White Paper

Drilling Polar Oceans: AURORA BOREALIS – a potential future IODP Platform –

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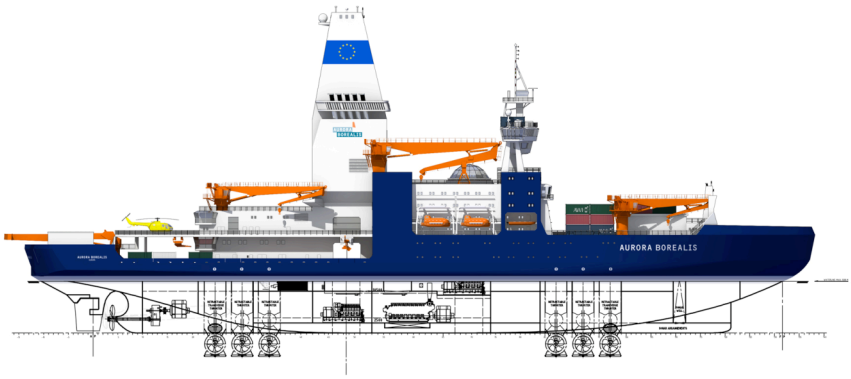

Abstract

The Arctic and polar Southern Ocean are critical for understanding the climate and tectonic evolution of the Earth, but remained essentially un-sampled by DSDP and ODP. While the first successful scientific deep-sea drilling in the central Arctic Ocean was carried out during the Arctic Coring Expedition (ACEX) 2004 and was as major scientific success of IODP, polar ocean basins remain a significant challenge for a future scientific ocean drilling program to access. The long-term environmental history and tectonic structure of these realms are insufficiently known. This lack of data represents one of the largest gaps of information in modern Earth Science (e.g. Nansen Arctic Drilling Program, 1997, Stein and Coakley, 2008, Naish et al., 2009). The new European Research Icebreaker *AURORA BOREALIS* is planned with state-of-the-art drilling facilities to fulfil the needs of a future program for a dedicated platform to drill in permanently ice-covered ocean basins. The icebreaker is powerful enough to autonomously perform dynamic positioning during drilling against drifting pack ice.

Dedicated research vessels capable to operate during all seasons of the year and under unfavourable weather conditions in the central Arctic Ocean and in the Southern Ocean are needed for polar ocean research in all marine disciplines. So far, no available ship has these required capabilities and capacities. The *AURORA BOREALIS* project fulfils the demands of diverse scientific communities, which in part overlap. The first one is the general polar science community that requires a ship for conducting year-round field and marine work and has a wide spectrum of scientific perspectives. The second is the deep-sea drilling community that would use the ship mainly during the summer months with optimal ice conditions.

Understanding the Polar Regions and their Global Significance

The properties of northern and southern high latitude marine areas are at present subjects of intense scientific debate. They react more rapidly and intensely to global changes than any other region on Earth. At the same time they are also a major driver of climate change and hence their impact is not only of regional, but also of global importance. Understanding and responding to these dynamics of ongoing global change is of high societal relevance and consequently immense attention is paid to the Arctic and Antarctic regions.

Polar oceans are characterized by extreme environmental conditions for humans and materials, and have remained the least accessible regions to scientists of the IODP. This contrasts with the lively scientific and public interests into polar oceans while signs of dramatic changes are observed: News about the shrinking Arctic sea-ice cover, potentially leading to an opening of sea passages for commercial traffic north of North America and Eurasia, of the calving of table icebergs from the Antarctic ice shelves, of changes in the Meridional Overturning Circulation in the deep polar oceans, and of the increase in global sea level rise witness such changes in real time. In addition, the polar oceans host considerable amounts of both living and non-living natural resources. The Arctic Ocean, in particular, bears vastly unconstrained resource potentials, including up to 25 % of the world's undiscovered hydrocarbons (e.g. Gautier et al., 2009). Scientific assessment and governance of these topics to support political decision-making of stakeholders is of critical importance for society.

Past Polar Marine Scientific Drilling

DSDP and ODP have for long faced specific technical and logistical problems when attempting to drill in ice-covered polar deep-sea basins. The Arctic Ocean and large areas of the high-latitude Southern Ocean remained largely un-sampled by ODP and remain one of the major scientific and technological challenges for IODP. Drilling in these regions has been discussed and anticipated for decades and the scientific rationales are reflected in the science plans of the international Nansen Arctic Drilling Program (NAD) or the Arctic Program Planning Group (APPG) of ODP/IODP, amongst others. More recently, the rationale to investigate the polar oceans in a holistic approach has been outlined by the Workshops on "Arctic Ocean History: From Speculation to Reality" (cf. INVEST White Paper by Stein & Coakley) and on "Developing an integrated strategy to recover paleoclimate records from the Antarctic margin and the Southern Ocean" (Naish et al., 1st SCAR-ACE Climate Symposium, Granada, Spain, 12-13 September 2009). The scientific cases for drilling in polar oceans are presented in documents published by these groups.

In the past, important progress to access the polar realm was made during ODP Leg 151, when *JOIDES Resolution*, supported by the icebreaker *Fennica,* was able to successfully drill the Yermak Plateau north of Svalbard, thus entering the Arctic Ocean for the first time. However, ice conditions were favorable and it wasn't until the ACEX leg in summer 2004 that scientific ocean drilling could be accomplished in the central Arctic, when *Vidar Viking* was escorted by two powerful icebreakers for ice management and sampled sediments from the Lomonosov Ridge. The successful Arctic Coring Expedition has proven that in principle IODP is able to drill in ice-infested waters, provided substantial logistical, technical and financial support is available. Even so, major operational and technical obstacles remain with the used expedition layout, ranging from dependancy on ice conditions to the availability of support vessels, to the full utilisation of IODP's drilling technologies (e.g. for basement drilling, borehole instrumentation, etc.) or maintaining a full analytical workflow offshore.

Thus, any further drilling operations in the Arctic Ocean remain to be executed yet. This delay is mainly due to unresolved problems in icebreaking and dynamic positioning capacity of a drilling vessel in thick pack ice, logistical hurdles as well as high associated costs for execution of expeditions in sea-ice covered oceans.

Innovative Technology for Polar Operations

The European Polar Board took the initiative to develop a plan for a novel and dedicated research icebreaker with technical capabilities hitherto unrealised. This research icebreaker will enable autonomous operations in the central Arctic Ocean and the Southern Ocean, even during the severest ice conditions in the deep winter, serving all marine disciplines of polar research including scientific drilling: The European Research Icebreaker and Deep-Sea Drilling Vessel *AURORA BOREALIS*. Such a ship offers new scientific potentials reaching beyond the capabilities of an individual nation.

AURORA BOREALIS is presently planned as a multi-purpose vessel. The ship can be deployed as a research icebreaker in all polar waters during any season of the year, as it shall meet the specifications of the highest ice-class attainable (IACS Polar Code 1) for icebreakers. During the times when it is not employed for drilling, it will operate as the most technically advanced multi-disciplinary research vessel in the Arctic or polar Southern Ocean. *AURORA BOREALIS* will be a „European scientific flagship facility" (fully open to non-European partners), a multidisciplinary platform for studies ranging from the sub-seafloor into the atmosphere.

The ability of *AURORA BOREALIS* to penetrate into the harshest conditions on Earth and to carry out research in the polar winter will set new standards both in the fields of polar research and naval architecture, including environmental safety of the highest standards. A first strategic science plan for *AURORA BOREALIS* was developed and published earlier by the ESF's European Polar Board and ECORD (Thiede and Egerton, 2004), and the ship will be operating based on competitive demands of the scientific user communities.

Principal Technical Design

Currently, no polar research vessel has the capability to autonomously operate in pack ice except during the optimal ice conditions of the late summer season. *AURORA BOREALIS*, in contrast, is planned as a multi-purpose icebreaking research vessel for Arctic and Antarctic operations with the capability to autonomously navigate in sea-ice with a thickness of more than 2.5 m and also break ice ridges of more than 15 m thickness by ramming. This will for the first time facilitate year-round research. The possibility to flexibly equip the ship with laboratory and supply containers, and the variable arrangement of other modular infrastructure, free deck-space and separate protected working areas, will allow the planned research icebreaker to cover the needs of most disciplines in marine research.

AURORA BOREALIS is planned with two moon pools (7x7 m each), unique for research icebreakers. The aft moon pool is mainly dedicated to drilling operations, while the forward moon pool is reserved for most other scientific works. This allows routine deployments of sensitive and expensive equipment, e.g. Remotely Operated (ROVs) or Autonomous Underwater (AUVs) Vehicles within closed sea ice cover. Scientific laboratories are located on several decks around the moon pool, which is designed in an atrium-like shape with circular walkways and preparation areas. In order to optimally equip the ship for polar-dedicated expeditions, containerized laboratories can be loaded and become fully integrated into the scientific workflow. The stern section of *the AURORA BOREALIS* was specifically designed to deploy seismic equipment in ice-infested waters, including special chutes with ramps for array deployment, combined with weather shelter areas. Additional technial equipment provided, the vessel is capable of performing 3D seismic surveys.

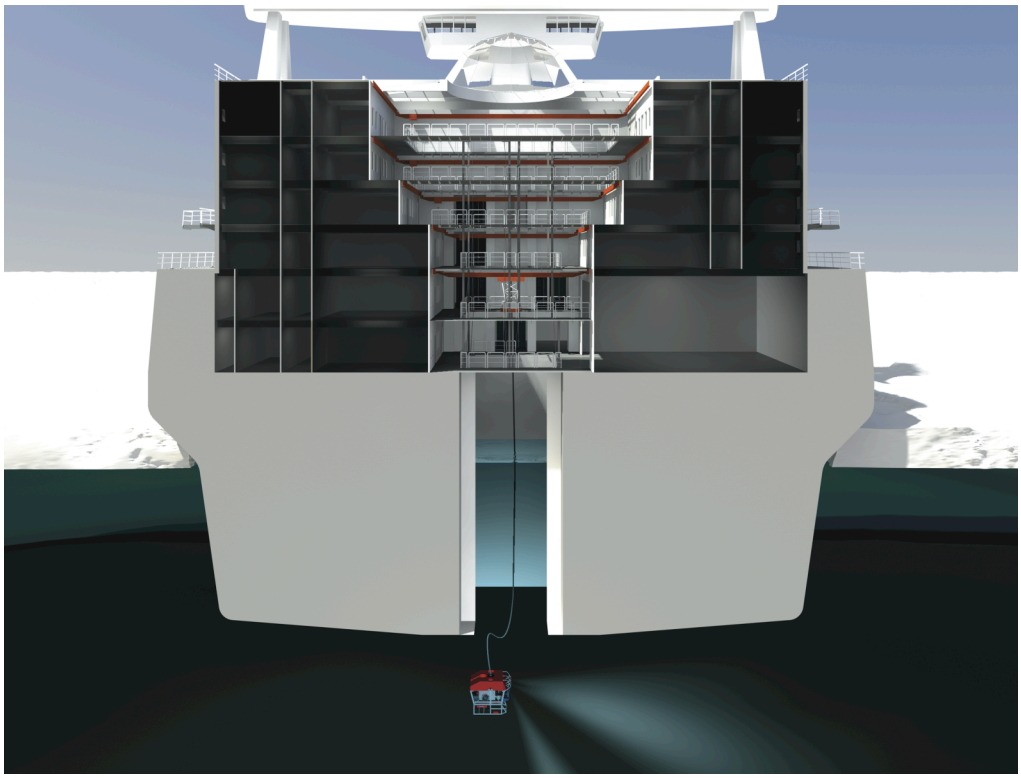

Fig 1: Cross-Section looking to bow section through Forward Moon Pool. Starboard staging hangar, laboratories (facing on starboard and port side MP), laboratory container spaces (front and aft section at MP), cabins (outwards on either side).

For the first time, routine scientific deep-sea drilling will become possible in drifting pack ice without support by additional icebreakers. To perform drilling operations *AURORA BOREALIS* has to use a dynamic positioning system in floating ice fields capable for manoeuvring and staying on a spot location – a novelty in the shipping industry. A principal technical design and general arrangement planning for the vessel was completed in 2009 and includes a full technical documentation. Extensive model tests in two independant ice tank facilities have proven that *AURORA BOREALIS* is indeed able to dynamically position in closed sea-ice cover with thickness of two meters and more.

Scientific Ocean Drilling with AURORA BOREALIS

The design of the rig and drilling components on *AURORA BOREALIS* is based on industry standards. It allows riser-less drilling in water depths between 100 and 5000 m with a standard maximum drill string length of 6000 m. All operations like coring, logging, installations, maintenance etc. are performed under full weather protection in the central tower with direct access to the ship's laboratories and service areas. Drilling depth below mudline is more than 1000 m, limited by formation type or stability, similar to established set-ups on *Chikyu* and *JOIDES Resolution* in riserless drilling mode. *AURORA BOREALIS* was planned for her role in deep-sea drilling in consultation with engineers and technical experts familiar with the program and the operation of these vessels. All techniques currently deployed on IODP expeditions can be implemented onboard the vessel under polar weather and ice conditions, including the full range of re-entry, casing and cementing, and instrumentation (e.g. ACORK, future instruments) options and the entire suite of downhole logging tools. Due to sufficient laboratory space (about 2500 m^2) a full analytical workflow can be easily established comparable to existing platforms, including clean rooms, diverse scanning and logging or incubation facilities.

While the vessel is equipped with a dedicated deep-sea drilling rig, other coring and drilling techniques can be employed if needed (e.g. Rockdrill, MEBO, large diameter Kasten cores). *AURORA BOREALIS* is fitted to operate a CALYPSO Piston Coring System in polar waters. Future mud-return systems currently under consideration and testing for IODP to provide controlled borehole conditions in difficult facies are compatible with the layout of *AURORA BOREALIS*. The berthing capacity of 120 personnel total (scientists, technical support and crew) allows to accommodate a sufficient number of science party members offshore.

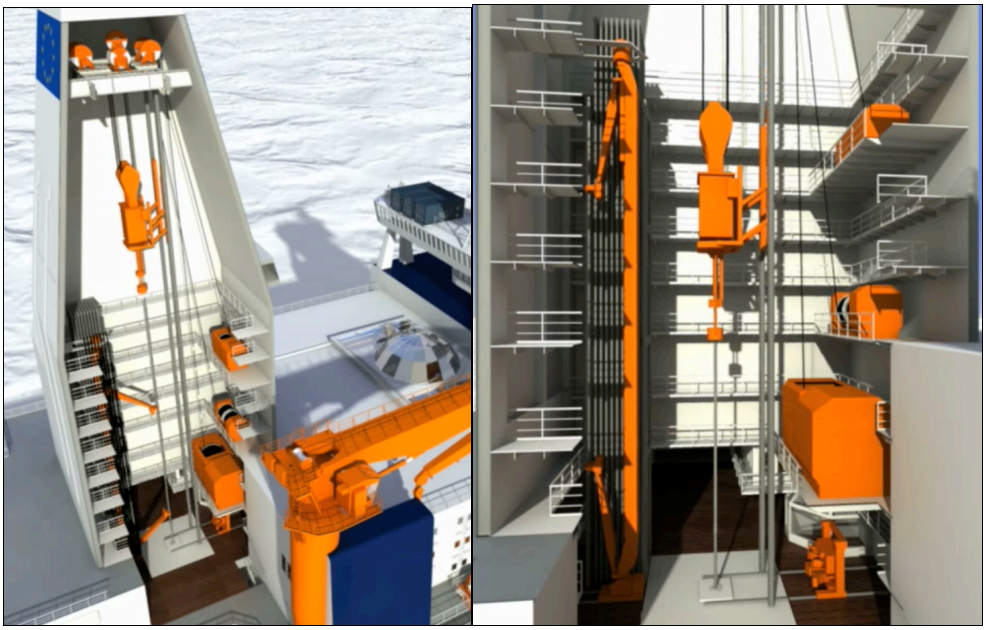

Fig 2: View into aft Moon Pool section with enclosed drilling rig. 6000 m drill pipe stored in vertical pipe racker, tools and corer storage and maintenance located to the aft (left), laboratory and catwalk to the front and back (right, behind the driller's cabin).

***AURORA BOREALIS*: Effects and Consequences**

The *AURORA BOREALIS'* Arctic and Antarctic deep-sea drilling perspectives shall be implemented in close cooperation with IODP and ECORD, and it is anticipated that it will serve as „Polar-dedicated" research platform for the ocean basins in the high latitudes. The present scientific implementation documents plan for about one polar scientific drilling expedition per year, currently seen as integral part of the future scientific ocean drilling program in a to-be-determined configuration. As the vessel is a multidsiciplinary platform, operations for the entire year are not dependant on drilling operations alone. While principal access to the vessel will be based on a competitive proposal review and evaluation system, the allocation of timeslots specifically for drilling would preferably be given over to IODP handling and planning systems in a cooperative and highly integrated mode using the strengths and capacitites of the future program. Depending on interests and needs of the scientific communities a preferential focus in non-drilling expedition planning could be established e.g. for dedicated geophysical pre-site survey works in areas inaccessible by other vessels to secure critical data needed for later drilling expeditions.

The *AURORA BOREALIS* project, through close connection with the European Science Foundation's European Polar Board, will support multidisciplinary research in areas like Climate Change, biodiversity assessments, geohazard analysis, resource engineering or long-term monitoring. It will foster the integration of diverse scientific disciplines such us Glaciology, Biology, Meteorology, Geosciences into

common scientific frameworks. The generation of joint research programmes at the European level will be an important facet of the cooperation.

The main strength of *AURORA BOREALIS* is to provide a unique platform for the solution of several scientific demands that have remained untackled for many years. Arctic deep-sea drilling indeed will be a scientific challenge for the next decades; it would produce a data set indispensable for understanding the evolution of Earth's climate and, through samples of basement rocks, it would contribute to solving the unresolved puzzle of the northern hemisphere´s plate tectonic and palaeogeographic evolution. The capacity for deep-sea drilling in ice covered oceans makes *AURORA BOREALIS* a powerful international research platform that complements the platforms provided by other partners and that can contribute to the European part of the future program in a mission-specific context.

European Research Icebreaker Consortium – *AURORA BOREALIS*

The 4.56 Million € European Project ERICON-AB (European Research Icebreaker Consortium – *AURORA BOREALIS*) is financed by the European Commission under the 7th Framework Program (FP 7) and managed by the European Science Foundation (Strasbourg) and the Alfred Wegener Institute (Bremerhaven). It runs from 2008-2012 and prepares the strategic, scientific, legal, financial and governance frameworks for the vessel. *AURORA BOREALIS* is included in the priority list of the European Commission's "European Strategy Forum on Research Infrastructures" (ESFRI) within the FP 7 and is explicitly stated as an official "Action Item" in the European Commission's recently published Arctic Communication. Currently, ten countries are participating in this preparatory project: Belgium, Bulgaria, Finland, France, Germany, Italy, The Netherlands, Norway, Russia and Romania. Denmark will become an official ERICON partner in the coming months. Interests to cooperate ERICON-AB have been expressed by the science communities in Spain and Ireland.

Financial Frameworks

Governance and financial models will be the subject of a business planning process conducted as part of ERICON-AB, currently it is calculated that running costs are projected to range between 30 and 40 Million € per year, including financial support to the core management structure. Exact costs and participation models will be generated and proposed during the business planning process with advice from a dedicated Financial Advisory Panel consisting of experts nominated by stakeholders. The ERICON project is continuing in negotiations with several countries on the political level to advance the decision on financing the project. ERICON-AB will work towards the foundation of a dedicated Political Council and legal entity, with decisions on financial commitments sought at the end of 2011.

However, already now it is safe to assume that the average costs for an Arctic or polar drilling expedition will be considerably lower than with an otherwise necessary multi-ship setup based on modelled expedition scenarios and annual operational cost calculations. Still, *AURORA BOREALIS* shall provide substantially enhanced scientific, operational, personnel and technical capacities offshore.

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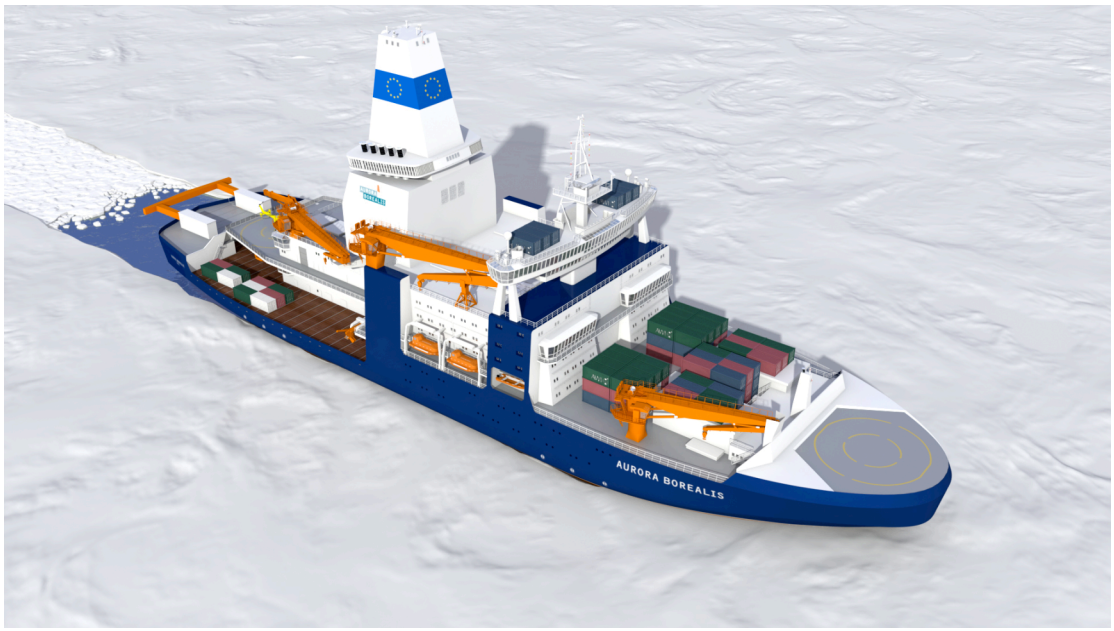

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