Last painting by Gilbert Stuart (1828). Considered by the family of Bowditch to be the best of various paintings made, although it was unfinished when the artist died.
I am honored to welcome you to the 2019 edition of Publication No. 9, The American Practical Navigator, or as most mariners refer to it, “Bowditch.” As a young Surface Warfare Officer serving on my first ship, I quickly learned Bowditch should be my first resource for all things related to navigation, oceanography and meteorology. I never imagined that 25 years later, I would be privileged to lead the team entrusted with updating this incredible document.

One can hardly imagine the time, effort, and pressure involved in undertaking such a task--this is Bowditch, after all. None of us alone can equal the talent, experience and skill of Nathaniel Bowditch, as expressed in his first edition of 1802. As a result, this edition is the outcome of countless hours of hard work by many dedicated, passionate, and skilled colleagues from a variety of disciplines. And it was this team of scientific and operational navigation experts, led by Dr. Jerry Clifford, which has created this contemporary edition that stands ready to address the challenges faced by today's navigators and mariners. Please take the time to read the long list of contributors to this edition, I know you will be impressed by the depth and quality of our team.

Since the last edition, there have been huge advancements in positioning methodologies and navigation systems. In some cases, what was old is new again, so we focused considerable effort into improving the celestial navigation and piloting chapters. Hand-plotting latent fixes on paper charts has been overtaken by Electronic Chart Display and Information Systems that continuously tell you where you are, provide warnings when standing into danger, and display radar and Automatic Identification System information to heighten situational awareness. Older graphics have been replaced by newer, higher resolution images to better illustrate the purpose of the text. And, we have tried to make this document more accessible by creating it in an electronic format which allows easier updating and online publication.

We are justifiably proud of this 2019 edition and equally honored to continue such a noteworthy legacy of the navigational expertise first introduced by Nathaniel Bowditch 217 years ago. Wherever you may sail, I trust this fine resource will assure your safe passage. I wish you all fair winds and following seas.

CAPT Brian D. Connon, United States Navy
Director, Maritime Safety Office
National Geospatial-Intelligence Agency
Springfield, Virginia
NATHANIEL BOWDITCH
(1773-1838)

Nathaniel Bowditch was born on March 26, 1773, in Salem, Massachusetts, fourth of the seven children of shipmaster Habakkuk Bowditch and his wife, Mary.

From the time William Bowditch migrated from England in the 17th century, the Bowditch family resided in Salem. Most of its sons, like those of other families in this New England seaport, had gone to sea, and many of them became shipmasters. Nathaniel Bowditch himself sailed as master on his last voyage, and two of his brothers met untimely deaths while pursuing careers at sea.

Nathaniel Bowditch's father, Habakkuk, was said to have lost two ships at sea, and by late Revolutionary days he was forced to return to the cooper trade that he had learned in his youth. Although cooper products such as the cask and barrel containers used for shipping flour, gunpowder, tobacco and liquids were in very high demand, this work delivered an insufficient income to properly provide for the needs of this growing family, who were often hungry and cold.

For many years the nearly destitute family received an annual grant of 15 to 20 dollars from the Salem Marine Society. By the time Nathaniel had reached the age of 10, the family's poverty forced him to leave school and join his father in the cooperage trade to help support the family.

Nathaniel was unsuccessful as a cooper, and when he was about 12 years of age, he entered the first of two ship-chandlery firms by which he was employed. It was during the nearly 10 years he was so employed that his great mind first attracted public attention. From the time he began school, Bowditch had an all-consuming interest in learning, particularly mathematics. By his middle teens he was recognized in Salem as an authority on that subject. Salem being primarily a shipping town, most of the inhabitants sooner or later found their way to the ship chandler, and news of the brilliant young clerk spread until eventually it came to the attention of the learned men of his day. Impressed by his desire to educate himself, they supplied him with books that he might learn of the discoveries of other men. Since many of the best books were written by Europeans, Bowditch first taught himself their languages, learning French, Spanish, Latin, Greek and German which were among the two dozen or more languages and dialects he studied during his life. At the age of 16 he began the study of Newton's Principia, translating parts of it from the Latin. He even found an error in that classic text, and though lacking the confidence to announce it at the time, he later published findings that were accepted by the scientific community.

During the Revolutionary War, a privateer out of Beverly, a neighboring town to Salem, had taken as one of its prizes an English vessel which was carrying the philosophical library of a famed Irish scholar, Dr. Richard Kirwan. The books were brought to the Colonies and there bought by a group of educated Salem men who used them to found the Philosophical Library Company, reputed to have been the best library north of Philadelphia at the time. In 1791, when Bowditch was 18, two Harvard-educated ministers, Rev. John Prince and Rev. William Bentley, persuaded the Company to allow Bowditch the use of its library. Encouraged by these two men and a third, Nathan Read, an apothecary who was also a Harvard man, Bowditch studied the works of the great men who had preceded him, especially the mathematicians and the astronomers. By the time he reached adulthood, this knowledge, acquired when not working long hours at the chandlery, had made young Nathaniel the outstanding mathematician in the Commonwealth, and perhaps even the country.

In the seafaring town of Salem, Bowditch was drawn to navigation early, learning the subject at the age of 13 from an old British sailor. A year later he began studying surveying, and in 1794 he assisted in a survey of the town. At 15 he devised an almanac reputed to have been of great accuracy. His other youthful accomplishments included the construction of a crude barometer and a sundial.

When Bowditch went to sea at the age of 21, it was as captain's writer and nominal second mate, the officer's berth being offered him because of his reputation as a scholar. Under Captain Henry Prince, the ship Henry sailed from Salem in the winter of 1795 on what was to be a year-long voyage to the Ile de Bourbon (now called Reunion) in the Indian Ocean.

Bowditch began his seagoing career when accurate time was not available to the average naval or merchant ship. A reliable marine chronometer had been invented some 60 years before, but the prohibitive cost, plus the long voyages without opportunity to check the error of the timepiece, made the large investment impractical. A system of determining longitude by "lunar distance," a method which did not require an accurate timepiece, was known, but this product of the minds of mathematicians and astronomers was so involved as to be beyond the capabilities of the uneducated seamen of that day. Consequently, ships were navigated by a combination of dead reckoning and parallel sailing (a system of sailing north or south to the latitude of the destination and then east or west to the destination). The navigational routine of the time was "lead, log, and lookout."

To Bowditch, the mathematical genius, computation of lunar distances was no mystery, of course, but he recognized the need for an easier method of working them in order to navigate ships more safely and efficiently.
Through analysis and observation, he derived a new and simplified formula during his first voyage.

John Hamilton Moore’s *The Practical Navigator* was the leading navigational text when Bowditch first went to sea, and had been for many years. Early in his first voyage, however, the captain’s writer-second mate began turning up errors in Moore’s book, and before long he found it necessary to recompute some of the tables he most often used in working his sights. Bowditch recorded the errors he found, and by the end of his second voyage, made in the higher capacity of supercargo, the news of his findings in *The New Practical Navigator* had reached Edmund Blunt, a printer at Newburyport, Mass. At Blunt’s request, Bowditch agreed to participate with other learned men in the preparation of an American edition of the thirteenth (1798) edition of Moore’s work. The first American edition was published at Newburyport by Blunt in 1799. This edition corrected many of the errors that Moore had introduced.

Although most of the errors were of little significance to practical navigation because they were errors in the fifth and sixth places of logarithm tables, some errors were significant. The most significant mistake was listing the year 1800 as a leap year in the table of the sun’s declination. The consequence was that Moore gave the declination for March 1, 1800, as 7° 11’, Since the actual value was 7° 33’, the calculation of a meridian altitude would be in error by 22 minutes of latitude, or 22 nautical miles. This infamous mathematical error would result in loss of life and at least two vessels, and contributed to numerous other hazardous situations. An outcome that Bowditch personally considered to be criminal.

Bowditch’s principal contribution to the first American edition was his chapter “The Method of Finding the Longitude at Sea,” which discussed his new method for computing lunar distances. Following publication of the first American edition, Blunt obtained Bowditch’s services in checking the American and English editions for further errors. Blunt then published a second American edition of Moore’s thirteenth edition in 1800. When preparing a third American edition for the press, Blunt decided that Bowditch had revised Moore’s work to such an extent that Bowditch should be named as author. The title was changed to *The New American Practical Navigator* and the book was published in 1802 as a first edition. Bowditch vowed while writing this edition to “put down in the book nothing I can’t teach the crew,” and it is said that every member of his crew including the cook could take a lunar observation and plot the ship’s position.

Bowditch made a total of five trips to sea, over a period of about nine years, his last as master and part owner of the three-masted *Putnam*. Homeward bound from a 13-month voyage to Sumatra and the Ile de France (now called Mauritius), the *Putnam* approached Salem Harbor on December 25, 1803, during a thick fog without having had a celestial observation since noon on the 24th. Relying upon his dead reckoning, Bowditch conned his wooden-hulled ship to the entrance of the rocky harbor, where he had the good fortune to get a momentary glimpse of Eastern Point, Cape Ann, enough to confirm his position. The *Putnam* proceeded in, past such hazards as “Bowditch’s Ledge” (named after a great-grandfather who had wrecked his ship on the rock more than a century before) and anchored safely at 1900 that evening. Word of the daring feat, performed when other masters were hoe-to outside the harbor, spread along the coast and added greatly to Bowditch’s reputation. He was, indeed, the “practical navigator.”

His standing as a mathematician and successful shipmaster earned him a well-paid position ashore within a matter of weeks after his last voyage. He was installed as president of a Salem fire and marine insurance company at the age of 30, and during the 20 years he held that position the company prospered. In 1823 he left Salem to take a similar position with a Boston insurance firm, serving that company with equal success until his death.

From the time he finished the “Navigator” until 1814, Bowditch’s mathematical and scientific pursuits consisted of studies and papers on the orbits of comets, applications of Napier’s rules, magnetic variation, eclipses, calculations on tides, and the charting of Salem Harbor. In that year, however, he turned to what he considered the greatest work of his life, the translation into English of Mecanique Celeste, by Pierre Laplace. *Mecanique Celeste* was a summary of all the then known facts about the workings of the heavens. Bowditch translated four of the five volumes before his death, and published them at his own expense. He gave many formula derivations which Laplace had not shown, and also included further discoveries following the time of publication. His work made this information available to American astronomers and enabled them to pursue their studies on the basis of that which was already known. Continuing his style of writing for the learner, Bowditch presented his English version of *Mecanique Celeste* in such a manner that the student of mathematics could easily trace the steps involved in reaching the most complicated conclusions.

Shortly after the publication of *The New American Practical Navigator*, Harvard College honored its author with the presentation of the honorary degree of Master of Arts, and in 1816 the college made him an honorary Doctor of Laws. From the time the Harvard graduates of Salem first assisted him in his studies, Bowditch had a great interest in that college, and in 1810 he was elected one of its Overseers, a position he held until 1826, when he was elected to the Corporation. During 1826-27 he was the leader of a small group of men who saved the school from financial disaster by forcing necessary economies on the college’s reluctant president. At one time Bowditch was offered a Professorship in Mathematics at Harvard but this, as well as similar offers from West Point and the University
of Virginia, he declined. In all his life he was never known
to have made a public speech or to have addressed any large
group of people.

Many other honors came to Bowditch in recognition of
his astronomical, mathematical, and marine
accomplishments. He became a member of the American
Academy of Arts and Sciences, the East India Marine
Society, the Royal Academy of Edinburgh, the Royal
Society of London, the Royal Irish Academy, the American
Philosophical Society, the Connecticut Academy of Arts
and Sciences, the Boston Marine Society, the Royal
Astronomical Society, the Palermo Academy of Science,
and the Royal Academy of Berlin.

Nathaniel Bowditch outlived all of his brothers and
sisters by nearly 30 years. He died on March 16, 1838, in
his sixty-fifth year. The following eulogy by the Salem
Marine Society indicates the regard in which this distin-
guished American was held by his contemporaries:

“In his death a public, a national, a human benefactor has
departed. Not this community, nor our country only, but the
whole world, has reason to do honor to his memory. When the
voice of Eulogy shall be still, when the tear of Sorrow shall
cease to flow, no monument will be needed to keep alive his
memory among men; but as long as ships shall sail, the needle
point to the north, and the stars go through their wonted
courses in the heavens, the name of Dr. Bowditch will be
revered as of one who helped his fellow-men in a time of need,
who was and is a guide to them over the pathless ocean, and of
one who forwarded the great interests of mankind.”

Bowditch is buried in historic Mount Auburn Cemetery
in Cambridge, Massachusetts. There is a bronze statue of
Nathaniel Bowditch within the cemetery that marks his life.
THE NEW AMERICAN
PRACTICAL NAVIGATOR;
BEING AN
EPITOME OF NAVIGATION;
CONTAINING ALL THE TABLES NECESSARY TO BE USED WITH THE
NAUTICAL ALMANAC,
IN DETERMINING THE
LATITUDE;
AND THE
LONGITUDE BY LUNAR OBSERVATIONS;
AND
KEEPING A COMPLETE RECKONING AT SEA:
ILLUSTRATED BY
PROPER RULES AND EXAMPLES:
THE WHOLE ILLUSTRATED IN A
JOURNAL,
WRITTEN FROM
BOSTON TO MADEIRA,
IN WHICH ALL THE RULES OF NAVIGATION ARE INTRODUCED:
ALSO
The Determination of the most useful Rules of Theodolity; With many useful Problems in Navigation, Determining
And Calculating; And a Brief Table of True Time, with the Means of performing the most common Determinations of
Time, Are Attached.
Some General Instructions and Observations on Nautical astronomy, Navigators of Weather, and other important Infor-
mation, Relative to Martrials Saving and Navigating the Shore.
FROM THE BEST AUTHORITIES.
ENRICHED WITH A NUMBER OF
NEW TABLES,
WITH ORIGINAL IMPROVEMENTS AND ADDITIONS, AND A LARGE
VARIETY OF NEW AND IMPORTANT MATTERS:
ALSO,
MANY THOUSAND ERRORS ARE CORRECTED,
WHICH HAVE APPEARED IN THE BEST SYSTEMS OF NAVIGATION YET PUBLISHED.

BY NATHANIEL BOWDITCH,
PUBLISHER OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES
ILLUSTRATED WITH COPPERPLATES.
First Edition.

PRINTED AT NEWBURYPORT, (Mass.) 1802,
BY
EDMUND M. BLUNT, (Proprietor)
FOR CUSHING & APPLETON, BOSTON.
AND BY LT. BROOKFIELD, CHIPPENHAM, AND NATHANIEL BOWDITCH,.
IN THE UNITED STATES AND ABROAD.
PREFACE

The Naval Observatory library in Washington, D.C., is unnaturally quiet. It is a large circular room, filled with thousands of books. Its acoustics are perfect; a mere whisper from the room’s open circular balcony can be easily heard by those standing on the ground floor. A fountain in the center of the ground floor softly breaks the room’s silence as its water stream gently splashes into a small pool. From this serene room, a library clerk will lead you into an antechamber, beyond which is a vault containing the Observatory’s most rare books. In this vault, one can find an original 1802 first edition of the New American Practical Navigator.

One cannot hold this small, delicate, slipcovered book without being impressed by the nearly 200-year unbroken chain of publication that it has enjoyed. It sailed on U.S. merchantmen and Navy ships shortly after the quasi-war with France and during British impressment of merchant seamen that led to the War of 1812. It sailed on U.S. Naval vessels during operations against Mexico in the 1840’s, on ships of both the Union and Confederate fleets during the Civil War, and with the U.S. Navy in Cuba in 1898. It went around the world with the Great White Fleet, across the North Atlantic to Europe during both World Wars, to Asia during the Korean and Vietnam Wars, and to the Middle East during Operation Desert Storm. It has circled the globe with countless thousands of merchant ships for 200 years.

As navigational requirements and procedures have changed throughout the years, Bowditch has changed with them. Originally devoted almost exclusively to celestial navigation, it now also covers a host of modern topics. It is that practicality that has been the mathematics involved in calculating lunar distances. It is that practicality that has been the Voyager’s most rare books. In this vault, one can find an original 1802 first edition of the New American Practical Navigator.

As navigational requirements and procedures have changed throughout the years, Bowditch has changed with them. Originally devoted almost exclusively to celestial navigation, it now also covers a host of modern topics. It is that practicality that has been the Voyager’s most rare books. In this vault, one can find an original 1802 first edition of the New American Practical Navigator.

One cannot hold this small, delicate, slipcovered book without being impressed by the nearly 200-year unbroken chain of publication that it has enjoyed. It sailed on U.S. merchantmen and Navy ships shortly after the quasi-war with France and during British impressment of merchant seamen that led to the War of 1812. It sailed on U.S. Naval vessels during operations against Mexico in the 1840’s, on ships of both the Union and Confederate fleets during the Civil War, and with the U.S. Navy in Cuba in 1898. It went around the world with the Great White Fleet, across the North Atlantic to Europe during both World Wars, to Asia during the Korean and Vietnam Wars, and to the Middle East during Operation Desert Storm. It has circled the globe with countless thousands of merchant ships for 200 years.

Seafarers have long memories. In no other profession is tradition more closely guarded. Even the oldest and most cynical acknowledge the special bond that connects those who have made their livelihood plying the sea. This bond is not comprised of a single strand; rather, it is a rich and varied tapestry that stretches from the present back to the birth of our nation and its seafaring culture. As this book is a part of that tapestry, it should not be lightly regarded; rather, it should be preserved, as much for its historical importance as for its practical utility.

Since antiquity, mariners have gathered available navigation information and put it into a text for others to follow. One of the first attempts at this involved volumes of Spanish and Portuguese navigational manuals translated into English between about 1550 to 1750. Writers and translators of the time “borrowed” freely in compiling navigational texts, a practice which continues today with works such as Sailing Directions and Pilots.

Colonial and early American navigators depended exclusively on English navigation texts because there were no American editions. The first American navigational text, Orthodoxal Navigation, was completed by Benjamin Hubbard in 1656. The first American navigation text published in America was Captain Thomas Truxtun’s Remarks, Instructions, and Examples Relating to the Latitude and Longitude; also the Variation of the Compass, Etc., Etc., published in 1794.

The most popular navigational text of the late 18th century was John Hamilton Moore’s The New Practical Navigator. Edmund M. Blunt, a Newburyport publisher, decided to issue a revised copy of this work for American navigators. Blunt convinced Nathaniel Bowditch, a locally famous mariner and mathematician, to revise and update The New Practical Navigator. Several other learned men assisted in this revision. Blunt’s The New Practical Navigator was published in 1799. Blunt also published a second American edition of Moore’s book in 1800.

By 1802, when Blunt was ready to publish a third edition, Nathaniel Bowditch and others had corrected so many errors in Moore’s work that Blunt decided to issue the work as a first edition of the New American Practical Navigator. It is to that 1802 work that the current edition of the American Practical Navigator traces its pedigree.

The New American Practical Navigator stayed in the Bowditch and Blunt family until the government bought the copyright in 1867. Edmund M. Blunt published the book until 1833; upon his retirement, his sons, Edmund and George, took over publication. The elder Blunt died in 1862; his son Edmund followed in 1866. The next year, 1867, George Blunt sold the copyright to the government for $25,000. The government has published Bowditch ever since. George Blunt died in 1878.

Nathaniel Bowditch continued to correct and revise the book until his death in 1838. Upon his death, the editorial responsibility for the American Practical Navigator passed to his son, J. Ingersoll Bowditch. Ingersoll Bowditch continued editing the Navigator until George Blunt sold the copyright to the government. He outlined all of the principals involved in publishing and editing the Navigator, dying in 1889.
The U.S. government has published numerous editions of the American Practical Navigator since acquiring the copyright. Over time the book has come to be known simply by its original author’s name and by its year of publishing. Thus, this work represents the 2019 edition of Bowditch. Like the previous edition, this one is also composed of a two volume set.

Today, mariners can access the official “digital” version of Pub No. 9 - American Practical Navigator - Bowditch, free of charge, from NGA’s Maritime Safety Information web portal. As with NGA’s other nautical publications, the digital online edition eliminates the need “to print” new editions in order to convey new information to the marine navigation community. The online edition is under continuous maintenance and therefore represents the most up-to-date version of this text, unlike a printed edition, which is only a static picture in time.

As much as it is a part of history, Bowditch is not a history book. In this edition, as in past editions, dated material was dropped and new methods, technologies and techniques added to keep pace with changes in the practice of navigation. The changes are intended to ensure Bowditch remains the premier reference work for modern, practical marine navigation. This edition replaces but does not cancel former editions, which may be retained and consulted as to historical navigation methods not discussed herein.

PART 1, FUNDAMENTALS, includes an overview of the topic of marine navigation and the organizations which develop, support and regulate it. These fundamentals include chapters relating to geodesy and chart datums; modern hydrography; the types, structure, use and limitations of nautical charts; electronic chart display and information systems; and finally a concise explanation and summary of the various navigational publications necessary for prudent marine navigation.

PART 2, PILOTING, mainly emphasizes the practical aspects of navigating a vessel in restricted waters, using both traditional and electronic methods. The closely related problems of finding the course & distance between one known point and another, and using The Sailings, are also discussed.

PART 3, CELESTIAL NAVIGATION, reflects the renewed interest in the age old art and science of navigation by the stars, planets, moon and sun. The update recognizes the trend to over rely on GPS and electronic navigation by offering the tried and true alternative method in the event of electronic failures.

PART 4, INERTIAL NAVIGATION, is often referred to as a sophisticated dead reckoning method. This section starts off with a discussion of gyroscopes and accelerometers.

PART 5, RF NAVIGATION TECHNIQUES, explains the nature of radio waves and electronic navigation systems. Chapters deal with several electronic methods of navigation--satellite, Loran, and Radar, with special emphasis on satellite navigation systems.

PART 6, ALTERNATIVE NAVIGATION TECHNIQUES, addresses the topic of bathymetric navigation. This comes in direct response to several Bowditch survey responses received by NGA.

PART 7, NAVIGATIONAL SAFETY, discusses recent developments in management of navigational resources, the changing role of the navigator, distress and safety communications, procedures for emergency navigation, and the increasingly complex web of navigation regulations.

PART 8, ICE AND POLAR NAVIGATION, in the Arctic is of renewed interest to the navigator as ice-free conditions allow shorter sailing distances.

PART 9, OCEANOGRAPHY, has been updated to reflect the latest science and terminology.

PART 10, MARINE METEOROLOGY, incorporates updated weather information and many new graphics.

NGA seeks and encourages critical feedback on this publication. Suggestions and comments for changes and additions may be sent to:

MARITIME SAFETY OFFICE
MAIL STOP N64-SFH
NGA
7500 GEOINT DRIVE
SPRINGFIELD, VIRGINIA, 22150-7500
UNITED STATES OF AMERICA
Email: mcdpubs@nga.mil
Website: https://msi.nga.mil

ACKNOWLEDGMENTS

This 2019 edition of The American Practical Navigator (Bowditch), Pub No. 9, exists to codify the latest body of marine navigation knowledge and practical application. Its publication success is a result of the dedicated efforts of many hands and voices from academia, science and seafaring experts. This edition has advanced from the judiciously shaped recommendations—some comprehensive, some minute, all indispensable—of a multitude of maritime and science professionals. At the same time, it was equally essential that those recommendations be compared, vetted, and applied in a consistent manner and with a clear vision, a challenging task performed in exemplary fashion by this edition’s principal editor, Dr. Gerard J. Clifford, Jr.

Many institutions, organizations, groups and individuals directly contributed or assisted in the success of this edition of Bowditch. Of particular note, grateful acknowledgment of effort goes out to the following:

California State University Maritime Academy:
Captain Tuuli Messer-Bookman, Samuel R. Pecota, Captain Scott Powell

Carnegie Science/Observatory:
John Grula, Tina McDowell

Civilian mariners:
James Baldwin on board the HORIZON CONSUMER, Allan B. Campbell, John A. Graham on board the USNS ARCTIC, Michael J. Holliday on board the USNS SISLER, Christopher Moore, Jere M. St. Angelo

College of William and Mary:
Dr. Christopher M. Bailey

Defense Logistics Agency:
Mr. Albert Zamora

European Space Agency:
Dr. Avila Rodriguez

Hempstead Maritime Training LLC:
Christian Hempstead

Huntington Library:
Dr. Daniel Lewis

International Hydrographic Bureau/International Hydrographic Organization:
Tony Pharaoh, David Wyatt

International Maritime Organization:
Simone Leyers

Johns Hopkins University-Applied Physics Laboratory:
Mr. Ned A. Brokloff, Ms. Leah C. Campbell, Mr. Jeffrey L. Girsch, Ms. Michelle C. Greiner, Dr. Shannon M. Hall, Dr. Daniel G. Jablonski, Mr. George H. Klaus III, Mr. Bradford J. Lapsansky, Mr. Andrew E. Love Jr., Dr. William R. Martin, Dr. David L. Porter, Mr. David R. Stark, Mr. Jonathan J. Thomas, Mr. Gregory L. Weaver

Maine Maritime Academy:
Captain Andy Chase, Captain Les Eadie, Captain Donald P. Eley, Captain Nathan D. Powers, Captain Adam Slazas, Captain Sam Teel

Maritime Institute of Technology and Graduate Studies:
Captain John Brennan, Mr. Glen Paine

Massachusetts Maritime Academy:
John L. Belle, Captain Michael R. Burns Jr., Captain Craig N. Dalton, Laurel Delong, David B. Mackey, Captain Patrick J. Modic, Linda Letourneau

NASA:
James White

Northrop Grumman Sperry Marine:
Michael R. Sawyer

Norwegian Coastal Administration:
Anne Grethe Nilson, John E. Hagen

Pennsylvania State University - Applied Research Laboratory:
Mr. Lee R. Insley

State University of New York Maritime College:
James Rogin

Teledyne RDI:
Blair Brumley, Paul Wanis

Texas A&M Maritime Academy:
Captain James P. Cleary, Captain Scott Putty, Captain Augusta “Gussie” D. Roth

U. S. Army Transportation Command:
Robert H. Brockman

U. S. Coast Guard:
LCDR Lawrence F. Ahlin, Mr. Jorge Arroyo, BMC Doug Bullock, Thomas R. Casey, BMCS Scott Cichoracki, LT Nick Cichucki (USN), LT Andrew Dennelly, George H. Detweiler, LT Brennan P. Dougherty, Mr. Clay Diamond (USCG Ret.), Mr. Paul Eulitt, LT Trip Fernandes, LT Nick Forni, LT Curt Gookin, LTJG Clay Haywood, CDR Michael Hicks, LT Mike Higbie, LT Eric W. Johnson, LT Taylor Kellogg, Mr. Robert D. Lewald, Mr. Vernon L. Mann, C. B. Mauro, CDR Gabrielle S. McGrath, USCG (Ret.), Mr. David Merrill, Mr. Russ Levin, BMC John C. Lobherr, CDR Stephen A. Love, LT Dan Miller, ENS Nickolette A. Morin, MST2 Daniel M. Morrissey, CAPT Steven W. Nerveus USN (Ret), LT Nathan Neuhardt, LT Andrew Norberg, Mr. Frank L. Parker, LCDR Michael A. Patterson, LT Patrick R. Powers, LT Eric Quigley, LT Jackie D. Ramirez, ET2 Chelsea Rasmussen, Mr. Bruce R. Riley, LT Sarah K. Shveda, CAPT Scott J. Smith, CDR John M. Stone, BMCM Tim Sullivan, E.J. Terminella, Mr. Robert
Acknowledgment must also be extended to the following dedicated maritime navigation experts who examined the penultimate draft of this manuscript and meticulously analyzed, commented, proofread, edited and prepared it for publication:

Mr. Keith E. Alexander
Mr. David E. Allen
Mr. David W. Anderson
Ms. Jacqueline Barone
Captain Anthony G. Bastidas
LCDR Daniel E. Butler, USN
QMCM Randy L. Bryant, USN (Ret.)
Mr. Sebastian P. Carisio
Mr. Howard J. Cohen
Mr. Matthew M Cronin
Mr. Brian M. Drew
Mr. Peter M. Doherty
Mr. Keith E. Dominic
Mr. Patrick V. Dorr
QMC Philip Dorsainvil, USN (Ret.)
Mrs. Jenny R. Floyd
Mr. James D. Ford
Ms. Billie Jean Gooch
Captain LeeAnne E. Gordon
Mr. Joseph A. Grzymkowski III
Ms. Misty R. Harris
Ms. Donna M. Harrison
Mr. John J. Haumann Jr.
Mr. Brian R. Heap
Mr. Walter D. Holtgren
Mr. Matthew C. Hume
Mr. Jerome Hyman
Mrs. Jennifer Keams
Mr. Carl G. Kaempfer
Mr. Virgil (Buddy) R. Klepper, Jr.
Mr. Michael S. Kushla
Ms. Prasnee K. Luebke
Ms. Ann M. Luken
Mr. Christopher J. Lonergan
Mr. Michael W. Mauceri
Ms. Sheryl L. McCash
Mr. Sean M. McGurgan
Mr. Philip Meeks
Mr. Ryan S. Milligan
Ms. Sara R. Mock
Mr. Eugene L. Moisan
ETC Robert J. Mueller, Jr., USN (Ret.)
Mr. Darryl R. Mulato
Mr. Mark E. Nueslein

U.S. Government Publishing Office
Mr. Kenneth Kerns, Mr. John M. Carey

U.S. Maritime Administration:
Kevin Kolhman, Kevin M. Tokerski

U.S. National Oceanic and Atmospheric Administration:
Dr. Benjamin Albright, Eric Blake, Johan Booth, Tyra Brown, Hugh Cobb, RADM Samuel De Bow, NOAA (Ret.), Patrick A. Dixon, James Franklin, Megan Greenaway, Mark Griffin, Colby A. Harmon, Robert Heeley, Craig Hodan, Paul Lee, Rick Lumpkin, John Brent Macek, CDR Gabrielle G McGrath (USCG), Martin Nelson, Richard Pasch, LT Joseph T. Phillips, Julia Powell, Dr. Scott D. Rudosky, Paula Rychtar, Joseph Sienkiewicz, Stacy Stewart, Dr. Rodney Viereck, LTJG Jason P. Wilson, Gregory Zwicker

U.S. National Geospatial-Intelligence Agency:
CAPT Brian D. Conn, USN (Ret.), Mr. Herman W. Dick, Mr. John A. Gandy, Ms. Dorthea Horne, LT Richard C. Johnson (USNR), CAPT Richard A. Kennedy Jr., USN, Dr. J.N. (Nikki) Markiel, Mr. Dennis J. Mc Cleary, Dr. Terry Monroe, Mr. Daniel F. Mullaney, Ms. Elizabeth Neise, CAPT Philip J. Saltzman (USNR), Ms. Carling R. Uhler, Mr. Muridith W. Winder

U.S. Naval Academy:
LCDR Andrew Storey, Royal Navy

U.S. Naval Institute:
Thomas J. Cutler

U.S. Naval Oceanographic Office:
Scott Davison, Susan Sebastian

U.S. Naval Observatory:
Jennifer Bartlett, James L. Hilton, George H. Kaplan, Demetrios Mataskis, Dr. Nancy A. Oliverson, OMC Tim Sheedy (USN), Susan G. Stewart, Mark S. Stollberg, Sean E. Urban

U.S. Navy COMPACFLT:
Daniel G. Morris, LCDR Mark H. Schaff

U.S. Navy Military Sealift Command:
Patrick T. Christian

U.S. Navy Space and Naval Warfare Systems Command:
Robert A. Greer

U.S. Navy Surface Warfare Officer School:
QMC Robert P. Hoops, LT Andrew P. McCarthy, LT Kevin F. Mullins, LCDR Douglas E Rainault, QMCS David A. Rodriguez, Captain Bud Weeks

University Corporation for Atmospheric Research:
Christopher J. Kennedy

University of New Hampshire:
Dr. Lee Alexander, Colleen Mitchell, Tara Hicks Johnson

UrsaNav:
Chuck Schue

WR Systems Ltd:
CAPT Paul K. Heim, USN (Ret.)
Mr. Steven R. Offenback
Mr. Jason J. Otero-Torres
Captain Geoffrey J. Phelps
Mr. Robert J. Raffles
Mr. James E. Rogers, Jr.
LCDR Douglas L. Roush, USN (Ret.)
Mr. Frederick R. Sanders
LCDR Jared B. Shorter, USNR
Mr. Christopher W. Sisson
Ms. DanaAnn T. Sisson
Mr. Jason D. Strom
Mr. Jamison N. Stubbs
Mr. Andrew M. Sullivan
Mr. Michael A. Theberge

Mr. Stuart Vick
Mr. John W. von Rosenberg
Mr. Brian S. Walker
QMC James F. Witts II, USN (Ret.)
Mr. Jeffrey M. Whittaker
QMC Shane T. Wilson, USN (Ret.)
Ms. Rachael C. Wold
Mr. Paul C. Youngs

QMC Michael G. Harrison, USN (Ret.)
Chief, Publications Branch
Maritime Safety Office
National Geospatial-Intelligence Agency
Springfield, Virginia