

## The R/H Sabvabaa—A research hovercraft for marine geophysical work in the most inaccessible area of the Arctic Ocean

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In 2003, we decided to assess a new platform for doing Arctic geomarine research. This decision was based upon our previous experience, which had shown that in many aspects there was no real substitute for actually spending extended periods of time on the ice. However, our cumulative experience on drifting ice stations indicated a need for greater economy, mobility, and especially survivable comfort. No more establishing an ice camp by icebreaker or aircraft with the hope that the constant drift of the ice would offer worthwhile targets for geophysical investigation and sampling. No more expensive aircraft or helicopters to give mobility at the whim of the generally inclement weather over a short spring season. And no more agonizing over competing demands on icebreaker cruises when half the scientists want to continue making underway measurements while the others want to lower other scientific equipment.

The alternative, we believed, was to finally implement an idea unsuccessfully pitched in a 1995 proposal to the European Community: the use of a hovercraft for marine geophysical, geological, and oceanographic work on the ice. Using hovercraft in polar regions is not a new idea. Over the years, they have become extremely useful, operating in the ice of the Arctic (Prudhoe Bay), the Baltic (a dozen in local coast guards), and even Antarctica (McMurdo Sound in the 1980s). The decade delay in implementation brought about instantaneous GPS navigation, worldwide Iridium satellite communication, as well as tremendous improvement in electronic equipment with crucial decreases in weight and power needs.

### The R/H Sabvabaa

The hovercraft chosen was a 2000TD Mark II, built by Griffon Hovercraft Ltd. in Southampton, UK. It was given the name *R/H Sabvabaa*, after the Inupiaq word for “flows swiftly over it.” The *Sabvabaa* (Figure 1) is 12 m long with a 73-cm obstacle clearance and 2200-kg payload above its 5000-kg empty weight. Its cabin is configured with four bunks, an after cabin, computer workspace, and kitchenette. In sea trials, we attained a maximum speed of over 43 kts, with full payload. The economical cruise “sweet spot” is around 25 kts.

The hovercraft was specially designed for Arctic conditions. It has double windows and 5 cm of insulation. A forward-looking, infrared (FLIR) sensor allows night vision. A full Furuno navigation suite with radar and map display is installed, together with marine and aircraft VHF radios, as both base stations and mobile units, and three Iridium satellite telephones with Internet and data-transmission capabilities. A local area network provides navigational information to up to eight laptop computers, operating off the science battery bank that is charged by a rooftop solar panel. There



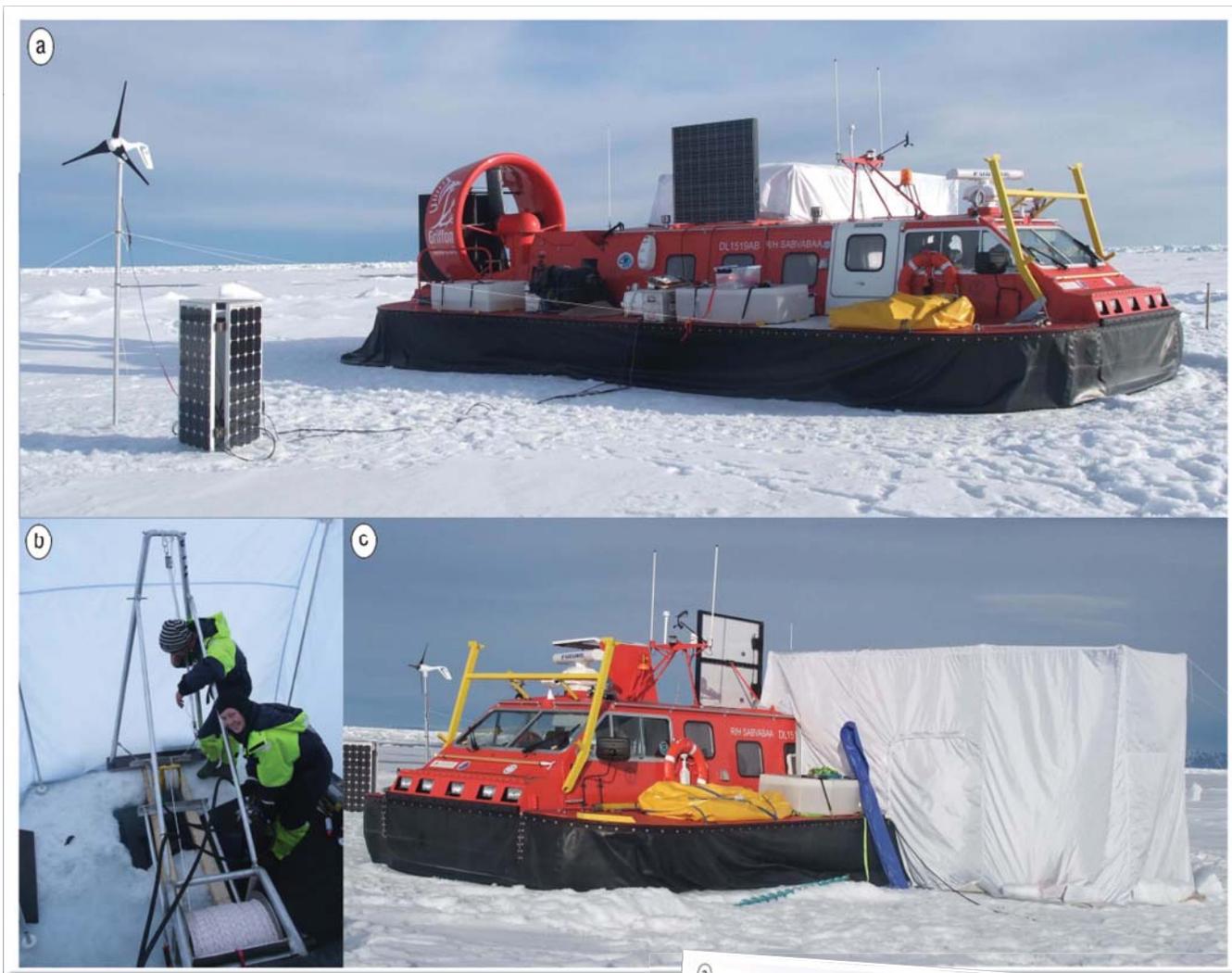
**Figure 1.** The research hovercraft R/H Sabvabaa crossing an open lead on the ice pack north of Svalbard over the Yermak Plateau.

is a full complement of mandated safety equipment (EPIRB beacon, life raft, etc.), as well as a portable winch that is attachable fore and aft for pulling the craft off obstacles or onto thick ice.

Four extra fuel tanks on the side decks provide 1500 liters of fuel for its water-cooled Deutz 440-hp diesel engine. About 40% of the power is used for the lift fan, with ground loading of about 0.05 bar. Thus, 60% of the power is available to the ducted, variable-pitch propulsion propeller. The engine has a very large alternator as well as a hydraulic pump, supplying energy to two battery banks as well as hydraulic implements such as an air compressor, winch, and ice drill. Baseboard heat is supplied while underway, and two economical, diesel-fed Danish Refleks heaters provide warmth and cooking surfaces when drifting. An exterior, diesel-powered 6KVA generator also has its own hydraulic pump for static use. While diesel fuel is our main operational umbilical, the consumption is minimal compared with all other modes of transport. Under power, the usage is 1.5–2 liters/km, and the craft can cover more than 800 km before refueling.

### Scientific equipment

The craft is completely outfitted for science. For depth measurements, there is a Knudsen 12/200-kHz echo sounder with 5000 m capability, which can also be used to follow the deep-scattering layer. A Knudsen four-element chirp supplies shallow sub-bottom information, while deep seismic profiling is done with a 20-in<sup>3</sup> air gun and a six-channel streamer. This equipment can either be towed in leads or open water, or used while parked on floes moving at rates up to 20 km/day. Figure 3a shows the seismic system deployed while the craft is parked. In parallel, two autonomous drifting seismic buoys are being built by Christian Michelsen Research (CMR) in Bergen. The hovercraft is the ideal platform for deploying



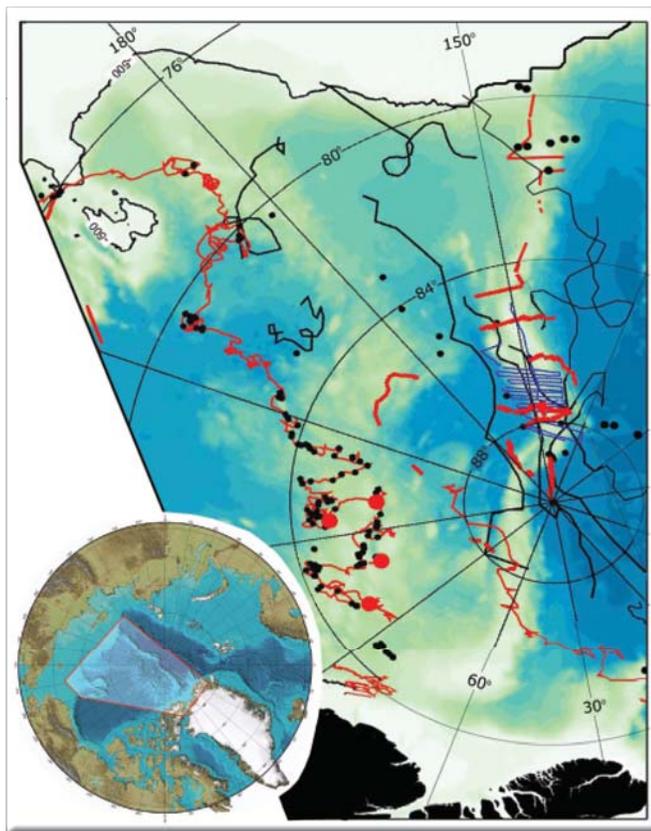
**Figure 2.** (a) The Sabvabaa in drift mode on an ice floe over the Yermak Plateau. The tent provides cover over an open hydro hole for bottom sampling and oceanographic stations etc. (b) Lightweight, hydraulically powered winch, and two of the IPY Classroom on the Ice high school students. (c) The wind generator and solar collectors are part of the test setup for the autonomous seismic buoys.

these systems, which consist of a sparker, hydrophone, solar panels, wind generator, computer, GPS, and Iridium telephone. After every 50 m of drift, the system fires the sparker and then transmits the received signals to Bergen as a short-burst data (SBD) packet.

Although the seismic capabilities may seem pretty low key to the petroleum geophysical community, one should keep in mind several facts. First, the deep Arctic Ocean is a very quiet place; the ambient noise is 10 dB below sea state zero. Second, until 2003, there were only about 20,000 line kms of mostly single-channel seismic available, of which Hall collected some 4000 km from Ice Island T-3 with a home-built seismic profiler that used a 9kJ sparker as a source, getting up to 3.5 s penetration. And third, the hovercraft is primarily intended to operate in areas of very thick ice, laced with long open leads, where icebreakers have yet to penetrate, and



**Figure 3.** (a) The Sabvabaa on the ice pack. Open water presents no problem, and the weight loading does not crack the ice. (b) The EM-31 ice-thickness system, which consists of an assembly of coils for the transmission and reception of low-frequency EM fields, and a laser altimeter.



**Figure 4.** Seismic reflection profiles and sediment cores collected from the Alpha and Lomonosov ridges and their vicinity: icebreaker surveys (heavy red lines); drifting ice stations (Russian = thin black lines; Canadian and U.S. = thin red lines); SCICEX high-resolution chirp sonar surveys (thin blue lines). The seismic data were acquired by “Polarstern” in 1991 and 1998, “Oden” in 1996, Arlis-II in 1964–65, CESAR in 1983, LOREX in 1979, T3 in 1966–74 and by Russian ice stations NP-13, NP-21, NP-22, NP-23, NP-24, NP-26, and NP-28. Sediment core locations are shown by black dots with red large dots representing the cores, which contained Cretaceous sediments. Sediment cores were recovered by “Polarstern” in 1991, 1995, and 1998; “Oden” in 1996; “Polar Sea” in 1994; CESAR in 1983; and T3 in 1966–74. Northern Greenland and Ellesmere Island are at bottom. (Kristoffersen and Mikkelsen, 2003.)

where the most intriguing results have been found from ice station work. Figure 4 shows the existing seismic coverage from icebreakers and drifting ice stations.

The hovercraft is also equipped for direct sampling of interesting sites on the seafloor detected using the seismic gear. A large tent can be affixed to the craft over the rear door, offering weather-free access directly to the ice from the after (air-lock) cabin. Figure 2 shows the tent deployed for bottom sampling. When installed over a suitable opening cut or drilled through the ice, the tent provides a workspace for a specially built, lightweight winch. This winch can handle up to 3000 m of Kevlar aramid fiber line, which is run around a hydraulically powered capstan. This line, with breaking strength greater than 2 tons, is spooled under light tension on three tandem drums. The winch system, which weighs just 170 kg, can be used for lowering a bottom camera and/or a patented lightweight corer. The corer consists of a cylinder at atmospheric pressure with a piston that is triggered upon im-

pact with the bottom. In 1000 m of water, the 99 bar pressure on the released piston provides a hydrostatic boost that drives the core barrel into the sediments.

Oceanographic measurements are also important for understanding what is happening now in the Arctic. For this reason, a new slip-ring winch with 500 m of conducting cable is being installed on the side deck. Rapid CTD measurements are then possible by simply stopping in open water or on the edge of a floe, and lowering the sensor. A new Aanderaa Doppler Current Meter is also available to augment such lowerings. Another very valuable measurement can be made while underway with an EM-31 system with a front-mounted instrument that uses EM pulses and a laser altimeter to determine the ice thickness. Every 2 s, it measures the delay between the outgoing pulse and the 180° phase-shifted reflection from the ice-seawater interface. It calculates the ice thickness by correcting for the 4-m separation of the source and receiver and subtracting the altitude of the instrument determined by the laser. Calibration is obtained by random checks of ice thickness by drilling and also from crossings of open water. Figure 3b shows the EM system as a calibration reading is being taken. The fact that the hovercraft travels on relatively level ice provides average ice thicknesses, without the spikes from anomalous pressure ridges or fields of ice rubble. These thicknesses, especially of thick multiyear ice, are very important for calculating ice inventory. In one week in 2008 the thickness was measured over 200 km of track.

#### Construction, sea trials, basing, and initial results

The *Sabvabaa* was ordered in October 2006. Construction was completed in September 2007 at a cost, including much of the scientific gear, of less than US\$1,500,000. Sea trials and acceptance tests were carried out successfully in the Solent between Southampton and the Isle of Wight in October 2007. On 2 June 2008, the hovercraft arrived by ship in Longyearbyen, Svalbard (78°-10'N, 10°-30'E), where it is based at the University Centre in Svalbard (UNIS). The month of June was taken up with field testing and trips as far north as northern King's Bay near Ny Ålesund at 79°N. During the first field season, the hovercraft made five week-long trips to the ice pack. Each trip consisted of two scientists and two Norwegian high school students who were chosen in a country-wide competition to select 10 young students interested in a career in polar geophysics. This program, the IPY Classroom on the Ice, introduces this entirely new operational paradigm to future scientists. During these forays, the students participated in geophysical, geological, and oceanographic studies carried out from the drifting ice. The components of the autonomous seismic buoy were also thoroughly tested, and a first short seismic profile was completed over the Yermak Plateau. A sixth trip occurred primarily to test the EM ice thickness gear.

In total, the *Sabvabaa* completed more than 3300 nautical miles during the first season, with a total of 318 hours on the engine. The craft performs at least as well as expected in pack ice. Pack-ice fields may look messy, but usable passages can always be found with little delay. A rule of thumb for all

ice-surface travelers is that the actual distance made between two points will be 1.5–2 times the great circle route. *Sabvabaa* moves with the same ease whether the ice is thick or thin, and the craft has proved to be useful for a variety of scientific tasks. It appears more efficient than any other platform for ice-thickness measurements and oceanographic work, i.e., ice melting/freezing processes in general. However, it is a small vessel and requires relatively good weather conditions for unsheltered open ocean passages. Future use of the craft jointly with an icebreaker expedition is expected to significantly increase the scientific efficiency of the total operation.

### The inaccessible Arctic today

Popular wisdom says that since the Arctic is expected to be ice free by the summer of 2030, one should only wait to explore it. A brief description of the state of the Arctic is in order.

The Arctic Ocean consists of two basins, the Eurasia Basin with the extension of the mid-Atlantic Ridge, and the considerably larger Amerasia Basin, north of Canada, the United States, and Russia. Due to the permanent ice cover, the quest for knowledge in these areas has been slow and arduous. Basically, the origin of the Amerasia Basin, with its continental prolongation of the Chukchi Borderland, and the broad and contorted Alpha-Mendeleev Ridge, remains the subject of much discussion and many models. The Chukchi Borderland in particular has been the subject of much study by icebreakers recently. They are mapping the 2500-m contour and the “foot of the slope” around the Northwind Ridge and southern flanks of the Alpha Mendeleev for a possible U.S. submission under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS). But even nuclear icebreakers have not ventured closer toward Ellesmere Island and northern Greenland, as this is the area of thickest ice out of the clockwise polar gyre that slowly sweeps around the basin, gradually delivering the ever-drifting pack ice to melt in the Atlantic.

This area of inaccessible thick ice extends from the western Canadian Arctic islands around northern Greenland and halfway down its western coast. It is largely unknown, except from the laborious work done from the 1968–1974 drift of Fletcher’s Ice Island (T-3), the meanderings of the Canadian two-month long occupation of the CESAR station, and several other short-lived, air-lifted ice camps such as Green Ice. This area is the primary target for the hovercraft, for two reasons.

The first reason is the suspicion among Arctic scientists that the key to the origin of the Amerasia Basin lies in the Alpha Ridge. Second, the ridge is incised by a number of apparently recent grabens in which the oldest cores sampled the much deeper strata. We suggest that this area was the site of an asteroid impact whose hydrostatic pressure wave caused the sediment deformation. The hovercraft presents a platform that could chase down better sites for sampling these oldest

sediments, as well as using the deep and shallow seismics to determine the probable point of impact.

### Possible modes of operation

The 2008 summer experience gave us confidence that our new platform performs as well as expected. We are in contact with groups using icebreakers to study the Arctic in the hope that it will be possible for icebreakers or even fishing vessels to either accompany us or carry us back and forth from the pack. They would also leave GPS/Iridium-tracked caches with diesel fuel in rubber bladders, food, spares, and special-purpose equipment. The hovercraft would then move around as needed while adapting to the ice conditions and the scientific plan. Farther into the future, there would be a need for a platform like the *Sabvabaa* to perform site surveys for the planned European icebreaking drillship *Aurora Borealis*, which would act as a mother ship.

Other opportunities lie in proper recognition of the advantage the sea-ice cover may represent relative to open ocean conditions for deployment of arrays of geophysical instruments. Array geometry can be maintained for days to weeks and even months due to coherent drift of large ice fields. An array of microearthquake instruments deployed on the ice drifting slightly oblique to the Gakkel spreading center is one application already tested. Another example would be a 3D seismic reflection/refraction survey using Reftek-type recorders or modified sonobuoys.

As we acquire a track record and fully check out the new equipment over the northern reaches of the Yermak Plateau in 2009, it is hoped that 2010 will see an opportunity to reach our full potential over the Alpha Ridge.

More information is available at our Web site, [www.polarhovercraft.no](http://www.polarhovercraft.no), where you can find daily updates on the *Sabvabaa*’s activities. **TLE**

**Suggested reading.** “Arctic Ocean geophysical studies; The Alpha Cordillera and Mendeleev Ridge” by Hall (Lamont-Doherty Geological Observatory, Technical Report No. 2, 1970). “The Canadian expedition to study the Alpha Ridge, Arctic Ocean” by Jackson et al. (Geological Survey of Canada, Paper 84-22, 1985).

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