APPLICATIONS OF REMOTE SENSING TECHNIQUES TO OCEANOGRAPHY AND SEA ICE

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Abstract: In chapter (1) the author describes different methods for satisfactory position-fixing and navigation in and under sea ice, all of great importance for exploration and transportation of natural resources, such as oil, gas and minerals, and he emphasizes the importance of a true knowledge of the bottom topography. In chapter (2) he gives information concerning the activity of "The Swedish National Defence Research Institute" in the civil field and technical advances in the submarine/diving area, seismology, and hydroacoustic/optic integrated system for navigation in Arctic waters. Chapter (3) deals with offshore activities, chapter (4) with cargo submarines and LNG submarine tankers, chapter (5) with viewpoints on radio communication systems and submarines operating under ice. Chapter (6) deals with "Swedish Space Corporation and Esrange-activities", chapter (7), finally, with plate tectonics and technology of deep ocean mining.

Sommaire: Dans le chapitre (1) l'auteur décrit les méthodes différentes pour la détermination satisfaisante de la position et navigation dans et sous la glace de mer, tout cela d'une grande importance pour l'exploration et le transport des ressources de la nature, par exemple l'huile, le gas et les minéraux, et il accentue l'importance d'une connaissance exacte de la bathymétrie. Dans le chapitre (2) il présente de l'information concernant les activités du Centre de Recherches de la Défense Nationale Suédoise dans la branche civile et les progrès techniques dans le domaine sous-marin/plongé, dans la seismologie et l'hydroacoustique/optique, systèmes unis pour la navigation dans les mers arctiques. Le chapitre (3) traite les activités hors de la côte, le chapitre (4) les sous-marins de cargaison et les LNG sous-marins tanks, le chapitre (5) les points de vue sur les systèmes de la communication radio-télégraphie et les sous-marins en activité sous la glace. Le chapitre (6) traite la Corporation Espace Suédoise et les activités d'Esrange, et le chapitre (7), finalement, la tectonique méplat et la technologie de l'exploitation des mines au profond de l'océan.

Zusammenfassung: Im Kapitel (1) beschreibt der Verfasser die verschiedenen Methoden zu einer ausreichenden Feststellung der Position und Navigation in und unter dem Meereis, dies alles sehr wichtig für die Erforschungen und Beförderungen der natürlichen Reichtümer, z. B. Öl, Gas und Mineralien. Der Verfasser betont weiter die grosse Bedeutung, genaue Kenntnisse der Tiefenmesstechnik zu besitzen. Im Kapitel (2) präsentiert er Informationen hinsichtlich der Wirksamkeiten der Forschungsanstalt der Schwedischen Landesverteidigung in den zivilen Branchen, sowie betreffs der technischen Fortschritte im Uboots-/Tauchgebiete, in der Erdbebenkunde und in der integrierten Hydroakustik/Optiksystem für die Navigation in den arktischen Meeren. Kapitel (3) behandelt die Offshore-Wirksamkeiten, Kapitel (4) die Last-Uboote unde die LNG Tanker-Uboote, Kapitel (5) die Gesichtspunkte auf die Radiotelegraphiesysteme und die Ubootswirksamkeiten unter dem Meereis. Kapitel (6) erörtert die Schwedische Korporation für Raumforschungen und die Esrange-Wirksamkeiten. Kapitel (7), schliesslich, behandelt die Plattentektonik und die Technologie der Ausbeutung von Tiefseegruben.

1. Different methods for satisfactory position-fixing and navigation in and under sea ice

Large areas of our World are more or less ice-covered, and wide waters of sufficient depth for navigating are often blocked by floating ice. Shipping in such areas is, however, in many cases of great importance throughout the year, especially for exploring natural resources and getting them available for international trade. For a successful ice navigation a true knowledge of prevailing ice conditions is obligatory. Formerly, the navigator was informed of the ice situation ahead of the ship by lookouts in the crow's-nest on the fore or mainmast, if necessary also at the ship's bow, and so it was aboard the Swedish Polar ship VEGA - the first ship in the World that successfully navigated from the Atlantic Ocean to the Bering Strait and circumnavigated Asia and Europe in 1878-1880. In the first decades of the twentieth century the ice situation was still observed by visual reconnaissance, reported, however, by wireless telegraphy or telephony. Thus, a kind of remote sensing technique was then introduced. In the early twenties the reconnoitred sea area was considerably widened by the use of airplanes and later of helicopters too. At the same time photography was introduced for picturing the ice situation. In the thirties radio navigation systems came into use, and the first radar systems were developed. The picture of the viewed area was continuously transmitted from plane or helicopter and received aboard the ship on a TV-screen. This was a great advance, indeed, and it offered the bridge officer a possibility to choose the most suitable route in the ice fields. In the early sixties satellites were put to use for ice studies, and some years later for making excellent ice charts.

In order for Sweden to acquire experience of her own and to assess the capability of remote sensing techniques for surveillance and mapping of sea ice, a comprehensive remote sensing experiment was organized in international cooperation in the Bay of Bothnia in March 1975. It was the first time such a comprehensive remote sensing experiment on sea ice was performed in Europe. Five aircraft, three helicopters, one icebreaker, and about fifty scientists and technicians took part in the experiment. Data were also received from two satellites. Installed in aircraft were forward-looking radar (FLAR), omnidirectional radar (ODAR), and side-looking radar (SLAR); further multispectral camera package and measuring camera as well as high-altitude camera and extensive field measurements. In helicopters were installed microwave radiometer, IR radiometer, IR scanner, and radar altimeter. The modern icebreaker was equipped, in addition to radar, with helicopter, hydrocopter, and sonar for underwater ice profiling.

To the ISP Commission VII Symposium in Freiburg, Federal Republic of Germany, in July 1978, I presented a paper entitled "Remote sensing as an aid for navigation in icecovered sea areas". In its last chapter I gave some viewpoints on the pioneering voyage of the Soviet icebreaker ARKTIKA to the North Pole in August 1977. Thick fog at times made the ice navigation difficult. Thanks to an advanced satellite navigation system presumably with 6 satellites in polar orbits and fixes available with gradually shorter intervals the closer the navigator was to the Pole, the ship's position was obtained with very high precision, good perhaps to 1 - 5 metres. In fog-free areas the position was generally determined astronomically.

To celebrate the centenary of A.E. Nordenskiöld's exploration of the North-East Passage in the Swedish Polar ship VEGA, see above, a Swedish Arctic interdisciplinary expedition was performed during June - September 1980 in the state icebreaker YMER in the northern Barents Sea, the Arctic Ocean north of Franz Josef Land, Svalbard and northeastern Greenland and in the sea between Spitsbergen and Greenland, the so-called Fram Sound. Chief of operation was Admiral Bengt Lundvall, former Chief of the Swedish Navy, and scientific leader the well-known Arctic and Antarctic explorer and glaciologist, Professor Valter Schytt, at the University of Stockholm. The ship was equipped for satellite navigation with Jungner Marine's new SAL-Satellite Navigator (model ESZ 4000) integrated with SAL-Automatic Omega Navigator (model ESZ 1001/2000). The satellite navigation equipment functioned to perfect satisfaction and was, according to the ship's captain, of great importance for the planned activities in the ice-covered regions, especially as the charts sometimes were completely incorrect. Aboard YMER, there were special electronics for accurate position fixing, satellite communication equipment (to the MARISAT system), weather/ice telefax etc., echo-sounder for very deep water, a variety of hydrographic instruments, helicopters and hydrocopter, equipment for night navigation, and a good deal of other equipment.

In the forties the U.S. Navy developed methods for "under-ice navigation", using effective sonars as sensors. Transmission at sonic frequencies was studied, and special sonar systems for "cruising under sea ice" as well as "for surfacing in ice" were developed. A decade later, in the summer of 1958, the U.S. nuclear-powered submarine NAUTILUS crossed the Arctic Ocean under the ice. She was the first ship in the world to reach the North Pole (on August 3). Her remote sensing system consisted of a forward-looking sonar beam, used to pilot the submarine past ice keels that extend deeply, a downward-beamed echosounder giving clearance above sea bottom, and an upwardlooking sonar recording a continuous profile of the under-surface of the ice canopy. In July 1962 one of the Sovietic Fleet Submarines, LENINSKY KOMSOMOL, made a renowned under-ice cruise to the North Pole, where she surfaced. By the aid of radio-technical means and "ice hydrophones", the navigator was able to measure the ice thickness and study the under-ice canopy. The echo-ice-measurer was continuously drawing the ice pattern on a tape.

At the XIIth ISP-Congress in Ottawa, 1972, television and photography systems as well as side-scan sonar, altitude sonar, and slant range transponder equipment were discussed. A chart was also shown of side-scan sonar imagery incorporating the use of rectified side-scan sonar records with image triangulation. The "bottom topography" is, as a matter of fact, always of great interest to the under-ice navigator.

2. The Swedish National Defence Research Institute

2.1 Technical advances in the submarine/diving area

The 2,700 km long coast line of Sweden with its archipelagos including more than 100,000 islands requires modern underwater technology and qualified work, made by divers, within a number of different fields. Harbours, power stations, dams and bridges are some of the areas where divers perform important tasks such as investigation of bottoms, underwater constructions as well as tests and repair work. The main task for the Swedish Navy, together with the other armed forces, is to protect our long coast line and archipelagos from being occupied by possible aggressors. An important part of this defence is hidden under the surface of the sea and consists of submarines, mine fields, and divers for both offensive and defensive tasks e.g. combat- and mine clearance divers. The high standard of the Swedish Navy's diving activities has been widely recognized for decades. Medical research in this field is being performed at the Naval Medicine Division of the National Defence Research Institute (FOA). It is based at the Navy Diving Centre (MDC) in the Stockholm archipelago and is known as one of the most modern in Europe, equipped with advanced pressure chamber facilities. This Diving Centre and special rescue ships ensure a high and efficient technical level in these fields and ensure that particularly the diving and submarine personnel have the highest possible degree of safety. There is always a risk, however, that a submarine, due to a technical failure, collision or running aground, may be trapped on the sea bed. For these reasons there are a number of alternative rescue systems for submarine crews. First of all, a collective rescue of the crew is made with a special submarine rescue vessel "URF" but under special circumstances e.g. due to the angle of the disabled submarine, it may be necessary to use the submarine rescue ship HMS Belos with its comprehensive resources for all types of diving and chamber facilities. The submarine rescue vessel URF, built at KOCKUMS AB, Malmö, Sweden, is a "minisub" designed especially for rescue of submarine crews, but it has also got a lock-out system for bounce or saturation diving. The URF can operate down to a depth of 460 metres, the deepest point of the Baltic. In a situation where the submarine is damaged so that a watertight seal cannot be obtained between the submarine and the URF, the crew can make a "free ascent" to the URF which has been pressurized to the equal depth and is positioned a few metres above the hatch of the submarine. After this type of rescue operation and when diving, the personnel must go through a decompression procedure, for which reason there is a special "transfer capsule" in the system to transfer personnel under pressure to a bigger decompression chamber onboard HMS Belos or at the Navy Diving Centre. The MDC-activities largely centre on applied research in diving physiology and ergonomy. Particular priority is given to the development of optimum decompression procedures. HMS Belos is equipped for conventional diving on air, using both hardhat diving and scuba equipment with surface supply. A diving bell and a chamber system for decompression are also important parts of the equipment. The main diving system is a complete deep diving system for all types of diving gases, heliox, trimix, etc. used for bounce or saturation dives down to about 350 metres depth. Deep diving is made from HMS Belos and when needed from the URF. The main task of the divers is submarine rescue. One of the major fields of research is the development of decompression tables for diving with new gas mixtures and different diving profiles. The industry is also able to have new materials and equipment tested in MDC:s chamber system and breathing simulators, tests that would not otherwise be possible to make in this country. This is one of the reasons why National Board of Industrial Safety uses MDC as the official testing institute for approval of diving equipment for civilian diving. Communication between the diver and the surface unit is mostly done by telephone. When breathing heliox or hydrox, one's speech will become distorted, because the sound transmission properties of these gases differ from those of air, and the speech may even become unintelligible. The Speech Transmission Laboratory of the Royal Institute of Technology in Stockholm has therefore developed an instrument, called DYKOR, which is capable of reducing speech distortion during heliox diving. This instrument will be adapted for use with hydrox breathing. Hydroacoustic and optical communication are alternatives to telephone communication. Project leader of Diving Physiology Medicine and Biotechnology at FOA is Anders Muren, Med. Dr. and Head of the Institution of Naval Medicine. Head of the Navy Diving Centre at Berga, Hårsfjärden, is Navy Captain Percy Björling.

2.2 Seismology

The seismological activities of the National Defence Research Institute (FOA) in Sweden are mainly involved in Seismic Discrimination and Nuclear Explosion Monitoring. Special attention is paid to the development of International Data Centers as a component of a global Monitoring System. The Institute started its work on seismic discrimination in 1969. This research work is focused on the establishment of a global seismic verification system as envisaged by the Seismic Expert Group established by the Committee on Disarmament (CD) in Geneva. Sweden has offered to establish and operate an International Data Center and considerable effort has been devoted to the development and testing of the various components of such a center. The Institute is also conducting a program, financed by the Swedish Nuclear

Power Inspectorate and the National Council for Radioactive Waste on earthquake risk estimation at nuclear power plant and nuclear waste disposal sites in Sweden. Data from a specially established local network of 20 short period stations, 17 in southern and central Sweden and 3 in Denmark, operated in cooperation with the Geodetic Institute in Copenhagen, have been collected on-line at the Seismic Data Center in Stockholm. The local recordings are continuously evaluated, and local earthquake observations are compiled and reported. Studies of microearthquakes down to magnitude -3 in the Swedish Research Mine at Kiruna not far from 68° North, enable us to investigate earthquakes and dynamic processes with a dynamic range of 6 orders of magnitudes even in Sweden, where seismicity is quite low. One project involves the further development of seismic methods for "oil exploration", and another the investigation of crystalline rock using seismic cross hole measurement. Present studies of marine seismic reflexion mehtods, which are supported by the Swedish Board for Technical Development, have concentrated on producing non-conventional seismic reflexion profiles in the southern part of the Baltic. Some of these profiles are aimed at investigating the possibility of mapping the deeper structures of the earth's crust. Head of the Division of Applied Seismology at FOA is Chief research scientist Ola Dahlman.

2.3 Hydroacoustic/optic integrated system for navigation in Artic Waters

Underwater imaging has been a part of FOA's research programme since 1970, also in severe winters, for instance in 1981-82, when large areas of the Baltic and the Kattegat were ice-covered. Tests have been carried out on laser scanning and range gating systems with the aim of improving visibility. Work has also centred on a range of TV equipment, light sources, and illumination geometries. In the field of hydroacoustic imaging, FOA is developing methods and equipment to facilitate observation and work also in turbid and ice-covered waters. Insonification of the target area is carried out in the ultrasonic frequency range, 0.5 - 3 MHz, and the electronic conversion of the reflected signals produces a picture perceptible to the human eye. An acoustic lens may be used for image generation or the camera may be lensless. In the latter case use is made of holographic recording. Underwater activity as a rule requires very accurate navigational means for position-finding, implying cooperation of units located both at and below the surface. The requirement for an absolute position accuracy of a few metres can be met where it is possible to arrange bottom-fixed navigation facilities. Tests have been carried out on the use of short laser pulses for the measurement of water depth, with both ships and helicopters being used as carriers of the laser equipment. Maximum depth penetration of more than 30 metres has been obtained from experiments performed with a CCRS-Mk-II lidar (laser infrared radar, commercially available from Optech. Inc.), installed in a helicopter. Mapping of an area close to a large shipping route demonstrated good agreement between sonar and laser profiles. For shipping in Arctic waters the Broströms Shipping Company, Gothenburg, and FOA have since 1979 made efforts in detecting small icebergs, so-called growlers, often transparent but appearing green or almost black in colour, extending less than 1 m above the sea surface and normally occupying an area of about 20 sq.m, by using different optical instruments. In 1979 the best improvement was achieved by nightvision goggles and low light level TV cameras. The optical systems, however, have some limitations and are dependent on weather conditions. In 1983 a new joint program therefore was started, focused on an integrated system making use of principally different techniques i.e. an hydroacoustic/optic system. The acoustical system consists of three different sensors, looking forward/down under the surface. A low light level TV camera is added to the system for detection above the surface. The main purpose is to determine how weather conditions, noise and different water qualities may affect the system, as well as to suggest how to display information to the operator. Engaged in Marine Technology research in general and in Hydrooptics at FOA are, among others, Senior Research Scientist Jörgen Lexander. Head of Hydroacoustics and Navigation research at FOA is Director of Research Lars Götherström and Head of the Hydrooptic Section (FOA 3), Linköping, Research Engineer Håkan Klevebrant.

3. Offshore activities

The exploration of the rich natural resources, such as oil, gas and minerals, continues to increase all over the world. During the last thirty years more and more of the world's oil has been produced from the seas adjacent to coasts rather than onshore. According to "Air Magazine", May 1983, this is 22 per cent of the world's supply produced from over 1,000 platforms worldwide. The design and application of offshore drilling platforms therefore is an area of technological progress. The Swedish Gothenburg yard "Götaverken Arendal", the offshore yard of the nationalized Swedish shipyard group Swedyards (Svenska Varv), has since 1978 delivered about ten semi-submersible rigs - flotels and drilling rigs. The rig GVA 5000 A, with a deck load capacity of 4,500 tons, is fully "winterized" with an enclosed working area (cellar deck, drill floor and pipe rack) and is thus suitable for operation in the toughest of climates. It is capable for drilling to 7,600 metres in water depths down to 450 metres. Four diesel-driven generators will produce a total output of 12 MW. Transit speed in calm weather is about 7.5 knots. Dimensions are 112 m in length, 85.5 m in width across the pontoons, and height to main deck 43 m. "Consafe Offshore AB", Gothenburg, is Europe's largest owner and operator of semi-submersibles. It has a fleet comprising 16 units, eleven of them semis, two jack ups and three barge-based units, so-called coastel, and has grown into an international group. SUTEC (Scandinavian Underwater Technology), Linköping, Sweden, is a leading supplier of remote-controlled hardware for underwater salvage and inspection operations. A combination of the Swedish companies SUTEC and KOCKUMS has developed a remote-controlled system for performing offshore underwater work, called SEA DOG. The Sea Dog remote-controlled underwarer vehicle is equipped with a manipulator, powerful lights and TV cameras (one fixed TV camera with a wide-angle lens and a zooming pan and tilt camera). This submersible weighs about 2.8 tons in air and operates to a maximum depth of 700 m. It is propelled by seven 6 kW thrusters giving surface operators a good view during transit and at the work site. Capabilities include search and identification, inspection of structures, cables and pipe lines, measurement and recording, subsea equipment assembly and disassembly, maintenance and repair, seabed sampling and surveys, salvage and recovery. Another submersible featured by KOCKUMS is the SEA OWL, a very light, easily handled underwater inspection vehicle for depths down to 250 m. Weighing only 80 kg in air, it has a TV camera and lighting (two fixed lights on either side of the submersible), and may be equipped with additional TV and/or still cameras. Six small thrusters give the SEA OWL excellent underwater manoeuvrability, SUTEC says, and in the event of a power failure the vehicle's positive buoyancy will bring it to the surface. All units, including the operator console and TV monitor and the 250 m umbilical, can be handled by just two men. In SEA TECHNOLOGY, October 1983, the Editor David M. Graham has written an article entitled "Gulf Canada Challenges Beaufort Sea Ice". Beaufort Sea oil-bearing structures were identified in the early 1970s through seismic surveys. Lacking suitable ice-reinforced drillships and support vessels, offshore drilling began its march into ice-laden waters via artificial islands dredged from adjacent seabed materials. Gulf Canada's new conical drilling unit is the first "drillship" designed and constructed to function in 1.2-m-thick ice. This enormous floating steel island, named "Kulluk", can drill on station six months - twice as long as conventional drillships in Arctic waters.

4. Cargo submarines and LNG submarine tankers

In PROCEEDINGS, U.S. Naval Institute, August 1980, Paul Cohen, then president of Subcom, Inc., published an article entitled "Cargo Submarines for Naval and Merchant Uses". In addition to military implications, he says, a purely commercial need for tanker submarines is emerging. This arises from the continuing discoveries of petroleum deposits in the Arctic, some far offshore and some on remote Arctic islands. Most of these discovery wells are being capped and are of geological interest only until a practical method of transporting this oil is devised. When the giant fields of Prudhoe Bay on the North Slope of Alaska were discovered, in 1967-68, the Electric Boat Company proposed to build a fleet of very large submarine tankers, with displacements of over 300,000 tons, for the long haul from the Western Arctic to the Atlantic Ocean. Bering Strait is too shallow for a submerged passage of submarine tankers under the sea ice. In the journal SEA POWER, December 1981, the Editor-in-Chief James D. Hessman describes a new imaginative project concerning underwater transport of liquefied natural gas from Prudhoe Bay under the polar ice fields to receiving terminals in Western Europe, Eastern Canada, and the Northeastern United States. There are, he says, over 26 trillion cubic feet of natural gas in the Alaskan Arctic's "proven reserves" - and probably several times that amount in the unproven reserves. According to Hessman, General Dynamics and other companies would build, in cooperation with a multinational consortium, a fleet of 28 massive submarine tankers especially designed to carry LNG from submerged cargo stations in the Alaskan Arctic under the North Pole, so to say, to surface unloading stations in Europe and North America. Either nuclear or non-nuclear propulsion could be used, but nuclear would be both simpler and more economical. In PROCEEDINGS, December 1983, the physicist William H. Kumm has written an article entitled "Non-nuclear Submarines with a Difference". He there mentions that during 1972-75 all studies referred to the nuclear propulsion plant as a necessary element of the system to permit the long transits under the polar ice cap. The assumption that a nuclear power plant was essential for a large polar transiting submarine tanker cut off further discussion in the 1970s because of the reactions against commercial nuclear ship propulsion. But today, Mr. Kumm says, a solution to this classic riddle has been found: the fuel cell-propelled submarine tanker. For a 165,000 deadweightton submarine tanker operating in the Arctic, the displaced volume fraction allocated to cargo is more than 80% of the displaced volume of the ship. Mr. Kumm points that the fuel cell becomes the clear choice for the Arctic submarine tanker because of its high energy conversion efficiency, simplicity, fuel compatibility with cargoes such as Arctic, natural gasfed methanol, and the lack of fundamental institutional barriers to its acceptance.

5. Viewpoints on radio communication systems and submarines operating under ice

VLF radio (3-30 kHz) provides good possibilities for reaching submarines in transit beneath the polar pack ice, not only with ordinary messages but with navigational signals as well. The communication, however, is always limited to one-way transmission - from shore stations, etc., to under-ice submarines. In the early thirties the author of this report experimentally used radio transmission with VLF frequencies to submarines in the northern Baltic Sea area and had good results down to about 30 m keel depth. During World War II the German VLF station Goliath at Calbe, in the middle of the country, used a frequency of 16 kHz and 1 MW efficiency for transmitting orders to the submarines in different parts of the oceans. It may be mentioned that in the Barents Sea and the Arctic Ocean, submarines were reached down to 13 to 18 metres depth of water above their frame antennas at distances of about 2,300 km (according to TELEFUNKEN-ZEITUNG, Jg. 33, Juni 1960, Heft 128). Thanks to improved receiving technique, however, the penetrating depths in sea water have nowadays increased considerably. Of great importance is the salinity. Sea water with high salinity has, as a matter of fact, much greater damping effect on the radio waves than fresh water. Heavy ice, which is very nearly free of salt, facilitates the receiving conditions of submerged submarines. As an example, the depth of penetration in salt-free ice at about 15 kc is about 100 times greater than in sea water with a salinity of $30^{0}/_{00}$ (corresponding to the average salinity of the surface layer of the Arctic Ocean Basin). Because of this, receiving conditions at a specific diving depth will be more favourable if the submarine leaves open water and moves in beneath an ice field (Thorén, R., 1963. Navigation Systems and Aids to Navigation for Nuclear-Powered Fleet Ballistic Missile Submarines and View-points on Conventional Submarines Operating under Ice). Radio transmission on the VLF band to under-ice submarines therefore may always be of current interest in the Arctic. As regards the ELF band ($3 \cdot 10^2$ Hz - 3 kHz) there was an interesting announcement, published in the September issue, 1979, of DEFENSE ELECTRONICS, entitled "VLF and ELF communications with ballistic missile submarines (TACAMO)". In view i.a. of the fact that LF and VLF communications suffer from jamming vulnerability in a higher degree than extremely low frequency (ELF) communications, it is mentioned in the announcement that signals at ELF frequencies can penetrate seawater to a depth of several hundred feet. Another interesting article, published in Aviation Week & Space Technology, September 3, 1979, by Philip J. Klass entitled "Laser Communications Plan Studied" may also be mentioned. By a way of introduction Mr Klass mentions a program to explore the feasibility of communicating with deeply submerged submarines using high-energy "laser beam". In the same article the well-known scientist Lowell Wood at Livermore Laboratory says that the laboratory group he heads several years ago developed an extremely sensitive detector that could be used by a submarine to receive signals modulated on the beam of a "blue-green laser", adding that such a laser communications system could be viewed as a useful supplement to ELF. He further points to the desirability that the laser in question would be modulated with digitally coded messages and designed for satellites in geosynchronous orbits. Deeply submerged submarines have to be equipped with very sensitive receivers and filters that allow only the wavelength of the laser transmitter to pass. According to Aviation Week & Space Technology, December 19, 1983, the Soviet Union is conducting laser communications experiment, propagating a blue-green laser beam to an orbiting mirror in space for relay to submerged ballistic missile submarines.

6. Swedish Space Corporation and Esrange-activities

The Swedish Space Corporation, SSC, is a state-owned limited corporation under the Ministry of Industry. It's activities cover the intire range of advanced technology. The SSC also operates Esrange, at Kiruna, in the north of Sweden, under contract from the European Space Agency, ESA. Esrange is an entirely non-military installation for rocket launchings and satellite tracking. It operates a remote sensing satellite receiving station as part of ESA's ground station network, Earthnet. The station covers the Polar region and the whole of Europe down to the Pyrenees. Quick-look pictures are dispatched to customers all over Europe on a daily basis. At SSC's head office at Solna, just outside Stockholm, an advanced interactive image analysis system is operated. Among the principal responsibilities of the Swedish

Space Corporation may be mentioned: "The technical implementation of the Swedish space and remote sensing program", "To conceive, specify and procure satellites for applications in addition to space science research", the reception of images from remote sensing satellites at Esrange, processing and analysis of all types of images for different applications and customers both in Europe and the rest of the world, to develop and run operational remote sensing systems for environmental control, and to operate the Esrange rocket launching facility and satellite tracking station.
During the Swedish Arctic interdisciplinary expedition "YMER-80", see chapter 1 above, performed in June-September 1980 in the state icebreaker YMER, the European Space Agency and the Swedish Delegation of Space Activities provided the expedition with Landsat-pictures. The satellite-transmissions were received at the SSC's station Esrange at Kiruna. From Kiruna the pictures were forwarded by wire to the naval coast radio station Älvsborg radio and from there on the wireless to YMER. In addition, the ship was also fitted with a telecopier for ice charts.
SSC has developed two different remote sensing systems for the Swedish Coast Guard. These systems operate from aircraft and are used chiefly to detect oil spills. One system is for use in good visibility and uses infrared/ultraviolet technology. The other is an all-weather system based on radar technology. SSC has also developed a mobile laser system for measuring atmospheric pollution.

7. Plate tectonics and technology of deep ocean mining

In 1915 the German meteorologist, geophysicist and arctic explorer Alfred L. Wegener, professor, Ph.D, published his very important hypothesis concerning the intercontinental drift, entitled "Die Entstehung der Kontinente und Ozeane". During many years these Wegener's hypotheses were scoffed at by scientists round the world. To-day, however, they are well proved and accepted. In 1972 I myself had an opportunity to study photographs of the mid-Atlantic ridge, taken at a water depth of about 2.500 metres, showing the new crack between the North-American plate and the Eurasian plate with quite clear edges. The seafloor spreading rate at this rift system is only 2 cm per year (1 cm towards east and 1 cm towards west). In other areas of the world's rift system, for example in the Pacific northeast of the Galápagos Islands the spreading rates are medium to fast (8-15 cm per year). Each rift is a narrow, fractured zone where plates of the oceanic crust are continually being pushed or pulled apart. At such a sea-floor spreading center molten rock or magma wells up from the mantle of the earth, filling cracks and generating new sections of oceanic crust.
In SEA TECHNOLOGY, January 1982, John B. Breaux mentions that 1981 has witnessed one of the most exciting discoveries in recent years - rich deposits of polymetallic sulphides along the rifts of the ocean seabed. These deposits, apparently plentiful in both abundance and mineral content, if proved to be commercially exploitable, will like deep seabed manganese nodules present the oceans community with wholly new technological and legal challenges. In the same issue of SEA TECHNOLOGY Dr. Alexander Malahoff (Chief Scientist National Ocean Survey, NOAA) has published an article, entitled "Polymetallic Sulphides From The Oceans To The Continents". He there mentions that detailed field mapping of the structural setting of the sulphide deposits, using shipboard multibeam sounding techniques, suggested that the "Galápagos Rift Polymetallic Sulphides" were formed during the past 100 years through extensive submarine hydrothermal activity along the northern boundary fault of the rift valley at a water depth of 2.600 metres. The hydrothermal reactions are proving to be the main source of the metal-rich sediments and nodules that carpet the floor of the ocean. In SCIENTIFIC AMERICAN, April 1983, there is an article by John M. Edmond and Karen von Damm entitled "Hot

Springs on the Ocean Floor". Hot springs are common at the bottom of the ocean along the submarine ridges where large areas of the surface of the earth are being driven apart and new oceanic crust is rising into place. Cameras, sensors and research submarines operating at ocean depths approaching 3,000 metres are finding large numbers of hot springs. When the first attempts were made in the early 1970's at finding the hot springs, knowledge of the sea floor and the capacity to explore it were rudimentary. The sonar devices then in service were adequate for flat terrain. At the rugged topography of the ridge axes they recorded a jumble of echoes. Nevertheless, the most sophisticated device, Deep Tow, operated by the Scripps Institution, made significant findings. Deep Tow, a vehicle towed at the end of a telemetry cable from a ship on the surface, carried television cameras, sonar, pressure sensors and probes to measure seawater temperature and electrical conductivity. In the mid-1970's changes began to come rapidly. For one thing, the authors call attention to the fact that the U.S. Navy made available to researchers the techniques it had developed for mapping the ocean floor. Thus high-precision deep-sea navigation systems came into routine service. Such systems depend on the measurement of the time that elapses between the broadcast of an acoustic pulse from an undersea vehicle and the reception of acoustic replies from an array of transponders moored to the bottom. If the relative positions of the transponders have been determined by sonar from a ship at the surface, the undersea vehicle can be navigated quite readily. Indeed, positional accuracies of a few metres are achievable.

During the Swedish Arctic interdisciplinary expedition "YMER 80" in June-September 1980 bottom sampling, chemical, physical and geologic research was performed also in the sea between Greenland and Spitsbergen, the so-called Fram Sound. There, at the northern part of the mid-Atlantic ridge, seawater temperature and electrical conductivity were measured close to the bottom. The very interesting physical properties of the sea water call for new scientific "YMER"-expeditions, among other areas in the Fram Sound.

According to a book review published in SCIENCE IN USSR, USSR Academy of Sciences, No 1, 1983, entitled "In Oceanic Depths" by A.A. Aksionov and A.A. Tchernov, attention has been focused lately on the study of the World Ocean's resources. In the course of the studies, off-shore deposits of those useful minerals that make up, according to some estimates, one-third of the world mineral extraction (not to mention oil and gas) were discovered. The book by Aksionov and Tchernov is lavishly illustrated with 100 photographs contributed by known Soviet, American, French and Austrian masters of underwater photography.