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Canada's Navy and the National Research Council

For much of its 100-year history the Canadian Navy has been a partner of the National Research Council in naval technology development. The relationship began in 1933, the year in which the NRC Hydrodynamics Laboratory acquired an operational towing tank with carriage and dynamometer. The tank made it possible to accurately predict the propulsion needs and performance characteristics of hull forms, although this was not the use to which it was originally put. The rationale for the 400-foot towing tank on Ottawa's John Street was to conduct scale model testing of flying boats and aircraft equipped with floats. Those experiments were performed as expected, but the work of the laboratory was quickly overtaken by the pressing needs of the Navy.

By 1939 the lab had completed studies on the requirements and performance of supply ships, tankers and other vessels needed in support of the anticipated war in Europe. Then, in the fall of 1940, the Council became the official scientific establishment of the Navy, responsible for all research development and scientific liaison. Collaboration intensified on projects like the development of towed targets for gunnery and sound detection training, the design of submerged "noise-makers" to combat the enemy's acoustic torpedoes, and the challenge of amphibious tracked vehicles for coastal landings. The NRC Division of Physics and Electrical Engineering took the lead on many projects, including the development of anti-magnetic minesweeping gear and the first Canadian-built active sound detection equipment (asdic). By the end of 1940 the first sea-borne radar set went into service and a shore-based harbour defence radar system, known as Night Watchman, was established.

The many research projects ranged from the mundane (the effect of immersion in water on the dimensions and hardness of condenser packing rings) to the leading edge of innovation. The latter included the development of unmanned, smoke-laying hydrofoil craft to cover sea-borne attack. As preparations were made for the Normandy landing, NRC and defence engineers worked to perfect hydrofoil vehicles capable of operating at 40 miles per hour in nine-foot waves. Unfortunately, they were adjusting the final piece of technology, a gyroscope to improve directional control, when the great landing went ahead without them.

Other projects had greater impact, and one of them was the stabilization of the Hedgehog. The Hedgehog was an anti-submarine weapon that needed to be kept horizontal when firing, in spite of the movement of the ship on which it was mounted. The Navy asked the NRC to adapt an artificial horizon instrument used in aircraft, along with other improvements. A prototype of the resulting stabilizer was first used at sea on HMCS Sea Cliff, with complete success. NRC also developed a mechanism that would automatically inflate a life jacket when immersed, while remaining insensitive to shock, spray, rain and ordinary changes in atmospheric pressure.

Resources were spent on ideas that had less practical value as well. The British devised a scheme for the construction of flat, artificial icebergs to be used as emergency landing strips on transatlantic flights. These were to have been built of enormous ice beams reinforced with wood fibre and steel rods. The experimental results were not encouraging, and it was decided that aircraft carriers would serve the purpose equally well. Advances in engine technology also allowed for dependable transatlantic flights by mid-war. Despite such diversions, successful NRC-Navy cooperation continued without interruption for the remainder of the war. Great gains were made in acoustical and asdic research while most of the work of the Hydrodynamics Laboratory was devoted to assisting the design of Canada's warships. It contributed to many successful vessels, like the Fundy-class minesweepers and the River-class destroyers, among others.

The old John Street towing tank, built on the site of a former lumber mill and in a building that housed a hydroelectricity plant, was replaced in 1944 by a new 450-foot facility on NRC's Montreal Road campus. Construction had begun at the outbreak of war, but the conflicting demands of the war effort delayed installation of the carriage and associated equipment until the conflict was almost over. This new lab featured a 9,000 pound carriage driven by a 30-horsepower electric motor. The new equipment provided for the capture of towing resistance, pitching moment, trim, sinkage and speed of hull forms. Self-propelled models were introduced, as well as the means of casting model propeller blades, and some ship models were equipped with dynamometers to measure the torque, thrust and speed of the screws.

These technical improvements coincided with the late-war formation of the Naval Research Establishment (NRE), an arm of the Department of National Defence. In the post-war years NRC and NRE would collaborate on demonstrating the seakeeping abilities of the hydrofoil ship as a small surface vehicle capable of sustained anti-submarine operations in the open ocean. Consequently the Navy embarked on an ambitious program in 1963 to design and construct the 200-ton HMCS Bras D'or. Rough water trials validated the concept, showing the ship capable of maintaining high speeds through sea state 5, with excellent seakeeping qualities. This technological breakthrough was unhappily shelved due to cost overruns and changing priorities.

Also during the post-war period, NRC collaborated with NRE on the development of the Variable Depth Sonar towbody, a technology still in use today. That work continued into the 1980s and 90s with full-scale trials to establish a safe operating envelope, development of a towing condition monitor, and assessment of the sonar signal degradation due to ship motions. More recent work has been focused on a new sensor strategy for submarine detection, the Canadian Towed Array Sonar System.

At the end of WWII the Royal Canadian Navy was the third-largest Allied naval force, with 434 commissioned vessels and a program of new ship design and building that continued throughout the 1950s and 1960s. NRC contributed its expertise to most of those vessels, including Bay-class minesweepers, Quest-class and Endeavour-class research ships, Prestonian-class escort frigates, Bird-class patrol vessels, and the reconfiguration of existing vessels like the Majestic-class aircraft carrier.

The 1970s brought the Tribal-class destroyers, and by this time the Hydrodynamics Laboratory had evolved into the Marine Dynamics and Ship Laboratory with a large outdoor manoeuvring basin to supplement its towing tank. Working with its naval partners, NRC began an extensive study of hull forms for fast surface ships – essentially variations on frigate designs – with the long-term goal of determining the optimal hull form for a new class of Canadian patrol frigates. That detailed design information was then used by the firms competing to build the vessels. The first of the patrol frigates, HMCS Halifax, was commissioned in 1992, and 11 more were to follow.

In 1985 the Marine Dynamics and Ship Laboratory was dissolved and NRC's new Institute for Ocean Technology opened in St. John's. This state-of-the-art facility, with a 200-metre towing tank, an offshore engineering basin, and the world's longest ice tank, enabled researchers to undertake considerably more complex experiments on behalf of the Canadian Navy. The Annapolis and St. Laurent-class destroyers underwent upgrades in the 1980s and the new Institute participated in many of their sea trials. At the same time, the Tribal-class destroyers were the subject of extensive phyical model studies on roll damping, slamming and the prediction of impact forces. The Tribal Upgrade and Modernization Program (TRUMP) extended the life of these ships beginning in 1990, and the Institute participated in trials for the post-TRUMP vessels.

The Institute's expertise in data acquisition and analysis for sea trials was used in many studies involving the Canadian patrol frigates during the 1990s. Researchers were able to apply their skills to measurement of speed, seakeeping and manoeuvring performance and propulsion, including shaft thrust, torque and RPM. Experiments were undertaken on the extreme motion response of the frigate hull form, and intricate hydro-elastic model tests were performed to determine loading on particular segments of the hull. This expertise in sea trials was also applied to a Small Waterplane Area Twin Hull (SWATH) advanced marine vehicle, for which DND wanted information on load, motion and structural response.

The Navy's acquisition in 1998 of its Victoria-class submarines resulted in many collaborative research projects between NRC and the DND agency Defence Research and Development Canada (DRDC). The NRC Institute for Aerospace Research conducted wind tunnel investigations of the submarines' hydrodynamics, while the Institute for Ocean Technology embarked on extensive model and numerical studies to determine hydrodynamic loads, resistance, surface seakeeping, ice penetration and other aspects of the subs' performance. To facilitate that research, DRDC contributed to the Institute's design and construction of a Marine Dynamic Test Facility, which was acquired in 1999. The facility is a unique and powerful tool for studying the design and operation of underwater vehicles as well as surface vessels.

Submarine models are extremely complex, and the Institute has been able to assist the Navy not only by testing them, but by developing the expertise to build them. A typical submarine model, for instance, would be 4.5m long, with a five-component force dynamometer to measure hydrodynamic loads in all three directions. An inertial navigation system is housed inside its nose to measure motions in all directions, as well accelerometers, inclinometers and a six-degree freedom of motion sensor. A carefully instrumented model allows a project team to take on challenging experiments such as littoral, or near-bottom, manoeuvres.

With the new millennium NRC and its Institute for Ocean Technology have completed a broad range of projects on behalf of the Canadian Navy. These are as diverse as roll damping for the Maritime Coastal Defence Vessels to better fuel efficiency for the patrol frigates. Those contributions have resulted in very practical benefits to naval operations, including improved safety and lower operational costs.

The Maritime Coastal Defence Vessels had acquired a reputation for large amplitude motions in moderate sea conditions. The Department of National Defence requested that the Institute, in conjunction with DRDC, investigate the possibility of using the ships' main Z-drive propulsors to reduce the motion while the vessels are in transit. The potential for using the propulsors to reduce motion first became apparent after reviewing data from earlier scale-model experiments carried out in the Institute's offshore engineering basin. This was followed up by sea trials on one of the 12 MCDVs in Bedford Basin, for the purpose of acquiring the manoeuvring data needed to develop a Z-drive roll reduction system. The control concept was then tested in simulation using a numerical model of the vessel along with the trials data.

Researchers came to the conclusion that the ships' roll could be reduced by 30 to 40%, under certain operational and environmental conditions, through the proper use of its propulsors. Of equal importance was the finding of potential for power reduction, and therefore reduced fuel consumption, through the proper tuning of existing autopilots. The end result of the study has been a potentially expanded operational envelope and reduced cost, which may enable the Navy to perform critical missions in higher sea states for longer periods of time. The Institute also completed a numerical simulation of the MCDV minesweeping system, intended to provide the Navy with a better understanding of the hydrodynamic behaviour of its mine counter-measures Towfish.

A similar project is planned on the relationship between hydrodynamic drag and water velocity on navy divers. These divers are routinely exposed to a range of risks, including low water temperature, water contamination, water density gradients, elevated hydrostatic pressure and variations in current. The impact of these conditions is well documented but there was limited data on the influence of water current on diver performance. The experimental program designed by the Institute will examine divers wearing different equipment arrangements, assuming various positions with respect to water flow, and carrying out a range of tasks. The results of the study will be of use in a number of underwater operations, including explosive ordnance disposal involving a towed diver search, special forces operating in a high-current environment, and search and rescue missions.

Other studies have included dedicated model tests to investigate the wave interaction between two ships during replenishment at sea. The process of transferring fuel and other materiel from a supply ship to a frigate is not without risk, and NRC was able to better define that risk and offer guidelines on operating envelopes. Another project that has yielded considerable benefit to the Navy involved its patrol frigates. Over several years of experiments, Institute personnel designed a stern flap appendage that would reduce ship resistance and therefore fuel consumption.

In 2007-08 DND requested that the Institute ensure there would be no negative impact related to installing the new appendage on the ships. A demanding wake survey was carried out to acquire data for input to DND software that predicts propeller cavitation inception speed. The speed that a propeller begins to cavitate is critical for any modern warship, especially one with a dominant anti-submarine role. The experimental program proved to be very challenging, as the Institute had never carried out a wake survey on such a large model, and modifications were required to the standard wake survey equipment to ensure quality data. Software engineering staff then conducted a number of verifications and post-calibrations to ensure data quality before it was forwarded for DND analysis. The experiments were a success, and the savings from reduced fuel consumption now amount to many millions of dollars over the life of the vessels.

The National Research Council has played an important role as technology development partner and advisor to the Canadian Navy for more than 75 years. Its unique facilities and expertise enable Canada's naval forces to accurately predict the performance of its equipment and to prepare for future technological challenges. NRC is proud of that role, and looks forward to continued collaboration in helping the Navy maximize its potential for operational effectiveness, safety and cost efficiency.