Arctic Patrol Hovercraft: An Initial Feasibility Study

David F. Dickins
DF Dickins Associates Ltd.
La Jolla, CA, USA
info@dfdickins.com
Malcolm Cox
Hovercraft Consultants Limited
Southampton, UK
hcl.duratank@btconnect.com
Jon Thorleifson
Defense R&D Canada
Ottawa, ON
jon.thorleifson@drdc-rddc.gc.ca

ABSTRACT

This study evaluates the feasibility of using air cushion vehicles (ACV's) as year-round patrol craft in the Canadian Arctic, focusing on key areas along the Northwest Passage from the Beaufort Sea to Lancaster Sound. The study concludes that there is no fundamental technical limitation or operating constraint preventing hovercraft from serving year-round in a Canadian Arctic environment, as long as the design and specification re drawn up with specific attention to the expected marine and ice operating environments.

KEY WORDS: ACV; hovercraft; Arctic; Canadian; patrol.

INTRODUCTION

This study evaluates the feasibility of using air cushion vehicles (ACV's) as year-round patrol craft in the Canadian Arctic, focusing on key areas along the North West Passage corridors from the Beaufort Sea to Lancaster Sound.

The primary objectives of this initial study were to:

(1) Document the expected hovercraft operating environment focusing on ice roughness;
(2) Establish basic operating requirements for a range of mission profiles;
(3) Assess the capabilities of existing hovercraft or new concepts; and
(4) Identify key areas of technical uncertainty, and suggest possible solutions incorporating a combination of testing and/or further studies.

The study was commissioned in response to media and political commentary regarding the possible opening-up of the Northwest Passage as a result of accelerating Arctic climate change, the theoretical result being expanded marine trade and military activities by other nations. Hovercraft could provide an effective and economic means of projecting and maintaining Canadian sovereignty claims over the Arctic, complementing an existing and planned presence afforded by seasonal patrol vessels, and long-range patrol aircraft.

Geographic operating areas and a possible suite of missions were developed by the authors as realistic starting point from which to gauge the feasibility of using hovercraft in Arctic patrols. Three broad areas spanning the Northwest Passage routes (NWP) are put forward as the geographic basis for this preliminary assessment, drawing on the distinction between rougher pack ice in the East and West and relatively smoother fast ice in the Central Coronation Gulf area.

1. NWP East – Lancaster Sound, North Baffin Bay and Jones Sound
2. NWP West – Beaufort Sea and Amundsen Gulf
3. NWP Central – Traditional southern passage through Coronation Gulf and channels connecting to Parry Channel

Specific missions contributing to the overall goal of projecting sovereignty could include:

- Search and rescue (ships, aircraft, local residents in distress);
- Oil spill response related to increased oil exploration and shipping;
- Monitoring foreign submarine activities (through the ice sonar dipping);
- Climate change monitoring, ice surveys and scientific research;
- Enforcement of the AWPPR, vessel inspections, port state control;
- Support for other Canadian Forces Arctic assets and exercises; and
- Emergency ice management around ships or communities

HOVERCRAFT HISTORY

There is an extensive body of experience extending over 40 years with hovercraft in military and commercial service in a wide range of marine environments. The study reviewed the history of hovercraft operation in cold climates and/or Arctic conditions, including:

- Northern Transportation Company (Mackenzie Delta) 1974-77
- Canadian Coast Guard (St. Lawrence River) 1974 to present
- Royal Navy (UK to Sweden) 1972
- Sohio Petroleum (Alaskan Beaufort Sea) 1983/84
- Scandinavian Airlines (Sweden to Denmark) 1984 to 1994
- Cominco Metals (Northern BC) 1991 to 1994
- Agip KCO (North Caspian Sea) 2003 to present
- Alaska Hovercraft Ventures (Lynden Inc.) 1993 to present
- British Petroleum (Prudhoe Bay, Alaska) 2003 to present
- East Aleutians Borough (Cold Bay, Alaska) 2007 to present

Several examples of these operations are illustrated in Figures 1 to 3.

Photo: W. Bacon Productions

Figure 1. Jeff (A) carrying a 75-ton payload at 35 knots over broken ice off Prudhoe Bay in July. Ref. Dickins (1984).

Photo: Kvichak Marine Industries & Crowley Alaska

Figure 2. Griffon 2000TD currently under charter to BP Exploration (Alaska), transporting personnel to the Northstar oil production island from a base at West Dock, Prudhoe Bay.

Photo: D. Dickins

Figure 3. Canadian Coast Guard AP.1-88/200 Waban-Aki over ice on the St. Lawrence River while under charter to Exxon Mobil for testing in 2002.

OPERATING ENVIRONMENT

The normal operating environment includes the important air, sea and ice parameters that can be used to evaluate the reliability of a specific hovercraft and to define the required capabilities of any new design. Primary environmental factors and some of their implications include:

- Wind speed (upper limits for acceptable craft control)
- Sea state (traditional design driver for open water craft)
- Ice thickness (related to potential icebreaking, deliberate or unintended)
- Ice surface roughness (ridging and rubble defining the minimum cushion depth)
- Visibility (related to ice obstacle detection and avoidance)
- Spray icing (most likely in over water or thin ice operations in cold temperatures)
- Extreme cold temperatures (limits of skirt materials and lubricants)

The study utilizes the web-based Canadian Ice Service Atlas for northern waters (1970-2000), together with climate statistics from the Atmospheric Environment Service to characterize the timing of breakup and freeze up and expected temperatures and wind speeds in the different regions.

Ice roughness is the most important and potentially the least understood parameter governing the overall size of hovercraft needed to operate reliably over a mixed surface of multi-year ice and first-year ridging and rubble. The cushion depth (also known as the hoverheight) defines the obstacle (or hard structure) clearance required to operate with an acceptable number of detours. Accepted design practice calls for a maximum cushion depth to beam ratio in the order of 0.15 to 0.18.

The statistical analysis of ice roughness from a combination of deformation processes (rafting, rubble and ridging) is critical to determining the probability of success or failure in completing a hovercraft mission during the winter months when a stable or close to 100% ice cover is present through much of the operating area (generally November to June). In some regions such as the Arctic Islands, the ice never clears completely during the summer and a hovercraft could face extended operations over almost complete coverage of old multi-year ice, much of it deformed.

There is no suitable database for the study area to properly define the levels of ice roughness that could be encountered in average or extreme years. A number of previous studies examining this issue agree on a fairly narrow range of cushion depths required to operate in different areas. For example, the US Arctic Surface Effect Vehicle Program (Harry et al. 1975) concluded that a hovercraft capable of routine operations over the Polar Pack in the central arctic basin would require a minimum cushion depth of 2.5 m (2.7 to 3 m preferred) based on extensive studies of ridging intensity in different areas. It may be possible to operate with a lower depth in localized areas with mostly first-year, stable ice cover such as Coronation Gulf, however patrols into areas further north with multi-year ice, West into the Beaufort Sea or East into Lancaster Sound and north Baffin Bay could face higher ridging intensities associated with mobile pack ice.

The optimum cushion depth required to safely clear ice obstacles and avoid any possibility of being stranded in rough ice is clearly the most critical design parameter affecting the technical and operational feasibility of an Arctic hovercraft.

OVERALL DESIGN REQUIREMENTS

Based on the expected operating environment, patrol areas and range of missions, the following overall design envelope emerges as a means of evaluating existing craft and future designs:

- Minimum hoverheight: 2.5m over mainly first-year fast ice in the central study area; 2.7 to 3.0 m over the offshore pack ice on the east and west approaches to the NWP.
- Range and endurance based on a number of hypothetical mission scenarios: in the order of 500 to 700 n miles, corresponding to over 20 to 30 hours at 20-25 kt average block speed.
- Minimum Craft size based on the need to carry a 2.5 m skirt with acceptable levels of stability: 80 to 100 tons, 13 to 14 m structural beam, 30 to 40 m length.
- Sea state capability: not expected to be an issue given the large hoverheight needed to clear ice obstacles and limited fetch during the short summer period in most Arctic areas.
- Payload: sufficient to carry a crew of 4 to 5, specialized equipment and occasional freight in addition to fuel to achieve necessary range and endurance with reserves.
- Cushion pressure: minimum achievable within the constraints of payload and size to minimize icebreaking, freezing spray and skirt damage/wear (typically less than 0.35 psi)
- Design optimized for Arctic operation: e.g. deicing critical areas, inside skirt attachments, underside landing rails or runners, ease of cold-weather maintenance/access to mechanical/hydraulic/electrical systems.
- Flexible overall layout to facilitate rapid conversion to multiple missions: e.g. rear-mounted crew cabin, forward rotating thrusters for maneuvering, an open well deck and bow ramp and rear-mounted propellers in ducts.
- Minimum environmental impact including minimum: noise (target standards achieved by current BHT150 generation craft with 67-75 dBA at 300 m fly-past), icebreaking (avoiding disturbance to the ice cover around communities) and fuel consumption (low CO_2 emissions). Diesel engines are likely favored over gas turbines.

REVIEW OF EXISTING CRAFT AND NEW DESIGNS

Reviews of all available hovercraft (US, Finland, Russia, UK) identified no existing ACV that meets the necessary requirements of obstacle clearance, low noise, low fuel consumption and ease of maintenance. There are a number of possible military craft that could be adapted or modified for Arctic use but such an undertaking would require careful study. Available hovercraft in this category date from the 1980’s in terms of technology and have serious drawbacks in terms of skirt design and depth, power plants, propulsion systems and noise. Three existing military hovercraft are illustrated in Figures 4 to 6.

The option of developing a new ACV design based on proven machinery modules is recommended as the best approach to achieving a hovercraft that is tailored to specific missions and capable of operating over the full range of expected ice regimes (Fig. 7). The principal specifications of four options evaluated in the study are summarized below in Table 1.

Table 1. Summary Specifications of Potential Craft Options

	Almaz *Zubr*	**Textron LCAC**	**Hoverwork BHT 150**	**Modular Craft MH30**
Type	Military	Military	Commercial	Commercial
Status	Built	Built	Evolution of Existing Design	New Design
Length x beam (structure) m	56.2 x 22.3	24.7 x 13.4	30.0 x 13.0	29.4 x 16.0
Installed power (h.p.)	49,350	16,000	4,680	4,930
Engine type	5 x gas turbines	4 x gas turbine	4 x diesel	6 x diesel
Standard hoverheight, m	2.7	2.1	1.65	2.8
Finger height, m	1.3	1.3	1.0	1.65
Enhanced hoverheight, m With redesign	Not needed	2.5 (Note)	2.2	Not needed

Note: Subject to model testing and design verification

Figure 4. LCAC in service with the US Navy as an over-the-beach landing craft.

Photo: Finnish Defense Forces

Figure 5. Views of the Aker T2000 prototype high-speed stealth assault craft for the Finnish Defense Forces.

The different options reflect wide range of capital costs: from a low of $10 to 15 Million for craft in the BHT150 size range (insufficient cushion depth to be considered fully operational year round) to $80 Million (order of magnitude – exact cost not known) for a much larger military craft such as the Russian Zubr. Fuel consumption is even more variable reflecting the relative power and engine type: from a low of 700 litres per hour to over 9,000. Procurement of any of the options could theoretically be achieved within two to years from a decision to proceed. Such a decision would likely be preceded by a minimum of 12 to 16 months of lead-in design verification work including model tests, specification and planning development of the Arctic operating bases.

Figure 6. Almaz *Zubr* in service with the Russian and Greek Navies.

Figure 7 shows a general arrangement of a possible new design option capable of achieving 2.8 to 3 m obstacle clearance.

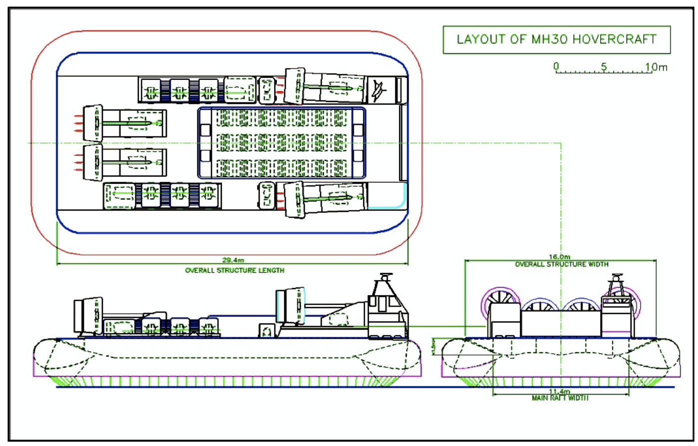

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Figure 7. MH35 new design option based on proven lift and propulsion modules in use on current commercial craft.

CONCLUSIONS AND RECOMMENDATIONS

Based on experience gained from ACV operations in cold temperatures and ice covered environments over the past 40 years, the study concludes that there is no fundamental technical limitation or operating constraint preventing hovercraft from serving year-round in a Canadian Arctic environment, as long as the design and specifications are drawn up with specific attention to the expected marine and ice operating environment.

The Russian *Zubr* shown above in Figure 6 is the only current hovercraft design that is capable of providing sufficient hoverheight to cope with the rough ice conditions expected in many years over part of the proposed patrol areas. However, the high capital costs, running costs (especially fuel and maintenance) and external noise levels present serious limitations to proceeding with this option.

It may be possible to modify an existing commercial design such as the BHT150 to increase the skirt depth but the result would still fall short of the minimum clearance considered necessary for year-round operation. Such a craft would be restricted in many years from entering key patrol areas such as the Beaufort Sea offshore and Lancaster Sound approaches to the Northwest Passage.

A much more attractive option is to design and build a new craft using proven machinery and components, tailored to the multi-role Arctic missions with adequate cushion depth (up to 3 m) and endurance to cover the full patrol area with a broad range of ice conditions. An example of such a craft is developed in the study to the level of general arrangement and overall specifications in terms of size, weight and power (see Table 1 and Figure 7).

Further work is required to reduce the overall program risk by tackling the key uncertainties in engineering design, economic parameters, infrastructure requirements and the procurement process. Studies aimed at achieving these objectives include:

- Defining the mission profiles in detail including: patrol area boundaries, payload, endurance, and specific requirements to fulfill particular roles (SAR, enforcement, submarine detection etc.).
- Investigating availability, costs and infrastructure requirements for the Russian Zubr hovercraft (the only off the shelf design capable of theoretically operating over the full patrol area)
- Deriving more accurate costs and timelines to design and build a suitably sized modular hovercraft tailored to specific CF mission requirements.
- Investigating suitable base locations, facilities and construction costs.
- Developing estimates of annual operating cost of various ACV patrol scenarios compared to other options (airborne patrols, ice strengthened patrol vessels etc.)
- Developing an overall program for research, testing, design and procurement in specific technology areas (following).

The study highlights three specific science and technology areas to improve the state of knowledge and reduce uncertainties:

1. Trafficability
   In order to fully assess the program risk associated with an Arctic Patrol hovercraft there needs to be a much more detailed analysis of ice conditions along projected patrol routes, focusing on surface roughness and distribution of ice features (ridges and rubble fields). The analysis and data collection can utilize a mix of latest generation satellite remote sensing systems (e.g. ICESat and Radarsat 2) and ground-truthing with low-level route proving flights with experienced hovercraft crews to gauge the severity of the operating environment within the different patrol areas.

2. Materials
   Previous hovercraft used in the Arctic have employed skirt materials optimized for marine operations at high speed in rough water and temperate conditions. The primary factors driving skirt material development for hovercraft in open water are resistance to high frequency fatigue and flagellation over waves. A research program leading to materials developed principally for over ice use would embody a very different set of design requirements. The result could be a more capable Arctic skirt system embodying the following desirable properties:
   - Very high tear strength without loss of flexibility and without excessive weight.
   - Low friction between the skirt material and cold ice or snow cover.
   - Better flexibility at very low temperatures (-40°C and below).
   - High abrasion and cutting resistance

3. Ice Detection and Avoidance
   The issue of being able to detect an ice obstacle that needs to be avoided far enough in advance is a critical factor determining safe speeds in different ice environments and controlling the risk of skirt or structural damage. Currently available sensors and technologies (radar, laser, forward looking infrared etc.) need to be assessed against this requirement.

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