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European Drilling Research Icebreaker (Aurora Borealis)

Note:

This statement given by a subgroup of the steering committee „Large research facilities for basic research“ of the German Science Council concentrates on the scientific and technical investigation of the project. The statement if the project should be funded or not is given by the Science Council itself by a final evaluation of all nine projects. This statement is given in a separate report.

A. Introduction and Background

A.I. Field of Research

The Aurora Borealis project addresses two scientific communities, which in part overlap and in part have divergent interests. The first one is the general polar science community, which requires a ship for conducting their field and sea work throughout all seasons of the year with henceforth wide scientific perspectives. The other is the deep-sea drilling community, which would use the ship mainly during the summer months to study the structure and properties of oceanic crust and the history of the oceanic depositional environments that can be deduced from the oceanic sediment cover. This has never been done in the permanently ice-infested waters of the Arctic, whereas around Antarctica substantial progress has been achieved by using the drilling platforms of the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Program (ODP) during the ice-free seasons and by using a small drill rig from the land fast sea-ice very close to shore (Cape-Roberts-Project).

<u>Natural science disciplines of polar research</u>

Polar research and in particular the properties of northern and southern high latitude oceans are currently a subject of intense scientific and environmental debate because they are (in real time) and have been (over historic and geologic time scales) subject to rapid and dramatic change. Repeated news about the shrinking of the Arctic sea-ice-cover leading potentially to an opening of sea passages to the north of North America and Eurasia as well as about the calving of giant table icebergs from the ice shelves of Antarctica are the latest examples for these modern changes which are debated world wide.

The Alfred Wegener Institute for Polar and Marine Research (AWI) plans its scientific contributions for future years within major themes that are relevant for the project “Aurora Borealis“ and which all require substantial amounts of ship time. Most data from polar seas have so far been collected during summer seasons, while the other seasons of the year must be urgently investigated in considerable detail too.

Large and medium-scale circulation of ocean and atmosphere

The polar ocean regions and their interactions with atmosphere and sea-ice control variations of the global ocean circulation and henceforth of the global climate. It will be necessary to carry out experiments with a variety of ocean models, using satellite data, analyses of the atmospheric circulation, and time series of hydrographical measurements, to evaluate this hypothesis. These studies have to be accompanied by detailed investigations of water mass transformations in polar latitudes and of the contributions of new deep and bottom waters to the global thermohaline circulation. From the NW European perspective this is particularly important in Arctic waters and hydrographical data will have to be collected during all seasons of the year, including studies of the decadal variability of the atmospheric circulation and its interaction with the ocean. Processes controlling the renewal of the bottom waters from Arctic and Antarctic sources have to be investigated by means of long-term observational programmes and high-resolution regional models with the aim to describe their strength and their variability in numerical simulations close to reality. It is indispensable to

include processes controlling energy and impulse exchange between the partly ice-covered ocean and the atmosphere as well as the spatial and temporal variability of the sea-ice cover.

Interactions between the pelagic ecosystems and the biogeochemical state of the water masses of the open ocean as well as of shelf seas, with particular emphasis on flux and natural material studies

Evolution and material fluxes of biota living in the oceanic water column and in the sea-ice to a large degree depend on the physical environmental conditions and on the availability of nutrients as well as trace compounds. Composition and evolution of pelagic communities in different Arctic and Antarctic Ocean regions will have to be determined to clarify the complex interactions between the biosphere and the oceanic hydrographies as well as currents. In AWI’s opinion it will be necessary to study the biological properties of these communities, their phylogenetic relations, nature and structure of their natural materials, their dominant species as well as their energy balances. An intense bentho-pelagic coupling has been detected in the ocean, but it is more pronounced in the shelf regions. There is a close coupling between the oceanic segments of the biosphere with turbulent current systems. Long-time series should not only be established for the German Bight of the North Sea, but also for Arctic (Svalbard) and Antarctic (Antarctic Peninsula) regions in order to register composition and standing stocks of living assemblages in extreme habitats. The aim is to develop models to predict the potential consequences of future environmental change on the ecosystems.

Physiology and population dynamics of benthic assemblages in the deep-sea and in coastal shelf seas, both in polar as well as in intermediate latitudes

The properties of benthic habitats depend upon vertical and horizontal advection of food materials from the pelagic realm and from the sea-floor. Besides water depths and local environmental conditions they control the biogeography and population densities on the seafloor. Rates of adaptability of benthic organisms to changing environmental conditions can be deduced from diversity, distribution patterns and composition of benthic assemblages. Such studies allow determining reaction times of benthic organisms to natural and anthropogenic disturbances. These studies will frequently be intertwined with studies of processes controlling the overturn of carbon in marine plants and animals, which can also be investigated by means of laboratory studies and numerical modelling.

Reconstructions of past climate systems from deposits in marine and periglacial environments including modelling of their properties and variability

Deposits from the ocean floor contain some of the best archives of past global climate changes, depending on sedimentation rates for short and long time spans ranging from millions of years to years. Impressive progress has been made over the past decade, but the high latitude ocean basins both on the northern and southern hemisphere are still poorly known in comparison to the mid- and low-latitude regions. Despite the patchy record it is clear, though, that they provide one of the driving forces for climate change for the entire later part of the Cenozoic. Correlation of marine palaeoclimate records to terrestrial and limnic ones as well as to ice cores will provide further insights into the interaction of the atmospheric and oceanic circulation contributing to understand the mechanisms of climate change, indeed one of the major challenges for mankind in the coming years.

Structure and kinematics of the lithosphere and the polar ice caps

The structure and properties of the lithosphere and its tectonics can be investigated by seismic, gravimetric and magnetic measurements at sea, on land and by means of airborne systems and satellites. Last but not least such data will be collected in large quantities because, in the near future, the regulations of the law of the sea require states with continental margins to support their claims by means of geophysical data. The Arctic and Antarctic are poorly known in this respect, and many open questions therefore exist when trying to reconstruct their plate tectonic evolution. Such detailed reconstructions, however, are baseline data for deciphering the tectonic history of the polar regions, for evaluating their potential for non-living resources as well as for understanding the palaeoclimatic history of the earth during the past 100 million years. They will remain a subject of study for many years to come.

Origin and evolution of the Arctic lithosphere

The Arctic basin is underlain by a lithosphere that is among the least understood in the world. The lithospheric history of most of it is either only barely understood or completely unknown. Of particular note is Gakkel-Ridge, the world's slowest preading ridge. This mid-ocean ridge provides a unique key to understanding both the formation of very slowly spreading mid-ocean ridges in particular and of basaltic magmas in general. This is because low-degree partial melts developed in the Gakkel-Ridge system can be studied in relative isolation from extensive magmatic plumbing ystems and from mixing with melts of higher melting degrees. Since low-degree partial melts are difficult to impossible to produce experimentally, Gakkel-Ridge provides a key intellectual resource for understanding the process of the formation of basaltic magmas worldwide.

Other parts of the Arctic basin are even less well studied. Lomonosov ridge is apparently a thin slice of Eurasian continental crust split from the continent by Gakkel-Ridge, and the age and origin of the basement in the Makarov-Basin and Alpha-Ridge are at present largely a matter of speculation. Lithospheric evolution is also important to the study of the origin of the continental shelf and slope (with their attendant mineral resources), so target areas for lithospheric study via drilling will include the Yermak-Plateau and similar structures. Of these regions, only the unsedimented western end of Gakkel-Ridge is amenable to investigation without the use of an icebreaking drill ship. Aurora Borealis will enable studies of the basement evolution of these basins for the first time.

<u>Ocean history and basement structure</u>

DSDP and ODP have always faced special problems when attempting to drill deep-sea basins in very high latitudes. Because of the special geography of the polar regions progress has been greater in the Southern Ocean around Antarctica than in the Arctic. The latter has remained totally undrilled, and obtaining stratigraphic sections through the upper Mesozoic and Cenozoic sediment cover of the Arctic Ocean currently has the highest priority of all proposed future drilling activities. This has been discussed for decades and the scientific aspects are well documented in the science plans of the international “Nansen Arctic Drilling Program” (NAD) as well as of the Arctic Program Planning Group (APPG) of ODP/IODP. The execution of deep drilling in the Arctic Ocean has yet to be accomplished – the delay being mainly due to the unresolved problems related to deep-sea drilling in sea-ice covered oceans. Arctic deep-sea drilling indeed will be a scientific challenge for the next 10 - 20 years; it would produce a data set indispensable for understanding the evolution of the earth’s climate and through samples of basement rocks, it would contribute to solving the unresolved puzzle of northern hemisphere plate tectonic and palaeogeographic evolution.

Despite the important progress that has been achieved off Antarctica, many drilling targets with a very high scientific potential remain in the Southern Ocean. Even though Aurora Borealis is primarily argued for with an Arctic perspective, one has to realize that this novel ship would also have an Antarctic perspective.

The Aurora Borealis project requires the formation of an international consortium of interested countries. Polar research, over the past years, has fostered many international contacts and projects. The type of co-operation which has developed over the past decades will grow in the future and from AWI’s point of view it is a logical step in this evolution to propose the first European research ice breaker also as a European contribution to the 3rd leg ("Alternate Platforms") of IODP that is going to begin in 2003. Consequently, the project Aurora Borealis is currently being planned by the European Polar Board (EPB) of the European Science Foundation (ESF) and by the European Scientific Committee for Ocean Drilling (ESCOD).

In the international context Germany belongs to the Ivy League in polar research since it decided to join the Antarctic Treaty with the consequence of founding the Alfred Wegener Institute for Polar and Marine Research (AWI) in 1980. The institute's headquarters is located in Bremerhaven and it has branches in Potsdam, Heligoland and Sylt. Its substantial research infrastructure (e.g. research icebreaker POLARSTERN and several other ships, two research planes), as well as permanently manned stations in Antarctica (NEUMAYER) and in the Arctic (KOLDEWEY) is available to the scientific staff of AWI as well as to all other German research institutions engaged in polar research. Through a wide international network of co-operation this infrastructure is also involved in many international projects and programmes so that a considerable number of users comes from scientific institutions outside Germany. The heavy emphasis of the German polar research programme on marine disciplines as well as the engagement in both polar regions are a special feature of the scientific perspectives which are pursued by AWI and its co-operating partners.

The Aurora Borealis project has an impact mainly on the use of the research and supply icebreaker Polarstern which originally had been built as a dual purpose ship, namely as a reinforced supply vessel for work on the Antarctic continent (NEUMAYER, traverses, large expeditions to explore terrestrial scientific targets) and as a large, modern and sophisticated research vessel which allowed to support substantial, international and multidisciplinary expeditions to the remote ocean basins of very high latitudes. While being obliged to employ Polarstern for logistics and science in the Southern Ocean as well as in the Arctic, with expensive and long annual transits between the polar regions of both hemispheres, AWI is now planning to move Polarstern permanently to the southern hemisphere (with a logistics base in Capetown). This 18-year-old ship will be available as a research vessel for approx. another 20 years and it is stable enough to withstand very rough weather as it occurs during the unfavourable seasons of the year in the Southern Ocean as well as for investigating new regions around Antarctica. For the first time there will be a capable vessel available to collect the long demanded data from fall, spring and winter expeditions. The additional ship time will allow to broaden its field of operations to the entire circum-Antarctic ocean, opening new scientific opportunities with new international partners. Considering the presence of the French research vessel MARION DUFRESNE and of the British JAMES CLARK ROSS for extended periods in high southern latitudes it also seems to offer an excellent opportunity to establish a decadal substantial Southern Ocean research programme where a number of European nations could play a leading role. The European Polar Board (EPB) provides a forum for developing such strategies.

There are currently two dedicated research icebreakers available for investigations in the deep Arctic Ocean, namely the new US Coast Guard Cutter HEALY and Polarstern. In addition there are research opportunities through a number of other icebreakers such as the Swedish ODEN, the Russian KAPITAN DRANITSYN and several others, but they are not able to measure up to the efficiency of a true research icebreaker. Moving Polarstern permanently to the southern hemisphere will mean a considerable reduction of the European capability to conduct research in the central Arctic and Aurora Borealis is meant to fill this void. In addition it will provide part of the 3rd leg of IODP. Contributions to IODP and research in the central Arctic Ocean have a high scientific priority in a number of European countries and it is therefore a natural step to try to make Aurora Borealis a European initiative based on joint finances and consequently joint use of a core group of interested European countries.

None of the modern research icebreakers has the characteristic features of the proposed Aurora Borealis:

- deep drilling capability
- power to operate year-round in the central Arctic and to keep position against drifting sea-ice
- a dynamic positioning system

- moon pools (necessary for deep drilling and sampling in completely ice-covered areas).

There will be no substantial overlap with the investment plans of other institutions since the Aurora Borealis project is unique world-wide and the potential users are involved in the planning. If Aurora Borealis is not realized, there will be no other research icebreaker to conduct deep-sea drilling and year round research in the deep Arctic Ocean.

A.II. The Facility itself

A.II.1. Scientific Objectives and Research Prospects

A.II.1.1. Research Programme

A detailed science plan for Arctic marine research for 1 - 2 decades, defining the needs for a large research icebreaker that can operate in ice-covered waters for most of the year will be established by a working group of EPB until April 2002. The working group consists of representatives from the involved institutions, the different scientific communities and the institutions and companies with qualification in the design of icebreakers.

New perspectives will open for almost all disciplines of marine polar research if a ship is to be operated most of the year in the Arctic Ocean. The new perspectives are illustrated by examples from climate research, biological research and geological research.

Climate Research

The Arctic Ocean is an important part of the global climate system and a unique environment that is currently subject to an obvious change. These long-term changes are reflected in the natural conditions such as the distribution of air pressure, sea-ice and water temperature in the ocean and will have evident effects on life in the Arctic.

These changes are best documented in the atmospheric circulation, since relatively long time series from atmospheric parameters are available. The Arctic circulation is subjected to the so-called Arctic oscillation, which describes a displacement and weakening of the Arctic high-pressure area above the Beaufort Sea. The profound change in all parts of the Arctic is named by the Inuit word “Onami”. Until now it is not clear if “Onami” is a natural fluctuation or due to human activity. This is why research is focused on the understanding of “Onami” in order to estimate its further evolution. Since “Onami” is a phenomenon of decades, long time data series of atmospheric and oceanic conditions are required for its understanding and prediction of its further development. Even if understanding “Onami” requires the investigation of the coupled system ocean-sea-ice-atmosphere the different parts will be addressed separately.

Physical Oceanography

The modification of water masses in the Arctic Ocean and the export of sea-ice are key elements in the global oceanic circulation. Due to the freshwater input of the Arctic rivers into the Arctic Ocean it plays a key role in the global fresh water budget, which has a direct effect on the stability of the water column and hence on the global circulation. These correlations demonstrate that the Arctic Ocean is of central relevance for understanding the global climate system.

The physical principle of the system is known as the interaction of the coupled system ice-ocean-atmosphere. Almost unknown are the quantitative connections over longer time periods, which are governed by sensitive feedback mechanisms. This means that the importance of temporal variations cannot be assessed if measurements in all parts of the system are not undertaken at the same time.

The aim of future Arctic research will be to:

- quantify the variability of the coupled system ice-ocean-atmosphere over decades and
- understand the processes that are causing these changes

in order to distinguish between natural fluctuations and the influence of human activity. A special emphasis will be put on the fresh water budget.

As a consequence for oceanographic field research hydrographical transects must be measured at least every five years. Since the observed fluctuations are quite fast, these large-scale measurements must be supplemented with permanent measurements by moorings of instrument arrays at defined sites. The new research vessel will enable measurements that would provide essential contributions to understanding regional phenomena such as “Onami” and the global climate system.

Sea-ice research

Related to the observations of changing climate the determination of growth or decline of ice volume in the Arctic is a central problem. To answer this question a large-scale determination of ice thickness as well as the observation of ice motion and properties, which will be extrapolated and interpreted by model calculations, is necessary. Even if in future decades remote-sensing techniques will be developed, these techniques will require on-site calibration and validation measurements (e.g. the validation of sea ice heterogeneity for the European Cryosat mission).

Central for judging the role of Arctic sea-ice for the global climate are studies on ice albedo and other physical properties that contribute to the understanding of energy budget and satellite data. In this case *in-situ* studies are necessary, which require sampling of ice and surface properties.

Meteorology

Future polar meteorological research is aimed at providing a better understanding of the role of the atmosphere in the polar climate system. The main focus will be on identification and quantitative description of the central feedback mechanisms in the polar atmosphere as well as in the system atmosphere-hydrosphere-cryosphere. This requires the combination of modelling and observation programmes as well as theoretical studies. An essential part of this research programme, to which ship based measurements will provide an essential contribution, is the investigation of the energy budget of the polar atmosphere.

Biological Research

Marine-biological studies in the Arctic are until now concentrated on areas off east Greenland, the Fram Strait, as well as on the Eurasian shelf seas (ice margin areas). The central Arctic Ocean with its deep basins is almost unexplored. Furthermore the few existing investigations have been conducted almost exclusively during the summer. Current models, e.g. of annual primary and secondary production, are lacking spatial and temporal high resolution data. Due to ice-cover, remote sensing techniques can only be applied in a restricted manner in studies of the Arctic Ocean and large-scale measurements become essential. The availability of a research platform such as Aurora Borealis will open the possibility of investigating the marine biota in the major part of the Arctic Ocean that is still unstudied. The most recent expedition of Polarstern and HEALY has revealed indications of widespread and unexpected hydrothermal venting along the Gakkel-Ridge; after Polarstern found fossil remains of faunas on the Laptev-Sea continental slope (intersection of the Gakkel-Ridge spreading centre with the continental crust) one can expect a substantial number of sites with living vent faunas along the rift valley of Gakkel-Ridge. Time series of life cycles and winter-over strategies of key organisms and populations will be investigated. These basic investigations become more important considering the background of predicted changes in Arctic ice regime, since ice is formative for Arctic ecosystems.

About 10 % of the freshwater input into the global oceans is going into the Arctic Ocean. Besides the relevance for sea-ice formation, ocean circulation, and surface productivity, this freshwater input is of great importance for the sediment budget. Rivers are transporting large amounts of suspended material into the Arctic Ocean. The material is subject to different biological and geochemical transformation and degradation processes. Aurora Borealis would open the possibility to investigate the amount of suspended material that goes into the Arctic Ocean, its fate and its importance for pelagic and benthic communities in different regions (shelf, slope, basin) and during different seasons.

In 1999 and 2001 active volcanoes were discovered at Gakkel Ridge deep beneath the Arctic ice cap. As an important end member of the global ridge system, as the last geologically and biologically unsampled ridges, as a unique combination of tectonic forcing functions, the Arctic Ridges are a challenge for future research. Arctic hydrothermal systems in general have a high probability of supporting novel fauna based on both the relative youth of the basin and ridge system, and their isolation from deep waters of Atlantic and Pacific Basins. The success of future programs in the ice-covered Arctic depends on new technologies such as the use of Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) through a moonpool of a research vessel.

The deployment of Remotely Operated Vehicles through a moon pool at sites completely covered by ice will raise new perspectives concerning targeted sampling and manipulative studies at the sea floor of the Arctic Ocean. This will be especially important for studies of complex but heterogeneously distributed communities e.g. at methane hydrate sites.

The instrumentation of deep-sea sites in the central Arctic Ocean for collecting long-term physico-chemical data, for describing material fluxes to the bottom and its turnover, and for investigating deep-sea communities is not yet possible, since a platform with the required facilities is missing. Aurora Borealis could be the platform to serve such deep-sea stations including the deployment, maintenance and retrieval of instruments and data.

Geoscientific Research

To a large extent, the new research icebreaker is supposed to conduct geoscientific research on the Arctic deep-sea floor. The demands of the geoscience research community are explained in this context first of all concerning deep-sea drilling in permanently ice-covered ocean areas.

The technique of deep-sea drilling to investigate geological features of the ocean floor has been used since the 1960s and has revolutionized our understanding of the Earth System. The ships of the Deep Sea Drilling Project (DSDP) namely the Glomar Challenger and of the Ocean Drilling Program (ODP) namely the Joides Resolution were not built to operate in ice and never visited ice-covered areas. The present

ODP, in which Germany is a formal member, will reach its conclusion in 2003 and plans are currently developed (the submitter is involved) to promote scientific perspectives in the context of the Integrated Ocean Drilling Program (IODP) under the theme “Earth, Ocean and Life”. The perspectives developed there envision the application of an entire fleet of drilling platforms. Japan will provide a large drill ship that, being equipped with a riser, which will be able to drill risky geological structures in deep-sea basins and continental margins. The USA will provide a new drill ship that is going to have similar technical facilities as the Joides Resolution but with modernized technology. Both Japan and the USA have decided to build their drill ships and are thereby ahead of the Europeans to whom it remains to develop scientific perspectives within the context of the so called “Alternate Platforms”. One of these initiatives comprises the construction of a new research ice-breaker Aurora Borealis with the capability of deep-sea drilling in ice-covered areas.

The scientific preparations for these drilling plans have been made for several years in the scope of international working groups. The Nansen Arctic Drilling Program (NAD) published its scientific concept and its science plan in 1992. Consequences of this science plan were e.g. that Joides Resolution was sampling a small area just north of Spitsbergen (northernmost branch of the North Atlantic Current system) during ODP leg 151 (the submitter was cruise leader) and that shallow drillings off North Siberia, a permafrost region, could be realized. However, the technical challenge of deep-sea drilling in a permanently ice-covered area of the Arctic Ocean could not be realized up to now. In the context of the planning of ODP, IODP, and Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) a working group recently passed a science plan “The High Arctic Drilling Challenge” completed at the end of January 2001 that encourages the conception and construction of a platform that enables deep-sea drilling in the Arctic.

Some of the scientific objectives of a long-term Arctic-drilling programme are:

- The Arctic and global climate (e.g. extreme climate in earth history, rapid climate
- Change)

- Evolution of polar biota
- Arctic gateway and basin evolution
- Potential for high resolution coring in the Arctic
- Gas hydrates in the Arctic.

Shallow water drilling targets in the circum-Arctic shelf seas can also be addressed by means of small geotechnical drilling vessels such as the Russian “Kimberlit” from Murmansk which in fall 2000 was used to conduct the first drilling into the submarine permafrost of the Laptev Sea.

For defining accurate and well accepted sites for drilling in the high Arctic, continuous site surveying is necessary also when the new platform is available. The site surveys will either cover new regions or will refine and look for new targets based on the drilling results gained with the Aurora Borealis. Currently only two-ship experiments allow to gather seismic data with sufficient quality to compete with other regions. Seismic surveys in the last decade were limited to four cruises at all, as it is extremely difficult to co-ordinate the available ships with the national science programmes. The new research platform, therefore, must have the capability to carry out geophysical investigations in most parts of the Arctic to ensure the scientific quality of the drilling programme. The vessel has to be equipped with the state-of-the-art geo-physical instruments (seismic, magnetic, gravity, swath system, sediment echosounder) in order to efficiently gather such critical data. For conducting seismic investigations in the heavy pack ice of the Arctic the experience of more than one decade of geophysical research in ice covered regions must be included.

In the long run, drilling platforms such as Aurora Borealis are also required in the Antarctic ocean. Drilling programmes in ice-covered circum-Antarctic areas were only realized within the Cape-Roberts-Project, which was conducted from a drilling platform situated on stationary sea-ice. Good progress was made in DSDP/ODP concerning the investigation of the history of the Southern Ocean, and objectives and strategies for shallow drilling of the Antarctic margin and nearby regions are developed in the “Antarctic Offshore Stratigraphy Project” (ANTOSTRAT), but there is still need for drilling directly at the ice margin.

A.II.1.2. Services

Aurora Borealis would have to enable meteorological, biological, oceanographic, glaciological, geological, and geophysical investigations and would have to satisfy the technical needs for remote sensing, ocean technology, sub sea-floor engineering and deep-sea drilling. From this platform all necessary sampling and data acquisition could be carried out within the water column down to the sea bottom with cranes and winches and with (semi-) automatic sampling devices such as ROV, AUV as well as from helicopters and with balloons. The platform would provide all necessary environmental data and the logistic support for data handling and processing, and it would serve as a laboratory to analyse and store all kind of samples. The ship itself would provide dry and wet laboratories as well as space and connections for sufficient modularized laboratories for specific scientific demands that allow an expedition-specific assembly of the laboratories (e.g. isotope-container, clean-container, cooling-containers etc.). The two moon pools and a dynamic positioning system would enable deployment and collection of scientific equipment (moorings, nets, box- and multicorers, CTD, AUV, ROV etc.) in 100 % ice-covered areas which, up to now has not been possible with any research or commercial icebreaker.

A.II.1.3. Main Strengths and Weaknesses

The main strength of the project Aurora Borealis is that it would be a unique platform providing the solution for several scientific demands that have been in part defined for decades. The project Aurora Borealis would be incorporated into several different European and international programmes. The Arctic Ocean remains unsampled by ODP and remains one of the major scientific and technological challenges for IODP. In particular European nations are interested in deep-sea drilling in the Arctic Ocean but drilling could not be realized due to the unconvincing technical concepts that have been proposed until now. The capacity of deep-sea drilling in ice covered oceans would make Aurora Borealis a powerful European research platform that compares well with the platforms provided by Japan (riser drill ship) and the USA (successor to Joides Resolution) and will contribute to the 3rd leg of IODP ("Alternate Platforms"). On the other hand, classical polar marine science would have a research platform that is able to operate most of the year in the deep and permanently ice covered Arctic Ocean. Considering the strong seasonality of polar environmental conditions, spring, fall and winter data are needed by almost all disciplines of polar research and Aurora Borealis would enable their collection for the first time. Operation of the ship, whose concept and task is without any competition world-wide, would require a co-ordination of European polar research programmes and a much closer cooperation of European research institutes. The new dedicated ice-breaker would strengthen the EU in terms of large scientific infrastructure and contribute to the realization of a European Research Area. Aurora Borealis would open long-term perspectives to European and international Arctic research and to deep-sea drilling in the Arctic and on a long term, also in the Antarctic.

At present state of affairs no serious shortcomings can be seen from a scientific point of view. Specifications of the science plan, which will be established in the course of 2002, will also define many details of the requirements for technical solutions. However, the mission of Aurora Borealis would make very great demands on the technical performance of the ship. Therefore, during the first phase of technical testing, minor and unforeseeable technical shortcomings might appear and would have to be eliminated. In AWI's opinion major technical shortcomings are not to be expected.

A.II.1.4. National and International Networks

The implementation of an Arctic drilling vessel is discussed in different working groups e.g. of Joint European Ocean Drilling Initiative (JEODI) and IODP. It is conceived as an “Alternate Platform” for the 3rd leg of IODP. The USA and Japan will each build a new research drill ship and Europe is engaged to develop mission-specific platforms for drill sites that are not accessible for the new IODP drilling vessels. If realized, Aurora Borealis would be committed about 3 months per year to IODP as a mission-specific platform for drilling in the central Arctic Ocean, where no drilling will be possible with the planned drilling platforms. The rest of the year it would be deployed as a European polar research platform that is integrated into the polar research programmes of the participating European countries. During that time, it would perform polar marine science in almost all disciplines of polar research. Running such a challenging project, as Aurora Borealis, would presuppose that the participating countries would co-ordinate their polar research programmes on a high level. On an international level, European Arctic research supported by Aurora Borealis would be contributing to large research projects such as CLIVAR (Climate Variability and Predictability), and Arctic Climate System Study (ACSYS/CLIC). In the framework of GOOS/EuroGOOS it was outlined, that powerful research icebreakers are essential for the implementation of an Arctic component of the Global Ocean Observing System (GOOS). Close co-operations would be established with international organizations such as the International Arctic Science Committee (IASC), the Arctic Ocean Sciences Board (AOSB) and others.

A.II.1.5. Enlarging/Upgrading

The new European drilling research icebreaker would be equipped with the newest technology and state-of-the-art scientific equipment. It would be the most advanced research icebreaker world-wide with several unique properties such as drilling facilities, moon pools, dynamic positioning in drifting ice, a powerful ice-going Azimuth propulsion system etc. All reasonable demands of the scientific communities and all predictable future developments would be considered in the construction phase. The modularized laboratory container system would leave enough flexibility for coming scientific innovations, thereby making sure that Aurora Borealis would always stay a state-of-the-art research platform. Although Polarstern was constructed 20 years ago, her design made sure that she can be modernized and refitted in order to stay one of the most advanced polar research platforms world-wide. The same is planned for AURORA BOREALIS.

A.II.2. Transfer of Research Results

The project Aurora Borealis is focused on fundamental studies in environmental science. Special emphasis is put on studies related to the past and present role that the Arctic Ocean plays in the Earth System in general and in the evolution of global climate in particular. The utilization of knowledge would first of all not be a commercial one although commercial companies, in particular those involved in hydrocarbon exploration, are interested in the project, too. The knowledge gained from studies conducted on Aurora Borealis would first of all increase the understanding of the complex processes of the Arctic System and its response to global change, and contribute to improved models of its future development. In general this insight is important among other things for agriculture, insurance industry, energy companies, tourism, coastal engineering and management.

The industry would benefit from the innovations concerning shipbuilding and drilling in ice-covered regions in general. The following business sectors and key technologies would profit by the project:

- Weather and ice-condition forecast authorities in polar regions
- Shipbuilders, regarding the hull form that is suitable for drilling in ice-covered areas as well as for navigating in open waters
- Producers of ship propulsion systems, regarding the powerful ice-going and extendible Azimuth propulsion system as well as pump-jets
- Deep-sea drilling technologies, regarding the development of a mobile derrick and the technology of deep-sea drilling in ice-covered areas
- Shipyards in general for developing an “environmentally clean” ship

- Information and computer technology, regarding the development of an advanced fibre network for data acquisition, processing and monitoring tasks
- Producers of new laboratory systems, regarding the flexible, modularized laboratory container system.

The design and construction of Aurora Borealis would lead to spin-offs in the mentioned business sectors and key technologies but their amount cannot be estimated currently. Measures to support expected spin-offs will be developed in the course of further planning.

A.III. The Institutions participating in the Project

Aurora Borealis is conceived as a European project and she can only be realized in a European consortium. All Scandinavian countries, France, the United Kingdom, the Netherlands, Italy, Spain, and Germany have indicated their interests in Aurora Borealis. Scientists from these countries as well as representatives from a number of other European countries will establish a science plan for Aurora Borealis. This plan will be presented to the various national funding agencies in 2002. The European Polar Board (EPB) within the European Science Foundation (ESF) promotes Aurora Borealis. The submitter is chair of EPB and the scientific secretary of EPB is co-ordinating the activities concerning the project Aurora Borealis. The institutions that have nominated members for the planning group up to now are:

Polar Sciences (nomination via the EPB)

- Geological Survey of Denmark (GEUS)

- Finnish Institute of Marine Research (FIMR). Its special competence is to be found in atmosphere-ocean interaction, sea-ice and global change studies as well as Arctic hydrography and circulation and oceanography. It will contribute to the planning of the overall strategy and the logistics.

- University of Bordeaux, The Department of Geology and Oceanography (DGO), France

- Alfred Wegener Institute for Polar and Marine Research (AWI), Germany. The AWI is running the research icebreaker Polarstern one out of two research vessels being able to operate in the central Arctic Ocean. AWI has besides its

- research work in all disciplines of polar science a special competence in running and maintaining large mobile (ships, aircraft) and immobile (polar stations) research platforms in polar regions.

- University of Oslo, Department of Geosciences, Norway

- All-Russian Research Institute for Geology and Mineral Resources of the World Ocean

Ocean Drilling (nomination via ESCOD)

- French Research Institute for Exploitation of the Sea (IFREMER), France

- French Institute for Polar Research and Technology (IFRTP), France

- Institute Nazionale di Ozeanographia e di Geophysika Sperimentale Trieste, Italy

- Research Centre for Marine Geoscience at Kiel University (GEOMAR), Germany

- University of Bergen, Norway

- British Antarctic Survey (BAS), United Kingdom

Icebreaker Technology and Ship Design

- Kvaerner Masa Yards Inc. Finland
- HSVA Hamburg, Germany
-

The listed institutions are the core of a scientific working group that will set up a science plan for Aurora Borealis for the next 1 - 2 decades. This working group represents universities, polar research institutions and industry, and it has formally been established under the umbrella of the ESF, and by ESCOD, which is combining the European contribution to ODP and from 2003 onwards IODP.

There will be no re-allocations of staff currently existing in the institutions.

A.IV. Users of the Research Facility

Aurora Borealis would provide the only year-round operable platform world-wide for environmental research in the Arctic Ocean. In particular, the project Aurora Borealis would open new perspectives for almost all disciplines of marine polar research. The icebreaker would have to satisfy the demands of meteorological, biological, oceanographic, glaciological, geological, and geophysical research and to satisfy the technical needs for remote sensing and ocean technology. Studies in these disciplines have been conducted using Polarstern since almost 20 years but due to her limited possibilities, only during summer and mostly not in the central Arctic Ocean. Polar marine research (biology, geology, geophysics, glaciology, meteoro-logy, oceanography, etc.) would henceforth be dominating on Aurora Borealis during fall, winter and spring expeditions to collect data during these not yet investigated seasons.

The drilling phase would be in summer for about 3 months when the conditions are most favourable for dynamic positioning in drifting sea-ice. To enable a maximum use of the ship, it is proposed to run Aurora Borealis for 11 months of the year.

The different European polar research programmes contribute to almost all large international research programmes in the Arctic and Aurora Borealis could be the central platform for realization, sustaining and expanding the European contribution to these programmes. This would require the co-ordination of the European research activities in the Arctic and would allow the European nations to continue to carry out cutting edge Arctic research in co-operation with their international partners. According to AWI implementation of Aurora Borealis would give the European polar research programmes the continuity that never existed before.

Aurora Borealis would be committed for about 3 months as a mission-specific platform to IODP and the use of the vessel would be under charge of IODP during that time. IODP published an initial science plan for 2003 - 2013 and developed appropriate structures to organize the access of users to IODP platforms. There are two key elements of this structure: (1) IODP will be a programme driven by proponents who develop scientific drilling proposals which will be peer-reviewed and ranked by the international community, and (2) The advisory structure will review all proposals and, with expert technical advice, determine the most appropriate drilling platform to use in addressing the scientific objectives.

The access of users from the classical polar marine research community during the rest of the year would be organized in a similar way. There would be a user board, consisting of representatives from all participating countries. Proposals from potential users would be reviewed and ranked according to their scientific quality. The allocation of ship time to users of the participating countries would also depend on their contribution to the construction and operating costs of the ship. Details of user access still have to be defined during the coming planning process.

Users from universities and other external users would have equal possibilities to submit proposals to IODP or the user board of Aurora Borealis.

A.IV.1. Scientific Education

The research facility Aurora Borealis would give young scientists the possibility to get trained and conduct research on this world-wide most advanced platform. Young scientists would be involved in all kinds of projects related to implementation and ope-ration of the vessel.

As Aurora Borealis would be a research platform for fundamental scientific studies most of the educated students would be employed as research scientists in the fields of the major disciplines addressed in polar science i.e. meteorology, biology, oceano-graphy, glaciology, geology, geophysics, and remote sensing. Further qualification could be mediated in the fields of ocean technology, sub sea-floor engineering and deep-sea drilling.

A.IV.2. Public Relations

Most of the involved research centres have well functioning press and public relation offices that are experienced in mediating projects, expeditions and scientific results of polar research to journalists, other scientists, government representatives and the general public. Public affairs activities would include promotional activities, news conferences and open ship events where the public can tour the ship and learn about the research of Aurora Borealis. The public affairs programme would also include developing materials, such as descriptive brochures and pamphlets, fact sheets, and designing and updating an Aurora Borealis web site dedicated to outreach. The web site might contain, for example, a virtual ship tour, scientist profiles, a daily log of ship activities, scientific highlights and links to world-wide activities of polar research and IODP.

A.I. A.V. Project Management, Location, Costs and Schedule

A.V.1. Project Management

Aurora Borealis would be a European contribution to the alternate platforms of IODP. The idea of deep-sea drilling in the Arctic has been developing in the scientific community for many years. With an increasing understanding of the Arctic Ocean's role in the past and present days climate as well as the fundamental new insights of the deep-sea drilling programmes DSDP and ODP, it became clear that the Arctic Ocean is one of the primary targets for new deep-sea drilling. Scientific working groups developed programmes such as the Nansen Arctic Drilling Program (NAD) that defined the need for deep-sea drilling in the Arctic. But the implementation of most of these programmes failed due to the absence of a suitable drilling platform. The idea of the project Aurora Borealis was originally brought up by AWI to overcome the obvious lack of urgently needed research platforms, and is now promoted by the EPB of ESF.

The next two steps in project planning are to:

- establish a science plan for the next two decades
- conduct a feasibility study for the design of an icebreaker that satisfies the respective scientific demands.

In the current status of planning there is no detailed budget responsibility organized. All countries that would contribute to the construction of the vessel would also have to contribute to the running costs and the contribution of each country to construction and operation costs would be considered in allocating ship time.

Who would be in charge for the project, either a single institute or a consortium of institutes, has to be resolved later. Nevertheless in AWI's opinion Aurora Borealis can only be realized as a joint European icebreaker.

An advisory board for Aurora Borealis would be established but its exact structure is not yet defined. The functions of the scientific advisory structure will include:

- Mentoring and review of proposals from potential users, programme recommendations
- Proposal ranking, programme development
- Programme approval and executive decisions

Since Aurora Borealis would be a joint European research vessel planning of the research programme for the new icebreaker would be a joint effort of the involved countries. In the present status of planning, it is not clear who will be ultimately responsible for maintaining permanent operation of the facility. The responsibility for maintaining permanent operation of the facility might either be in the responsibility of an institute with long experiences in running polar research ships or in the responsibility of a consortium of the involved research institutions. From a scientific point of view the need for a permanent operation of the facility would be defined by setting up a science plan for Aurora Borealis by the involved institutions.

A.V.2. Location

The port of registry for the new Arctic research icebreaker is not yet settled. If Bremerhaven or another European harbour (e.g. Tromsø) is the most efficient port of registry for the new ship remains to be investigated.

Bremerhaven fulfils favourable requirements for operating a large and sophisticated research icebreaker. It is the port of registry of Polarstern, therefore the know-how and experience in operating large research icebreakers is present. Shipyards and suppliers for technical service and scientific installations, which have been used to the service of research vessels of different kind for years, are present in the region. Another possibility would be to station Aurora Borealis in an Arctic harbour e.g. Tromsø where the ship would be closer to its operational area.

A.V.3. Costs

Costs for the preliminary conceptual design for an icebreaking research drill ship by the Hamburgische Schiffsbauversuchsanstalt - Ship Model Basin (HSVA) have been 5 TEURO. They have been financed through the AWI budget.

Currently a proposal for a technical feasibility study of Aurora Borealis is prepared to the EU infrastructure funds. The study is supposed to have a volume of about 1 - 1.5 MEURO.

Aurora Borealis would have to provide accommodations for at least 40 - 50 scientists. Operation and maintenance of the ship would have to be organized by a commercial shipping company, similar to Polarstern. The ship's crew would comprise roughly 35 persons. Additionally approx. 10 – 12 persons would be necessary for the scientific-technical service (operation of scientific equipment, data processing etc.). For scientific drilling, a specialized drill crew (engineers, technicians) of at least 30 persons would have to be available for 24-hour drill operation. Appropriate specialized personnel is available in the participating countries. The total personnel for operating the ship including deep-sea drilling would be organized through private enterprises.
These costs are included in the operating costs of the ship.

The participating institutions will set up a science plan to ensure that Aurora Borealis is operating with its particular scientific programme in the Arctic Ocean most of the year. The scientific staff would come from all interested institutions in Europe and overseas and there would be no additional staff requirements from the participating institutions to operate the ship.

So far there are only preliminary estimations of the total costs for development and construction of the new research icebreaker Aurora Borealis. A reliable estimation can be given after the scientific needs on that ship will be defined and the respective feasibility study will be finished. Following the emerging costs will be listed:

- Feasibility study for the technical design and detailed planning of the whole ship. Total costs approx. 1.5 MEURO. A proposal to the European infrastructure fund will be prepared.
- Estimated construction costs: 250 MEURO. The estimation is preliminary but approved by the engineers from the shipbuilding industry involved in the project. It is based on the construction costs for Polarstern (1982, 100 MEURO) and the technical expense for the mobile container laboratory system as well as the drill equipment.
- Running costs, according to those of Polarstern approx. 10 - 15 MEURO

Concerning the present state of planning a core group of European nations with interest in Arctic research shall bear the construction and operating costs of Aurora Borealis. Until now there have been no negotiations about spreading the costs between the interested partners. It is expected that a core group of European nations will build a consortium for constructing and operating the ship. France, the United Kingdom, the Netherlands, Spain, Italy, all Scandinavian countries, and Germany have indicated their interests in Aurora Borealis. Partners in the USA, Canada and Russia are informed about the planning but up to now no decision about the participation of these countries in the project has been promoted. One possibility for sharing the costs would be to subdivide the costs into something like 20 - 25 shares; both for the expenses for construction as well as for running the ship. Individual countries or a core group of countries could - based on their scientific interest in Arctic research - buy into these shares. The distribution of shares would then control how many man-days per year each country could dispose of. Potential funding mechanisms through the European Investment Bank (EIB) are explored. The EIB loan for similar projects is usually up to 50% of the initial investment and the pay-back period for the loan could be over 10 – 15 years.

A.V.4. Schedule

Planning of Aurora Borealis is currently promoted in national and international working groups. An intensive co-operation exists with IOPD, which in 2003 will replace ODP, of which Germany and several other European nations are members. The European Polar Board (EPB) and an appointed working group that will document the European interests in the presence and operation of Aurora Borealis promote the preparative work. This working group will furthermore develop a science plan for the next 1 - 2 decades and define the technical requirements on the ship.

Service and maintenance of the ship as well as modernization of the scientific equipment to keep up with newest developments would be performed during one month per year. Under these conditions Aurora Borealis would be an outstanding research platform in AWI’s opinion for at least 30 years before it would have to be seriously refitted.

B. Statement and Recommendations

B.I. Field of Research

In the context of global warming and global climate change, polar research occupies a special position. Of all regions on Earth, the Arctic regions are the most sensitive to climatic change. In fact, these regions are considered an important amplifier on climate change, through positive feedback. The nature of this feedback is not well understood. However, it is known that it is highly nonlinear. Nonlinear feedback processes are difficult to predict from first principles and require long-term observation and experience. Much of the essential data for understanding past and future climate changes in the Arctic can be acquired only by drilling the sediments of the Arctic basin.

Despite the central importance of the Arctic to climate research, there is a remarkable dearth of long-term observations. In addition, there is a complete absence of data on climate history on any time scale. Among the more than 1000 sites occupied for the purpose of scientific ocean drilling, none explore the deep Arctic. The Arctic as a whole remains the last large unknown area on the planet, in this (and other) respects.

The European drilling research icebreaker Aurora Borealis is designed to fill this gap in knowlege, which is an item of international concern. The timing is such that the world community of scientific drilling is looking to Europe for an important contribution to IODP. Thus, the proposed project would be embedded in international efforts and integrated with drilling efforts led by Japan (centered on earthquakes and methane resources) and the U.S. (centered on global tectonics, climate and deep-Earth biology, outside of the polar regions). This ensures a high visibility and international collaboration from the beginning.

For many reasons, the central Arctic is expected to contain the best record of climate change through time, in the sediments of the deep basins as well as those draped over Alpha Ridge and other elevations. Geophysical surveys (seismic profiling) by

AWI have established promising regions for future drilling. The record is known to reach back into the late Cretaceous (from outcrops sampled by piston coring).

The Arctic realm is thought to be involved in large-scale climate oscillations that are directly coupled to the North Atlantic Oscillation that is known to dominate short-term changes in climate in all of Europe. It is expected that continuous meteorological-oceanographic observations in the central Arctic will yield important time series for determining the dynamics of these oscillations. These oscillations reflect the sensitivity of the North Atlantic climate to disturbance. As long as they are not under-stood, not much credence can be given to projections regarding the future development of climate.

The age of deep water in the Arctic is related to the rate of uptake of pollutants from the atmosphere. Of special interest is carbon dioxide and fluorocarbons. A platform in the central Arctic would allow year-round measurements of changes in the water chemistry (carbon dioxide, oxygen) that are related to life processes.

The tectonics of the central Arctic, the last unexplored ocean basin, are poorly understood. Gakkel Ridge is a slow spreading center, where hydrothermal activity has been recently discovered. Apparently Lomonosov Ridge is a slice of continental crust split off from the Eurasian continent. The nature of Alpha Ridge is not clear.

A better understanding of the origin and development of the Arctic as a whole would improve the ability of geophysicists to explore the margins for hydrocarbon resources. Hydrocarbon resources, mainly derived from Cretaceous source rocks, are common along the northern shores of Alaska. Presumably, learning about the Arctic Cretaceous environment would greatly improve the assessment of additional resources. Metal deposits might be expected where Gakkel Ridge intersects the continental crust.

The pelagic life in the central Arctic is poorly known. It is characterized by extremely low and pulsed productivity, with algal growth in ice playing an important role. The life

forms in this environment are highly specialized, including bacteria. One expects a high degree of tolerance to freezing and brine formation, as well as freshwater.
These adaptations will be genetically programmed. The relevant programming, as genes, may be transferable between organisms, and open interesting vistas for genetic engineering (cold-tolerance, salt-tolerance, euryhalinity).

Little is known about the distribution of organisms within the water column. The expectation is for a desert situation, with adaptations for extremely low food supply, and special over-wintering strategies. Some or most of the pelagic organisms may be derived from elsewhere, with long-distance transport in subsurface currents. One area of pulsed production that would presumably be a source area for such dispersion would be the ice rim, which is quite productive during early summer melting.

An important question in connection with benthic-pelagic coupling is the degree to which organic matter stays on the shelf, for recycling, and the degree to which it is removed into deeper waters by transport processes (currents, tides, storm waves, ice transport). Attacking these kinds of questions makes it necessary to study sedimentation processes in some detail, throughout the year, and not just when the waterways are open.

An important aspect of ecologic theory is the general distribution pattern of the diversity of species in different major groups. Little is known about this in the high Arctic. Specifically, the change in diversity in benthic organisms, on sampling the habitats downslope below the shelf break, has not been mapped. In the Atlantic and Pacific, such transects have been made. They seem to show maximum diversity at intermediate depths.

Human influence (including recovery of hydrocarbons and military activity) on the environment around the shores of the Arctic has greatly increased over the past. Effects of pollution on biota need to be assessed year-round, because of the strong seasonal character of life activities. The movements of pollutants through the unusual physical and biological systems are of special interest. They cannot be modeled without having the direct observations, because of the lack of analogs in lower latitudes.

B.II. Scientific Program

Drilling Program

Much of the science plan for the drilling is documented in the Nansen Arctic Drilling program (May 1997). This implementation plan is a mature document written by a committee of experts in the field and presents a full assessment of science issues, strategic development, drilling targets, site survey and drilling technology, work plan and organization and links to other programs. The drilling plan itself focuses on the continental margins and topographic highs of the Arctic Ocean, which provide technologically easier targets than the basins.

Arctic continental margin drilling incorporates both the margins themselves and their adjacent plateaus and present opportunities for studying both the environmental and tectonic evolution of the Arctic. Drilling is expected to reveal the following signals:

- Decadal to millennial scale climate changes
- Fluxes of sediment, water and ice to and across the Arctic Shelves
- Sea level fluctuations and their effects
- The glacial history of ice sheets and permafrost
- Biotic evolution in the neritic zone.

Potential drilling targets of this type include the Laptev Sea, the Barents and Kara Seas, the Yermak Plateau and Morris Jessup Rise, east Siberian and Chukchi Seas, the Chukchi borderland and the Beaufort Sea.

The topographic highs and ridges of the central Arctic Ocean also contain records of both the environmental history and tectonic evolution of the Arctic Region. Drilling of these features will address:

- Mesozoic/Cenozoic climate changes
- Nature and origin of the Alpha Ridge

- Initiation and subsequent history of Arctic sea ice cover
- Biotic evolution and paleo productivity.

Potential drilling targets of this type include the Lomonosov and Alpha Ridges and flat-topped seamount associated with Gakkel Ridge.

The present proposal envisages the program beginning with two phases of drilling. Phase 1 focuses on drilling the Laptev Sea continental shelf, which contains an expanded Pliocene to Holocene sedimentary sequence in an accessible location. It proposes a simultaneous giant piston core program for the ridges to initiate study of the long-term history of the central Arctic Ocean paleo-environment. Phase 2 is a full scale drilling program with sites on topographic highs in the Central Arctic. The drilling plan recommends an offset drilling strategy to extend the paleo-records and to reach basement. The case for drilling topographic highs is that low sedimentation rates make the entire Cenozoic and at least part of the Cretaceous accessible to drilling. In contrast drilling of the shelf sequences with their high sedimentation rates is expected to offer high resolution sedimentary records for key time intervals.

Non-drilling Program

This part of the program includes a contribution to site selection for the drilling (although routine site surveys are expected to be done using other ships) together with research on climate and ocean dynamics and ecosystems.

The detailed science plan for the non-drilling aspects of the proposal is currently being compiled by AWI and its national and international collaborators. However, considerable scientific planning has already occurred in the Arctic Climate System Study (ACSYS) and Climate and Cryosphere (CliC) projects of the World Climate Research Programme and projects of the International Geosphere Biosphere Programme.

Climate and Ocean dynamics

The research activities relevant to ocean and climate dynamics should incorporate elements of ongoing international projects of the World Climate Research Programme, including the Arctic Climate System Study and the developing Climate and Cryosphere program. Activities undertaken are expected to include:

- Full depth and basin wide measurements of ocean and sea-ice properties (temperature, salinity, nutrients, carbon parameters and other tracers) to establish the present baseline conditions
- Regularly repeated ocean and sea-ice measurements to document ongoing change (as suggested by presently incomplete records)
- Continuous long-term time series ocean measurements at selected sites and using drifting floats
- Atmospheric observations to understand key feedback mechanisms in the climate system and air/sea exchange
- Process studies to understand key aspects of the Arctic Ocean system
- Observations to calibrate and verify satellite data sets, including thickness of sea ice using helicopter based measurements.

A long-term aim should be to collect a data series of atmospheric and ocean conditions in order to understand the Arctic/North Atlantic Oscillation. These data sets are essential to predicting the evolution of the climate system, the detection and attribution of climate change and its impacts on the European and global environment.

Arctic Ecosystems

Research activities in this area should include:

- Estimates of seasonal primary and secondary productivity
- Documentation of the unstudied marine biota of the central arctic
- Time series of life cycles and the evaluation of over-wintering strategies of key organisms
- The biological and geochemical transformation of the suspended material entering the Arctic

- Deployment of ROVs through the moon pool at sites completely covered by ice for studies of complex but heterogeneously distributed communities
- Instrumentation of deep sea sites in the central Arctic Ocean for collecting long term physical/chemical data for describing material fluxes to the bottom and its turnover and for investigating deep sea communities.

An important goal is the establishment of baseline conditions and documentation of long-term changes in the ecosystem.

Benefits to Antarctic Research

The successful operation of Aurora Borealis would allow the more efficient use of Polarstern for year round observation in the Southern Ocean. Austral winter is the time when many key processes in the Southern Ocean occur but these are only very poorly studied and require the operation of ships with the capability of Polarstern if we are to understand and confidently project the evolution of the Antarctic and Southern Ocean region.

B.III. Technology

Aurora Borealis is a unique, technically innovative and very challenging project with the goal to deploy a scientific platform for all seasons in the polar region, especially in the Arctic Ocean. The overall concept is a reasonable and convincing approach and the proposed time schedule is realistic. Aurora Borealis would satisfy the needs of a drilling ship and a multidisciplinary polar research vessel.

The proposal is presently based on a preliminary pre-feasibility study. The next logical step towards a realization is a feasibility study, which is currently proposed for funding through the EC. This EC proposal addresses all fundamental questions for the establishment of a technological baseline of Aurora Borealis. Furthermore it will also result in a management plan. In view of the importance of the feasibility plan for the implementation of the Aurora Borealis project, a contingency plan should be developed in case the EC funds are not granted.

Aurora Borealis would combine – for the first time – in one polar research vessel five basic modes of operation:

- icebreaking during profiling and in transit,
- icebreaking during stationary work,
- deep-sea drilling in ice infested water,
- providing a permanent sheltered window through the ice for all seasons, and
- serving as a mobile research platform.

From this combination a series of major technological challenges arise and some of these new capacities are technically very demanding.

Deep-sea drilling in ice-infested water or in water covered by thin ice would be the major technological challenge, as Aurora Borealis would have to maintain her position in a moving ice system by dynamic positioning using the novel azipod thrusters. Furthermore, drilling in this environment requires an emergency decoupling of the drill string in case of thick and massive ice passing by. The difficult connection to the abandoned drill string is obligatory for a successful operation. Based on the experience with the long-term evolution of the ODP drilling techniques, the adaptation and development of the drilling system at Aurora Borealis would have to be staged in evolutionary steps which are expected to be technically feasible.

The provision of a sheltered window through the ice for the summer and winter season by two moon pools is of paramount importance for all scientific disciplines. This concept of sheltered moon pools allows the employment of ROV, autonomous underwater vehicles (AUV), seafloor observatories, and conventional systems as oceanographic moorings, rope-bounded sampling, and observation systems. In combination with a helicopter pad Aurora Borealis would serve as a carrier and logistical basis for investigations of the sea floor, the water column, the ice and the atmosphere in the neighborhood of the ship’s position.

An advantage to German or even European industry in developing new technologies for working in polar environments ranging from ship building to electronics is to be expected.

There are no conflicting national or international overlaps. No other nation has a ship of the capabilities proposed for Aurora Borealis that would be able to conduct oceanographic and biological investigations in all seasons.

Aurora Borealis as a drilling research icebreaker would be unique and a welcomed addition as the third leg (alternative platforms for Arctic drilling) to the proposed IODP. This would open up the use of the vessel to the international community beyond Europe (principally USA, Japan and Canada).

Preliminary steps have been taken to establish a Polar Network of Excellence that could potentially involve 17 countries. This is a most welcomed activity that would further integrate world polar science around Auroa Borealis and the Arctic activities of IODP.

B.IV. Project Management, Location, Costs and Schedule

The management structure of this large, diverse and technically challenging project is essentially nonexistent and is a significant weakness of the proposal. At such an early stage of development of the project the management would not be well defined, nor can it be until all the players and activities are better known, but a tentative management structure could have been proposed.

There is no other polar institution in Europe, and indeed in the world, that would be more capable than AWI to lead this project. AWI has the expertise, manpower and commitment to see the project succeed.

Tromsø (close to operating area) or Bremerhaven (home port for Polarstern) are proposed as the home port of Aurora Borealis. It should be left to the shipping experts to decide the merits of each.

The cost of building and operating Aurora Borealis are, of necessity, poorly known.

The proposal is presently in a preliminary stage and requires further development. The present proposal is one of a number of activities that are being actively pursued for adoption of the project by an international consortium. Because of all the uncertainties, a firm schedule cannot be presented, but the tentative schedule looks reasonable.

B.V. Users of the Research Facility

Access to the facility should be controlled by a steering committee consisting of a science group (polar research community and drilling community), a logistic group, and a technical advisory group on the basis of research proposals. The proposals would have to go through a confidential review process (peer-review according to DFG standards). Successful proposals would be transfered to the logistic group for cruise planning. It is important to have an open system which makes access of the facility transparent for potential users. It should be aimed at a forward planning of 3 – 5 years with a certain degree of flexibility for short-notice projects. A performance evaluation (quality control) should be based on a rigorous assessment of publications resulting from the individual projects.

AWI should consider the Aurora Borealis project as an opportunity to create a „Center of Excellence for Polar Research“ at Bremerhaven involving at least the University of Bremen and the International University Bremen but also the European polar research community.

The facility could serve as a state-of-the-art research laboratory for the training and education of young scientists with multiple skills. These would be acquainted with an interdisciplinary and international working environment, team work and coordination, as well as the application of modern technology. It is expected that these young scientists could be employed in various sectors related to natural and computer sciences.

The facility would have a significant potential for the promotion of science in society and thus would have important relevance for society. Projects aiming at „Public Understanding of Science" would greatly benefit from the existence of such an extraordinary research platform.

B.VI. Transfer of Research Results

The envisaged platform would have a paramount importance for a better understanding of the paleoclimate, the present and the future climate, both regionally and globally. New data stemming from a multitude of different disciplines would yield much better and more reliable constraints for modelling.

New experiences with the construction, the technical realisation and the operating of such platforms under severe meteorological and oceanographic conditions would be gained and future projects for research vessels would profit from this.

Furthermore, a new centre for Polar Research would emerge from this initiative under the leadership of AWI.

A hitherto poorly known and nevertheless very important part of the earth would be investigated which has great importance for regional and global issues in such fields as geology, geophysics, biology, meteorology and oceanography.

A positive impact of the results on societies could be expected. They would encompass, among many aspects, new data on the history of climate and environment, new insights into the geology of the arctic shelf areas and their resources, a new platform for polar research in general in the fields of biology and earth sciences.

The platform would be a unique training place for staff members and students. They would learn to do research under the severe conditions of an arctic winter season.

Aurora Borealis would promote the geosciences in societies and serve as an attractor for excellent students in the various disciplines involved.

C. Conclusion

In the context of global warming and global change, the Arctic regions are the most sensitive to climatic change. Understanding of these regions is essential to predicting the evolution of the climate system, the detection and attribution of climate change and its impacts on the European and global environment. Unlocking the history of this region currently contained in sediment cores as well as an accurate description of present ocean and sea ice conditions in the Arctic Ocean and their evolution will underpin this understanding. Aurora Borealis is currently the only proposal which will allow the collection of the necessary ocean cores and year round ocean observations.

Aurora Borealis is a unique, technically innovative and very challenging project with the goal to deploy a scientific platform for all seasons in the polar region, especially in the Arctic Ocean. The European drilling research icebreaker would satisfy the needs of a drilling ship and a multidisciplinary polar research vessel. There is no other ship of the capabilities proposed for Aurora Borealis that would be able to conduct investigations in all seasons. The vessel would be a welcomed addition to the proposed IODP. This would open the use of the ship to the international community beyond Europe. The drilling research icebreaker would have a paramount importance for a better understanding of the paleoclimate, the present and the future climate, both regionally and globally. AWI has the expertise, manpower and commitment to see the project succeed. There is no other polar institution in the world that would be more capable than AWI to lead this project. The overall concept is a reasonable and convincing approach and the proposed time schedule is realistic. The proposal is presently in a preliminary stage and is actively being developed further, including pursuing its adoption by an international consortium.

List of Abbreviations

ACSYS/CLIC	Arctic Climate System Study
ANTOSTRAT	Antarctic Offshore Stratography Project
AOSB	Arctic Ocean Sciences Board
APPG	Arctic Proramme Planning Group of ODP/IODP
AUV	Autonomous Underwater Vehicle
AWI	Alfred Wegener Institute for Polar and Marine Research
BAS	British Antarctic Survey
CLIVAR	Climate Variability and Predictability
CTD	Conductivity-Temperature-Depth
DGO	Dept. of Geology and Oceanography (Univ. Of Bordeaux)
DSDP	Deep Sea Drilling Project
EIB	European Investment Bank
EPB	European Polar Board
ESCOD	European Scientific Committee for Ocean Drilling
ESF	European Science Foundation
EU	European Union
FIMR	Finnish Institute of Marine Research
GEOMAR	Zentrum für marine Geowissenschaften an der Universität Kiel
GEUS	Geological Survey of Denmark
GOOS	Global Ocean Observing System
HSVA	Hamburger Schiffbau- und Versuchsanstalt
IASC	International Arctic Science Committee
IFREMER	Institut Français de Recherche pour L'Exploitation de la Mer
IFRTP	Institut Français pour la Recherche et la Technologie Polaire
IODP	Integrated Ocean Drilling Program
JEODI	Joint European Ocean Drilling Initiative
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
NAD	Nansen Arctic Drilling Program
ODP	Ocean Drilling Project
ROV	Remotely Operated Vehicle