Patents Issued for Technologies for Deep Seabed Polymetallic Nodule Exploration and Mining (1960-1998)

INTERNATIONAL SEABED AUTHORITY

AUTORITÉ INTERNATIONALE DES FONDS MARINS

AUTORIDAD INTERNACIONAL DE LOS FONDOS MARINOS

国际海底管理局

السلطة الدولية لقاع البحار

МЕЖДУНАРОДНЫЙ ОРГАН ПО МОРСКОМУ ДНУ

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International Seabed Authority

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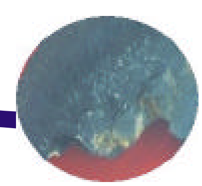

[1] Produced by the Office of Resources and Environmental Monitoring of the International Seabed Authority.

The International Seabed Authority

The Authority came into existence on 16 November 1994, upon the entry into force of the 1982 Convention. The headquarters of the Authority are in Kingston, Jamaica. All States Parties to the 1982 Convention are members of the Authority. At the end of 1999, there were 132 members of the Authority. The governing bodies of the Authority are the Assembly and the Council.

- The Assembly consists of all members of the Authority. It is the supreme body of the Authority to which other bodies are accountable.
- The Council is the executive body of the Authority and consists of 36 elected members. The Council establishes the policies of the Authority and, as well as approving applications for exploration or exploitation rights, has the power to oversee the implementation of the provisions of the Convention and the Agreement and the rules and regulations of the Authority.

In addition, there is a Legal and Technical Commission, which provides technical advice to the Council, and a Finance Committee, which deals with financial and budgetary matters. These are expert bodies, composed of experts nominated by governments and elected to serve in their individual capacity. The Authority has a small technical Secretariat, headed by a Secretary-General.

Functions of the Authority

The principal function of the Authority is to regulate deep seabed mining. The Authority is required to give special emphasis to ensuring the marine environment is protected from any harmful effects which may arise during mining activities, including exploration.

The Authority also has the responsibility to promote and encourage marine scientific research in the international seabed area and to disseminate the results of such research.

Exploration or mining in the international seabed area can only be carried out under a contract issued by the Authority. The Authority may issue contracts to mining Companies or States which wish to carry out such activities, and must ensure that their activities are carried out in accordance with the contract.

Economic benefits from mining activities will take the form of royalties from profitable commercial mining operations. These are to be distributed equitably by the Authority taking into consideration the interests and needs of developing countries.

When a potential contractor applies to the Authority for an exploration contract in respect of an area of the seabed, it must also provide the Authority with survey data and information of another area of equal estimated commercial value. This area is then reserved for the Authority and may in the future be utilized by developing countries or by the Enterprise. The Enterprise is the commercial arm of the Authority. It will come into operation only when seabed mining becomes feasible on a commercial scale and will most likely operate through joint ventures with eligible mining Companies or Member States of the Authority. Until seabed mining becomes a commercial reality, the functions of the Enterprise are to be carried out by the Secretariat of the Authority.

As part of its substantive work programme, the Secretariat of the Authority also:

- carries out detailed resource assessments of the areas reserved for the Authority;
- maintains a specialized database (POLYDAT) of data and information on the resources of the international seabed area;
- monitors the current status of scientific knowledge of the deep sea marine environment.

The Pioneer Investors

Prior to the entry into force of the 1982 Convention, some countries and mining consortia had already made large investments in the survey and location of polymetallic nodules. These entities were accorded a special status as registered pioneer investors.

In 1997 plans of work for exploration by seven registered pioneer investors were formally submitted to the Council of the Authority. Those investors were:

- Government of India
- Institut français de recherche pour l'exploitation de la mer (IFREMER)/Association française pour l'étude et la recherche des nodules (AFERNOD) (France)
- Deep Ocean Resources Development Co. Ltd. (DORD) (Japan)
- Yuzhmorgeologiya (Russian Federation)
- China Ocean Mineral Resources Research and Development Association (COMRA) (China)
- Interoceanmetal Joint Organization (IOM) (Bulgaria, Cuba, Czech Republic, Poland, Russian Federation and Slovakia)

- Government of the Republic of Korea

These seven entities will be the first to receive contracts from the Authority to undertake exploration activities.

The first priority of the Authority has been to formulate detailed regulations for prospecting and exploration for polymetallic nodules. This process includes elaborating the respective responsibilities of seabed explorers and the Authority in order to ensure environmentally sustainable development of seabed mineral resources.

Prospects for Deep Seabed Mining

There have already been substantial investments in prospecting for minerals on the ocean floor and in developing deep water mining technology. However, the prospects for deep seabed mining on a commercial scale depend to a large degree on the market conditions for the relevant metals as well as on the availability of cost-effective mining technology. Recent scientific studies have aroused interest in resources such as polymetallic sulphides and cobalt-rich crusts, found in the international area. Polymetallic sulphide deposits are known to contain high concentrations of zinc, lead, copper, barium, silver and gold, while the cobalt-rich crusts, commonly found on the flanks of seamounts, contain nickel, copper, zinc, iron and manganese as well as cobalt. Other resources, such as gas hydrates, oil and gas, phosporites and precious metals have also aroused the interest of research institutions and mining companies. It is expected that the 21st century will mark the beginning of systematic efforts worldwide to develop the resources of the deep seabed.

The Authority has convened a number of workshops to develop knowledge on specific aspects of deep seabed mining. These include:

- Workshop on the development of guidelines for the assessment of the possible environment impacts arising from exploration for polymetallic nodules (Sanya, China, June 1998).
- Workshop on proposed technologies for deep seabed mining of polymetallic nodules (Kingston, Jamaica, August 1999)
- Workshop on the available knowledge on mineral resources other than polymetallic nodules in the deep seabed (scheduled for Kingston, Jamaica, in June 2000).

The existence on the deep ocean floor of potentially valuable polymetallic nodules has been known for over a century. Scientists investigating these nodules found they contained valuable metals such as nickel, manganese, copper and cobalt. Initially, because the nodules were located in very deep water, in excess of 5,000 metres, commercial mining was not considered viable. By the late 1960s, with advances in technology, it appeared that harvesting of the nodules would soon become a commercial reality. At the same time, it was feared that the economic benefits from mining would accrue only to those few developed states which possessed the necessary capital and technology.

The 1982 United Nations Convention on the Law of the Sea

In 1970, the General Assembly of the United Nations adopted a resolution declaring the resources of the seabed and ocean floor, beyond the limits of national jurisdiction, as the common heritage of mankind, to be governed by an international regime. The development of such a regime was one of the main tasks of the Third United Nations Conference on the Law of the Sea, convened from 1973 to 1982.

The United Nations Convention on the Law of the Sea was adopted in 1982. Part XI of the Convention establishes an international regime for the management of the mineral resources of the deep seabed.

The fundamental principles of the regime, as reflected in the Convention and in the Implementation Agreement adopted by the General Assembly in 1994, are that:

- the mineral resources of the international seabed area shall be the common heritage of mankind and not subject to appropriation by any State;
- all rights in the mineral resources of the international area shall be vested in mankind as a whole and the economic benefits from deep seabed mining are to be shared on a non-discriminatory basis for the benefit of mankind as a whole;
- the International Seabed Authority is established as the organization to administer such resources and to promote and encourage the conduct of marine scientific research in the international area.

Background

Deep seabed mining of polymetallic nodules : A patent study to determine trends in the development of recovery technology (1960-1998)

Background paper prepared by The Secretariat[1]

1. Deep-sea polymetallic nodules were discovered on the ocean floor in 1873 by the HMS Challenger Expedition. Almost a century later, the desire to exploit these deposits to recover the significant quantities of manganese, nickel, copper and cobalt that they contain led to development of an international framework for seabed mining. Under the 1982 United Nations Convention on the Law of the Sea and the 1994 Agreement relating to Implementation of Part XI of the United Nations Convention on the Law of the Sea, the International Seabed Authority, an autonomous international organization, is the organization through which the international community is to organize and control activities in the area beyond the limits of national jurisdiction.

2. Deep seabed mining is a formidable task. Nodule mining technology developers have to address the basic question of how to pick up the nodules from the ocean floor and bring them up to the surface facility, most likely a ship. During the past forty years, three basic design concepts for mining technology have been pursued. Picking up nodules with a dredge-type collector, and lifting them through a pipe; picking up nodules with a bucket-type collector and dragging up the bucket with a rope or cable; and picking up nodules with a dredge-type collector and having the collector ascend by the force of its own buoyancy. In an effort to assist in further development of technologies for exploitation of polymetallic nodules in a rational manner, the Authority commissioned a survey of international patents to identify trends in the development of deep seabed mining technology. The survey covered the period 1960 to 1998. The purpose of the survey was to define the state of the art in deep seabed mining as it relates to polymetallic nodule exploitation and to analyze the patent data in order to identify trends in seabed mining technology. Patents are a public record of invention and innovation. While realizing that not all technologies for deep seabed mining have been patented, the public record allows an examination of the evolution of the technology through time and identifies key contributors in this field.

3. The survey resulted in 352 patents identified from 12 patent systems (see Table 1). The majority (85%) of the patents issued were from the United States, Japan and the former USSR (later the Russian Federation). More than half of the patents found were from the US Patent System, although not necessary filed by inventors in the United States. The search focused on recovery technologies. Research and development activities commenced in 1960s, peaked in 1983 with 34 patents issued and today continues at much reduced pace. Since 1984, on average 6 patents have been issued per year (see Figure 1).

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[1] The Secretariat gratefully acknowledges the assistance of Mr. Ron Simmer, Patscan, University of British Columbia, Vancouver, British Columbia, Canada (rsimmer@unixg.ubc.ca) in conducting the patent search.

Table 1. Contribution by countries to the patent database.

Country Code	Country	Patents Issued		Year of First Record	Relative Contribution (%)
US	United States		200	1961	56.8
JP	Japan		57	1976	16.2
SU	Union of Soviet Socialist Republics	31		1976	
RU	Russian Federation	9	40[a]	1994	11.4
GB	United Kingdom		15	1966	4.3
DE	Federated Republic of Germany		14	1976	4.0
FR	France		9	1969	2.6
EP	European Patent Organization		5	1980	1.4
CA	Canada		4	1973	1.1
NL	Netherlands		3	1979	<1
CN	China		2	1997	<1
KR	Republic of Korea		1	1997	<1
WO	World Intellectual Property Organization		2	1997	<1

[a] *Total from the USSR and the Russian Federation*

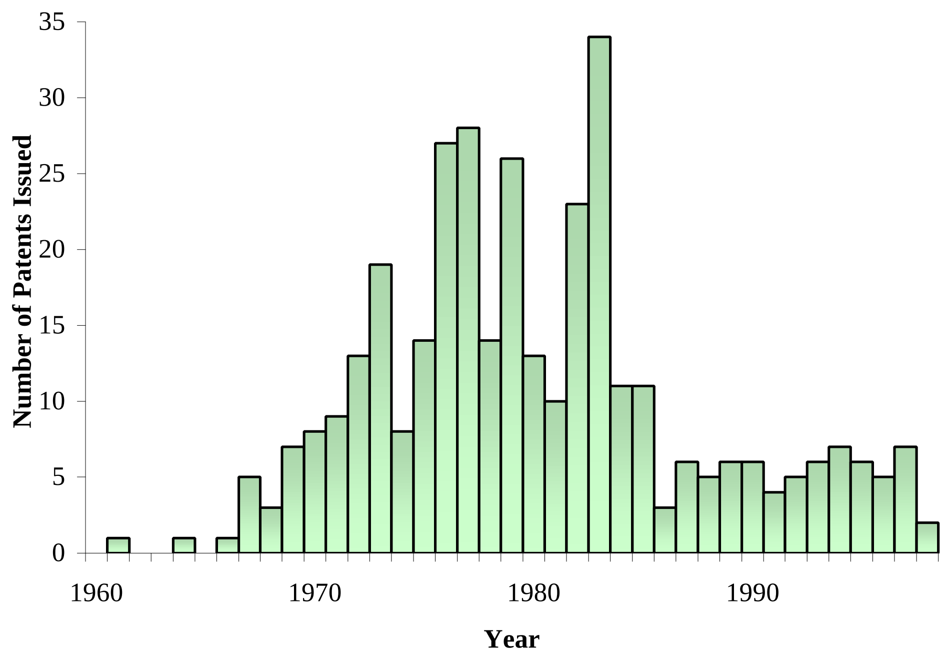

Figure 1. Number of patents issued on an annual basis

2 Patents, Patent data and their Interpretation

(i) Patents

4. The three essential requirements for patentable inventions are generally said to be novelty, utility and the nonobviousness of the subject matter in relation to the prior art. Firms may choose to rely on trade secrets, however, because of the pace of technology development, or the difficulty in policing intellectual property. It has been noted that in cases where technology advances are very difficult and costly to copy, patent protection may not seem worthwhile.[2] In practice, many engineering firms keep their know-how as trade secrets rather than filing patents.

5. Patents issued are one way to observe the behavior of private firms and government agencies at a formative stage in industry's development when, for strategic reasons, these participants are careful about disclosing details of their activities. The seabed mining industry is a good example of an industry in its formative stages.

6. Although they are not essential for the development and introduction of commercial inventions, patents are scientific documents that contain unique and valuable technical information. They are issued to inventors by national governments granting them the right to exclude others from making, using or selling their inventions in the granting country for a limited period of time. In exchange, the inventor discloses the details of the invention to the public. Patent disclosures may be published at the time the patent is granted, before it is examined for patentability, or both, depending upon the laws in effect in the country in question.

7. In order for inventors to easily patent the same invention in more than one country, international treaties have been established which grant reciprocal patent rights to applicants for patents in the signatory countries. The most important of these treaties is the Paris Convention for the Protection of Industrial Property, which has been signed by most of the industrially advanced countries. Under the Convention, an applicant for a patent may file a patent application on the same invention in any other member country within one year and make a formal claim for priority on the basis of the original filing.

(ii) Patent Systems

The United States of America

8. Patents have been granted in the United States since 1836. The issuance of a patent provides protection to inventors that their patented devices or concepts are not used by others, but there is no guarantee of a workable system. Early patents were not conceived as ocean mining patents, but rather as dredging methods (For example, Figure 2).[3]

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[2] Edwin Mansfield (1986), Patents and Innovation: an empirical study. *Management Science* 32,173-181.

[3] For earlier review of US Patents in ocean mining see Manfred G. Krutein (1977), Ocean Mining Patents. Direct Import & Distribution, Los Angeles,70 p; Peter Hoagland III (1986), Seabed Mining Patent Activity: Some first steps toward an understanding of strategic behavior. *Journal of Resource Management and Technology* 14, 211-222.

9. From the US Patent System, 200 patents were identified. Patent activity within the US Patent System has dramatically declined since the height of research and development activity in the early 1980s. In the last ten years, only 14 patents have been issued, representing 7% of the database.

10. The top US Patents are listed in Table 2 with the number of citations in subsequent patents indicated. The most cited patent, US3504943, entitled, "Deep Sea Nodule Mining' by James E. Steele and George W. Sheary assigned to Bethlehem Steel Corporation was cited 30 times (Figure 3).

11. Of the top 34 US patents that are cited more than 8 times in other patents, the ratio of consortia to corporate to individual was 10:11:13. It would appear that patents by individual inventors are slightly more cited than those by corporations or consortia members especially given the ratio of total patents in the database of 102:152:100. However, such a small set may not be statistically significant. The subject matter of the patents is a broad spectrum, reflecting the content of the database, in which the hydraulic lift technology predominates. Patent citation analysis theory would indicate that patents which are seminal and innovative will be highly cited by newer patents building on that technology[4]. A correlation of citations with patent families found that large patent families were not an indicator of being highly cited.

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[4] M.M.S. Karki (1997) Patent citation analysis: a policy analysis tool. *World Patent Information* v.19, n. 4, 269-272.

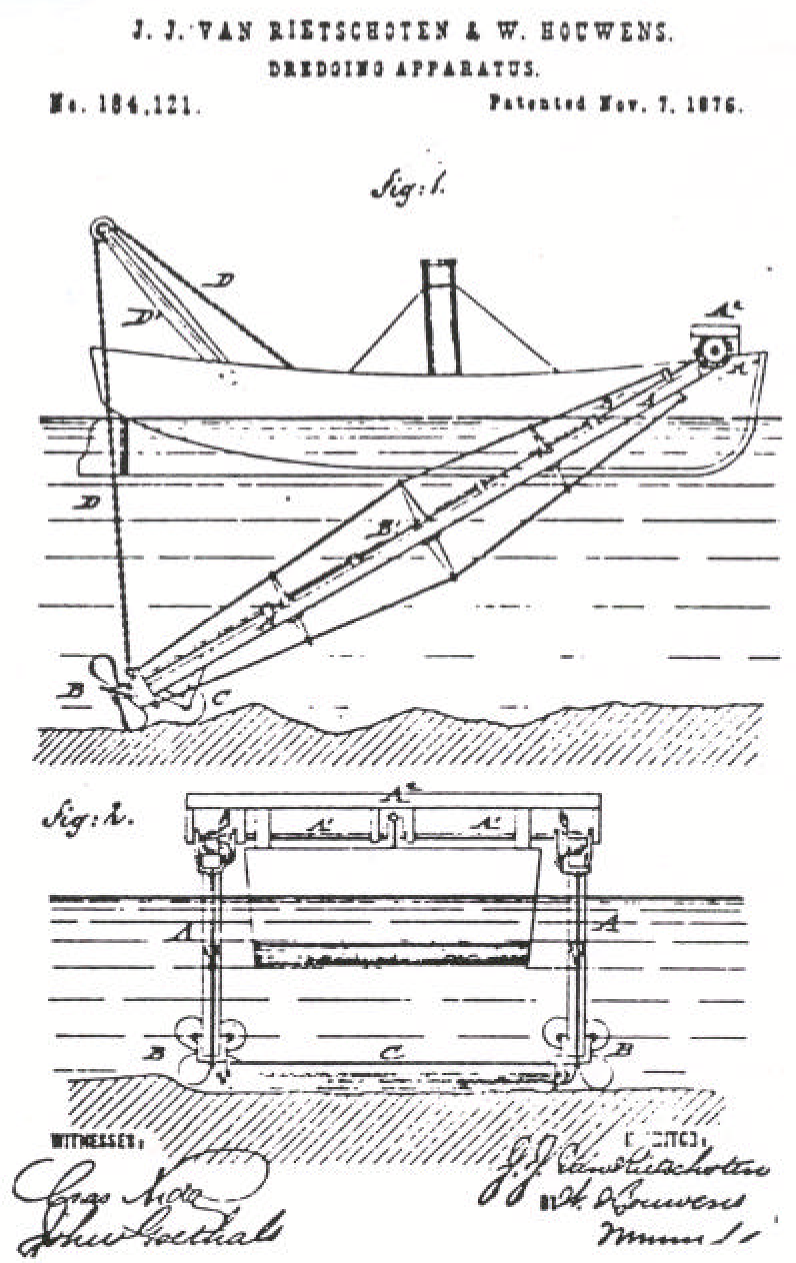

Figure 2. Example of an early dredging system from which modern mining technology is derived (US184121; 1876, J.J. Van Reietschoten and W. Houwens.)

Table 2. Top cited US Patents.

Rank	Title (*Assignee*)	Year	No. Cit.
1	Deep Sea Nodule Mining (*Bethlehem Steel Corp*.)	1970	30
2	Mechanical Deep Sea Nodule Harvester (*Bethlehem Steel Corp*.)	1969	26
3	Submersible Dredge (*Ocean Science and Engineering*)	1972	19
4	Apparatus for Underwater Mining (*Newport News Shipbuilding and Drydock*)	1970	18
5	Pulse Repetition Interval Autocorrelator (*Hughes Aircraft Co. System*)	1980	18
6	Process and Apparatus for Mining Deposits on the Sea Floor (*Kennecott Copper Corp.*)	1969	17
7	Collector Assembly for Deep Sea Mining (*Bertram, J. and Andre M. Rossfelder*)	1971	16
8	Method of Extraction of nodular sediments or the like from the Sea Floor and Installation for Carrying (*Commissariat Energie Atomic*)	1976	15
9	Excavating, Dredging, Raising and Transmitting Earthy and other Loose Matter (*Skakel, J.C.*)	1961	14
10	A Floating Tower for Underwater Dredging (*Gariel, Paul*)	1972	14
11	Process for Solution Mining Nacholite (*Shell Oil Co.*)	1973	14
12	Deep Water Harvesting System (*Nelson, Daniel E. And Arthur J. Nelson*)	1969	13
13	Apparatus for Hydraulically Raising Ore and other Materials (*Klein Schanzlin & Becker AG*)	1973	13
14	Method and Apparatus for Mining Manganese Nodules from the Deep Seabottom (*Masuda, Yoshio*)	1972	12
15	Deep Sea Mining Method and Apparatus (*Earl and Wright*)	1972	12
16	Heave Compensation Apparatus for a Mining Vessel (*Global Marine Inc*.)	1976	11
17	Method and Apparatus for Dredging Employing a Transport Fluid Flowing in Substantially closed Recirculating (*Bos Kalis Westminister*)	1976	11
18	Underwater Mining (*Newport News Shipbuilding and Drydock Company*)	1967	10
19	Ocean Floor Mining System (*Scientia Corporation*)	1968	10
20	Mining Collector (*Westinghouse Electric Corp*.)	1971	10
21	Compressed Air Operated Apparatus for Raising Underwater Deposits (*Trondle, Alois*)	1972	10
22	Hydraulic Dredge having articulated Ladder and Swell Compensator (*Barker, Paton George*)	1973	10
23	Navigation System and Method for Determining the Position of an Ocean Mining Ship (*Gen Dynamics Electronics Div.*)	1978	10
24	Underwater Collecting and Lifting Device (*Ocean Recovery Corp. of America*)	1971	9

25	Endless Bucket Dredge with Articulated Ladder and Swell Compensator (*Barker, Paton George*)	1973	9
26	Process and Apparatus for Transporting Mined Deposits from the Sea Floor (*Kennecott Copper Corp*)	1973	9
27	Deep Ocean Mining, Mineral Harvesting Salvage Vehicle (*Stechler, B.*)	1974	9
28	Marine Riser System with Dual Purpose Lift and Heave Compensator Mechanism (*Global Marine Inc.*)	1979	9
29	Scraper Bucket Apparatus for Deep Sea Mining (*Dane, Ernest B.*)	1972	8
30	Benthic Dredge Construction (*Trippensee Corp.*)	1973	8
31	Submersible Dredging Pump and Shovel arrangement with Suspension and Towing means therefor (*Faldi G.*)	1974	8
32	Method and Apparatus for Separating Solid Particles from a Mixed Fluid Stream (*Deepsea Ventures Inc*.)	1976	8
33	Deep Sea Mining Apparatus and Method (*Diggs, Richard E.*)	1977	8
34	Ocean Mining System and Process (*Lockheed Missiles and Space Co.*)	1980	8

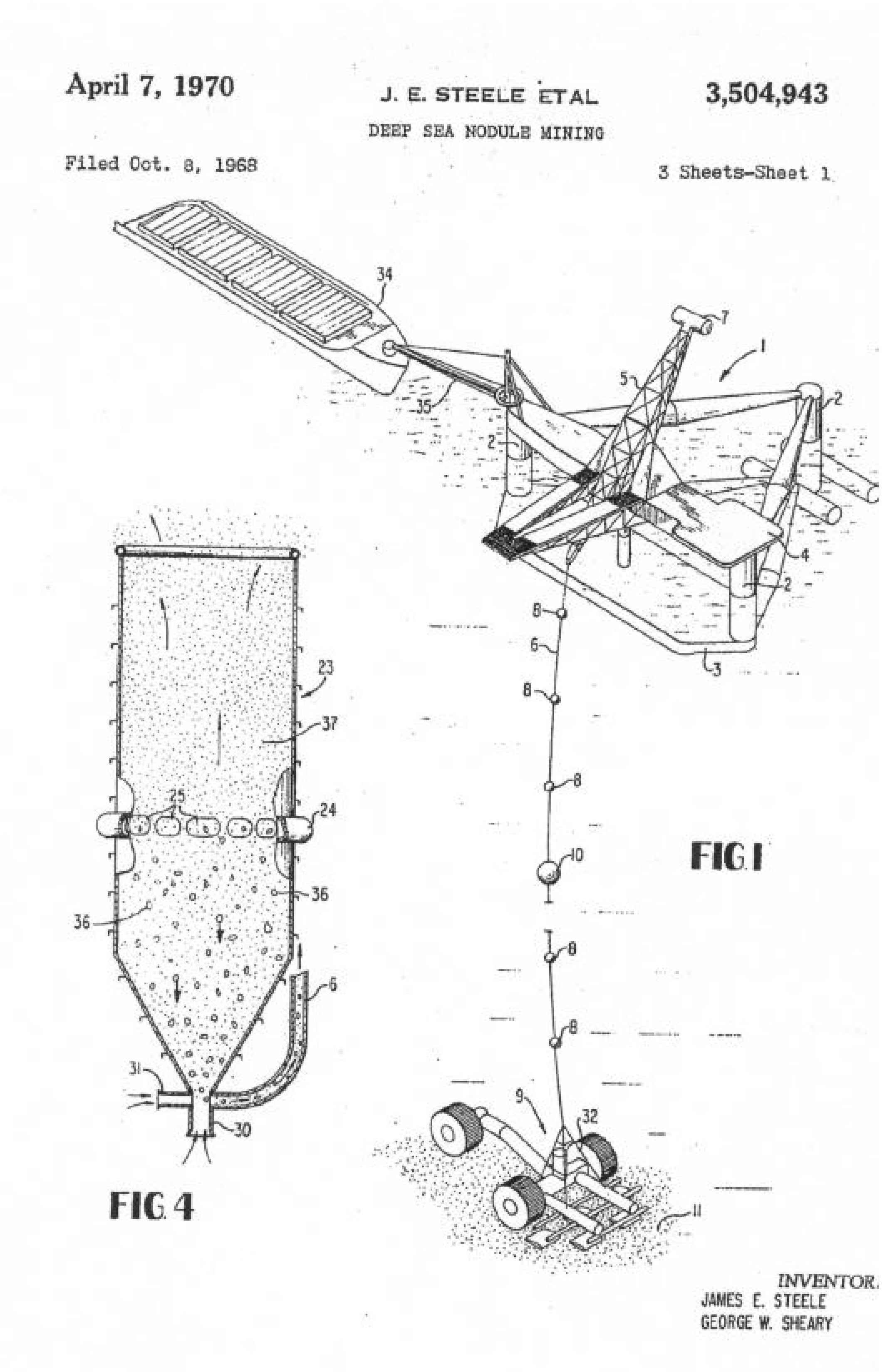

Figure 3. Top cited US Patent (US3504943; 1970, J.E. Steele et al.)

Japan

12. Japanese companies file about 20% of the patents issued in the United States, where foreigners in total obtain 45% of US patents. However, in Japan the barriers against foreign applications are such that only 17% of patents in total are issued to non-Japanese[5] persons or consortia.

13. In this study, similar levels were found. Of the 57 patents with Japanese priority dates, only a few have western equivalents. On the other hand, many of the large patent families for inventions held by the major US and European subsea mining consortia include Japanese counterparts. Japan usually ranks about sixth in preference, after US, Germany, the UK, France, and the Netherlands.

14. One feature that stands out immediately upon reviewing the list of Japanese inventions (Table 3) is the 17 patent filings by Kawasaki, covering a wide range of subsea mineral recovery technologies, all of which were filed in 1983. It is not known whether Kawasaki filed these patents on behalf of the DORD (formerly DOMA) consortium[6], or for their new interests.

15. The other anomaly is the series of 11 early patents on trawl net technology for nodule harvesting, held by private inventor Kingo Yoshida who obviously adapted commercial fishing equipment to new uses.

16. The Japanese consortium also favored mechanical dredging and the continuous line bucket (CLB) technology over a series of projects and tests studies (see Figure 4)[7].

17. Although the patent literature indicates a low volume of patents recently for seabed mining, the Japan Marine Science and Technology Center and the Japanese Metal Mining Agency are said to be conducting research in this area.

Table 3. Chronological List of Japanese Patents

Date Issued	Patent ID	Title	Assignee ID
01-Aug-95	**JP7208061**	Bucket Mining Device of Deep-Sea Minerals	Fukada Hideaki
01-Oct-93	**JP5256082**	Method of Collecting Submarine Mineral, Etc and Device Thereof	Kaiyo Kogyo KK
01-Jun-93	**JP5141175**	Mining Method of Seabed Mineral Resources and crusher thereof and coupler	Takeyama, Hisashi
01-Nov-91	**JP3247892**	Device for Excavation and Collection of Undersea Mineral	NKK Corp
01-Sep-90	**JP2229390**	Method and Device for Lifting Water Bottom Resource	Meiriyou Kogyo KK
01-Jun-90	**JP2164997**	Mining Machine for Abyssal Bottom	Hitachi Zosen Corp

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[5] Thomas J. Klitgaard (1995) The context for innovation in Japan: Comparative competitive aspects and some practical comments. *Canada-United States Law Journal* 21, 55-

[6] DORD consortium: Deep Ocean Resource Development Corporation (DORD) was formed in September 1982. Among it's membership was the Deep Ocean Minerals Association (DOMA) that coordinated the activities of the Japan.

[7] For example see Yoshio Masuda, Michael J. Cruickshank and John L. Mero (1971), Continuous bucket line dredging at 12, 000 ft. *Proceedings Offshore Technology Conference*, Houston, Texas, v. 2, 94-99.

01-Nov-88	**JP63280805**	Energy Recovery System For Airlift Device	Agency of Independent Science and Technology
01-Nov-87	**JP62255298**	Submarine Prospector for Undersea Resources	Nippon Kokan KK
01-Apr-86	**JP61064996**	Abyss-Bottom Metallic Nodule Continuous Sampler With Detachable Type Bucket	Masuda, Yoshio
01-Oct-85	**JP60193558**	Gas-Solid-Liquid Separating Apparatus in Manganese Module Mining System	Agency of Independent Science and Technology
01-Apr-85	**JP60076496**	Method of Coupling Seabottom Resource Collecting Ship With Resource Carrier Ship	Hitachi Zosen Corp
01-Jan-85	**JP60010094**	Gas-Solid Separation Apparatus in Manganese Nodule Mining System	Agency of Independent Science and Technology
01-Jan-85	**JP60010095**	Gas-Solid-Liquid Separation Apparatus in Manganese Nodule mining System	Agency of Independent Science and Technology
01-Oct-84	**JP59178314**	Method for Detecting and Controlling Position of Submarine Construction on Seabed from Sea-Surface	Agency of Independent Science and Technology
01-Mar-84	**JP59055995**	Mining Device for Nodule-shaped Sea-Bottom Resource	Uchida, Masaaki
01-Jan-84	**JP59018894**	Apparatus for Collecting Resources Accumulated on Sea Bottom	Uchida, Masaaki
01-Sep-83	**JP58153890**	Particle Size Sorting Apparatus For Mineral Collecting Apparatus of Manganese	Kawasaki Heavy Ind. Ltd
01-Sep-83	**JP58153891**	Particle Size Sorting Apparatus for Mineral Collecting Apparatus of Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Sep-83	**JP58153892**	Particle Size Sorting Apparatus for Mineral Collecting Apparatus of Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Jul-83	**JP58120993**	Collector for Manganese Nodule, Etc.	Kawasaki Heavy Ind. Ltd
01-Jun-83	**JP58094594**	Apparatus for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Jun-83	**JP58094595**	Apparatus for collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Jun-83	**JP58094596**	Apparatus for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-May-83	**JP58076696**	Apparatus for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd

01-May-83	**JP58091290**	Device for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-May-83	**JP58091291**	Device for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-May-83	**JP58091292**	Device for Collecting Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013890**	Manganese Nodule Collecting Apparatus	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013891**	Manganese Nodule Collecting Apparatus	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013892**	Skid for Manganese Nodule Collecting Apparatus	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013893**	Skid for Manganese Nodule Collecting Apparatus	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013894**	Ore Collecting Machine for Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Jan-83	**JP58013895**	Ore Collecting Machine for Manganese Nodule	Kawasaki Heavy Ind. Ltd
01-Nov-81	**JP56142997**	Method of and Apparatus for Separate Sampling of Submarine Manganese Nodule	Hamanaka, Naoyuki
01-Jan-81	**JP56009589**	Mining Rocket for Manganese Nodules	Fujita, Chuzaburo
01-Jul-79	**JP54083601**	Mining Machine of Manganese nodule	Mitsui Engineering and Shipbuilding Co Ltd
01-Jul-79	**JP54088802**	Mining Apparatus of Manganese Nodules	Mitsui Engineering and Shipbuilding Co Ltd
01-Jun-79	**JP54077201**	Mining Apparatus of Manganese Nodule	Yoshida, Kingo
01-Jun-79	**JP54077202**	Mining of Manganese Nodule and Conveying System in Sea	Yoshida, Kingo
01-Jun-79	**JP54082301**	Mining Machine of Manganese Nodule	Mitsui Engineering and Shipbuilding Co Ltd
01-Jun-79	**JP54082302**	Mining or Manganese Nodules and conveying System in Sea	Yoshida, Kingo
01-Jan-78	**JP53003901**	Method of Prospecting Wide Region for Manganese Nodule	Yoshida, Kingo
01-Dec-77	**JP52149202**	Device for Picking up Manganese Nodule by Magnetic Induction	Mitsubishi Heavy Ind. Ltd
01-Dec-77	**JP53149202**	Device for Picking up Manganese Nodule by Magnetic Induction	Mitsubishi Heavy Ind. Ltd
01-Nov-77	**JP52142601**	Device for Mining Manganese Nodules	Mitsui Engineering and Shipbuilding Co Ltd
01-Oct-77	**JP52119402**	Manganese Nodule Trawl Mining Machine	Yoshida, Kingo
01-Aug-77	**JP52099902**	Trawlnet for Collecting Manganese Nodules	Yoshida, Kingo
01-Jul-77	**JP52085001**	Manganese Nodule Trawl Mining Device	Yoshida, Kingo

01-Jul-77	**JP52085002**	Manganese Nodule Pickup Device	Yoshida, Kingo
01-Jun-77	**JP52072303**	Winglike Pickup Device For Manganese Nodule	Yoshida, Kingo
01-Apr-77	**JP52053702**	Method of Mining Manganese Nodule	Yomatsu Mfg Co Ltd
01-Mar-77	**JP52029402**	Trawlnet Exclusively for Manganese Nodule	Yoshida, Kingo
01-Jan-77	**JP52004401**	Trawlnet for Mining Manganese Nodule	Yoshida, Kingo
01-Jan-77	**JP52005601**	Trawlnet for Mining Manganese Nodule	Yoshida, Kinkichi
01-Jan-77	**JP52006301**	Manganese Nodule Mining Machine	Yoshida, Kingo
01-Jan-77	**JP52007802**	Method of Trawl Mining of Manganese nodule	Yoshida, Kingo
01-Oct-76	**JP51115201**	Trawlnet for Mining Manganese Nodule	Yoshida, Kingo

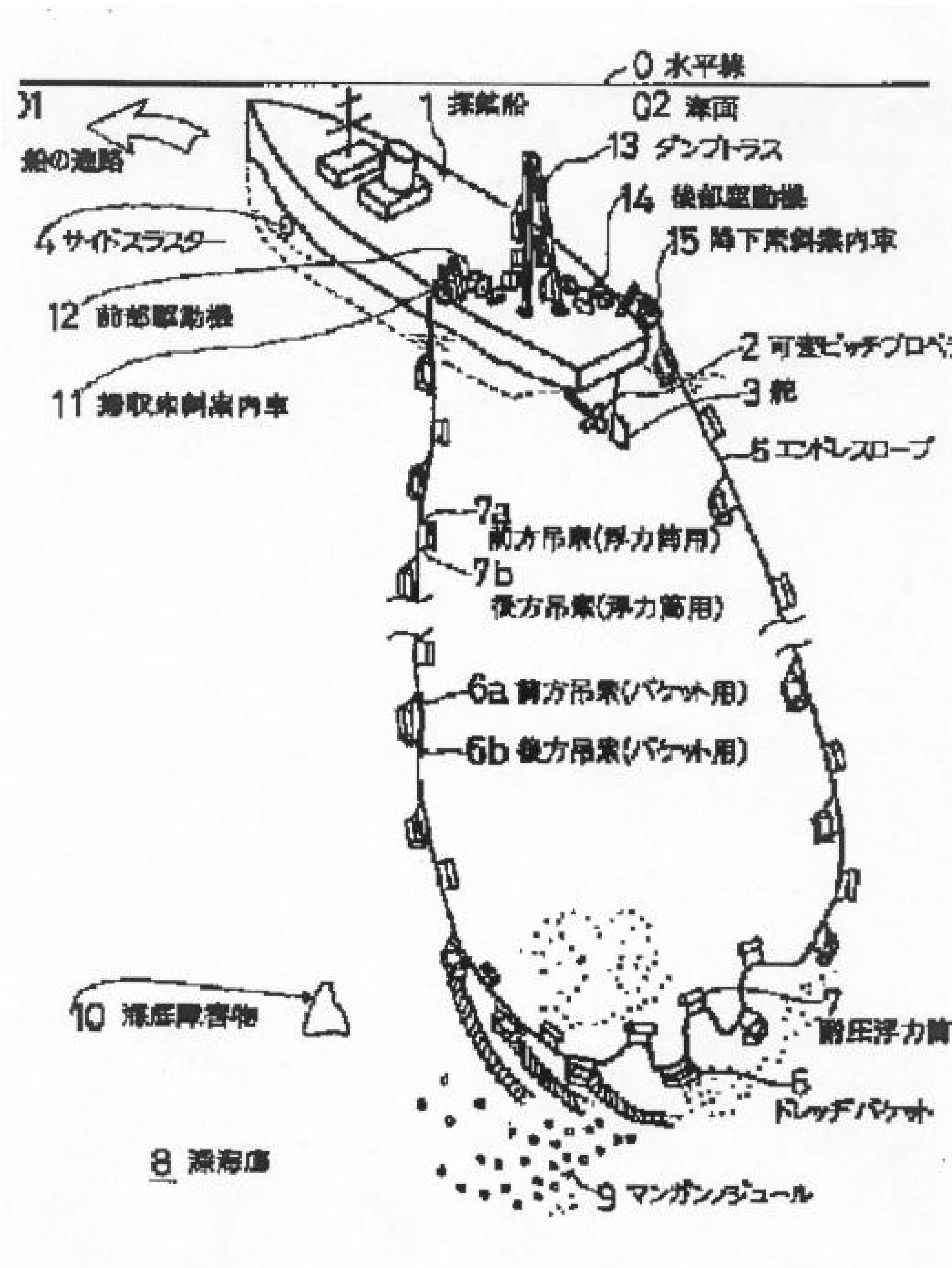

Figure 4. Example of a mechanical system (JP7208061; 1995, Yoshio Masuda)

The Russian Federation

18. The Patent Law of the Russian Federation of June 18, 1992 attempts to harmonize Russian patent practice with the rest of the world. It contains language on the subject of licensing (including compulsory licensing) and reflects an open door attitude towards technology transfer.

19. There appears to be gathering interest in seabed mining technology, since many of the patents are quite recent (40% of the filings in the last five years)(see table 4). All Russian or Soviet patents identified have no foreign counterparts with one exception, and therefore are only available in Cyrillic text. The inventions represented by these patents were filed by research institutions dedicated to various areas of mineral extraction such as placer gold, salt deposits, etc.

20. Probably the most important institution from the point of view of deepsea polymetallic nodule extraction is Okeangeotekhnika Yuzhmorgeologiya, which holds at least four patents directly on the subject as well as a number of other patents on such devices as subsea hydraulic drives.

21. For the most part, patents from this region that are included in the study are represented by Derwent (World Patent Index) abstracts, which are the best obtainable. However, quality translation is lacking in some cases, and it may be difficult to say whether the technology described is for deep-sea applications or only a modification of shallow-water dredging systems. Unfortunately the coverage of Russian patents on WPI and INPADOC does not go very far back in time. Nevertheless, Russian technologists have compiled an excellent book on innovative solutions for deep-sea mining illustrating 100 primary priority patents and listing 286 patents.[8]

22. There is no evidence that the patents from the Russian Federation that are listed were filed as part of the effort of one consortium. Articles in the ocean mining literature indicate that some of these institutes have developed and field tested ocean mining equipment.

23. It should be noted that on commercial databases there is often no distinction made between the two kinds of intellectual property protection under the former USSR for Russian inventions – patents and inventor's certificates. Soviet inventors generally obtained inventor's certificates while foreign interests usually took patents.

24. Current information suggests increased activity in the area of underwater robotics in the new Russian Federation.

[8] Igor L. Alexandrov and Vladimir A. Kozlov (1992), 100 Inventive Solutions for Deepsea Mining: Reference Survey of Patent Documents of Leading Industrial Countries. IRIS Ltd., Moscow, Russia. This document lists 286 patents.

Table 4. Chronological List of Russian/Soviet Patents

Please note that hyperlinked text are in blue. All brown text within the following table signifies that the data can be found in CD2.

Date Issued	Patent ID	Title	Assignee ID
01-Dec-97	**RU2098628**	Method of Underwater Development of Ore Deposits and (the set up?) for Applying the Method	"Energy" Cosmic-Rocket Corp. named after S.P. Koro
01-Aug-97	**RU2086457**	Hull for Underwater Mineral Exploitation Vessel	St. Petersburg Malakhit
01-Jan-96	**SU1387553**	Unit for Underwater Mineral Extraction - Has Mineral Movement Mechanism	Okeangeotekhnika Yuzhmoreologiya
01-Jan-96	**SU1538610**	Unit for Underwater Mineral Extraction	Okeangeotekhnika Yuzhmoreologiya
01-Jan-96	**SU1610969**	Unit for Underwater Extraction of Mineral	Okeangeotekhnika Yuzhmoreologiya
01-Dec-95	**RU2049849**	Floating Construction	Papkov, G.V.
01-Mar-95	**RU2030583**	Method of Underwater Extraction of Mineral Materials	Energiya Res Prodn Assoc Constr Bur
01-Mar-95	**SU1714991**	Underwater Mineral Extraction Complex, which is Lowered from Boat	As Ukrainia Electrohydraulic Des Bur
01-Mar-95	**SU2032030**	Installation for Extraction of Iron-manganese Concretions from Ocean Bed	Okeangeotekhnika Yuzhmoreologiya
01-Sep-94	**RU2020287**	Production of Gas-lift Flow for Raising Liquid Up Submerged Vertical Pipe	Mekhanobr Des Inst
01-Sep-94	**RU2020291**	Method of Creating Gas Flow in Fluid Immersed Pipe	Mekhanobr Des Inst
01-Aug-94	**RU2017968**	Underwater Poly-metal Ores Extraction Plant	Punko, N.P.
01-Jun-94	**RU2014460**	Unit for Raw Mineral Lifting from Underwater	Dalmorgeologiya Prodn Association
01-May-94	**RU2013303**	Catamaran Submarine Craft	AS USSR Fare E Sect Mech Metal Inst
01-Jan-94	**SU1750304**	Installation for Raising Mineral from Ocean Bottom	Nonferrous Noble metals Geology Survey
01-Dec-93	**RU2004808**	Device for Raising Minerals from the Ocean Bed	Nonferrous Noble metals Geology Survey
01-Nov-93	**RU2002903**	Underwater Mining Device Working Unit	Moscow Mining Inst
01-Sep-92	**SU1761880**	Submersible Pump for Minerals Extraction Underwater	Moscow Mining Inst
01-Sep-92	**SU1761956**	Underwater Mineral Beds Mining Plant	Moscow Mining Inst
01-Aug-92	**SU1756568**	Scraper Bucket for Underwater Mineral Excavation	Dalmorgeologiya Prodn Association
01-Jun-91	**SU1656128**	Method of Winning and Processing Deep-Water iron Manganese Nodules	Inst Morskikh Dalnevostochno
01-Feb-89	**SU1461948**	Underwater Mining Dredger	Sverd Mining Inst

01-Jan-89	**SU1453006**	Underwater Minerals Extractor	Moscow Mining Inst
01-Oct-88	**SU1434040**	Underwater Minerals Mining Dredge	Salt Ind. Res Inst
01-Mar-88	**SU1379411**	Dredge Shovel	Chizov, A.E.
01-Mar-85	**SU1146452**	Unit for Underwater Extraction of Iron and Manganese Minerals	Geology of Foreign Countries
01-Feb-85	**SU1138461**	Airlift for Subsea Mining	Novos Transport Cons
01-Sep-84	**SU1112097**	Underwater Mining Equipment	Salt Ind. Res Inst
01-Jun-84	**SU1096406**	Automatic Airlift Control	Don Poly
01-Feb-84	**SU1076585**	Subsea Mining Machine Tooling - Has Spiral Intake Vanes and Connections with Rings Linked to Suction Throat for Uniform Consistency Pulp Intake	Salt Ind. Res Inst
01-Apr-82	**SU0924269**	Underwater Mineral Excavator	Foreign Geological Res
01-Mar-82	**SU0909182**	Underwater Mining Machine with Bucket Chain	AS USSR Fare E Sect Mech Metal Inst
01-Mar-82	**SU0916670**	Underwater Mining Device	Urals Copper Ind.
01-Oct-81	**SU0874886**	Shovel Chain for Subsea Minerals Excavation	Moscow Mining Inst
01-Aug-81	**SU0853108**	Dredge Suction Intake for Underwater Mining	Novos Transport Cons
01-Apr-81	**SU0825777**	Underwater Ore Mining Digger	Karakulkin GG
01-May-79	**SU0662716**	Subsea Mining Installation with Grab	Shevelev, Y.U.G.
01-Nov-78	**SU0632828**	Subsea Miner Grab Shutter	Krainev, P.K.
01-Sep-76	**SU0514955**	Subsea Mining Excavator Bucket - Has Pneumatic Exhaust Line with Non-Return Valve to Maintain Sufficient In-System Back Pressure to Keep Water Out	Transport Cons Res
01-Sep-76	**SU0526694**	A Dredger for Underwater Minerals	Non-metal building Mat
01-May-76	**SU0502119**	Ground Pump for Subsea Mining	Non Ore Cons Materi

(iii) Interpretation of patent data

Patent family databases

25. Although there are dozens of databases that index patents, only a few actually provide a patent family data online. Those that do so vary considerably in country coverage and in the cost of obtaining a family of patent numbers[9].

[9] INPADOC: The International Patent Documentation Center produces the world's largest patent family database. The data is supplied directly by the patent offices of 51 countries and international patenting authorities, and is not restricted

26. An international patent search was conducted on-line using available electronic databases (INPADOC, INPI-3, DERWENT, APIPAT, CLAIMS)[10] to define the state of the art in seabed mining technology. The search was restricted to the time period 1960 to 1998. The search reported on trends in seabed mining technology, including analysis of citation and patent family weighting taking into consideration the economic history of seabed mining exploration, and development of deep water technology.

27. The basic patent data serves as the primary data set. Several assumptions, commonly held by practitioners in this area, were made in the analysis of the patent data. They are:

- That a patent that is highly cited represents seminal and valuable technology, since later inventors seek to improve upon it.
- That an invention with many equivalent or counterpart patents reflects a higher research and development investment and probably a more developed technology than an innovation protected by one or two patents.
- That a patent that has attracted litigation or reexamination proceedings probably represents a valuable technical asset.
- That a patent which cites technical literature may be the result of a higher level of scientific or engineering inquiry than one that does not.
- That an entity that owns many inventions in and around a technology may be assumed to have a considerable engineering and financial stake in the commercial success of that technology.
- That a patent held by an entity with considerable experience, expertise, and financial commitment to an industry probably is more significant economically than one held by a private inventor or an entity with little experience in the field.
- That a patent issued from source employing a high standard of examination such as the European Patent Office will carry more weight in terms of novelty than one from a jurisdiction such as the Republic of South Africa, where examination does not exist. However, there is no guarantee that any patent represents a technology that actually works as disclosed.
- That the value of a specific patent will first depend on the quality of the drafting and the enforceability (not the quantity) of claims before the subject of the technology is addressed.

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covering 8 countries, including such information as whether the patent has lapsed due to non payment of maintenance fees. The PFS/PRS may be searched only with priority application numbers or with patent numbers from a few countries. PATSDI is a similar INPADOC update file, which includes only the most recent 6 weeks of patent citations. It is available from INKA Karlsruhe. PATSDI may be searched freely for patent family data, and citations are displayed online for a nominal fee.

INPI-3: The Institute National de la Propriete Industrielle (the French Patent Office) produces the INPI-3 database. The database includes patents from 16 patent issuing authorities, with most countries being represented from the late 1960's. INPI-3 is exclusively a patent family database; patents are indexed by patent number and priority data only, but without subject matter restriction.

DERWENT: The World Patents Index databases include patent family information from 28 countries.

APIPAT is the patent database of the American Petroleum Institute, and covers primarily patents relating to the petroleum industry, most of which are chemical patents. Patent family information from 8 countries, later increased to 9, was included in the database from its inception in 1964 until 1977.

The CLAIMS databases are produced by IFI/Plenum and are available on DIALOG. Although only United States patents are indexed in the CLAIMS databases, equivalent patents from 5 countries were added to the records of chemical patents from the beginning of the service in 1950 through 1979.

[10] INPADOC: The International Patent Documentation Center;
INPI-3: The Institute National de la Propriete Industrielle (the French Patent Office;
DERWENT: The World Patents Index databases;
APIPAT American Petroleum Institute patent database;
CLAIMS by IFI/Plenum only United States patents.

28. Some of these assumptions may be contested, but the general belief is that the more resources that are dedicated to the creation of an invention, the more chance that the invention will be successful as a result of a higher level of research, engineering design, and testing. A high percentage of patents are improvements on prior art technology. There are many cases in the literature indicating that minor improvements to a mechanism or process allow for differentiation and success in the marketplace. These improvements are often the result of persistent and planned engineering effort by research teams rather those breakthroughs by individual inventors, but of course there have always been independent innovators of outstanding genius.

29. In the field of mechanical engineering, generally, patents are not as critical to the survival of corporations as they are in the areas of pharmaceuticals and chemicals. Often the corporate culture of an industry dictates whether they are technological leaders or followers, whether they are innovators or licensors and imitators.

30. Mining technology on land compared to propose technology for deep seabed mining might not be appropriate, as historically the terrestrial mining industry does not rely on patents for survival. The technology in the land-based industry has developed over generations and generally the players are slow adopters of innovative technology.

3. Deep Seabed Polymetallic Nodule Mining Patent Data

31. The nascent deep seabed mining industry has been characterized in large part by research and development (R&D) of technology to recover minerals from deep seabed polymetallic nodules and to process them metallurgically into metal products. The nearly 400 seabed mining patents that have been granted worldwide are a rough measure of this R&D activity.

32. Patent issues can reveal several interesting aspects of an industry: (a) the identity of participants; (b) the generic type of technology; (c) the technological concentration of patent holders; (d) the technological integration of patent holders; and (e) the timing of inventive activity.

33. In some cases, industrial motivations and strategies may be inferred from these aspects. Moreover, seabed mining might be subject to the cyclical fluctuation of markets for the metals contained in polymetallic nodules[11]. Patent activity could provide some insight into the nature of a possible seabed mining industry cycle.

(a) Related industry comparisons with Seabed Mining

34. A tempting comparison to deep seabed mining is that of deep water petroleum drilling and production, in which engineering expertise provides a measure of economic advantage to

[11] Peter Hoagland III (1986), Seabed Mining Patent Activity: Some first steps toward an understanding of strategic behavior. *Journal of Resource Management and Technology* 14, 211-222.

technically aggressive companies. The development of seabed mining technology has had aspects of a gold rush, since a wide spectrum of professionals and amateurs speculated with different approaches to the engineering challenges offered until political events stalled the process.

35. Offshore oil and gas technology development's applicability to deep seabed polymetallic nodule development is unquestioned. The adjustments from the former to the latter consist of taking into account the crucial factor of pressure resistivity in deeper water.

36. It is recalled that in the summer of 1970, Deepsea Ventures successfully conducted the first manganese nodule mining test in 740 meters of water in the Atlantic Ocean, and became the first company to attract attention to the feasibility of hydraulically mining nodules. The conclusion of this prototype test established a significant milestone in man's attempt to commercially mine natural resources from the ocean floor. Nearly all of the shipboard equipment was originally developed for the oil industry. The information gathered from the prototype dredging test confirmed that new technology combined with conventional equipment could be used to permit the commercial hydraulic dredging of deep ocean ore deposits.

37. Ocean mining technology and deep water drilling technology will combine for the mutual benefit of both enterprises. In general, many ocean mining techniques will be an extension of those used in the offshore drilling industry. As John Flipse wrote in 1969, "... the final success of underwater mineral exploitation lies in imaginative, thorough development of conventional engineering techniques rather than in new and highly-sophisticated devices."[12]

38. The contribution of the marine and oil industry to the success of the first deep ocean mining system has been clearly established. It was the utilization of oil field pipe handling equipment aboard a ship, which permitted the prototype project to be successfully completed in a short time span. The interrelationship of ocean mining with the oil and marine industries will be beneficial to both and will permit the orderly development of deep ocean resources.

(b) Results of the survey

39. The international search resulted in over 350 patents in the area of deep seabed mining. The technology represents ten major classifications (Table 5) and several subclasses per category.

(i) Category 1: Ships, Submersibles or Semisubmersibles Dedicated to Ocean Mining.

40. Many of the early patents in this category are clearly conceptual and not the result of extensive design and testing. However, Newport News, a member of the OMA consortium[13], holds one of the earliest US patents **(US 3522670)**.

41. The Global Marine patent (**US 3918380**) relates to the drillship Glomar Explorer which was used to retrieve a Russian submarine under the cover of a seabed mining contract with Hughes Tool Co.

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[12] John E. Flipse (1969).

[13] Ocean Mining Associates (OMA) was formed in May 1974; Deepsea Ventures was the service contractor for this consortium.

42. Operating characteristics needed for ocean mineral prospecting ships have been discussed at Offshore Technology Conferences[14]. Specifications for a recently constructed deepwater drillship are reviewed in published studies[15]. The state of the art in drillships and semisubmersibles chartered for operations in water depths up to 3,000 metres are examined in recently published trade journal[16]. All the technology exists on these vessels for dynamic handling of very long riser pipes in a range of sea-states.

(ii) Category 2: Mechanical Conveyors for Nodule Harvesting.

43. This category concerns mechanical harvesting systems, which are attractive in their simplicity, requiring one or two vessels with appropriate traction winch systems. Represented here is a wide spectrum of inventions from all over the world, with several held by members of the AFERNOD French consortium.

44. Designs including uncomplicated variations on dragging buckets attached to a continuous line over a swath of ocean floor and then to the surface are contained in the following patents: US4802292, FR2561306, JP07208061, US3889403, US3908291, and US3968579. These patents are mostly held by private inventors in the US or Japan. Several claim buoyancy means.

45. Other continuous bucket systems involving a seafloor vehicle are represented (FR2404584, SU909182, US4155491, US3675348 and US4503629). Patents such as JP59018894 and US3943644 include dredge heads or sledges with continuous line bucket (CLB) devices.

46. The most well developed technology would appear to be represented by US3947980, US3955294 and US3999313 assigned to Hawaii Marine Research. Their patents include a towed sledge crawler controlling the bucket conveyor and a neutrally buoyant track.

47. While hydraulic lift systems were preferred by most of the consortia that actually performed nodule-mining tests, the Japan-based DORD group experimented with the continuous bucket line systems. Their experiences are documented in technical publications[17]. Although there are many Japanese patents in this category, the only invention by the DORD group appears to be US4055006 (Mitsubishi). Possibly there are earlier DORD consortium patents that were not retrieved via the electronic database.

48. The patents of private inventor Kingo Yoshida, who applied trawl-fishing technology to nodule gathering, dominate the category 2-B regarding dredge nets. Results obtained in using simple dragline techniques to dredge for nodules are published in the proceedings of the Offshore Technology Conference[18].

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[14] Johnson, P. (1970), The Design of Ocean Mineral Prospecting Ships. *Proceedings Offshore Technology Conference*, Houston, Texas, v. 2, 95-102.

[15] Schoonmade, W., Janse, W., J. Lusthof and B. Rietveldt –INC Gusto Engineering BV (1998), A new generation DP Drillships, the Gusto 10000 and Gusto P-10000. *Proceedings Offshore Technology Conference*, Houston, Texas, 575-582.

[16] For example, see Offshore Engineer.

[17] Masuda, Y., M. Cruickshank and J. Mero (1971), Continuous Bucket-Line Dredging at 12,000 Feet. *Proceedings Offshore Technology Conference*, Houston, Texas, v. 1, 837-844.; Masuda, Y. (1991), Crust Mining Plans of the Japan Resources Association. *Marine Mining*, Vol. 10, pp. 95-101.

[18] Fernando V. and A.V. Sonawane (1991), Design Improvements in Box Dredges to Enhance the Collection of Manganese Nodules. *Proceedings Offshore Technology Conference*, Houston, Texas, 51-56.

(iii) Category 3: Hydraulic Conveyors.

49. Most of the research into deep ocean seabed mining has focused on hydraulic conveyors, defined as vertical pipes carrying entrained nodules or nodule particulate/slurries upward in a fluid stream.

Gas Lift:

50. Generally speaking, gas or airlift devices are a well-known old technology. Gas lift systems work on the principle of injecting gas into a conveyor pipe to lift nodules with expanding gas bubbles to the mining ship on the sea surface. Since the gas compressor may be shipboard, subsea pumps are avoided, making for an uncomplicated system. However, the pipe string must be very strong to resist buckling due to sea pressure differential, and also of large diameter because of the low spatial concentration of nodule matter in the water[19].

51. Generally, many of the patents in this area claim novelty in the manner of controlling and varying the gas injection rate at positions in the lift pipe. US4319782 discloses a density measuring system to automatically control the matter entering the lift system.

52. A patent by Rhone Poulenc Chimie (US487871) includes a high-molecular weight suspension polymer injected into the lift simultaneously with pressurized gas to provide more efficient lift.

Pump Assisted Conveyors:

53. Usually pumps provide lift in a hydraulic conveyor by being submerged and integrated into the pipe, such as with jet lift pumps, or as part of the subsea vehicle or dredge head. A majority of the patents in this category disclose methods to control a pump system dealing with a variable supply of nodule containing media.

54. Dutch patent NL7803634 offers a novel method by using a ship mounted pump to force a mixture of water and solid buoyancy units into the lift pipe.

55. US3685294 by private inventor Daniel E. Nelson involves compressed air and fuel ignited at the terminus of the collector pipe to provide lift. It is difficult to say whether the device is a pump or gas lift mechanism.

Hydraulic Lift Systems Involving Intermediate Stages:

56. Intermediate stage systems appeared very early, apparently for a variety of reasons. Most appear to be buoyant, offering a midwater platform to refine the nodules, store them temporarily, or involve a different lift system for transportation to a surface ship. JP2229390 is unique in offering capsules loaded with nodules traveling in an ascending stream in a conduit.

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[19] See H.E. Engelmann, (1978), Vertical Hydraulic Lifting of Large-Size Particles – A Contribution to Marine Mining. *Proceedings Offshore Technology Conference*, Houston, Texas, 731-738.

Valves and Control Systems:

57. This category is dominated by International Nickel and Sedco. It would appear that Donald Taylor's patents were used by Sedco.

(iv) Category 4: Risers for Hydraulic Conveyors.

58. Well-known offshore engineering and construction companies such as Coflexip and Hydra Rig hold some of the patents in this area, but Global Marine and consortia member Deepsea Ventures hold many.

59. All of the patents borrow from the well-developed petroleum drilling and production riser technology of the era. Since petroleum riser technology represents proven methods of raising fluid and mud from impressive depths, it was logical to apply it to raising slurries or entrained nodules from the seabed.

60. The basic engineering problem confronted when attempting to connect a moving ship with a seabed harvesting device is that the variable weight of the riser and its fluids must be counterbalanced by a dynamic tensioning system. In the offshore oil industry rigid pipe risers were tensioned by a variety of active and passive methods involving counterweights on wire ropes, pneumatic springs, and pneumohydraulics.

61. The patents in category 4-C resemble the methods used in the offshore oil industry for motion compensation and pipe handling. There is a very large amount of offshore engineering literature in this area as well as a wealth of US Navy reports[20].

62. The two inventions by Coflexip are the only representatives of flexible riser technology, pioneered by Coflexip and copied by others in offshore services. Flexible riser technology avoids the problems of motion compensation and tensioning at the ship interface by use of buoyancy modules. Cost considerations have been a factor against flexible risers. The scarcity of patents held by Coflexip and its competitors generally speaking may be a result of the tendency of firms in the elastomer industry to prefer trade secrecy to patents.

63. Dutch patent NL7804625 is the only representative of the concept of the articulated riser, a hybrid of rigid and flexible systems, which however still seems to involve a tensioning system. US4031919 represents another form of articulated riser involving universal joints. One concept

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[20] B. Rudshaug and T. Skibelid (1999) Modern use of closed loop hydraulics for controling and positioning of cylinder-based hoisting systems, *Proceedings of the 1999 SPE/IADC Drilling Conference*. Part 1 Sydney Australia; Geir Mose and Bjorn Larsen (1997) Dynamics of deep water marine risers – asymptotic solutions. *Proceedings of the International Offshore and Polar Engineering Conference* v. 2 123-130.; Thomas C. Austin, Roger Stokey, Chris von Alt, Richard Arthur and Rob Goldsborough (1997) RATS, a relative acoustic tracking system developed for deep ocean navigation. *Proceedings of the 1997 Oceans Conference*, Halifax, Nova Scotia, Canada, v. 1, 535-540.; Franz S. Hover, Mark A. Grosenbaugh and Michael S. Triantafyllou (1994) Calculation of dynamic motion and tensions in towed underwater cables. *IEEE Journal of Oceanic Engineering* v. 19, p. 449-457.; H. Ormberg and K. Larsen (1998) Coupled analysis of floater motion and mooring dynamics for a turret-moored ship. *Applied Ocean Research* v. 20 p. 55-67. Andre J.P. Leite, Kazuo Nishimoto, J.A.P. Aranha, and Celso K. Morooka (1992) Minimization of vertical wave exciting force and heave motion of a production semisubmersible with rigid risers. *Proceedings of the 11th International Conference on Offshore Mechanics and Arctic Engineering*, Calgary, Alberta, Canada. p. 215-222.; N. Ismail, R. Nielsen and M. Kanarellis (1992) Design considerations for selection of flexible riser configurations. *Offshore and Arctic Operations, 1992 American Society of Mechanical Engineers.* p 45-57.; E.D. Valenzuela (1988) Dynamic Behavior and cost comparison of surface and nonsurface piercing Deepwater Production Risers, *Proceedings Offshore Technology Conference*, Houston, Texas, 481.

represented by US 3736077 uses buoyancy tanks spaced on a rigid riser column to support the riser pipe category and associated load of nodule slurry.

64. US4147454 discloses a method of constructing large diameter mineral harvesting pipes on the high seas by wrapping sheet metal on a tubular core. This is not a new concept, but a recycled idea from the pipelaying industry in which a pipeline is continuously fabricated onboard the pipelaying barge as it is laid.

65. There are parallels between pipelaying equipment and some ocean mining systems, since they both require positioning and tensioning long pipe strings. US3908290 discloses an apparatus for allowing the inclination of the riser tube, in a way similar to the variable angles achieved on pipelaying vessels.

66. The deepest petroleum production or drilling riser system discussed in the literature reach water depths in the range of 3,000 meters. Such rigid riser technology was used on the offshore nodule mining tests conducted by the American-based consortia. Some recent published articles on riser innovations include steel catenary systems that do not need complex motion compensation devices [21].

(v) Category 5: Dredge Heads for Hydraulic Conveyors.

67. Category 5 contains most of the inventions for the collection of nodules. This category therefore contains inventions related to dredge heads, and suction heads that are passively pulled over the seabed.

68. Early patents in this section such as US 3010232 are highly cited by later patents, indicating technology that was worth building upon. It is assumed that the designers of nodule mining systems adapted some of their innovations from existing suction dredge technology, such as the highly cited UK patent GB 1156547, "Dredge for harvesting molluscs".

69. A specific invention may claim several elements, but for ease of review category 5 has been broken into five subclasses relating to the principal element of inventive novelty.

70. Patents by prime members of the early consortia, especially Deepsea Ventures, are well represented in all five subclasses. For example, in class 5-D "Roller Drum Systems," Preussag, Bethlehem Steel, and Deepsea Ventures all filed protection for inventions relating to rotary drum systems for gathering nodules.

71. Patents filed in Japan (most often by Kawasaki) appear in all five subclasses in the 1980's. There would appear to have been an effort by Japanese companies to protect in Japan some of the technology developed in other nations active in the area.

(vi) Category 6: Seabed Traveling Subsea Vehicles Tethered to Hydraulic Conveyors.

[21] Anon.(1997) Steel catenary riser for a taut-leg moored semi-submersible platform. *Proceedings Offshore Technology Conference* v. 4 p. 15 p.; Lyle Finn (1998) Reliable riser systems for Spars. *Proceedings of the 1998 17th International Conference on Offshore Mechanics and Arctic Engineering*, Lisbon, Portugal 8 pp.; L.F. Bensimon (1998) Potential dynamic instability of free-hanging catenary risers in very deep waters. *Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering* 9 pp. ; K. Zare and T.K. Carra (1990) Dynamic response of Lazy-S Risers in random seas. *Proceedings Offshore Technology Conference* 117.

72. This category relates to subsea vehicles that have a degree of steering or self-propulsion involving more mobility than a simple dredge head. These inventions would appear to be a second phase of development, many offering multi-tasking vehicles with combined separation, communition, and pumping elements.

73. Some technical papers relating to remote controlled subsea tractors, including experiments by Kennecott with their dredging vehicle have been published[22].

74. The NAMSSOL diamond harvesting project off Namibia currently involves a 100-ton crawler tractor, but no patents for it could be definitively identified.

(vii) Category 7: Independent Subsea Vehicles for Nodule Transport.

75. In this category are generally classified vehicles without tethered conduits to support vessels, vehicles that gather quantities of nodules from the seafloor and ascend by buoyant means to the sea surface for retrieval.

76. Regarding autonomous remote-controlled vehicles (7-a), French research institutions seem to dominate, with inventions protected with large patent families. The Centre National de Exploration des Oceans (now IFREMER) has one invention and the Commissariat a l'Energie Atomique has two (US 4231171 and US 4343098 are in the same patent family). Mainly private inventors and Russian academies hold the remaining inventions.

77. Concerning manned submarine vehicles for ocean mining (7-b); there are few inventions. The costs and liability of manned work systems at great depth are a consideration. Shell Oil's submarine dredging apparatus (US 3706142) includes a manned diving bell. Shell purchased several dry subsea oil production chambers services by a Lockheed one atmosphere diving system in the 1970's. The Lockheed Petroleum Services (later CanOcean Resources) diving system was successfully deployed on deepwater production manifolds and sold to Shell and Petrobras for over 10 years with no fatalities or environmental accidents.

78. SEAL (Subsea Equipment Associates) an international consortium active in the North Sea at the same time developed a similar diving bell system. The history of these developments may be reviewed in the monograph entitled, “Deepwater Oil Production and Manned Underwater Structures"[23].

79. Only a few patents appear in the third section (7-C) on launch and recovery systems, although this is a critical part of the system for using small submersibles. The design and operation of launch and recovery systems is a challenge in conditions involving variable sea states. The US Navy and several oceanographic research institutions have conducted considerable research into the handling of snap loads by a variety of active and passive motion compensation and shock-absorbing systems.

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[22] Heine, O. and S. Suh (1978), An Experimental Nodule Collection Vehicle Design and Testing. *Proceedings Offshore Technology Conference*, Houston, Texas, 741-749.

[23] Michael E. Jones, (1981) *Deepwater Oil Production and Manned Underwater Structures*. Graham & Trotman, London.

(viii) Category 8: Novel Technologies.

80. The technologies classified in this section did not fit in the usual areas of nodule retrieval devices. Dutch patent NL7804897 in 9-a claims a method of adhesively attaching buoyant material to nodules.

81. In section 8-b related to magnetic gathering, major companies such as Preussag, Komatsu, Mitsubishi, and Chevron are represented. The remaining constitutes one Korean and several Russian inventions.

82. In category 8-c, concerning nodule gathering by freezing, two private inventors hold a pair of German and French patents respectively.

83. Relating to electrochemical methods of ocean mineral recovery in section 8-d, only private inventors are represented. These inventions would appear to be somewhat prophetic and conceptual.

(ix) Category 9: Subsea Mining Technologies Specifically for Minerals other than Polymetallic Nodules.

84. Ocean mining techniques have borrowed from standardized systems developed for seaway excavation. It is obvious that most of the functions of the devices designed for ocean mining dredge heads are listed, such as screens, crushers, pumps, airlift, jet nozzles, etc.

85. As an example of the volume of US patents in this area, the range of classes from 37#317 to 37#329 contains 333 patents from 1974. Obviously there is a large body of prior art in the area of shallow-water suction and excavating dredges some of, which might be applicable to deepwater applications. Without a doubt, there is a great deal of dredging technology, which is either not protected by patents or is in the public domain.

86. Engineering philosophies related to underwater mining for diamond and other minerals are discussed in reference [24].

(x) Category 10: Ancillary Technologies.

87. There appears to be very little patent data related to the subject of environmental protection in ocean mining systems.

88. Category 10-b contains patent data found regarding instrumentation, exploration, monitoring, and bottom sampling for ocean mining.

89. Concerning bottom-sampling devices, a preliminary search of US patent records indicates over fifty patents issued in this subject area. Since bottom sampling instrumentation for scientific research is a low volume product area, one could safely assume many bottom-sampling instruments have been created that are not evident in the patent records.

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[24] Denovan, R. and R. Norman (1996), Engineering Philosophies Associated With Subsea Diamond Sampling and Mining. *Proceedings Offshore Technology Conference*, Houston, Texas, 589-609

90. Some patents by consortia members such as Preussag appear for bottom sampling grabs. Most of the sampling devices appearing in this section are simple mechanical devices, with a few exceptions. US 3942003 may be of interest, in that it is an *in situ* system of mineral analysis. Sumitomo patent (US 4319348) discloses a nodule survey system. US 4135395 by INCO relates to a monitor for transmitting the rate of nodule collection. Experiences related to sampling manganese nodules have been reported in the literature[25].

91. A couple of patents related to undersea mineral exploration turned up, JP53003901 and US 4075599. Many such patents exist for methods of analyzing various stresses in risers and other offshore systems by firms such as Honeywell and Schulumberger. Recently the patenting of software has become popular, but the vast majority of engineering software remains protected by copyright.

92. Category 10-c contains some older patent data related to subsea navigation, positioning and motion compensation. Comparing the systems and instrumentation on modem pipelaying and petroleum drilling/production systems, this is antiquated technology. There are many other technologies which could be reviewed to include in ancillary systems for ocean mining such as underwater communications, marine robotics, and subsea power, possibly involving fuel cells, nuclear generators, rebreathing diesels, hydrazine engines, etc.

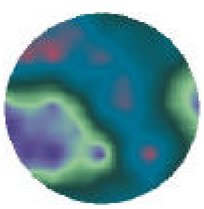
Table 5. Classification of Deep Seabed Mining Patents

Classification Category	No. Patents	
	SubClass	Class
1. Ships, submersible or semisubmersible vessels dedicated to nodule mining.		21
a. Ship shape vessels	9	
b. Vertically positioned vessels, submersibles and semisubmersibles	10	
c. Ship based nodule separation/classification	2	
2. Mechanical conveyors for nodule harvesting.		42
a. Line bucket systems	20	
b. Dredge nets	13	
c. Dragline scrapers, grab buckets	9	
3. Hydraulic conveyors.		52
a. Gas or air lift	17	
b. Pumps	21	
c. Intermediate stage systems	10	
d. Valves and controls		
4. Risers for hydraulic conveyors.		24
a. Flexible risers	3	
b. Pipe section rigid risers	6	
c. Pipe handling and motion compensation systems for rigid risers	15	
5. Dredge heads for hydraulic conveyors.		57
a. Hydraulic jets	13	
b. Separating or classifying means	17	

[25] Fernando V. and A.V. Sonawane (1991), Design Improvements in Box Dredges to Enhance the Collection of Manganese Nodules. *Proceedings Offshore Technology Conference*, Houston, Texas, 51-56.

c. Comminuting or crushing means	2	
d. Roller drum systems	12	
e. Supports, fixtures, and screens	13	
6. Seabed traveling subsea vehicles tethered to hydraulic		35
conveyors.	8	
a. Sleds	3	
b. Wheeled	18	
c. Tracked or crawler	6	
d. Variably buoyant vehicles		
7. Independent subsea vehicles for nodule transport.		21
a. Autonomous remote-controlled vehicles	13	
b. Manned vehicles	4	
c. Launch and recovery systems for vehicles	4	
8. Novel technologies.		15
a. Adhesive gas bubbles raising nodules	1	
b. Magnetic gathering	6	
c. Freezing	4	
d. Electrochemical	4	
9. Subsea mining technology specifically for minerals other than polymetallic nodules.		51
Excavators, bucket dredges, grabs	18	
Hydraulic dredges, suction heads	19	
Stockpiling, slurry lines	2	
Drilling, leaching	6	
Structures	6	
10. Ancillary technology		23
a. Environmental protection	1	
b. Instruments, bottom sampling systems	16	
c. Positioning, navigation systems	6	
Total Patents		341

* Some of the technologies disclosed in these patents may fall into more than one of the following categories or classifications. Not all patents fell into the categories, 11 were outside this classification scheme.



4 Findings from the Survey

93. The majority of seabed mining patents have been issued in those countries where private firms or government agencies have been the most active participants in the seabed mining industry: the United States, Japan, the Soviet Union, the United Kingdom, West Germany, France, and Canada. In some cases, firms have patented their inventions in more than one country to provide extra protection for that invention.

94. It is evident that more seabed mining patents have been granted in the United States than in any other country. It is probable that most seabed mining firms envisioned the United States as the primary location for the manufacture, use, or sale of seabed mining technology, and therefore patents rights were perceived as more valuable there.

Consortia.

95. By the early 1980s, several of the world's largest private firms entered into partnership arrangements or joint ventures for the purpose of forming seabed mining consortia. In many cases, only a few companies that participate in each consortium hold patent rights.

Potential entrants

96. Several other large private firms have conducted seabed mining R&D and hold patent rights to seabed mining inventions. These firms have not joined with others to plan for or conduct seabed mineral development and are generally not considered active members in the industry. These firms are considered as potential entrants to the seabed mining industry.

Individuals.

97. Other small firms or individuals hold patents to seabed mining inventions. This group includes small engineering firms and patent development companies. Some potential entrants may be in the engineering business, conducting R&D with the intention of selling experience or patent rights to more active firms.

98. Seabed mining consortia firms as a group hold more of both nodule recovery and metallurgical process patents than either the potential entrants or engineers. Interestingly, potential entrants and engineers considered together hold more nodule recovery patents than the consortia as a group; they have emphasized recovery technology. The consortia have tended to emphasize both recovery and processing technology, which may reflect interests in achieving vertically integrated operations.

Timing of patent activity

99. The timing of patent activity is an important quantitative measure of rate of invention in an industry. R&D usually are a prerequisite to invention. Therefore, the timing of patent activity may provide a rough measure of the timing of R&D activity. This is especially useful in an understanding of the seabed mining industry, because much of this effort has been directed at R&D. If the seabed mining industry is cyclical in nature, a trait that generally is characteristic of mining industries, an examination of patent timing may help to describe the nature of the cycle.

100. In the United States, the process of application for the issue of a patent on an invention takes an average of two years due to a tremendous backlog of patent applications and a limited examining staff at the Patent and Trademark Office. This rule-of-thumb holds true for seabed mining patents as well. Because most seabed mining patents were granted between 1973 and 1978, it follows that applications for these patents most likely were filed between 1971 and 1976.

101. As roughly indicated by this timing pattern, most seabed mining R&D, which resulted in applications filed during 1971-76, must have taken place in the late 1960s and early 1970s.

102. Although the lag time of seabed mining R&D to economic conditions in the metals markets is unknown in this industry, a complex interaction of factors probably worked first to spur and then to slow seabed mining R&D. These factors may be related to economic signals, political events at the Third UN Conference on the Law of the Sea, and legal uncertainties

associated with the status of exploration sites. R&D accelerated during the early 1970s when economic conditions generally were bright. Subsequent to the time of the 1973-74 recession, which was precipitated by the energy crisis, seabed mining patent activity leveled-off and declined steadily thereafter. Thus, if a seabed mining R&D cycle exists, the period can be very crudely estimated at twenty years.

103. Interestingly, if this period should persist, the next upswing would occur in the early 1990s. This coincides with the beginning of the expiration dates for the bulk of the seabed mining patents. As these patents expire, the technology that they describe can be manufactured, sold, or used without restriction. This increased availability of technology might then enhance a renewed industrial interest and reinforce any tendency for cyclical behavior in seabed mining activity.

104. It is known that the consortia had constructed timetables for their R&D programs. When their programs had been completed, the consortia decided not to continue seabed mining R&D. It is possible that the individual strategies of seabed mining consortia may have been important factors in shaping this round of patent activity.

105. The production of metals from seabed nodule ores involves two broad problems: the recovery of nodules from the seabed and the metallurgical processing of those nodules. Each problem can be separated into several generic categories of technology. The recovery of nodules consists of collection, lift, surface support, and transportation technologies. The metallurgical processing of nodules consists of reduction, extraction, and electrowinning of nickel and copper, and beneficiation of other metals like cobalt and manganese.

106. Because patents afford the patent holder the right to exclude others from the manufacture, use, or sale of inventions, patents are an important part of the strategies of firms and agencies as they operate within an industry. In a formative minerals industry that has focused primarily on R&D, observations of patent activity are one way to uncover and examine the behavior of participating firms and government agencies.

107. As might be expected, those firms or government agencies that have ventured together as seabed mining consortia hold the greatest concentration of seabed mining patents or seabed mining patent claims. This is a clue to one possible strategy. Firms or government agencies have ventured together in order to spread the risks of investment in seabed mining R&D. Because seabed mining is a formative industry that has not yet reached commercial proportions, and because there is plenty of room for further technological developments, the risks for a single firm are quite large.

108. For reasons related to a number of interdependent economic, political, and legal reasons, seabed mining patent activity for all firms and agencies commenced in the late 1960s, peaked in the mid-1970s, and has fallen today to a reduced rate. This pattern is a rough representation of R&D activity in seabed mining and may indicate the possibility of a seabed mining industry cycle. From an international perspective based upon patent activity, one might very well expect to see a renewed industrial interest in seabed mining before the turn of the century.

109. R&D and patent activities will continue through the life of the industry as competitors seek new, less costly methods of producing metals from deep ocean polymetallic nodules. If and when another surge of seabed mining activity occurs, the technological information contained in the early patents undoubtedly will facilitate progress toward innovation and thereby speed the rate of eventual commercialization. The lis of valid patents, representing approximately 39% of the database is contained in table 6.

Table 6. Patents Under Protection

Please note that hyperlinked text are in blue. All brown text within the following table signifies that the data can be found in CD2.

Patent ID	Date Issued	Title
US4506591	01-Mar-85	Ocean Floor Dredge System Having A Pneumohydraulic Means Suitable For Providing Tripping And Heave Compensation Modes
US4407716	01-Oct-83	Liquid Flow System Including Multi-Axial Liquid Flow Screening Means for Excluding Oversized Slender Objects Carried by a Liquid
US4387518	01-Jun-83	Separable Liquid Flow Screening Means for Excluding Oversized, Slender Objects Carried by a Liquid, and Dredge Means Including Same
US4327505	01-May-82	Remotely Steerable Dredge Vehicle
US4347029	01-Aug-82	Pipe Transfer System
US4323216	01-Apr-82	Balanced Support Plates
US4347675	01-Sep-82	Dredging Means Having Means for Excluding Oversized Slender Objects
US4382361	01-May-83	Ocean Floor Dredge System Having A Pneumohydraulic Means Suitable For Providing Tripping And Heave Compensation Modes
US4365787	01-Dec-82	Pipe string lift system
US4438902	01-Mar-84	Pipe String Lift System
US4367601	01-Jan-83	Separable Means for Excluding Oversized Slender Objects
US4408404	01-Oct-83	Pivotable Articulated Support Shoe for Hydraulic Nozzle
US4346937	01-Aug-82	Dredging Apparatus Including Suction Nozzles
JP58013891	01-Jan-83	Manganese Nodule Collecting Apparatus
US4398361	01-Aug-83	Recovery of Sediments from the Bottom of the Sea by Suspended Suction Pipe
US4386473	01-Jun-83	Recovery of Sediments from the Bottom of the Sea
JP58120993	01-Jul-83	Collector for Manganese Nodule, Etc.
JP58076696	01-May-83	Apparatus for Collecting Manganese Nodule
JP58091290	01-May-83	Device for Collecting Manganese Nodule
JP58091291	01-May-83	Device for Collecting Manganese Nodule
JP58091292	01-May-83	Device for Collecting Manganese Nodule
JP58094594	01-Jun-83	Apparatus for Collecting Manganese Nodule

JP58013890	01-Jan-83	Manganese Nodule Collecting Apparatus
JP58094596	01-Jun-83	Apparatus for Collecting Manganese Nodule
JP58013895	01-Jan-83	Ore Collecting Machine for Manganese Nodule
JP58153890	01-Sep-83	Particle Size Sorting Apparatus For Mineral Collecting Apparatus of Manganese
JP58153891	01-Sep-83	Particle Size Sorting Apparatus for Mineral Collecting Apparatus of Manganese Nodule
JP58153892	01-Sep-83	Particle Size Sorting Apparatus for Mineral Collecting Apparatus of Manganese Nodule
JP58013894	01-Jan-83	Ore Collecting Machine for Manganese Nodule
JP58013893	01-Jan-83	Skid for Manganese Nodule Collecting Apparatus
JP58013892	01-Jan-83	Skid for Manganese Nodule Collecting Apparatus
JP58094595	01-Jun-83	Apparatus for collecting Manganese Nodule
US4357764	01-Nov-82	Submarine Vehicle for Dredging and Raising Minerals Resting on the Sea Bed at Great Depths
US4448145	01-May-84	Unmanned Submarine Vessel for Dredging of Salvage
US4666347	01-May-87	Hydraulic Conveying of Solids
US4343098	01-Aug-82	Apparatus for Mining Nodules Beneath the Sea
US4324194	01-Apr-82	Stabilized Hoist Rig for Deep Ocean Mining Vessel
US4652055	01-Mar-87	Device for Collecting Manganese Nodules
DE3638998	01-May-88	Apparatus for Picking up Mineral Deposits from the Seabed
US4377186	01-Mar-83	Floating Flexible Tubes
US4878711	01-Nov-89	Method and Apparatus for Mining of Ocean Floors
US4932144	01-Jun-90	Remote Underwater Excavator and Sampler
US4368923	01-Jan-83	Nodule Collector
JP59178314	01-Oct-84	Method for Detecting and Controlling Position of Submarine Construction on Seabed from Sea-Surface
JP60010095	01-Jan-85	Gas-Solid-Liquid Separation Apparatus in Manganese Nodule Mining System
JP60193558	01-Oct-85	Gas-Solid-Liquid Separating Apparatus in Manganese Module Mining System
JP63280805	01-Nov-88	Energy Recovery System For Airlift Device
JP60010094	01-Jan-85	Gas-Solid Separation Apparatus in Manganese Nodule Mining System
US4718835	01-Jan-88	Mining Apparatus and Jet Pump thereof

US5259130	01-Nov-93	Floating Grab Installation for the Recovery of Sand and Gravel
US4334370	01-Jun-82	Method of Transporting Flowable Media of Changing Consistencies
US4685742	01-Aug-87	Equipment for Extracting Ores from Sea beds
SU1761880	01-Sep-92	Submersible Pump for Minerals Extraction Underwater
EP302762	01-Feb-89	Ocean Floor Dredging
SU1761956	01-Sep-92	Underwater Mineral Beds Mining Plant
SU1453006	01-Jan-89	Underwater Minerals Extractor
RU2002903	01-Nov-93	Underwater Mining Device Working Unit
US4892202	01-Jan-90	Deepwater Extended Hold Travel Attachment
US5553976	01-Sep-96	Fluid Riser Between Seabed and Floating Vessel
US5150986	01-Sep-92	Process and Apparatus for Depositing Silt on the Bottom of the Wet Open Working or Dredging
US4937956	01-Jul-90	Ocean Floor Dredging
US5544983	01-Aug-96	Method of Transferring Material from the Bottom of a Body of Water
SU1538610	01-Jan-96	Unit for Underwater Mineral Extraction
DE3237889	01-Apr-84	Multistage Underwater Pump for Winning Minerals from Seabed - Has Ducts to Admit Outside Water for Clearing Solids from Sensitive Gaps
SU2032030	01-Mar-95	Installation for Extraction of Iron-manganese Concretions from Ocean bed
SU1387553	01-Jan-96	Unit for Underwater Mineral Extraction - Has Mineral Movement Mechanism
US4533526	01-Aug-85	Process for Recovering Polymetal Compounds Discharged from a Submarine Hydrothermal Source and Devices for Carrying Out the Same
SU1610969	01-Jan-96	Unit for Underwater Extraction of Mineral
JP61064996	01-Apr-86	Abyss-Bottom Metallic Nodule Continuous Sampler With Detachable Type Bucket
US4328835	01-May-82	Automatic Dump Valve
JP60076496	01-Apr-85	Method of Coupling Seabottom Resource Collecting Ship with Resource Carrier Ship
JP2164997	01-Jun-90	Mining Machine for Abyssal Bottom
JP59018894	01-Jan-84	Apparatus for Collecting Resources Accumulated on Sea Bottom
US4842336	01-Jun-89	Method and Device for Collecting Objects from the Seabed
JP59055995	01-Mar-84	Mining Device for Nodule-shaped Sea-Bottom Resource

US4503629	01-Mar-85	System for Collection and Conveying Undersea Mineral Resources
SU1112097	01-Sep-84	Underwater Mining Equipment
DE3228317	01-Jul-83	Ecological Subsea Mining Plant
SU1076585	01-Feb-84	Subsea Mining Machine Tooling - Has Spiral Intake Vanes and Connections with Rings Linked to Suction Throat for Uniform Consistency Pulp Intake
DE3223219	01-Dec-83	Ecologically Sound Deep-sea Mining
DE3225728	01-Jan-84	Ecologically Friendly Deep-sea Mining
SU1434040	01-Oct-88	Underwater Minerals Mining Dredge
JP62255298	01-Nov-87	Submarine Prospector for Undersea Resources
SU1756568	01-Aug-92	Scraper Bucket for Underwater Mineral Excavation
WO9725488	01-Jul-97	Improvements in or relating to Underwater Mining
DE4039473	01-Jun-92	Procedures for Obtaining Objects from Any Type Body of Water
SU1750304	01-Jan-94	Installation for Raising Mineral from Ocean Bottom
US4497519	01-Feb-85	Metal Particle Recovery at Sub-surface Locations
US4446636	01-May-84	Oceanic Mining System
DE3035904	01-Apr-82	Ores and Minerals Recovered from Sea-bed are Conc. - by underwater flotation before delivery to ship
US4398362	01-Aug-83	Oceanic Seaplow System
US5199767	01-Apr-93	Method of Lifting Deepsea Mineral Resources with Heavy Media
US4585274	01-Apr-86	Mineral and Metal Particle Recovery Apparatus and Method
SU1138461	01-Feb-85	Airlift for Subsea Mining
JP7208061	01-Aug-95	Bucket Mining Device of Deep-Sea Minerals
FR2561306	01-Sep-85	Apparatus for Collecting Polymetallic Nodules from Ocean beds
FR2648510	01-Dec-90	Device for Extracting Nodules by Freezing
RU2004808	01-Dec-93	Device for Raising Minerals from the Ocean bed
RU2013303	01-May-94	Catamaran Submarine Craft
RU2014460	01-Jun-94	Unit for Raw Mineral Lifting from Underwater
FR2650859	01-Feb-91	Device for Extracting Nodules with the Aid of Freezing
RU2020287	01-Sep-94	Production of Gas-lift Flow for Raising Liquid up Submerged Vertical Pipe

RU2020291	01-Sep-94	Method of Creating Gas Flow in Fluid Immersed Pipe
US4802292	01-Feb-89	Continuous Mining Device for Crust Deposits, etc. and Continuous Line Bucket Method with Turning Movement
DE19715284	01-Oct-98	Underwater Mineral Recover Unit Operated in Conjunction with Ship
EP0837192	01-Apr-98	Method and Device for Removing Material from the Seabed
CN2253391U	01-Apr-97	Hydraulic Combined Collecting Device for Deep-sea Multi-metal Nodule Production
JP5256082	01-Oct-93	Method of Collecting Submarine Mineral, Etc and Device Thereof
JP5141175	01-Jun-93	Mining Method of Seabed Mineral Resources and Crusher Thereof and Coupler
JP2229390	01-Sep-90	Method and Device for Lifting Water Bottom Resource
DE3129228	01-Feb-83	Underwater Suction Scraper-Dozer
EP0188924	01-Jul-86	Oceanographic Method for Lifting Loads Collected at a big Depth, Especially Polymetallic Nodules
JP3247892	01-Nov-91	Device for Excavation and Collection of Undersea Mineral
SU1461948	01-Feb-89	Underwater Mining Dredger
US5431483	01-Jul-95	Submarine Solution Mining Containment and Regulation Cover and Method
US5328250	01-Jul-94	Self Propelled Undersea Nodule Mining System
US4999934	01-Mar-91	Dredging Apparatus
US4681372	01-Jul-87	Deep Sea Mining Apparatus
US4656959	01-May-87	Vertical Ship
US4413433	01-Nov-83	Apparatus for Extracting Muddy Materials and Feeding Them to a Treatment Station
US4391468	01-Jul-83	Method and Apparatus for Recovering Mineral Nodules from the Ocean Floor
US4384459	01-May-83	Ocean Energy and Mining System
US4373278	01-Feb-83	Single Line Deep-sea Bucket and Release
US4336662	01-Jun-82	Apparatus for Collecting and Raising Materials from the Ocean
US4333828	01-Jun-82	Automatic Dump Valve
SU1146452	01-Mar-85	Unit for Underwater Extraction of Iron and Manganese Minerals
SU1656128	01-Jun-91	Method of Winning and Processing Deep-Water Iron Manganese Nodules
KR97069136	01-Nov-97	Method for Sorting and Recovering Valuable Metal From Manganese Nodule

WO9842922	01-Oct-97	Underwater Mining Machine
SU1379411	01-Mar-88	Dredge Shovel
CN1167872	01-Dec-97	Oceanic Multi-Metal Nodule Hydraulic Collecting Mechanism
SU1096406	01-Jun-84	Automatic Airlift Control
SU0924269	01-Apr-82	Underwater Mineral Excavator
RU2098628	01-Dec-97	Method of Underwater Development of Ore Deposits and (the set up?) for Applying the Method
RU2086457	01-Aug-97	Hull for Underwater Mineral Exploitation Vessel
RU2049849	01-Dec-95	Floating Construction
RU2030583	01-Mar-95	Method of Underwater Extraction of Mineral Materials
RU2017968	01-Aug-94	Underwater Poly-metal Ores Extraction Plant
NL8005464	01-May-82	Werkwijze voor het regeien van de produktie bijeen drejvend baggerwerktuig
SU1714991	01-Mar-95	Underwater Mineral Extraction Complex, which is Lowered from Boat

5. *Trends in Marine Mining Technology*

110. Over the past decades there have been identifiable general trends in marine technology that would affect applications to seabed mining.

1. Reduced risk to human life in diving and other marine operations because of safety concerns. Remotely operated vehicles (ROV's) that have inspection and some tool handling capabilities have largely replaced Costly and dangerous saturation diving system. Manned one-atmosphere submarines and hard suits have a niche existence.

2. More sophisticated communication systems have made possible the reliable operation of remote-controlled subsea devices including sensors and monitoring devices.

3. Advances in electrohydraulics such as manipulators adapted from nuclear industry have provided for better underwater robotic work systems.

4. Computer technology has made possible such advances as better offshore riser and ship design, modeling of vessel/ocean interactions, and satellite navigation.

5. There has been a strong public awareness of and legislation addressing environmental concerns. Legislation of low-pollution levels has spurred development of non-polluting system and added costs to offshore operations.

6. Better materials and corrosion prevention technologies have extended the life of marine work systems and reduced both maintenance and fabrication costs. Applications vary from impressed-current cathodic protection systems to seawater hydraulics and space age coatings.

6. Conclusions

111. With the exception of three corporations (Deepsea Ventures, Kawasaki and International Nickel corporation), it would appear that much of the technology developed and tested in the 1970's by the consortia active in seabed mining were never patented. Dividing inventions into three groups (consortium members, other corporations, and private inventors) reveals that while consortium members filed few patents in relation to the high cost of R&D they undertook the inventions they did protect often had patent equivalents in many jurisdictions. Also consortia members often had large patent portfolios in the important area of nodule processing and refining, indicating a vertically integrated technology approach. Kennecott as an example holds over 50 inventions for metallurgical processing of nodules.

112. Small numbers of patents were issued to prime members of consortia. Japanese companies hold approximately 17% of the consortia patents. A review of the patents held by the Japanese DORD consortium indicates that many did not have equivalents in other countries.

113. Inventions were found to be 29% held by corporate consortia members, 43% by other corporations, and 28% assigned to individual inventors. Of the companies holding the remaining non-consortia patents, some are well-known offshore supply and contracting firms. Many of the other entities are renowned consultants. Also in this list are universities, research institutions, and the US Navy.

114. The engineering arms of some of the major oil companies are poorly represented by invention patents. Some of these oil companies were involved with consortium members. At the time the offshore oil business viewed ocean mining as a logical extension of their activities. Some papers reviewed the technology transfer process between the seabed and offshore petroleum industries at the time[26].

115. Patents held by private inventors tend to reflect in their mixed quality a lack of technical expertise and research resources. Many are prophetic and conceptual in nature, which may account for why they are slightly more cited by later patents. Private investors perhaps intended to eventually extract value from major operators by suing for infringement. A private inventor regarding trawl net technology holds a large number of Japanese patents.

116. The study indicates the jurisdictions most popular for patent filing for seabed mining technology are the USA, Germany, the UK, France, the Netherlands, Japan, Norway, the USSR (or Russian Federation), the European Patent Office, and Canada. Since the European Patents have become popular, they have tended to replace individual patents filed in individual European countries.

117. Valid patents represent approximately 140 inventions or 39% of the technology. All the earlier patents are now in the public domain. However, the inventions represented by valid

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[26] See for example, John S. Pearson, (1975), Ocean Floor Mining. *Ocean Technology Review*. No. 2.; Michael E. Jones, (1981) *Deepwater Oil Production and Manned Underwater Structures*. Graham & Trotman, London.

patents in rapidly developing areas that involve computers such as navigation, communications, position keeping, control systems and motion compensation systems are probably obsolete.

118. A review of the reports for patents not yet expired, indicates that a growing number of recent patents are generated from Asian countries and Russia, while the older patents filed in the last wave of patent activity in the early 80's from the US and Japan are about to expire. Hydraulic lift methods still appear to be the most popular method of ocean mineral mining. Current active companies in seabed mining do not apparently have patents assigned.

119. The most significant data concerns European applications, which disclose remotely, controlled subsea vehicles for mining diamonds. Another application related to a typical nodule-mining vehicle with a hydraulic lift system. All three applications designate the maximum number of states for coverage.

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