Oceanographic Research Ships

History and Future Needs

by Richard F. Pittenger

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Dr. Robert (Bob) Pickart stood in my office at the Woods Hole Oceanographic Institution (WHOI) over the drugstore on Water Street in Woods Hole, Massachusetts, U.S.A. Pickart, a cross country skier, was very fit but also very purposeful. "What can I do for you?" I inquired. "I'd like to talk to you about using *Knorr* [WHOI's large research ship] for a cruise next year." "Great! Where do you want to go? When?" His answer stunned me for a moment. "I'd like to go to the Labrador Sea; in February and March." "What?! Why in the *world* would you want to go there that time of year?!"

The Labrador Sea is one of the most hostile places on the planet. In the winter, very cold winds blow constantly out of the Canadian Arctic and, when they encounter the water of the Labrador Sea, create clouds, storms, snow, and blowing, freezing fog. Think of lake effect snow [a phenomenon where cold winds blow across a lake, collect water vapour, which freezes and is then deposited on shore] on a grander scale. It is just plain nasty.

Pickart then explained that there was a phenomenon of major significance that occurred precisely because it was so harsh. This phenomenon was practically un-studied and the *only* way to observe it was to go there while it was happening. He needed a ship.

Oceanography has always turned to ships to explore and study the vast expanse of the ocean which covers 70% of the Earth's surface.

The Past

As we look back in history we find ships like Royal Navy Captain James Cook's *Endeavour* and *Resolution*, which he commanded on three voyages to explore the Pacific and the Southern Oceans that were, until his explorations, almost entirely unknown to the western world. Cook brought with him "naturalists," who chronicled the flora and fauna of these new places. New areas were charted and claimed in the name of the British Empire. Many natural discoveries came out of these cruises.

Endurance (Shackleton)

Vincennes (Wilkes)

Fram (Amundsen, Nansen, Sverdrup)

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Early exploration was driven by national interests and scientific curiosity including voyages by Captain James Cook aboard *Endeavour* and *Resolution*, which were used to explore the Pacific and Southern Oceans.

Similarly, in the 19th century, United States (U.S.) Navy Commodore Charles Wilkes led three ships including USS *Vincennes* on an exploration voyage during which he discovered Antarctica. Wilkes went on to survey islands in the Pacific including Fiji, the Hawaiian Islands, and the west coast of North America.

One of the most successful purpose-built research ships was the *Fram*, built on the design of Norwegian scientist and explorer Fridtjof Nansen. *Fram* was designed to withstand the rigours in the Arctic, including crushing forces of the ice. Nansen conducted several science cruises including *Fram* being frozen into the ice for extended periods and confirming the Arctic Transpolar Drift, which carries huge amounts of fresh water from Russian rivers to the Atlantic Ocean. Roald Amundsen also used *Fram* in the dash to be the first to reach the South Pole.

The 20th century began with the epic Ernest Shackleton expedition to Antarctica in *Endurance* (also built in Norway). Shackleton was an experienced Antarctic explorer having been with Robert Falcon Scott earlier and, although he failed to reach the South Pole, the lessons of leadership and survival, along with discoveries in the natural sciences, still resonate today.

Those early voyages of exploration and discovery were spectacular achievements especially when one considers that they were done in smallish – by today's standards – wooden ships, dependent on sail for propulsion, operating (sometimes for years at a time) in remote, previously uncharted regions without logistic support, requiring the ships' crews to be totally independent when it came to all matters of food, water, navigation, medical and repairs.

It was those ships that enabled the expansion of human knowledge and ships would continue up until present time to facilitate ocean research.

In the 20th century, oceanography evolved. In the U.S., much of this evolution was driven by international events and national security. Institutions dedicated to oceanographic research were established. First the Scripps Institution of Oceanography was created in La Jolla, California. It soon became one of the premier ocean research labs in the world. Then the U.S. National Academy of Sciences recommended creation of a comparable institution on the east coast, which led to the establishment of WHOI. From the outset, the Woods Hole founders stated the need for a purpose-built research ship with the result that RV *Atlantis*, a 42.6 metre ketch was designed and built for WHOI. Continuing the Scandinavian shipbuilding tradition, *Atlantis* was built in Denmark to WHOI specifications and is still serving oceanography today, 82 years later, in Argentina – its new home after being retired from WHOI in 1966.

Atlantis was the essential tool for WHOI's research in both fisheries and the other disciplines such as physical oceanography and geology. It takes skill to safely and effectively conduct over-the-side operations from ships. Sea going expertise has to be the stock and trade of research vessel operations. The Institution also developed ocean engineering and instrumentation skills. (The reader might note that U.S. space shuttles were named after famous research ships reflecting the standing of these ships in exploring Earth.)

World War II dramatically changed the focus of ocean research. The U.S. called upon the scientific community (through initiatives such as the Office of Scientific Research and Development led by Vannevar Bush) to aid in the war effort. This "applied research" with basic/fundamental research under-pinnings looked into virtually every aspect of marine science from understanding acoustic (sound) propagation in the ocean to biofouling to underwater explosive effects. Scientists moved the boundaries of knowledge of tides and currents and marine weather. They collected data from ships of all descriptions and synthesized it into forms useful to operating forces. Much of the work was done from war ships because of the risks of enemy attack. (It is important to point out that, although much of this research was classified at the time, it

The 42.6 metre ketch RV *Atlantis* was designed and built in Denmark for the Woods Hole Oceanographic Institution (WHOI) in the 1930s. *Atlantis* was the essential tool for WHOI's research in both fisheries and other disciplines including physical oceanography and geology. It was retired from WHOI service in 1966.

was the express intention that as much as possible be made available to the public following hostilities, which was done. That practice continued after WWII with the Office of Naval Research (ONR) encouraging publication of papers resulting from ONR-funded research.

After the war, oceanography continued with some of the inertia of WWII but with a focus on more basic research. The research vessels of that post-war era were mostly surplus ships left over from the great expansion of the naval forces. These ships were modified and adapted to do research – a mission for which they had not been initially designed, but resourceful academics made do.

The next major evolutionary change in U.S. oceanography was precipitated by the "Sputnik" event. The Soviet Union's dual surprise of launching a satellite into orbit and also the adaptation of nuclear propulsion to submarines had a galvanizing effect of huge proportions.

The strategic significance of a survivable and, perhaps, undetectable nuclear missile threat was quickly understood. Suddenly the submarine changed from being an anti-commerce/anti-shipping threat by diesel-battery powered submarines to submarines with virtually unlimited submerged endurance and high speed armed with long range ballistic missiles. Daunting enough was the then existing Soviet submarine force, numbering in the hundreds in the years following WWII, but the nuclear submarine constituted a sea change. Memories of the Battle of the Atlantic, which Hitler had precipitated with just 57 submarines, were fresh in many minds in those days so there was no underestimating the seriousness of the evolved submarine threat.

In the U.S., federal agencies, notably the ONR and the National Science Foundation (NSF), worked with academia (who were formally charged and empowered to provide a plan and advice) to devise a national response.

ONR funding was increased and NSF doubled its ocean research budget. New ships were included as a central feature of the plan that went forward. Both ONR and NSF funded new ship construction vetted in full cooperation with the academic community.

Research programs were devised that not only looked at direct naval relevance but also at the full range of hypothesis-driven fundamental or basic research that served to provide the tapestry of knowledge behind all applied research particularly in the ocean environment. The NSF sponsored several major science programs that utilized these ships to conduct research around the globe.

It is important to note the significance of this research to world and national security. The Cold War was a war of deterrence. It was essential that we (the allies – NATO) never create a condition of perceived weakness or vulnerability. Our purpose was to prevent a war not fight one by demonstrating our ability to counter any threat. In that respect, in my opinion, the Cold War was one of the most successful wars never fought.

Pacing the threat, as we called staying ahead of Soviet submarine technology development, took an enormous amount of investment in research and development and operations. There were setbacks such as major successful Soviet espionage efforts, which revealed many of our secrets and boot-strapped their programs. This precipitated a major new Navy initiative in oceanography, which covered education, research, and the most ambitious oceanographic ship building program this country has ever known. The Navy's own survey and research fleet was tripled. Three large, new construction oceanographic research ships and two major, large ship conversions were funded. This, along with several NSF-funded intermediate and coastal research ships, gave the U.S. a global ocean research capability that had not been known in our history. In the U.S. these ships are operated by private research/education institutions as a combined resource for the entire community under the aegis of the University-National Oceanographic Laboratory System. This manner of operating and scheduling ships as well as setting safety operating standards for them began in the early 1970s; it remains an exceptionally successful operating model 40 years later.

One of the ships to come out of the Navy initiative was RV *Knorr*, which had been modified in conversion by extending its length by 10 m and completely changing its propulsion system. *Knorr* was the ship we had tabbed to do the Labrador Sea expedition for Bob Pickart. *Knorr*'s captain was A.D. Colburn, a second generation WHOI mariner. Although not specifically designed or equipped to conduct research in the presence of ice or in extreme temperatures, *Knorr* had a reputation of doing extraordinary tasks. Its past accomplishments included finding RMS *Titanic* and the deep ocean hydrothermal vents with their surprising populations of biota existing at depths far below the reach of sunlight. This latter discovery is arguably one of the most significant discoveries of the 20th century; it revolutionized our understanding of ocean chemistry, plate tectonics and chemo-synthetic rather than photo-synthetic life.

How harsh was it?	
Mean air temperature (with only one day above freezing)	-8.0°C (17.6°F)
Coldest temperature	-17°C (1.4°F)
Mean/Maximum wind speed	23 KT (11.8m/s)/65KT(34m/s)
Twice recovered CTD package (conductivity, temperature, depth – CTD)	>50KT(25.7m/s)
Snow constant	
Snow and freezing steam fog accreted ice which had to be cleared daily to ensure ship stability	~20 tons / day
Food	Anecdotally, the exertions required to function in those conditions and clear all the ice resulted in very healthy appetites with the result that *Knorr* completed the cruise with practically no food left in its larders.

Table 1: Conditions observed by RV *Knorr*, February 2-March 20, 1997 (47 days), in the Labrador Sea.

RV *Knorr* was used by the Woods Hole Oceanographic Institution for research in the harsh environment of the Labrador Sea during a 47-day period in February and March of 1997.

So how did the Pickart cruise work out? It was an expedition judged by proposal reviewers to have great scientific merit but little chance of success. The location was just too harsh to permit collecting data from a ship. But Pickart had a reputation for doing the impossible in the Arctic and *Knorr*, with its well trained and expert WHOI mariners, had a proven track record of performance no matter how challenging.

Therefore the cruise was mounted and, despite the conditions, was extraordinarily successful. Table 1 gives the reader an idea of the enormity of the challenge.

Despite these conditions, *Knorr* successfully "occupied" more than twice the requested oceanography stations between Greenland and Labrador where deep water samples and conductivity, temperature, depth measurements were made. Over 140 expendable bathythermographs were dropped and numerous oceanographic floats were launched.

The cruise was successful from the perspective that it was accomplished safely and data collected exceeded expectations. More important the phenomenon which was the objective of the science hypothesis was observed and robustly measured. Pickart noted that atmospheric forcing of deep convection – a primary driver of all ocean circulation – was observed and documented. He also noted that *Knorr* and its crew made the work possible.

The Present

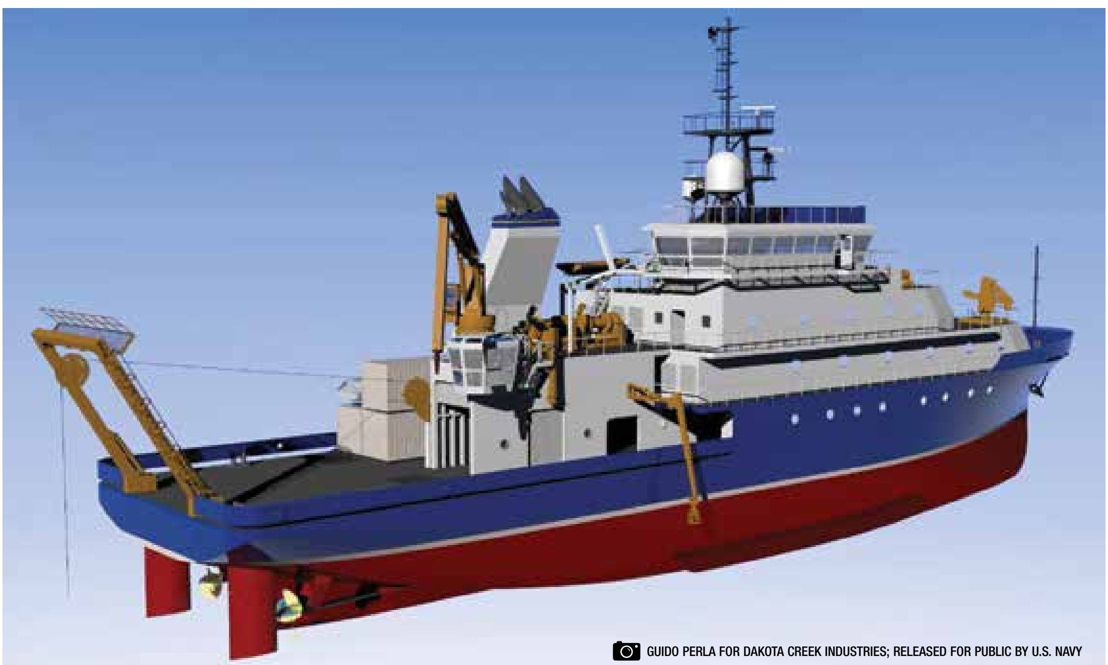
With the end to the Cold War (might I say successful end?) many things have changed. The imperative of pacing the Soviet submarine threat all but disappeared. Budgets and budget priorities were realigned. Other claimants within the research community clamoured for a bigger slice of the pie. The ONR research budget was sharply reduced and emphasis on Arctic and Anti-Submarine Warfare (ASW) research diminished. NSF, which had usually supported the Navy agenda, also moved on. New technologies and methods were advocated. These included ocean observatories, science infrastructure designed to take longer looks at ocean phenomena than ships are capable of, but at fixed locations. Robots, drifters and ocean gliders offered opportunities for measuring ocean parameters without the presence of ships (once having been launched from ships). NASA and the space community developed and deployed an array of satellite based sensors that were able to measure vast areas of the world ocean in ways that no other platform can. Attempts were made to use active sound to remotely sense the ocean synoptically and in three dimensions – however, this concept died when it got crossed up with a very contentious and emotionally charged issue of the possible effect of such measurements on marine mammals.

In a shrinking budget situation all of these "good ideas" and solid programs were competing for the same but smaller pot of dollars.

It is well known that operating ships is expensive – and has been even more so in the Post-Cold War era when the cost of operating ships increased with the price of oil and other factors. This combination of factors is driving a significant reduction in the size of the academic fleet. With gestation periods of two to three decades these days, new ship construction lags the expected service lives of research ships. But some new ships are coming. After about four decades of waiting, an Arctic research ship, RV *Sikuliaq*, will join the academic fleet next year. Also the Navy is building two ships, which will be delivered late next year for service beginning in 2015. These will be fine ships. However, *Knorr* and her sister ship, *Melville*, operated by Scripps, will be retired in the next year or so and several others are slated to follow them out of service.

Some of the new oceanographic research paradigm advocates have hinted or stated outright that the day of the research ship is over. New technologies and methods would make them no longer viable or needed.

I am afraid that these arguments do not really hold up to close scrutiny. Observatories are a wonderful idea that provides the "t" dimension, *time*, to the data, which ships are capable of doing as well. However, observatories are located offshore with some of them in remote high-latitude positions, which require regular care and servicing – BY SHIPS. Estimates are that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Scheduled for completion in 2014, Woods Hole Oceanographic Institution's newest research vessel, RV *Neil Armstrong,* will replace the RV *Knorr. Neil Armstrong* meets the range, endurance, and technical requirements to support oceanographic research in tropical and temperate oceans around the world.

72.5 metres (m) long; 15 m beam; 4.5 m draft; 3,204 tons displacement; 40 days endurance; 11,500 nautical miles range; 20 crew berths; 24 scientists berths

Scheduled for delivery in 2014, RV *Sikuliaq* is owned by the National Science Foundation and will be operated by the University of Alaska Fairbanks School of Fisheries and Ocean Sciences. One of the most advanced vessels in the world, *Sikuliaq* will operate in polar and sub-polar regions of the world.

80 metres (m) long; 15.8 m beam; 5.7 m draft; 3,665 tons displacement; 45 days endurance; 9,000 nautical miles range; 22 crew berths; 24 scientists berths

several large ships per year are required to support "observatory" research.

Space based experiments are fantastic but generally only sense the surface of the ocean and usually require ship-based measurements to "ground truth" and supplement those remotely sensed data.

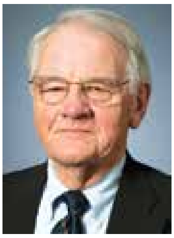
And the increasingly large arrays of independently drifting/gliding instruments are generally limited in depth and types of measurements. Ship based experiments or measurements are needed to get the detailed, multi-parameter data required for careful analyses and research. That is not to say that these new instruments/vehicles have no role to play; to the contrary, autonomous vehicles have already proven their worth. In some tasks, such as close-bottom surveying, they are much more efficient than ships.

Finally, for some types of oceanographic research, you simply have to go there with ships carrying large multidisciplinary science parties collecting and analyzing information, samples and data of many sorts. As a practical matter all research on the ocean floor (called the benthos) requires instruments or vehicles (such as the manned submersible *Alvin*) deployed from ships, which are on station above them, usually collecting a wide range of complementary data.

Also most geology and geophysic research requires ships to deploy instruments such as dredges and bottom sediment samplers. Much of marine biology is done from ships.

So I say "Not so fast!" when it comes to declaring ships obsolete. The ocean is so vast and so complex and so minimally sampled that the need for them exists and will continue to exist. We will need ships to study climate change and the world's troubled fisheries. We will need ships to study the vast, unknown mid-water and benthos domains. We will need ships to study the growing set of coastal issues ranging from pollution to erosion and sea level rise. We will need ships to respond to the inevitable natural and human-induced environmental disasters such as the Gulf oil spill (*Deepwater Horizon*) and Fukushima nuclear disaster. And then there are the unknown discoveries. With only a small percentage of the ocean having been thoroughly studied, the age of discovery is not over when it comes to oceanography. The truth is we simply do not know what lies ahead. But we do know that new ships will be needed and the existing fleet will have to be modernized and tailored to the new paradigms, but there is nothing new about that. Oceanographic research ships are continually updated.

Let's be smart about how many ships we retain and outfit with what sorts of gear in anticipation of the inevitable day when oceanographers like Dr. Robert Pickart say that only a ship can do their science.



After graduating from the U.S. Naval Academy (USNA), Rear Admiral Richard F. Pittenger (Ret.) served mostly in destroyers in positions related to Anti-Submarine Warfare (ASW). He served as ASW Officer in two ships and as Weapons Officer and Executive Officer in two others. He commanded an ocean mine sweeper off Vietnam and, later, a fast frigate equipped with a prototype tactical towed array, advanced active sonar, as well as an ASW helicopter. Command of a destroyer squadron with two deployments to the Mediterranean, Black and Baltic Seas, as well as substituting for the British Royal Navy Flag Officer Flotilla 2 in a major Strike Fleet Atlantic Exercise during the Falklands conflict, rounded out his sea-going experiences. Ashore his duties included tours as Force ASW Officer on the surface type commander's staff, positions relative to surface ASW systems development and sponsorship on the Chief of Naval Operations (CNO) staff and Chief of Staff of U.S. Naval Forces, Europe. His final two tours of duty were as the CNO's ASW Officer and finally the Oceanographer of the Navy. In addition to his USNA degree (BS Engineering), RADM Pittenger earned a Master's of Science (Physics, Underwater Acoustics) and attended the Naval War College. Since retiring from the Navy, RADM Pittenger has been at the Woods Hole Oceanographic Institution where he served as the Arctic Research Coordinator and then as Vice President for Marine Operations.