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## TECHNOLOGY AND THE LAW OF THE SEA: THE EFFECT OF PREDICTION AND MISPREDICTION

*J.P. Craven\**

The impact of new technology on the evolutionary development of the Law of the Sea is not always clear or discernible at the time of its introduction. In this time of technological revolution the development alternatives for enjoyment and exploitation of the sea and its resources are legion, but recent history is replete with proof that neither economic determinism or rational military strategy is a major factor in determining which technologies are developed and which are neglected. It does not take an astute observer who has read the text of the United Nations Treaty on the Law of the Sea to realize that large portions of the text are based on major mispredictions as to the resources of the deep seabed and the imminence of their development. Less obvious but equally true is that major ocean development alternatives have been overlooked or ignored in the developing law of the sea. The author has been involved for more than thirty years with this process of prediction and misprediction and prudence would suggest that he excuse himself from the process. The temptation to use these experiences as feedback for the next estimate is, however, too great, and once again an attempt will be made to predict the directions that sea technology will take and the probable effect of these technologies on the Law of the Sea.

The author's first major undertaking in this regard appeared in The Naval Institute Proceedings of April 1966 which, by virtue of normal delay in preparation and publication, had a prediction benchmark of 1964-65. The ocean developments which were deemed significant related to nuclear powered deep submersibles, saturated diving and man-in-the sea, and the tools and sensors associated with these forms of entry into the sea. The relevant technological conclusions were as follows:

For the greater portion of the continental shelf (0 to 3000 feet) the economic use of man and machines for extensive and prolonged engineering operations is virtually assured within the next decade [*i.e.*, by 1975]. The magnitude of national effort devoted to this technology is still contingent upon the assessment of the military significance of the continental shelf, and the assessment

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of its resources and of its scenic and recreational potential. For the next geographic areas of interest, the ocean ridges and sea mounts (6000 to 8000 feet), the capability to deploy vehicles and to mount installations is virtually assured within the next decade (sic 1975). In the next two decades [*i.e.*, by 1985] the commercial deployment of vehicles and machines in these areas is highly probable; and by the end of the century the economic use of men and machines in these areas is again contingent upon an as yet unassessed military, economic and cultural potential. For the final areas of interest, the broad ocean basins (12,000 to 20,000 feet), within the next decade [1975], the capability to visit selected areas of the bottom and to perform light engineering missions is virtually assured; within the next two decades, the deployment of vehicles and machines in these areas is highly likely; and by the end of the century, the extensive economic deployment of a wide class of commercial and military vehicles is a distinct possibility.

A hindsight modification of this forecast would not materially change the technological capability forecast but would downplay the commercial application and highlight the military and scientific developments. Commercial continental shelf capability did indeed develop and men and machines are commercially available to depths of 1000 feet. A few commercial submersibles are capable at depths from 3000 to 6000 feet. There are no commercial deployments on the ocean ridges and sea mounts but submersibles and towed devices are now exploring the manganese crusts and polymetallic sulfides at these depths. The military capability at these depths is best exemplified by the Soviet titanium submarines said to have a depth capability of 6000 feet. In the deep ocean the Japanese and the Americans have developed and proved a number of configurations of deep ocean mining machines but their commercial use at the end of the century must now be deemed a possibility, not a "distinct possibility."<sup>1</sup>

The author's 1966 paper was completely silent as to polymetallic nodules, the use of the ocean for the disposal of toxic and nuclear wastes, the development of ocean thermal energy, and the development of aquaculture as a significant alternative to fishing.

As late as 1965, the International perception of the Law of the Sea could be summarized by the author as follows:

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1. Craven, *Sea Power and the Sea Bed*, United States Naval Institute Proceedings 36, 48-49 (Apr. 1966).

The present embodiment of the Law of the Sea can be found in the partially ratified United Nations Convention on the Law of the Sea of 29 April 1958. Although agreement on this convention was hampered by unilateral attempts to extend the territorial waters from three miles to six to even 200 miles, no significant effect on the basic rights and freedoms of the seas has yet been discernible.

. . . .

It is already established that emoluments of sovereignty or ownership already obtain in the sea bed. The relatively recently ratified Treaty of the Continental Shelf confers sovereign rights to the continental shelf out to a depth of 200 meters, or to the depth of practicable exploitation to those nations having borders on the sea. Granting the technology that has been forecast here and using the latter of these definitions, it is clear that the ability to exert sovereign rights in the sea bed has already received tacit approval.<sup>2</sup>

On the basis of the forecast technology and this capsule summary of the Law of the Sea as then constituted, the author made his projections on the future of the Law of the Sea as follows:

The next question which will certainly be raised with respect to the law of the sea, is the extent to which these sovereign rights in the seabed confer additional rights in the waters above the sea bed, the waters well above the seabed, and the free surface above the sea bed. Certainly some rights akin to those which have delineated the legal rights on land from those in the air will develop. If an exact analogy were drawn, (though it probably will not be) the right to transit over that portion of the seabed whose sovereignty has been established would be the prerogative of the sovereign and the cherished freedom of the sea would thereby be abolished. While this extreme limit may not be reached, the right to regulate the jettison of material over occupied areas of the sea bed, the right to regulate traffic above and around occupied areas of the seabed, and the right to discriminate between peaceful and belligerent transit over occupied areas of the sea bed may well result as emoluments of sovereignty. The establishment of boundary lines, particularly along elements of the bottom which define major geographic entities across which commercial and military passage will be regulated is not a far fetched extension of the trend of law and technology.

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2. *Id.* at 37, 49.

If, now, sovereignty over the bottom is established to a depth of 3,000 feet and the accompanying technology developed, then the British Isles, Cuba and the other Caribbean Islands will lose their status as islands. The Soviet Union and the United States will have a common border no longer separated by the Bering Strait. . . . If sovereignty is further established to a depth of 10,000 feet and the accompanying technology develops then the Atlantic ocean will be cleaved by a great ridge in the Northern and Southern hemispheres which divides it into an eastern and western basin. In the Pacific, the extensive chains of seamounts divide the Pacific ocean into a significant number of basins which are now identifiable by the sea mounts which constitute Wake, Guam, the New Hebrides, the Fijis, the Gilberts, the Marshalls, the Ryukyus, the Kuriles, etc. . . . If ultimately, sovereignty is established to the full depths of the ocean, effectively 20,000 feet, then there exists the complex and politically difficult task of dividing a territory more than three times as large as that of the present land mass and the establishment of appropriate international relationships which will still admit of the control, management and utilization of the mineral, animal, and plant rights which are contained therein.<sup>3</sup>

As of 1985 this projection of the division of the seabed into regimes of National Sovereignty and the extension of this Sovereignty to the water column and the free surface through some mechanism of "creeping jurisdiction" seems incorrect or premature. Article 76 of the United Nations Convention on the Law of the Sea (hereinafter referred to as UNCLOS III) limits Continental shelf jurisdiction to a maximum of 350 nautical miles from the base line of the coastal state, to that depth which occurs not more than 100 miles from the 2,500 metre isobath, and in any event not less than 200 nautical miles.

The bathymetry definition (were it the only criterion) would be all-inclusive of the East China Sea, the North and Baltic Seas, the Arabian Sea and the Bay of Bengal but would not be all-inclusive of the Caribbean or the Mediterranean. The mid-Atlantic ridge is excluded as are most sea mount chains except where the islands in the chain are not separated by more than 400 miles. Coastal states, rights in the continental shelf are sovereign and exclusive but limited to the exploration and exploitation of natural resources.

The seabed beyond the limits of national jurisdiction is defined in UNCLOS III as "The Area" and the common heritage of mankind. No state may claim sovereignty, and a United Nations Authority acts as the trustee for "mankind." While not claiming sovereignty over the Area or any part thereof, the United States rejects the United Nations'

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3. *Id.* at 49-50.

claim of exclusive jurisdiction over the management and allocation of the resources of the Area. Whether or not a property right over the resources of the deep sea bed vests in the "common heritage" and is not subject to alienation without permission of the Authority is a matter of international legal debate.<sup>4</sup> Thus, eventual national sovereignty in the sea bed beyond current areas of national jurisdiction is not yet foreclosed but seems far less likely than it did in 1965.

The author's projection of the future of the Law of the Sea had little if any effect on the course of events, but assessments of technology played a major and determinative role in the substance of UNCLOS. It was his own technology assessment (not dissimilar to that of the author's) that prompted Arvid Pardo<sup>5</sup> to introduce the famous "Malta Resolution" in 1967. Although no specific ocean resource was identified in that document, the preliminary conference in Geneva and the first session of UNCLOS III in Caracas devoted a great deal of time and attention to an assessment of deep ocean resources.

On the basis of existing literature, it is highly unlikely that Pardo had the polymetallic (*i.e.*, manganese) nodules in mind when he introduced the resolution. The previous year the Law of the Sea Institute had held the first of its annual meetings. The paper on ocean mining was presented by Bascomb.<sup>6</sup> He stated, "I should perhaps note that in our search for undersea minerals, we began at the top of the scale with diamonds, and then we descended through platinum and gold, tungsten, tin and we are getting down to the lower levels now. I think we may never get down to manganese nodules." In 1968 the Second Report of the President to the Congress of Marine Resources and Engineering

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4. See M. Pinto, Alternatives in Deep Sea Mining 13 (S. Allen & J. Craven eds. 1978). ("The 'common heritage' of these resources is not *res nullius* to be had for the taking; is not *res communis* simply for enjoyment or use in common; it is more akin to property held in trust—held in trust for 'mankind as a whole,' for the public. It is therefore closest to *res publicae*, the property of the people to be administered by the people and for the people.'").

5. See United Nations General Assembly, Proposal for a Declaration and a Treaty Reserving the Sea Bed and Ocean Floor Beyond Territorial Limits For Peaceful Purposes and Use in the Interest of Mankind. Note *verbale* from the Permanent Mission of Malta to the United Nations addressed to the Secretary General, U. N. Document A/6695 Aug. 18 1967). The memorandum states in part: "In view of the rapid progress in the development of new techniques by technologically advanced countries, it is feared that the situation will change and that the seabed and the ocean floor, underlying the seas beyond present national jurisdiction, will become progressively and competitively subject to national appropriation and use. This is likely to result in the militarization of the accessible ocean floor through the establishment of fixed military installations and in the exploitation and depletion of resources of immense potential benefit for the world, for the national advantage of technologically developed countries."

6. Bascomb, Mining in the Sea, in *The Law of the Sea* (L. Alexander).

Development<sup>7</sup> was highly optimistic with respect to ocean minerals but referred to polymetallic nodules only by implication.

The initial international interest in this specific resource was probably initiated by John Mero through both his Ph.D. dissertation<sup>8</sup> and his book on Ocean Minerals.<sup>9</sup> As President of the newly formed Ocean Resources Corporation, Mero reported on Alternatives for Mineral Exploitation at the Second Conference of the Law of the Sea Institute.<sup>10</sup> In that paper he gives nearly equal prominence to ocean thermal energy (and its associated artificial upwelling) and to the manganese nodules. He predicts economic viability for both in "from ten to twenty years" (*i.e.*, 1976-1986).

In 1973 the conference fixed upon the manganese nodules of the deep sea bed as the primary mineral resource of the Area. Although the stimulus for this interest was probably initiated by John Mero, the credibility of his projection was given impetus by the much publicized Summa Corporation venture. It was clear to observers that a great deal of capital was being invested in the experimental ship Glomar Explorer and its equipments. Other consortia concerned over the impending shortage of strategic metals and not wishing to lose the competitive edge had also launched exploratory development programs. Deep Sea Ventures was organized in 1968 and developments on the part of Kennecott and International Nickel were initiated at about the same time. By 1977 there were five major consortia who were actively involved in evaluation of the technology and economics of manganese nodule mining.<sup>11</sup>

It was not revealed until 1975, well after the establishment of manganese nodule mining as the basis for the Deep Sea Bed negotiations that the Glomar Explorer operation was in whole or in part a cover for and intelligence operation of the United States Central Intelligence

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7. See Marine Science Affairs—A Year of Plans and Progress: Second Report of the President to the Congress on Marine Resources and Engineering Development ch. 4 "Encouraging Development of Non-Living Resources" (Mar. 1968) (Industry might be quickly attracted to the deep sea, however, if rich deposits of a mineral in high demand such as nickel and copper are discovered in the deep sea, or if there are technological breakthroughs.).

8. J. Mero, *The Mining and Processing of Deep-Sea Manganese Nodules* (Univ. of Calif. at Berkeley, Institute of Marine Resources, 1959).

9. J. Mero, *The Mineral Resources of the Sea* (Elsevier Publishing Corp., New York, 1965).

10. J. Mero, *Alternatives for Mineral Exploitation*, Proceedings Second Conference, Law of the Sea Institute (June 1967).

11. The major consortia were: Deep Sea Venture Group (U.S. Steel, Union Minier of Belgium and the Sun Corp.)—International Nickel Group (INCO Ltd., Canada; AMR-Metallgesellschaft Preussag, Germany; Domco-Sumitomo, Japan; and SEDCO Inc., U.S.)—Kennecott Group (Rio Tinto Zinc, U.K.; Noranda Mines, Canada; Mitsubishi, Japan; BP Minerals, U.K.)—Lockheed Group (Lockheed, U.S.; Amoco Minerals Co., U.S.; Billiton International Metals, Netherlands; and Bos Kalis Westminster, Netherlands)—Afernod Group (BRGM, France; CNEXO, France; and Chantiers, France).

Agency.<sup>12</sup> By this time the Convention was fully involved in a debate over the economic significance of this deep sea bed resource. The conference in Caracas itself devoted an evening to a technical seminar featuring three projections of the worth of the nodule resource. A political overlay was clearly evident in the projections, it was the view of the United States<sup>13</sup> and the industrialized nations not possessing land based resources of cobalt, copper, and nickel, that only with advanced technology and continued growth of world demand would the deep sea bed operations be marginally profitable and that there would not be a significant surplus available for distribution to developing nations. It was the view of the mineral-rich nations such as Canada, Chile, Zaire, etc., that either as the result of subsidy or because of economies of scale that there was a danger that deep sea bed mining would flood the world markets with nickel and thereby destroy the income of land-based producers and in particular third world land-based producers. It was the view of third world nations who were not mineral producers that the deep sea bed mining would indeed supply adequate return to justify the establishment of both an Authority and an Enterprise. As a result of these competing views the negotiated regime became very complex, resembling more a mining code than a treaty. It is probably a historical first for a treaty to contain a regression formula in the body of the text. In any event, the text on the Area deals almost exclusively with the particulars of the manganese nodules and manganese nodule mining. As against the elaborate provisions in the text (Article 151 production policies) and Annex III (Basic conditions of prospecting, exploration and exploitation) as they relate to polymetallic nodules is the simple paragraph 9 of Article 151 which states "The Authority shall have the power to limit the level of production of minerals from the Area, other than minerals from polymetallic nodules under such conditions and applying such methods as may be appropriate by adopting regulations in accordance with Article 161, paragraph 8."

The protracted negotiations for the treaty were in the process of being concluded at about the time that the technology evaluations and economic projections of the consortia were being completed. The technology development was indeed successful in the sense that equipments

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12. See C. Bursleson, *The Jennifer Project* (1977). This account alleges that the genesis of this project was the loss of a Soviet submarine in 1968 resulting in an attempt on the part of the Central Intelligence Agency to recover portions of the lost submarine. The recovery was to be effectuated utilizing a ship, the *Glomar Explorer*, specifically designed and constructed for this recovery operation. The account further alleges that the recovery of manganese nodules was the cover for this operation and that this cover story was publicly promulgated by the Summa Corporation in 1971.

13. See A. Capstaff, Jr. *Profitability of the Industry and Competition*, Proceedings, Tenth Conference, Law of the Sea Institute (1976). The "MIT" model predicts "that with careful management and the absence of royalty impositions, first generation ocean mining projects can allow the sponsoring firms to be competitive and realize a profit."



and the knowledge required to design equipments for the harvest of manganese nodules from the deep ocean now exists. On the other hand, the most pessimistic of estimates of the economic viability of nodule mining proved to be highly optimistic. A leveling off and even a decrease in world consumption of these metals, the depressed state of the world economy, and the high cost of initial capital conspired to make investment in ocean mining a losing proposition. In a landmark paper delivered in October of 1981 Flipse concluded that

[f]or a gross investment of one and one half billion dollars or a fixed capital investment of about one billion dollars in a complete vertically integrated deep ocean manganese nodule mining system producing three metals (nickel, copper and cobalt) yielding approximately \$420 million in annual revenues, a before tax profit of about \$140 million can be expected. With after tax profits of about \$71 million, the simple return on investment is less than 5%, resulting in a payback period that exceeds the productive life of the project. The internal rate of return after taxes is *only* 4.7%.<sup>14</sup>

This economically depressing news was accompanied by the discovery of the polymetallic sulfides, high density pipes of metallic sulfides where the metal content is 25% or more and where the energy to extract the metal from the ore is substantially less than that associated with the nodules. In 1985 Malahoff<sup>15</sup> reported the results of current investigations of pipes of polymetallic sulfides located in the shallower ocean fracture zones at depths of about 2,500 meters. These deposits if located on land would be immediately exploited as mineral mines. A different suite of equipments but having the same ocean technology characteristics as required for nodule mining must be developed to exploit these resources, but the relative richness of the deposits suggests that the world priority for deep sea minerals will refocus on these newly discovered deposits. In addition, national interests have focused on the cobalt-manganese crusts within the two hundred mile zones associated with oceanic sea mounts. While the economic value of these cobalt crusts does not immediately seem to be different than the economics of the nodules, protagonists point to the shallower depths, 3,000 to 6,000 feet and the strategic value of the cobalt to nations who do not have a ready land-based supply. In any event, the author's 1965 prognostication that commercial exploitation of the mineral resource of the ocean would not take place before the turn of the century now seems to be an accurate prophecy and the polymetallic sulfides now seem to be the most likely prospect.

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14. J. Flipse, *The Economic Viability of Ocean Mining*, Proceedings, Fifteenth Conference, Law of the Sea Institute (E. Miles & S. Allen eds. 1982).

The misprediction of technology by the conference has thus resulted in the establishment of an Authority and an Enterprise, a number of mine sites, and the expenditure of millions of dollars to meet the requirements of a "pioneer investor." In the long run, the most significant deficiency of the Seabed portion of the UNCLOS text is in its omissions, in its failure to provide an appropriate regime for those resources in the area beyond national jurisdiction which will have economic and social significance.

Before we examine the possibilities in this regard we should identify the deficiencies which may also exist in the regime for the territorial sea, the contiguous zone and the exclusive economic zone.

If there has been a misprediction of technology with respect to these zones it has probably been a misprediction as to the cost and capability of the system which is required for enforcement. In the absence of additional bilateral agreement, adherence to the UNCLOS text places the burden of enforcement and remedy for damages on the technology of enforcement. Article 73 states that the "coastal state may, in the exercise of its sovereign rights to explore, exploit, conserve and manage the living resources in the exclusive economic zone, take such measures, including boarding, inspection, arrest and judicial procedures as may be necessary to insure compliance with the laws and regulations adopted by it in conformity with this Convention."

The absence of other mechanisms of enforcement suggests that the framers of the treaty expect that the dominant remedy is arrest by a military warship of the coastal state followed by an action in rem. In view of immunities associated with the high seas such arrest can not take place unless there are "reasonable grounds" for believing that the ship has violated the rights of the coastal state in the exclusive economic zone. Article 111 stipulates, for example, that "hot pursuit is not deemed to have begun unless the pursuing ship has satisfied itself by such practicable means as may be available that the ship pursued or one of its boats or other craft working as a team and using the ship as a mother ship is within the limits of the territorial sea, or, as the case may be, within the contiguous zone or the exclusive economic zone or above the continental shelf."

Enforcement thus implies a technology of surveillance by aircraft or on rare occasions when the lack of cloud cover permits, by satellite, of continuous track and trail by the surveillance craft until a military or government enforcement ship can arrive on the scene and an arrest can be made. In areas such as the Hawaiian archipelago this involves (for that one region alone) an area of 600,000 square miles and transits from the port of Honolulu as great as 1200 nautical miles before an arrest can be made. If purposeful violations occur, the evidence of their occurrence is at best anecdotal. Arrests which do occur are limited in liability to the value of the ship and cargo. If the economic cost of arrest is significantly less than the economic gain of violation then the regime will be unenforceable.

The United States through the Magnuson Fisheries Conservation and Management Act (MFCMA)<sup>15</sup> has greatly eased the burden placed upon its Coast Guard. The MFCMA requires nations who wish to fish in the 200 mile zone to have concluded a Governing International Fishery Agreement. This agreement must contain a number of specific provisions of which the most important may be permission for an authorized United States officer "to board and search or inspect, any such vessel [*i.e.*, fishing vessel] at any time," to require transponders or other position fixing equipment to be placed aboard the fishing vessel, to station observers on the vessels, to have agents appointed who are authorized to receive and respond to process, and to carry the burden that "it shall be a rebuttable presumption that all fish found on board a vessel seized in connection with an act prohibited by section 307 were taken or retained in violation of this Act."

These substantial surrenders of traditional high seas freedom rights are not applicable to nations who have not signed the agreement. For such nations enforcement is heavily dependent upon the technology of enforcement and the additional sanction of prohibitions on the import of fish and fishing products which are caught by those nations. This, of course, raises the very real problem of "laundered fish" and high seas "laundries."

As a result of the GIFAs the situation in the 200-mile Fishing Conservation Zone of the United States is almost devoid of armed conflict, but the combination of anecdotal information, the cost of enforcement, budget restrictions, the ever increasing mission requirements of the Coast Guard, and the huge area of the economic zone suggest that violations are, or would be, difficult to detect. The problems will be greatly compounded if technology is employed by the violators to prevent their detection and/or arrest.

Although the MFCMA has greatly eased but not eliminated the enforcement burden of the United States with respect to fisheries, far more aggressive challenges to the "at sea enforcement" capabilities of the Coast Guard exist with respect to the importation of drugs and other illicit substances and the illegal immigration of aliens. Once again the United States has eased its enforcement burden through bilateral agreements which surrender traditional high seas freedoms, but the evidence is so abundant that these measures are at present ineffective that no citation is needed.

If the United States is unable to cope with the enforcement problem in its territorial waters, contiguous zone, and exclusive economic zone, then the problem must be compounded for less wealthy and less tech-

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15. See A. Malahoff, *Polymetallic Sulfide/Cobalt Crusts: Where Are They and What Are They Worth*, Proceedings, Eighteenth Conference, Law of the Sea Institute. Malahoff cites submersible, multi-beam sounding and towed body technology as being the keys to the discovery, assessment and evaluation of the poly-metallic sulfides and cobalt crusts.

nologically developed nations. The *de facto* situation in the South China Sea and the Gulf of Siam has been documented as well as it can by Child.<sup>16</sup> She describes a continuous saga of armed conflict at sea between fishermen and patrol craft, of illegal detentions, of extensive loss of life, and enforcement by "a stance of territorial bravado." She concludes "enforcement of ocean law is disturbing in a jurisprudential sense to the extent the process indicates that resort to armed violence as a problem-solving device is preferred to legal decision making processes."

Thus, mispredictions of technology have resulted in a regime beyond national jurisdiction which is specific and detailed with respect to a resource that will probably not be developed and vague or silent with respect to resources that are more promising, and a regime of coastal state jurisdictions which is unenforceable without substantial and co-operative bilateral and multi-lateral agreements. These deficiencies will of necessity be remedied, but the appropriate remedy itself requires a new prediction of the thrust of ocean technology. These technologies will be divided into those which will have an effect on the law of the sea in the area beyond national jurisdiction, and those technologies which will affect the scope and substance of coastal state jurisdictions. Some new technologies will take place within all of these jurisdictions which will have a profound social and economic impact, but will not affect the law of the sea. These will not be considered here.

In the area beyond national jurisdiction, it is the opinion of the author that the most significant technological developments are those associated with the development of ocean thermal energy and the concomitant resources associated with the induced artificial upwelling.

The UNCLOS III treaty is not silent on the subject of ocean energy but limits its consideration to a clause of paragraph 1(a) of Article 56 to the effect that coastal state jurisdiction extends to activities "such as the production of energy from the water, currents and winds." This brief entry suggests that the technological forecast for ocean energy did not portend a major ocean resource. It is now clear to the developers of this resource that this is not the case. They now recognize that while the search for ocean resources has concentrated on offshore oil, manganese nodules, and fishing, except for Mero's prescient prediction in 1967, we have overlooked the fact that deep ocean water is itself a resource that might result in the economic production of energy, fresh water, and marine protein. The late John Isaacs<sup>17</sup> has pointed out that the productivity of the ocean is equal to the productivity of the land but that the standing crop of ocean biomass is a very small percentage

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16. T. Child, Enforcement of 200 Mile Exclusive Economic Zone Claims Over Living Marine Resources in Southwest Asia Proceedings, Thirteenth Annual Conference Law of the Sea Institute, University of Hawaii, Honolulu, Hawaii.

17. Personal communication, John Isaacs, Professor Scripps Institution of Oceanography (circa 1975).

of land biomass. He further pointed out that if oceanic plant life had found an evolutionary path which would have permitted the development of roots of the length of one thousand feet or more, then the standing crop of the ocean would be able to match the standing crop of the land and the farming of such biomass would constitute the source for the major productivity of the ocean. In contrast, the present harvest of fish, which in the main is limited to areas of natural upwelling, would be a minor element of this productivity. The absence of protein derived from the hunt is, of course, the characteristic of land-based animal protein supply.

Most of us associate the deep ocean water with the source of cold required for the production of ocean thermal energy. Indeed, the original developers of ocean thermal energy conversion (OTEC) did not envision the cold water pipe as having the nature of an "Isaacs root." The aquaculture potential of the deep ocean water was clearly recognized by some of the pioneers and in particular by Oswald Roels.<sup>18</sup> On the other hand, protagonists for the open cycle system recognized the value of OTEC as a generator of fresh water. As a result, an increasing number of advocates now see the potential of Ocean Thermal Energy systems as the source of the three building blocks of a sea based society—food and fibre, fresh water, and energy.

Various aspects of OTEC have been explored at the Natural Energy Laboratory of Hawaii since its inception in 1974.<sup>19</sup> It is from the results of this laboratory that we can now appreciate the true nature of the deep ocean resource. Fundamentally, the deep ocean water has four important characteristics: (1) the medium is biologically pure and has no pathogens, no bio-fouling organisms, and no unwanted organisms; (2) the medium contains abundant quantities of nutrients which though diluted are easily recovered; (3) the medium is cold by commercial standards; and (4) the energy costs for bringing this fluid to the surface are trivial. The beneficial qualities of this fluid have revealed themselves in experiments on coldwater biofouling,<sup>20</sup> the aquaculture of nori, spirulina, salmon, trout, lobster and abalone,<sup>21</sup> the utilization of the fluid in laboratory processes requiring chilling or air conditioning, and even

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18. O. Roels, K. Haines & J. Sunderland, *The Potential Yield of Artificial Upwelling Mariculture*, Tenth European Symposium on Marine Biology (1975).

19. T. Daniel, *OTEC and Coldwater Aquaculture Research at the Natural Energy Laboratory of Hawaii*, Ke-ahole Point, *Proceedings of the Pacific Conference on Marine Technology PACON 84*, Marine Technology Society (Honolulu, Hawaii 1984).

20. B. Larsen, *Effect of Biofouling and Countermeasures on Heat Transfer in Surface and Deep Ocean Hawaiian Waters*, ASME/JSME Thermal Engineering Joint Conference (Honolulu, Hawaii Mar. 1983).

21. F. Menscher, R. Spencer, J. Woessner, S. Katase & D. Barclay, *Growth of Nori in an Experimental OTEC Aquaculture System in Hawaii*, 14 *J. World Mariculture Soc'y* 458 (1983). See also F. Mencher & R. Spencer, *OTEC Energy Transfer via Biomass: The Pros and Cons*, *Proceedings Eighth Ocean Energy Conference*, 695-98, MTS (June 1981).

in the successful agriculture of strawberries.<sup>22</sup>

We have thus learned that a major asset of the cold in the cold water lies in its temperature regulating qualities as much as in the absolute value of the temperature. As is well known to marine biologists the growth rate of marine animals and plants is highly sensitive to the precise temperature of the water (within about one degree Celsius) with a different temperature required at different times in the life cycle. To achieve this result by chilling (the reverse process of ocean thermal energy production) is inefficient and therefore requires a great deal of energy. The warming of the deep water through some form of heat exchange is on the other hand a very economic process. Because different processes require different temperatures, the water can be used a number of times. For example, water which is appropriate for the production of energy is too cold for aquaculture. Since the cold water does not need to be treated to prevent biofouling, the discharge water can be used for aquaculture. Waste water from the aquaculture is still cold enough to be used for the agriculture of plants like strawberries or for the utilization for air conditioning and other industrial chilling processes.

The nutrient value or artificial upwelling value of the cold water has been dramatically demonstrated in the production of seaweed and kelp. Growth experiments on nori demonstrate that algal forms such as this are capable of absorbing as much as forty percent of the nutrients in the water in a single pass. This rapid and efficient conversion is demonstrated in the production of abalone. Here the deep ocean water is employed to grow an algae which is the appropriate food for abalone in the juvenile phase. The deep ocean water is also employed as the growth medium for large tanks of giant kelp which are harvested as food for the growing abalone. The same fluid is employed for the abalone. The nutritional specifics are, of course, proprietary but the ocean nutrients are an important element of the growth process.

The major significance of the deep water aquaculture projects is in the proven establishment of industries which are now economically viable and profitable. This permits the other uses of the deep water to be developed as by-products which need not amortize the cold water pipe and pumping system. An evolutionary developmental path is thus established which will ultimately lead to the development of grazing ocean thermal plants on the high seas which produce energy, fresh water, and marine protein for export. The export of energy will require the production of a transportable fuel. The Applied Physics Laboratory (APL) of Johns Hopkins University<sup>23</sup> has developed a process for the production of methanol utilizing grazing ocean thermal energy plants for the pro-

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22. See Annual Report Natural Energy Laboratory of Hawaii (1984).

23. W. Avery, "OTEC Methanol" Applied Physics Laboratory Johns Hopkins University, October 1981.

duction of hydrogen by electrolysis of fresh water which is combined with carbon monoxide from soft coal to produce the desired product. The economic studies by APL aver that this process is economically viable in today's market without the need for by-product income. Given the experience with the economic models for manganese nodule mining, such a projection might well be tempered with skepticism, but given the already proven commercial viability of OTEC aquaculture, the economics of energy production are drastically altered in a most favorable way. Similarly, the use of open cycle energy generation systems will produce large quantities of fresh water. The product value of the energy, the fresh water, and the marine protein will be of the same order of magnitude.

The author has already demonstrated<sup>24</sup> that legal constraints on the design and operation of these ocean thermal plants will give the economic and competitive edge to grazing plants which operate on the high seas in waters beyond national jurisdiction. The imagined scenarios associated with the manganese nodule resource will not become real as applied to the ocean thermal energy resource. Coastal states in the tropical waters will desire that competitive production be limited or eliminated in areas beyond national jurisdiction. Third world nations, on the other hand, will probably identify the resource as the common heritage of mankind and will seek to include its management and development under the Enterprise and the Authority. No present construction of the treaty text would authorize such jurisdiction. It is interesting to speculate as to the legal situation which would result if the ocean thermal energy operation was a part of a mining enterprise. In such instance and under the terms of the UNCLOS text, would the enterprise be allowed to engage in the sale of energy aquaculture and freshwater byproducts of the energy generating operation? Jurisprudential scholars who have studied the history of the Commerce Clause of the United States Constitution would undoubtedly argue that some form of creeping jurisdiction from sea bed mining to ocean column economic exploitation is not inconceivable.

One such path derives from the nature of the geothermal vents associated with the generation of polymetallic sulfides. The water temperatures associated with these vents is on the order of 300 degrees Celsius. A simple pipe loop containing a process fluid (*e.g.*, fresh water) would produce commercial steam at the surface. The *in situ* generation of power for such a loop would clearly be one of the world's most economic forms of power generation, involving, as it would, a conventional standard commercially available steam generation plant and a fuelless source of steam. One or two minor technical problems associated with the positioning of the loop in the geothermal resource would require

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24. J. Craven, Legal Constraints on Ocean Thermal Energy Systems Design, Proceedings at Spring Meeting Society of Naval Architects & Marine Engineers (Honolulu, Hawaii 1983).

the application of engineering expertise but are clearly resolvable. The primary economic problem is the identification of a sea-based product which could benefit from the application of this low cost energy. Quite obviously a hybrid OTEC-geothermal vent plant would be highly efficient in power generation and at the same time highly productive of aquaculture protein and fresh water. It is probably not debatable that such an energy source would be a resource of the deep seabed. Its full economic potential would not however be realized without the addition of the resource of the water column.

Given political and economic inhibitors it is highly likely that the development process for these ocean resources will be delayed beyond the turn of the century. If, however, current projections of world energy demand in the twenty-first century materialize, then on the basis of technology acquired in the last few years, the development of these ocean resources is virtually assured.

Of much more imminence on the horizon is the inadequacy of the coastal state regimes and the speed with which advanced technology is accelerating the inadequacy. The first intimations of a perceived need for these modifications appears in the New Zealand decision to declare the ports of that country as nuclear free zones. Quite obviously the New Zealand intent is to limit the now virtually inevitable (author's conclusion) nuclear exchange to the Northern hemisphere. The prohibition of nuclear weapons from its ports is however, quite meaningless unless a legal regime is established which prohibits the deployment of nuclear weapons on the high seas and establishes some legal means for inspection and verification of military ships and aircraft. At the present time the nuclear powers find such a regime to be anathema.

Of more immediate concern to the United States is the flow of illicit substances and illegal aliens across its coastlines. Attempts at resolution have already caused the United States to substantially modify merchant ship immunity through the concluding of bilateral agreements. Indeed a number of such agreements already exist which permit the military ships of one nation the right to detain and inspect the ships of another on the high seas. Such arrangements are encouraged by Article 108 of the UNCLOS treaty. The treaty already includes an enlargement of the circumstances under which an otherwise immune ship can be detained, inspected, and arrested on the high seas. These include the traditional "reasonable grounds" associated with piracy and the slave trade, unauthorized broadcasting, failure to show a flag, and disguised nationality when confronted by a warship of the same nationality. To this is added the arrest and inspection rights associated with the exclusive economic zone and the arrest and detention rights under paragraph 6 of Article 219 for vessel source pollution when it appears that major damage impends.

New technologies will clearly favor those who would violate existing law. This will most probably take place when low-cost, long-range submersibles are introduced on a scale comparable to that which now



exists with aircraft. The first (and as yet unrecognized) breakthrough in this regard has been the development of the Knapp pre-buckled submarine hull.<sup>25</sup> Stripped of the sophistries of structural analyses it suffices to say that this hull can be constructed of flat plates which are glued or welded together in an unsophisticated and relatively crude manner. A second (in fact unneeded) breakthrough is in the development of a device which can extract oxygen from sea water such as fish extract oxygen from sea water, or in the alternative the development (as is now underway) of an efficient fuel cell. In either of these last two alternatives, or with the cumbersome but none-the-less effective use of conventional storage batteries, it is possible to develop sustained undersea voyages for one of these low-cost backyard submersibles for voyages of the order of 500 to 1000 miles. The potention for smuggling of illegal aliens or illicit cargoes is obvious. The current law seems to be based on the presumption that all submarines are military vessels and enjoy military vessel immunity on the high seas. Unless restrictions are placed upon military submarines in the contiguous zone and exclusive economic zone so that they may be appropriately identified, then the smuggling submarine will enjoy an unacceptable ambiguity until it reaches the territorial sea.

But advances in military technology itself will place heavy pressure on coastal states toward the modification of the law of warship immunity. In this regard technology advances may make strange reversals of view. For example, the current direction of United States strategic policy is toward the development of space-based weapons for the intercept of ballistic missiles which, being launched at a distance from the United States, require an out-of-atmosphere trajectory. The complete and successful development and deployment of such a system will however be impotent against even the current array of SLCM (Sea Launched Cruise Missiles) and SLBM's (Sea Launched Sub-orbital Ballistic Missiles) which are legally deployed outside of the three mile territorial sea. It is not only the proximity of these seabased weapons that is threatening, but the fact (of which the public and indeed a substantial fraction of the military are unaware) that the titanium hull submarine is virtually indestructible, even when opposed by nuclear weapons.<sup>26</sup> For example a 6000-foot-depth-operating submarine is invulnerable to a uniform overpressure of approximately 3000 psi when operating at depth, or approximately 6000 psi when operating near the surface. A nuclear weapon which is launched against one of these submersibles would therefore have to be quite close to the submarine in order to have a destructive effect. The submarine itself has a good defense since the most tech-

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25. R. Knapp, *Numerical and Experimental Stability Analysis of a Pseudo-cylindrical Shell* IASS/cism, Symposium on Folded Plates & Spatial Panel Structures (Undine, Italy Sept. 1974).

26. *Janes Fighting Ships—1984-1985*, at 507 (London 1986).

nologically sophisticated attack weapons will have a maximum underwater velocity of not more than one hundred miles per hour. A response time of approximately one minute is thus available to the submarine for the launch of interceptors and for evasive action. The submarine kill rate in such an encounter will be very low.

In the face of such a peacetime seabased threat the only alternative for the United States (or for that matter the Soviet Union) is the legal establishment of either nuclear free or militarily free zones in order to force the sea based weapons into the area which is protected by the ballistic missile intercept system. Given the long lead time for a strategic missile intercept system, its cost, and the low probability of technical success, the need for this nuclear free ocean option is probably deferable to the turn of the century; however, all arms control strategies are directed toward that day when there is adequate inspection of potential launch sites wherever they may be.

Other technologies of significance are under development or are being implemented—stable platforms for floating factories, stable ships for marine mass transportation, and even floating cities.<sup>27</sup> However, all of these will take place in the territorial sea where coastal state sovereignty is already supreme. The United States may still wish to reexamine its own decision to limit its territorial sea to three miles, and coastal states of the United States may wish to benefit from any extension of this zone of sovereignty, but it is most probable that these changes will come about more by politics than by technology. In any event, the author has now set the stage for his own prediction and misprediction of technology and the law of the sea for the next twenty years and looks forward to that happy day when he can once again assess the validity of long-term prediction and the prediction process.

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27. J. Craven, *Cities of the Future: The Maritime Dimension—How Big and Still Beautiful? Macro-Engineering Revisited* (Davidson, Meador, & Salkeld eds. 1980).

