Coast Guard Polar Icebreakers

Past, present, and future.

by CDR Thomas Wojahn
Ice Operations Program Manager,
U.S. Coast Guard Division of Ice Operations and Mobility

The United States has extensive economic, environmental, and security interests in the polar regions. Much of the state of Alaska lies within the Arctic circle, and the U.S. maintains geopolitical relations with other Arctic nations. In the Antarctic, the U.S. participates in a number of international agreements, such as the 1961 Antarctic Treaty. Over the decades, repeated high-level reviews have reaffirmed the importance of U.S. presence and leadership in the polar regions.

For the past 140 years, the U.S. Coast Guard has conducted a variety of missions in these regions, and for the past 40 years has been the sole operator of heavy U.S. icebreakers in the harshest marine environments in the world. To continue protecting its interests in the polar regions, the nation must have vessels with the capability to operate in these severe environments.

The U.S. Becomes an "Arctic Nation" and USCG Ice Operations Evolve

The purchase of Alaska in 1867 stimulated the need for vessels capable of operating in ice-covered waters to provide a U.S. maritime presence. The task of patrolling the vast waters of the newly acquired territory was assigned to the Revenue Cutter Service, the predecessor of today's USCG.

Years of studying foreign icebreaker design proved beneficial in 1941 when USCG contracted the construction of the 269-foot "wind"-class icebreakers. *Northwind*, *Southwind*, *Eastwind*, and *Westwind* were completed by 1944. These vessels were not only the most sturdy and powerful icebreakers in the world, but they also possessed a number of innovative design features unprecedented for their time, including fore, aft, and side-heeling tanks and pumps that essentially rocked the ship free from ice. Eventually, a total of seven wind-class icebreakers were built for the U.S. Coast Guard and the U.S. Navy.

All icebreakers returned to the Coast Guard in the 1960s when it was determined that—with its long history of operations in the ice-covered waters of Alaska, Antarctica, Greenland, the Great Lakes, and the East Coast—it was the best service to execute all of the nation's icebreaking missions. Upon the return of the last wind-class vessel, the USCG fleet included eight heavy icebreakers, the seven wind-class icebreakers, and the *Glacier,* which was built for the Navy in 1955.

In 1955, the USCG returned to Antarctica to facilitate the first Operation Deep Freeze (resupply of the U.S. Antarctic program) in support of science and national security missions on the continent, which have continued annually ever since. In 1957, during efforts to resupply northern distant early-warning radar stations, cutters *Storis*, *Bramble*, and *Spar* became the first U.S. vessels to transit the Northwest Passage.

Arctic research aboard USCG icebreakers intensified in the late 1960s and early 1970s, when the prospect of increased oil and gas exploration in the Alaskan Arctic required ecological baseline surveys in the Chukchi and Beaufort Seas. The 1970s brought new challenges with the discovery of oil on the north slope of Alaska, which suddenly added a new dimension to Coast Guard duties in Arctic waters. In 1969, cutters *Northwind* and *Staten Island* escorted the tanker *Manhattan* during its test voyages through the Northwest Passage. In 1971, *Northwind* surveyed the north slope and also freed an icebound convoy of 20 tugs and 40 barges en route to Prudhoe Bay.

The upshot of new needs and aging vessels brought the authorization of the polar-class icebreakers, *Polar Star* and *Polar Sea*, commissioned in 1976 and 1978, respectively. These were the first U.S. polar icebreakers built since the *Glacier*. In the 1980s, the older vessels were decommissioned as the polar-class icebreakers joined the fleet. The two polar-class icebreakers were designed to carry out a range of missions in the Arctic and Antarctic regions, including escorting non-icebreaking vessels through the ice, conducting oceanographic research, and resupplying military and research bases.

After a 10-year effort to develop a national polar icebreaker policy, and following a White House report to Congress regarding U.S. polar icebreaker needs, funding was appropriated for a new USCG polar icebreaker in 1990. This led to the cooperative development of CGC *Healy*, which was built to be a state-of-the-art Arctic research polar icebreaker. *Healy* was commissioned in 1999 and has supported annual Arctic research projects since 2000, with one deployment to support Operation Deep Freeze in 2003.

In 2006, the National Research Council completed an independent analysis entitled "Polar Icebreakers in a Changing World: An Assessment of U.S. Needs," which concluded with seven key recommendations:

1. The United States should continue to project an active and influential presence in the Arctic to support its interests. This requires U.S. government polar icebreaking capability to assure year-round access throughout the region.
2. The United States should continue to project an active and influential presence in the Antarctic to support its interests. The nation should reliably control sufficient icebreaking capability to break a channel into and assure the maritime resupply of McMurdo Station.
3. The United States should maintain leadership in polar research. This requires icebreaking capability to provide access to the deep Arctic and the ice-covered waters of the Antarctic.
4. National interests in the polar regions require that the United States immediately program, budget, design, and construct two new polar icebreakers to be operated by the U.S. Coast Guard.
5. To provide continuity of U.S. icebreaking capabilities, the *Polar Sea* should remain mission capable and the *Polar Star* should remain available for reactivation until the new polar icebreakers enter service.
6. The U.S. Coast Guard should be provided a sufficient operations and maintenance budget to support an increased, regular, and influential presence in the Arctic. Other agencies should reimburse incremental costs associated with directed mission tasking.
7. Polar icebreakers are essential instruments of U.S. national policy in the changing polar regions. To assure adequate national icebreaking capability into the future, a presidential decision directive should be issued to clearly align agency responsibilities and budgetary authorities.

Future of U.S. Coast Guard Polar Icebreakers

Polar Star and *Polar Sea* are both nearly 30 years old, and years of heavy icebreaking deployments have taken their toll. Extraordinarily severe ice conditions in McMurdo Sound during the past five years have required two icebreakers to complete Antarctic resupply operations. This schedule has accelerated wear on the ships, curtailed maintenance periods, and increased repair costs to the point that both *Polar Sea* and *Polar Star* have exceeded their economical service lives.

In 2005, the Office of Management and Budget decided to shift budget authority for the USCG polar icebreaker program direct costs to the National Science Foundation until a new national policy was determined. In order to fund significant sustainability upgrades on *Polar Sea*, *Polar Star* was placed in "caretaker" status in 2006 until the polar icebreaker policy dilemma is resolved.

Even though we are one of seven nations with territory and claims north of the Arctic circle, fiscal concerns regarding replacement of our two aging heavy icebreakers in recent years have cast significant doubt over U.S. support and commitment in the polar regions, especially when other world powers such as Russia, China, Japan, the European Union, and Korea are bolstering their polar icebreaker capabilities.

Following the National Research Council recommendations (see inset), the USCG is actively pursuing a new national polar region policy to include requirements regarding the need for U.S. maritime surface presence in the Arctic and Antarctic. Additionally, the Coast Guard is working to initiate a polar icebreaker major acquisition, as outlined in the study.

Until the national policy debate on polar icebreakers is resolved and an acquisition is completed, the *Polar Sea* will be used on an annual basis to support the U.S. Antarctic program, and *Healy* will be used to continue its support for Arctic research.

About the author:
CDR Thomas Wojahn is the U.S. Coast Guard's Ice Operations program manager. CDR Wojahn graduated from the U.S. Coast Guard Academy in 1989 and from the Naval Postgraduate School in 1996 with an M.S. in meteorology and physical oceanography. He has seven years' sea time on USCG polar icebreakers, patrol boats, and medium-endurance cutters.

Bibliography:
Http://www.uscg.mil/history/.

Committee on the Assessment of U.S. Coast Guard Polar Icebreaker Roles and Future Needs, National Research Council, "Polar Icebreakers in a Changing World: An Assessment of U.S. Needs," the National Academies Press, 2007.

National Requirements for Polar Icebreaking Capability

U.S. need for polar icebreaking capability should be considered on three levels:

(1) direct mission tasking,

(2) potential contingency operations,

(3) the vital benefit of having a sovereign national presence in the polar regions.

Direct mission tasking: Experience tells us that transporting bulk cargo and fuel and conducting research in a polar marine environment requires polar icebreaker support. Icebreakers have routinely provided these functions for a variety of U.S. agencies. These missions include:

- U.S. Antarctic program resupply,
- Arctic marine polar research,
- Antarctic marine polar research,
- monitoring and regulation of commercial and government vessel activity in the Arctic,
- support of commercial and government vessel mobility in the Arctic,
- national security support missions.

Potential contingency operations: These include unplanned tasking that may require the capabilities of polar icebreakers or other ice-capable USCG vessels. The U.S. has long-standing national interests in both polar regions, and the Coast Guard has observed increasing maritime traffic in the Arctic regions, especially in the U.S. Exclusive Economic Zone and within extended continental shelf regions.

Commercial growth activities such as fishing and ecotourism in the Arctic and Antarctic have increased substantially in recent years. All of these factors will require the Coast Guard to routinely extend its presence in the Arctic and possibly the Antarctic, with the capability to support such USCG missions as:

- enforcement of laws and treaties;
- ports, waterways, and coastal security;
- national security;
- marine environmental response;
- search and rescue;
- protection of living marine resources;
- support for the marine transportation system.

Sovereign national presence: Growing world pressures for food, fuel, and mineral resources will likely force developed nations to look more to the environmentally sensitive polar regions to tap the vast resources that have been sheltered by the polar ice caps. The ability of the U.S. to exert influence and support national polar interests depends heavily on a continuing engagement, manifested in both special and routine operations. A U.S. vessel, crewed by its Coast Guard, enables the broadest and most flexible application of statutory authorities and influence.

This includes projecting capability, power, and influence in the polar regions and supporting U.S. foreign policies in the Arctic and Antarctic. This effect is most clearly illustrated by the U.S. Antarctic program, but it will apply increasingly in the Arctic as human activity there grows. Icebreakers provide the only reliable means of projecting a surface presence, especially in the Arctic Ocean basin.

The Arctic Ocean lacks a process similar to the Antarctic Treaty that guarantees political and environmental stability. Although the U.S. Antarctic program requires polar icebreakers to support its land-based stations, U.S. Arctic policy requires a maritime presence to guarantee U.S. security interests, enforce U.S. laws, and maintain influence in the foreign policy process. As the United Nations Convention on the Law of the Sea (LOS 1982) and related international claims to the Arctic Ocean basin evolve, the U.S. will undoubtedly require an active and perhaps continual presence in the Arctic.

There has been increasing concern about international activities that are growing in the Arctic, not all of which align with U.S. objectives such as:

- growing Chinese polar activities,
- assertive Russian and Danish seabed claims,
- foreign international polar year initiatives that outpace our own,
- Canada's rising nationalism regarding Arctic territory and sovereignty rights.

Other trends, such as growing interests in Arctic maritime shipping routes, rising energy prices, doubling of the world's ice-capable vessel fleet, increasing interest in the Antarctic, and declining Arctic ice conditions indicate that the U.S. will need to have a greater capability in the polar regions to protect and enforce our national interests. One-fourth of the world's energy reserves are located north of the Arctic Circle. This requires that the U.S. be able to project power and influence into the Arctic as energy resources become more scarce.

Icebreaker Innovations

A brief history of technological advancements in icebreaking.

BY DR. ALFRED TUNIK
Naval Architect, U.S. Coast Guard Engineering Logistics Center

Ships have been operating in ice-covered waters for more than a century. This experience has proven that the most effective way to break ice cover is by using the weight of a moving ship sliding on the ice cover, further driven by propeller thrust and inertia.

During the first half of the 20th century, operators found that it is best for an icebreaker to have a generally wedge-shaped bow (Figure 1), although some deviations from this can be effective for particular applications. The operators also learned that propeller wash from either stern or bow propellers can be effectively used in certain ice conditions to improve icebreaking performance. During this time, most icebreaking methods were perfected by trial and error. Shipbuilders mainly incorporated moderate variations of the bow lines to aid in icebreaking.

Figure 1: The Russian nuclear-powered icebreaker *Rossia*, shown here at the North Pole in 1990, features the classic wedge-shaped bow. Photo by A. Tunik.

The booming oil exploration in Alaska in the late 1960s also greatly boosted innovation. First, in 1969 the tanker *Manhattan* was heavily ice-strengthened and fitted with a wedge-shaped icebreaking bow to make an experimental delivery of Alaskan crude oil through the Northwest Passage. This technological achievement manifested an unprecedented, and still unmatched, jump in the size of Arctic icebreakers from 20,000 tons (for example, the nuclear-powered *Lenin*) to almost 150,000 tons in displacement.

Icebreaking technology innovations in the 1970s and 80s followed three major paths:

(1) searching for bow shapes more effective in icebreaking than the wedge;

(2) enhancing the frictional and abrasive resistance characteristics of the hull surface against ice;

(3) efforts to develop less expensive propulsion systems than the traditional diesel electric systems, whose overtorque characteristics are so well suited to icebreaking.

Bow Shapes: In the first area of development, icebreakers fitted with a spoon-shaped bow, a flat-sloped bow or bow attachments, a sledge-shaped bow, and others performed nicely in level ice, but were problematic in other ice conditions and in open water. As a result, the traditional wedge-shaped bow is still the preferred choice, while mildly spooned bows have been successfully used on a few small icebreakers.

Resistance: The efforts to improve frictional resistance resulted in numerous efforts to supply air and/or water to the ice/hull interface of a moving icebreaker. Time has proven that these methods are not as successful in practice as expected.

The development of low-friction, high-ice-abrasion-resistant coatings in recent decades has been a more successful effort. Today, such coatings are used on virtually every icebreaker except those where much more durable and more expensive clad steels are used.

Propulsion Systems: During the mid-1980s significant development efforts were made to develop geared diesel propulsion plants, which proved to be lighter and much less expensive than traditional diesel electric propulsion plants. Geared diesel propulsion plants have proven to be effective in certain ice conditions. However, probably the most significant development in icebreaking propulsion technology was the development of azimuthing propulsion systems.

Azimuthing podded propulsors were developed in the early 1990s in Finland for icebreaking services and installed in many (mostly Finnish-built) icebreakers and icebreaking cargo vessels, including the USCGC *Mackinaw* (Figure 2). Azimuthing propulsors dramatically increase the maneuverability of ships in ice, making it possible for the vessel to perform a U-turn on the spot (zero circulation diameter). Moreover, in astern motion, ships fitted with azimuthing

Figure 2: The USCG icebreaker *Mackinaw*, the first icebreaker in North America to be fitted with azimuthing podded propellers, features two Azipods® at the stern. The *Mackinaw's* stern is an example of the “sledge” shape. USCG Photo.

propulsors benefit considerably due to combining both thrust and wake wash actions of the propellers. They are therefore capable of breaking 5-10 percent thicker ice cover, compared to what the ships can break by moving forward. In addition to the operational impact, the azimuthing podded propulsors made a noticeable impact on the design of icebreakers, eliminating shaftlines and rudders, reducing space required for propulsion machinery, redistributing weights and buoyancy, and changing ice loads on hull structures.

But the benefits brought by azimuthing podded propellers come with a price. As the pod is a heavy rotating unit that is not rigidly fixed to the hull, the propeller-induced vibrations of hull structures are inherently greater, especially in ice conditions, than those caused by traditional shaftline propellers. As a result, complying with the vibration, noise, and habitability standards for ship structures and spaces is a challenge.

The introduction of azimuthing podded propeller propulsion became the basis for the so-called double-acting ship concept, another recent Finnish innovation. A vessel built to the double-acting concept is fitted with azimuthing podded propellers in the stern and is designed to operate by moving astern in the heaviest ice conditions, i.e. breaking ice by the sledge/spoon-shaped stern assisted by the podded propellers, while moving bow-forward in all other conditions. The bow can be shaped either for open water operations only, or for ice and open water conditions. A few double-acting icebreaking vessels (including the Arctic container ship *Norilskiy Nickel*) have already been built to the later version of the concept, and many more are in the order books.

In spite of growing popularity, the operational experience with double-acting vessels is very short yet, and a number of experts are skeptical or cautiously reserved about the extent of claimed economic efficiency. Only a decade of operations will eventually confirm the viability of this idea. Alternatively, it is possible this idea may not prove to be as successful as some other initially well-regarded innovations of the 1970s and 80s, such as air bubbling systems and water jet lubrication systems installed on dozens of vessels for over a decade but almost forgotten now.

Of particular interest for the future is the recent development of the prototype small waterplane area twin hull (SWATH) ferry for the U.S. Office of Naval Research. The vessel is designed for use in Cook Inlet (near Anchorage, Ala.), where ice conditions are usually light or moderate even in the worst seasons. The vessel is designed to break the ice upward with the sharp-nosed, very slim struts of widely spaced semi-hulls (Figure 3). Model tests in an ice testing basin demonstrated very good performance in both continuous breaking of level ice and in maneuvering. If the full-scale trials of the 195-foot ferry will confirm the model test performance, this will open a venue for small SWATH craft exploratory operations in marginal ice conditions.

Figure 3: An ice test of a small waterplane area twin hull ferry model. Photo courtesy U.S. Navy.

About the author:

Dr. Alfred Tunik is a naval architect at the U.S. Coast Guard's Engineering Logistics Center. Dr. Tunik graduated from Leningrad Shipbuilding Institute. For decades, he has been involved in the design and operation of icebreakers, first at the Arctic and Antarctic Research Institute in U.S.S.R., and then at the American Bureau of Shipping in New York, prior to joining the Coast Guard in 2001. He is the author of dozens of papers on icebreaking ships and ice mechanics.

Going for Bust

The challenges facing the Coast Guard domestic icebreaking fleet.

by LT Brendan O'Shea,
U.S. Coast Guard Office of Maritime Transportation, Mobility and Ice Operations

For those who live in areas where ice forms on the waterways, Coast Guard icebreaking operations are critical to the local economy and ensure the year-round delivery of vital supplies. Without the aid of the Coast Guard domestic icebreaking fleet, ice formation on the Great Lakes and on the rivers and harbors of the East Coast would render most vessels inoperable during winter months.

On the Great Lakes, icebreaking allows for an extended shipping season for cargo such as iron ore, coal, and grain. In the Northeast, icebreaking ensures that critical shipments of heating oil are delivered. In addition, Coast Guard icebreakers break ice jams to help prevent flooding in the Great Lakes, the Northeast, and the mid-Atlantic regions.

Ice Operations

The majority of Coast Guard domestic icebreaking operations is accomplished by 10 icebreakers. The icebreakers consist of the newly commissioned CGC *Mackinaw* and nine 140-foot icebreaking tugs (called WTBGs). Additionally, 11 65-foot small harbor tugs provide icebreaking services in shallow waterways.

A successful icebreaking program is one that allows commercial traffic to continue uninterrupted during the winter months. In winter 2006, the Coast Guard did exactly this for the Great Lakes, resulting in the shipment of an additional $750 million in goods.[1]

The Coast Guard domestic icebreaking program measures its effectiveness by recording the number of days that a critical waterway is closed due to excessive ice during an ice season. "Critical" waterways are defined by considering factors such as the amount of commerce moved on the waterway, the availability of an alternate route, and the density of traffic. The domestic icebreaking program has met its critical waterway performance measure (to have no more than two critical waterway closure days per winter) for four out of the past five years. Severe winter conditions, coupled with a decision to try to extend the ice season longer than normal, led to the program not meeting its goal in 2003–2004.

Uncertain Future

Despite its consistent success, the icebreaking program faces a serious challenge. The 140-foot icebreaking tugs commissioned from 1978 to 1987 are rapidly approaching the end of their 30-year service life, with no mid-life extension maintenance scheduled or funded. During the winter of 2004–2005, the icebreaking tug *Mobile Bay* was inoperable for six weeks during the middle of the ice season due to an engineering casualty. During the 2003–2004 ice season, another of the WTGBs, *Morro Bay*, was also inoperable for several weeks.

Replacement parts are typically not readily available because some of the equipment and systems on the icebreaking tugs are outdated and the parts need to be specially ordered, if they are commercially available at all.

The domestic icebreaking fleet has proven itself to be a vital capability for a multitude of missions, and its positive impact on the nation's economy is substantial. The WTGBs are a critical part of ensuring that the nation continues to enjoy the benefits of domestic icebreaking, but unless an extensive maintenance or replacement plan for these assets is put in place soon, they face an uncertain future.

About the author:
LT Brendan O'Shea has served in the Coast Guard for five years. Prior to joining the Mobility and Ice Operations Division, LT O'Shea completed tours on a high-endurance cutter and an icebreaking tug. LCDR Bernard Sandy, a WTGB sailor of eight years, also provided invaluable assistance with this article.

Endnote:

1. CG memo from CAPT M.D. Hudson CGD Nine (dpw) to COMDT (G-PWN) 16500.

Changing Times, Changing Missions

In 1936, President Roosevelt issued Executive Order 7521, directing the Coast Guard to assist with keeping channels and harbors open to navigation by means of icebreaking "in accordance with the reasonable demands of commerce."
Since 1936, there have been significant changes to what would be considered the reasonable demands of commerce.
Likewise, there have been significant changes in the expectations and roles of Coast Guard icebreakers.

Icebreaking

One example of the changing demands of commerce involves the shipment of oil in the Northeast, particularly on the Hudson River. In order to reduce costs, oil companies have adopted a "just-in-time" approach for oil deliveries, which requires that shipments be delivered within 36 hours. Many storage facilities maintain only a few days' supply on hand. An interruption in the delivery of petroleum products would cause severe hardship for the approximately 20 million Americans who live in the product delivery area.

In 1936, oil facilities maintained a larger reserve supply and may have tolerated a two- or three-day delay in providing icebreaking services. However, the just-in-time delivery concept can no longer tolerate such delays. It is simply unacceptable to allow millions of citizens to run out of heating oil in the dead of winter.

Escorts

WTGBs and small harbor tugs also provide security for military outloads in the Delaware River. Often, these vessels will provide vessel escorts typically provided by other Coast Guard assets when those assets are unable to do so because of the presence of ice.

Stewardship

In addition, ice jams in some areas on the Great Lakes and the East Coast can cause severe flooding if left unattended. For example, the damage done by a flood on the Kennebec River in Maine in 1936 was greatly increased due to an ice jam above the Richmond bridge. As a result of the Coast Guard's efforts in promptly relieving those jams, there have been no floods caused by ice jams on the Kennebec River since that time.

Security

One of the latest challenges to the ice operations mission does not even involve ice. In the last few years, the WTGBs have been increasingly used to conduct the ports, waterways, and coastal security (PWCS) mission. Over the three years following 2001, the average annual PWCS hours for all icebreaking tugs rose by more than 10 times what it had been in the three prior years.[1] In the three years prior to 2001, the annual average employment hours for all of the WTGBs for all missions was 8,475. In the three years following 2001, the average annual employment of the icebreaking tugs rose to 10,771.

Despite such added responsibilities and increased demands, the domestic icebreaking fleet has continued to meet the demands of commerce by keeping the waterways open.

Endnote:

1. Over the three years following 2001, the average annual PWCS hours for all WTGBs was 4,057, compared to a 325-hour annual average over the three years prior to 2001.