nearly 10 years before their planned retirement.

Other analogue cables also met the same fate, resulting in a number of such submarine cables to be available for reuse for real-time geophysical observatories on the deep-sea floor, with high reliability and at a reasonable cost. Based on this thought, scientists in Japan and the USA started to use the retired telecommunication cables between Japan and the USA for scientific purposes in 1990, with the GEO-TOC project that used the TPC-1 between Guam and Ninomiya, and the second from 1996-99, under the name VENUS, that used the TPC-2 between Guam and Okinawa. Other observatories, such as the H_2O, which was funded in 1996, started operation in 1998, repaired and reinstalled in 1999, operated till 2003 and used the HAW-2.

ALOHA cabled observatory (ACO) by the University of Hawaii was the first ocean laboratory that used a retired first generation fibre-optic cable, HAW-4, for which installation commenced in 2007 and got completed in 2011. This project was the last of the efforts with reuse of retired submarine cables. The ACO is currently the deepest operating cabled observatory.[42] Though some of the instrumentation is not working, it has allowed the community to improve and perfect the engineering, and sample the abyssal and overlying ocean at its location.

Two models have been followed in re-using retired coaxial submarine telephone cable systems to provide telecommunications and power to the seafloor. For TPC-1, an instrumentation package was spliced into the cable, while the cable remained connected to the cable stations on both ends. For Hawaii-2, the original cable was cut in the middle and the H_2O junction box was attached to the section going to the Hawaii terminus and the other section was effectively retired to the seafloor. This approach provides a more reliable architecture as discussed earlier in the article by permitting easy repair, replacement, addition of sensors, and provides additional power, available from the repeaters in the unused section.

As seen in Figure 1, only a fraction of the retired telecommunications cables have been used for scientific purposes, leaving a large area of the ocean unmapped. Due to the limited life of the retired submarine cables and high costs of the equipment for the ocean observatories, the use of retired submarine cables for such ocean observations was not pursued after 2003.

Purpose built cabled ocean observatories

The Hawaii undersea geo-observatory (HUGO) was the first purpose-built cabled ocean observatory connected to the land. It was installed in October 1997 using 47 km of electro-optical telecommunications cable donated by AT&T and laid by a small oceanographic vessel from the Island of Hawaii to Loihi volcano.[43] After six months of operation, the cable developed a short-circuiting, due to seawater, making it non-operational. Subsequently, in 2004, the HUGO package was recovered from the sea and parts were used for the construction of the ACO cable termination. Even though the project failed to operate for a prolonged duration, it allowed demonstration of all the essential elements necessary for a purpose-built cabled ocean observatory. HUGO thus provided the proof-of-concept for all the essential elements of what we now think of as a "cabled ocean observatory".

In October 2003, the Regional Cabled Observatories and funding agencies decided to focus on transformative technologies to consider the construction of purpose-built cabled ocean observatories such as the Ocean Observatories Initiative (OOI,[44] at the time called ORION by the United States), the North East Pacific Time-integrated Undersea Networked Experiments[45] (NEPTUNE, now part of Ocean Networks Canada by Canada), Advanced Real-Time Earth monitoring Network in the Area (ARENA[46] by Japan) and the European Seafloor Observatory Network (ESONET[47] by Europe), as opposed to funding the re-use of retired telecommunication systems.

Modification of existing submarine cables

In the 1960s and 70s, for higher capacity, electrically powered repeaters were required at every 6 to 9 km. With the introduction of optic fibre cables in the 1980s, the distance between these repeaters increased to 60 km for transoceanic spans of 7,000 to 12,000 km, and to 120 km or more for shorter distances of 600 to 3,000 km.[48] Modifying the existing repeaters by adding sensors such as those for temperature, sea current, salinity/conductivity, pressure, seismic, hydroacoustic and cable voltage at every 60 to 65 km enables these existing submarine cables to be used for real-time monitoring of environmental threats and disaster mitigation.[49] Today, technology has permitted the integration of sensors in the repeaters of submarine telecommunication cables at a cost that is only a fraction of the deployment of a new cable system. Estimates indicate that the unit cost of a single sensor package is expected to be around $0.2 million. Accordingly, a modest system with an expected life of twenty-five years would cost under $10 million.[50]

In February 2012, one of the principal manufacturers of the undersea telecommunication cable systems, TE SubCom (formerly Tyco) announced that it has a cost-effective solution to integrate scientific instruments into trans-oceanic telecommunication systems. This allowed the company to enter into an exploratory partnership with the Scripps Institution of Oceanography at the University of California, San Diego, and the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory; however, details of TE SubCom solution are not available.[51]

Some possible options for collecting scientific data through these repeaters include in-line seismometers[52] and acoustic modems on each repeater powered by batteries which would allow the collection of data by a passing ship acoustically, and would not require placing instruments inside the repeater as initially proposed.[53]

As can be seen in Figure 1 and is evident from the aforesaid discussions in the article only a fraction of the ocean floor has been covered by these ocean observatories. Another observation one makes is that submarine telecommunication cables are laid across the globe and if used as dual-use systems, could provide a large coverage area of the ocean floor which would reduce the unmapped area of the sea while being relatively cost effective as compared to cabled ocean observations. However, such dual-use cables would require specialised repeaters.

New dual-use cables

To be able to produce a green repeater, a specialised repeater is required, that needs to be designed to house additional circuit boards, sensors, and a power feed current, while being able to withstand forces inherent to the installation of such cables so as to survive and provide useful data in a variety of seabed conditions. The task of designing such a repeater is made more challenging due to the non-availability of long life, small sized, robust, and stable scientific instruments. Once available, the repeater housing would need to be designed to incorporate seals and materials to meet industry standards while being compatible with the equipment inside. After the design is proven, the necessary integration would be required to be undertaken by telecommunication cable manufacturers.[54]

Since 2011, a number of meetings and workshops between academicians, government, scientists, and the telecommunication industry have allowed scientific foundations to be laid to resolve various technical and legal issues. A number of white papers and workshop reports on the scientific and societal needs, legal issues, and the technical feasibility have hence been generated.[55] Thus, if the cables have to be used for environmental monitoring, the involvement of the private sector is vital, as these cable systems are installed, operated, and maintained by these private sectors. The main challenge that exists in the use of these green cables lies in being unable to identify a robust source of funding, and calculating the full cost and the return of investment for these repeaters, thus disallowing identification of suitable system developers that might be willing to introduce green cables. While significant challenges to this endeavour remain, in order to allow fruition of the green cable concept, the need of the hour is prototype funding and ocean testing both of which are necessary before any telecom company considers risking a major investment in this technology.

These issues, notwithstanding, some manufacturers such as Alcatel-Lucent Submarine Systems, Huawei, XTERA & TE Subcom have expressed interest in SMART cables, while Japan has decided against the use of dual-use cables.[56] To demonstrate collection of scientifically useful data from a trial system with the same mechanical footprint, using "observatory grade" power and communication equipment, and to address the effectiveness and practicality of the proposed green cable approach, the concept of a "wet demonstrator"[57] was proposed in March 2016,[58] with a modest-scale pilot system in the South Pacific linking several islands, for which EMSO (Europe), ACO (Hawaii), Ocean Networks (Canada) all responded positively.[59]

Conclusion

There is no denying the fact that marine scientific data from the oceans is essential for the overall well-being of mankind. There is also no denying that the presently available "snapshot" data from the ocean is not sufficient to meet this requirement and hence real-time, continuous, and high-resolution data from the oceans is necessarily required, and cannot be collected with the limited mapping provisions of "ocean observatories" available at present. The benefits of better detection and quantification of ocean data are evident and it is opined that the availability of such data could have saved thousands of lives and billions of dollars in the 2004 tsunami, had this been available at the time. In order to get something more than "snapshots" of the ocean data, the two options that have been discussed in the present article are either to use *dual-use cables*, or to position *ocean-observatories* on the entire ocean-floor. While the second option is costly and technologically intensive, it is free from serious legal issues. The first option, on the other hand, is simpler and relatively less costly but riffled with legal challenges.

If the entire ocean needs to be mapped, as is considered essential in order to obtain comprehensive information on sub-marine phenomena, one needs to invest heavily. Naturally, the question that follows is, "where is the money and who will pay?" Unfortunately, there is no money and no government or institution is currently ready to pay for such a venture. Private companies who can generate money through loans and cash reserves can invest but are unlikely to do so as a philanthropic endeavour.

Thus, for the moment, we are left with no option other than to follow the cheaper alternative of modifying the existing repeaters on submarine telecommunication cables which have been analysed to be a mere 5–10% of an additional cost of the existing submarine telecommunication cable system and hence explore the use of "green cables" which has been the focus of this article. The second part of this article will focus on the associated legal challenges that exist in the usage of these "green cables" and how these legal challenges can be addressed.

Notes

1. First founded in 1974 and were underwater viewing public aquariums; also see https://en.wikipedia.org/wiki/Coral_World_Underwater_Observatory.
2. First established off Japan in 1993 and were individual cabled or self-contained observatories that were managed from the sea surface through dedicated remotely controlled tethered vehicles; also see http://www.whoi.edu/oceanus/feature/seeding-the-seafloor-with-observatories.
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