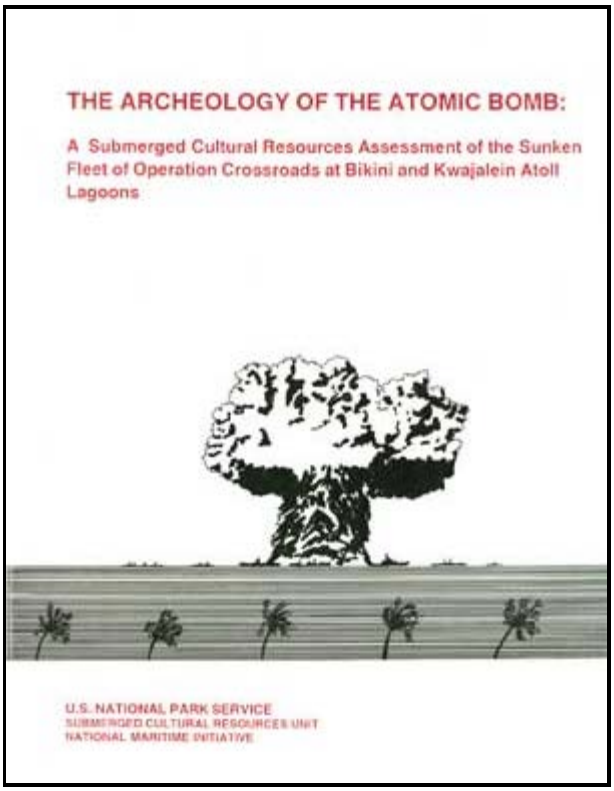
National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

THE ARCHEOLOGY OF THE ATOMIC BOMB:

The Archeology of the Atomic Bomb: A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

REPUBLIC OF THE MARSHALL ISLANDS



By
James P. Delgado
Daniel J. Lenihan
(Principal Investigator)
Larry E. Murphy

Illustrations by
Larry V. Nordby
Jerry L. Livingston

Prepared for
The Kili/Bikini/Ejit Local Government Council

1991

Submerged Cultural Resources Unit
National Maritime Initiative

United States Department of the Interior
National Park Service

Southwest Cultural Resources Center
Professional Papers
Number 37
Santa Fe, New Mexico

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FOREWORD

THE SECRETARY OF THE INTERIOR
WASHINGTON

July 8, 1991

This assessment report compiled by a special team of National Park Service underwater archaeologists sheds light on the historical importance of the sunken ships in Bikini Lagoon.

The information provided here will assist the people of Bikini to make informed decisions concerning these sunken ships. I hope that it will also serve to open new areas of interest and increase awareness to inform readers the world over of the importance of events at this historic place.

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ACKNOWLEDGMENTS

Foremost, we wish to thank the Bikini Council for inviting the National Park Service (NPS) to work at Bikini.

Jonathan Weisgall, attorney for the Bikinians, has conducted considerable research on Bikini; his voluminous files made research a much easier task. We are grateful for his and his research associate Alison MacDonald's hard work. Jack Niedenthal served as liaison for the Bikini Council during the period NPS operations took place.

William Livingston and Lee McEachern are preparing a documentary on Bikini for ABC television. Lee shared his research, including footage of the tests that provided a clearer understanding of the effects of the blast on *Saratoga.*

The field operations at Bikini Atoll were in part funded by the United States Department of Energy (DOE), Pacific Area Support Office, J. H. Dryden, Director. Holmes and Narver, Inc., DOE's contractors and managers of the Bikini Field Station, coordinated and hosted the National Park Service (NPS) team. Kent Hiner, Project Manager; Dr. Catherine Courtney, Project Coordinator; John "Alan" Brown, Holmes and Narver representative on Kwajalein, and his assistant Lance Yamaguchi tackled and ultimately removed every obstacle, from transporting equipment to arranging flights and making arrangements. In the field, the staff of the Bikini Field Station provided one of the most comfortable working environments the team has ever had. Richard Giles, the station manager, Stephen Notarianni, Eric Hanson, Wayne Olival, Edward Maddison, John Lajuan, Roger Joel, Thompson Johnson, Harry Nashon, Wilma Riklon, and Kane Janer provided invaluable assistance. The captain and crew of the DOE research vessel *G. W. Pierce* provided logistical support which was critical to the success of the project.

The Office of the Assistant Secretary of the Interior for International and Territorial Affairs supported the project; we particularly wish to thank Larry Morgan of the Assistant Secretary's office. In the National Park Service, present Director James M. Ridenour, former Director William Penn Mott, Southwest Regional Office Director John Cook, Western Regional Director Stan Albright, Associate Director Jerry L. Rogers, Associate Director Rick Smith, Pacific Area Director Bryan Harry, Deputy Associate Director Rowland T. Bowers, Chief Anthropologist Doug Scovill, and Chief Historian Edwin C. Bearss lent their support and released the team for work at Bikini.

The United States Navy, through the auspices of the Supervisor of Salvage and Mobile Diving and Salvage Unit One (MDSU 1), provided logistical support. Help was provided by the Commander-In-Chief, Pacific Fleet; by Capt. Dave McCampbell, commander of Mobile Diving and Salvage Unit One; and by Lt. Dave Rattay, commander of the Explosive Ordnance Disposal Unit One, Detachment 63, at Pearl Harbor, as well as by the men of MDSU 1 and EOD Mobile Unit One in locating the target ships, buoying them, safing ordnance, and providing detailed coverage of the ships through dive observations and remote

operated vehicle surveys.

The issue of radiation was a concern for the team. Dr. W. L. (Bill) Robison of the University of California, Lawrence Livermore Laboratory, provided data on radiation levels at Bikini, as well as an appendix to this report. Jim Sprinkle, a lab specialist in radiation monitoring and detection, also provided a personal assessment of the radiation hazards--an independent source second opinion--to project director Lenihan. Cdr. Roger Chatham, Director of the U.S. Navy's Nuclear Survivability Program at the Pentagon also provided an assessment and opinion of the radiation hazards associated with the Crossroads ships.

Considerable information about Operation Crossroads and the ships involved in the tests was provided by a number of persons. Informative discussions were held with several staff members of the Los Alamos National Laboratory (LANL). Roger Meade, Historian and Archivist at the Los Alamos National Laboratory provided archival sources, photographs, and helped us contact Los Alamos veterans of Operation Crossroads. Interviews with Crossroads participants Robert W. "Bob" Henderson, Albuquerque, New Mexico, the chief engineer of the Los Alamos Group at Crossroads; Leon D. Smith, also of Albuquerque, the "Able" weaponeer; and Woody P. Swancutt of San Antonio, Texas, the pilot of "Dave's Dream," were very helpful in answering questions not addressed by the written record.

The generosity of Battleship Cove in Fall River, Massachusetts, particularly Mark Newton, is especially appreciated. Mr. Newton provided historical references, photographs, and technical manuals for radar, ordnance, and armament and was present in spirit at Bikini as a valued member of the team. Russell Booth, manager of USS *Pampanito* (SS-383) in San Francisco, California, provided information on Mark 13 torpedoes and shipboard radar systems and gave an informative tour of his submarine that answered many questions about *Apogon* and *Pilotfish.* B. J. Dorman, Museum Director, and Jeffrey L. Crawford, Assistant Museum Director for the Pacific Fleet Submarine Memorial Association, provided material on *Pilotfish, Parche, Balao*-class submarines, JP sonar, and 20 and 40mm weapons, as well as an informative tour of USS *Bowfin* (SS-287) in Honolulu, Hawaii. Sue Moss and Carolyn Scheffer of the Texas Department of Parks, Fish, and Wildlife, provided a tour of USS *Texas* while the battleship was in the drydock in the Todd Shipyard in Galveston, Texas. That tour was invaluable in providing a better understanding of *Arkansas.* Mark Pinsel provided a tour of USS *Cabot* (CVL-28) in New Orleans, Louisiana, that served as an excellent orientation of carrier operations and characteristics. Ironically, *Cabot*, sole survivor of the *Independence*-class carriers, shares a common origin with *Saratoga*--both were built at the same yard, and more importantly, were carriers converted from cruiser hulls. Timothy Rizzuto, curator of USS *Kidd* (DD-661) in Baton Rouge, Louisiana, provided a tour of his destroyer that greatly assisted our understanding *Anderson* and *Lamson;* among the bonuses of the tour was a greasy but informative foray into the Mark 37 director atop the bridge. John Smith, Vice President of Merchant Marine Veterans of WWII, Inc., gave an excellent tour of SS *Lane Victory* in San Pedro, California, that helped us better understand *Gilliam* and *Carlisle.* Dennis Ditmanson, Superintendent, White Sands National Monument, Nancy S. Dumas, Public Affairs Officer, and Robert J. Burton, Archaeologist, White Sands Missile Range, provided a tour of Trinity Site that proved to be very helpful in understanding the development of the bomb and early test instrumentation.

Linda Jackman of the Navy's Naval Sea System Command's Shipbuilding Support Office provided a listing of the Crossroads ships and their fates as well as other information. The staff of the Naval Historical Center in Washington, D.C., were as usual a tremendous help; among those who provided support and assistance were John Reilly of the Ships History Branch, Mike Walker in Operational Archives, and Charles Haberlein, the photographic archivist in the Curatorial Branch. Henry Vadnais, the Navy's Chief Curator, helped track down items removed from the ships prior to the tests, such as *Saratoga*'s bell and *Lamson*'s

homeward bound pennant, which is on display in the Navy Memorial Museum at the Washington Navy Yard. Paul Stillwell at the United States Naval Institute, Annapolis, Maryland, provided access to oral histories that included reminiscences of Operation Crossroads. Paul also provided the address of Capt. Dick Laning, former Commanding Officer of *Pilotfish*, who put us in touch with the other skippers of the target submarines at Bikini. Joe Fetherston, one of *Saratoga*'s ship's photographers, loaned his postwar "mugbook" and history of *Saratoga* and several original photographs of *Sara*'s trying hours off Iwo Jima. Roy Alton, president of the USS *Arkansas* (BB-33) Association, loaned his "mugbook" and arranged for a meeting with *Arkansas'* crew at the ship's fourth annual reunion. Kevin Foster, formerly with the National Maritime Initiative, provided considerable information on the tests and faxed needed documents to the team in the Pacific.

Lawrence E. Wilson, Research Technician at the National Air and Space Museum, Smithsonian Institution, identified three of the aircraft in the hangar of USS *Saratoga* as Helldivers before the BuAer report was located and provided reference materials on the SB2C/SBF Helldiver for this report. Norman Polmar read the text, made many critical suggestions, and provided information from his files. This report also was reviewed by Betty Perkins and Roger Meade of LANL. Their assistance and review is appreciated.

Linda Cullen of the U.S. Naval Institute opened her photographic files on the Crossroads ships and tests. The staff at the Philadelphia Maritime Museum, particularly curator Jane E. Allen and librarian Ann Wilcox, provided access to the photographic archives of the New York Shipbuilding Corporation, which assisted the task of assessing *Saratoga* and *Arkansas*, both products of that shipyard. Steve Hailer, archivist at San Francisco Maritime National Historical Park, directed our attention to the recently processed San Francisco *Call-Bulletin* photographic archives, which included a few dozen invaluable views of *Saratoga*, including photographs of the ship being prepared for the tests and underway to Bikini. Bruce McElfresh and Alice Hall, National Geographic Society, are gratefully thanked for arranging underwater photography by Bill Curtsinger for *National Geographic* in August 1990. Mr. Curtsinger is thanked for the use of selected photos in this report.

The staffs of the following organizations and institutions are also here acknowledged: Los Alamos National Laboratory, Los Alamos, New Mexico; Military History Branch and Still Pictures Branch, National Archives, Washington, D.C.; Naval Historical Center, Washington, D.C.; Pacific Fleet Submarine Memorial Museum, Honolulu, Hawaii; J. Porter Shaw Library, San Francisco Maritime National Historical Park, San Francisco; USS *Arizona* Memorial, Honolulu, Hawaii; War in the Pacific National Historical Park, Agana, Guam; U.S. Naval Institute, Annapolis, Maryland; United States Naval Academy Museum, Annapolis; National Air and Space Museum, Smithsonian Institution; Philadelphia Maritime Museum.

Robbyn Jackson of the NPS Historic American Buildings Survey/Historic American Engineering Record, redrafted the Able and Baker arrays and plotted and drafted the sunken ship position chart from data supplied by the U.S. Navy. Tom Freeman granted permission, with all rights reserved, to publish his painting of *Saratoga* on the bottom. The painting was first published in the U.S. Naval Institute *Proceedings* in October 1990.

Drafts of this document were prepared by the National Maritime Initiative with the assistance of Fran Day of the Submerged Cultural Resources Unit. Design, layout, and final production of the camera-ready text was undertaken by J. Candace Clifford of the National Maritime Initiative staff.

swcr/37/ack.htm
Last Updated: 22-Sep-2008

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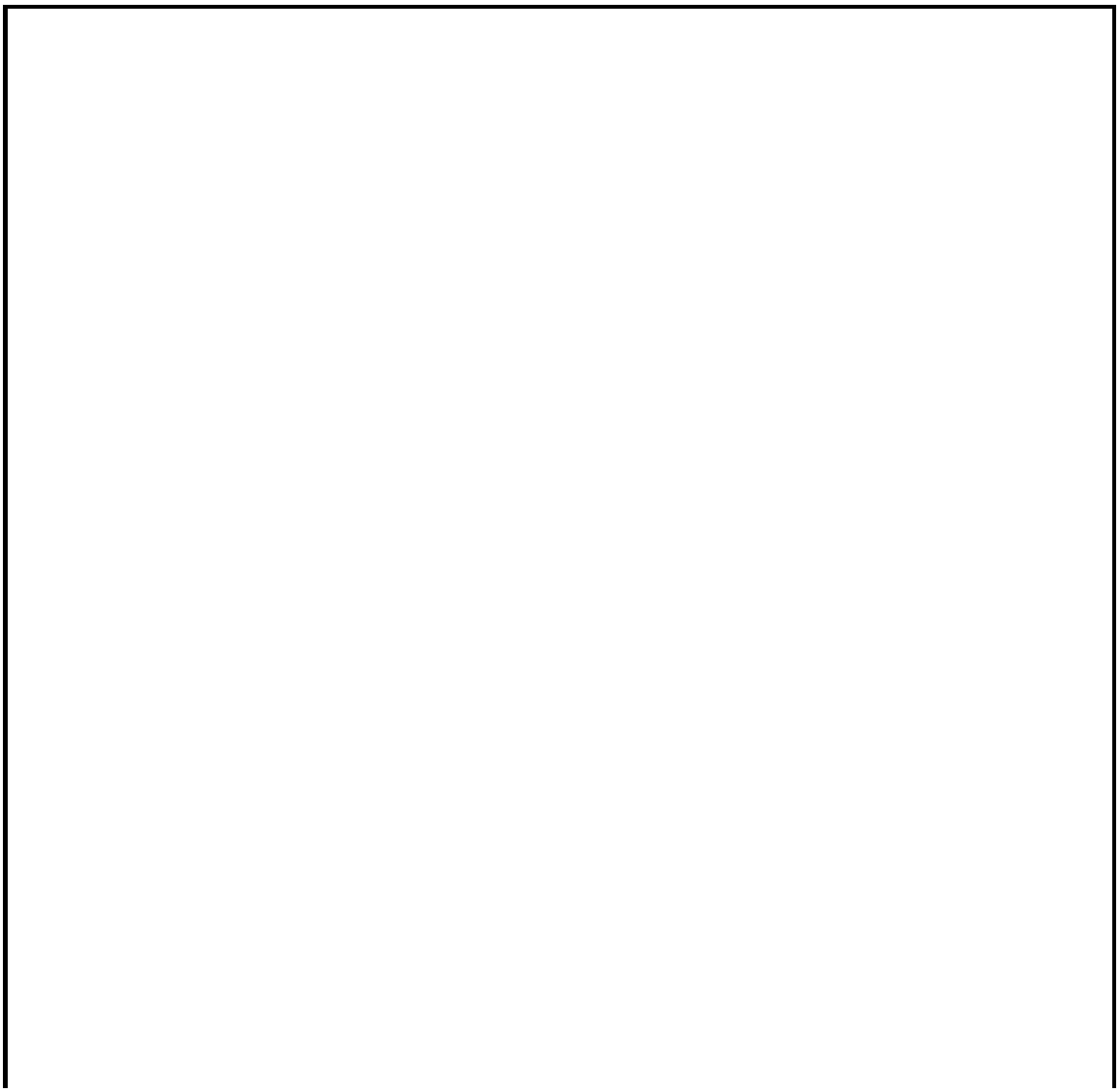
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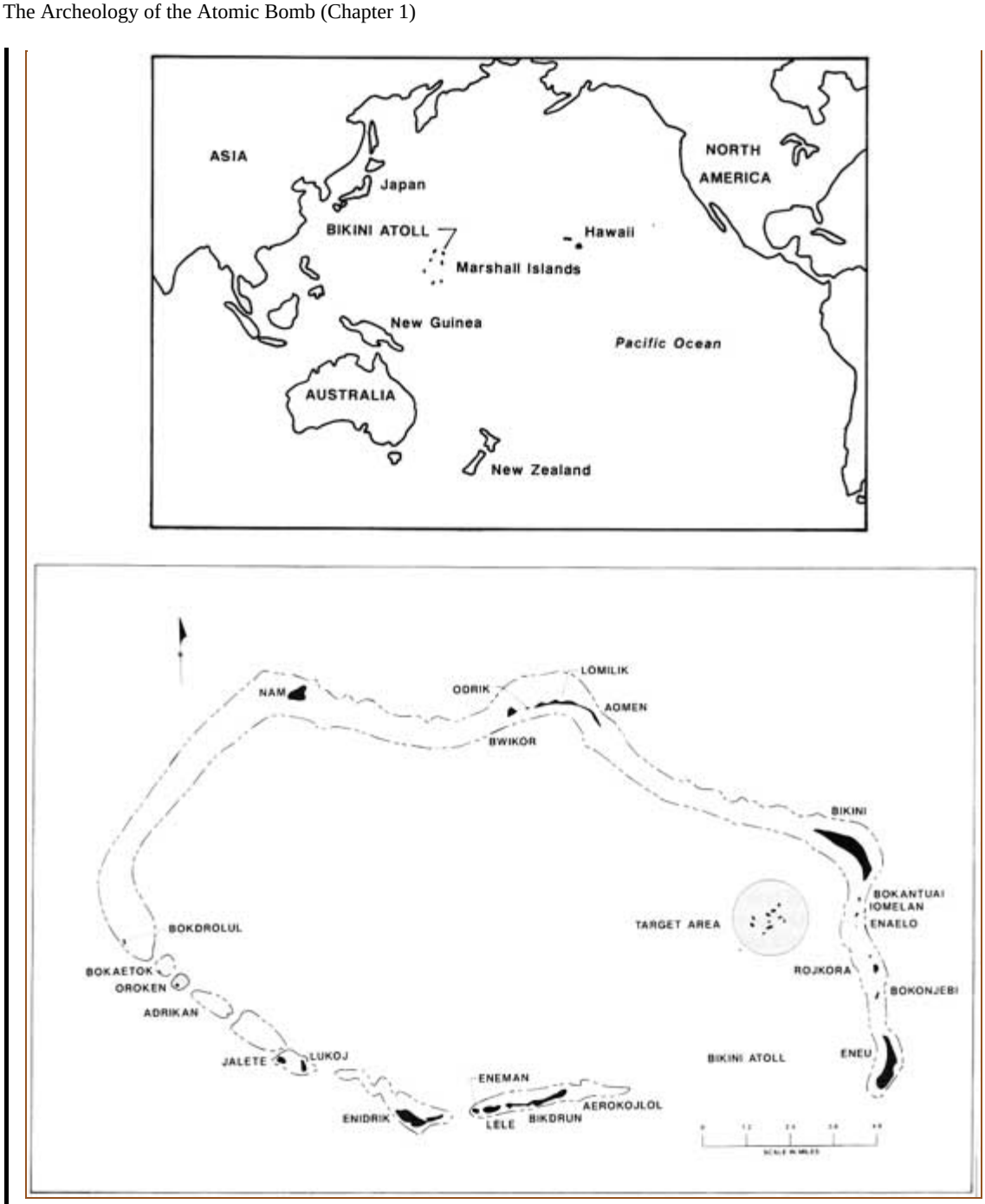
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER ONE: INTRODUCTION

Daniel J. Lenihan

In June 1988, while returning from a cooperative NPS/Navy diving operation in Palau, Dan Lenihan, Chief of the National Park Service Submerged Cultural Resources Unit (SCRU) was approached regarding a potential sunken ship survey at Bikini Atoll. Dr. Catherine Courtney of Holmes and Narver, representing her client, the Department of Energy (DOE), described the nature of the research problem in a presentation at the headquarters of U.S. Navy Mobile Diving and Salvage Unit One in Honolulu. Cdr. David McCampbell, Unit Commander, had been in communication with Dr. Courtney about the project for some time and recommended a joint effort using NPS and Navy personnel--a combination that had proved effective in numerous prior operations known collectively as Project SeaMark.





Bikini Atoll. *(NPS) (click on image for a PDF version)*

As formal requests for assistance were initiated and arrangements were made for a field operation in the summer of 1989, the NPS underwater team began preparations for one of the most challenging and compelling projects it has ever been asked to undertake. The ships of Operations Crossroads lying at the bottom of Bikini Atoll Lagoon and Kwajalein Lagoon are the remains of a fascinating event in American history, an event with international dimensions, including implications for the restructuring of geopolitical alliances in the latter part of the 20th century.

The notion that these ships might be considered as the focus for a marine park, which is the specific forte of SCRU, only further fueled the team's interest. Efforts to evaluate the ships as historical, archeological, and recreational resources for disposition by the Bikinian people began in August 1989 and resulted in the completion of this report in March 1991.

Although "ghost fleets" related to World War II exist at Truk Lagoon, etc., nowhere in the world is there such a collection of capital warships, augmented by a largely intact aircraft carrier, USS *Saratoga*, and the flagship of the Japanese Navy at the time of the attack on Pearl Harbor, *Nagato.* Through chance or intent, vessels of great symbolic importance to the history of World War II were included in the test array and now reside at the bottom of the lagoon. These ships, all within a few hundred yards of each other, comprise an incomparable diving experience.

During the course of the project the team members, without exception, were impressed not only with the extraordinary cultural and natural resources of Bikini but with the compelling human dimension of the problem of displacement and resettlement of the Bikinian people. We hope the discussions in this report will help expand the range of options available to the Marshall Islanders in reestablishing their community on Bikini and other islands impacted from nuclear testing.

PROJECT MANDATE AND BACKGROUND

Under the terms of the Compact of Free Association between the Government of the United States and the Governments of the Marshall Islands and the Federated States of Micronesia (Public Law 99-239), the United States, in Section 177, accepted responsibility for compensating the citizens of the Marshall Islands, the Federated States of Micronesia, or Palau, for "any losses or damages suffered by their citizens' property or persons resulting from the U.S. nuclear testing program in the northern Marshall Islands between June 30, 1946, and August 18, 1958." The U.S. and the Marshall Islands also agreed to set forth in a separate agreement provisions for settlement of claims not yet compensated, for treatment programs, direct radiation-related medical surveillance, radiological monitoring, and for such additional programs and activities as may be mutually agreed. (99 Stat. 1812) In section 234, the United States transferred title to U.S. Government property in the Marshall Islands to the government of the Marshall Islands except for property which the U.S. Government determined a continuing requirement. (99 Stat. 1819)

Based on section 177, an agreement between the U.S. and the Government of the Marshall Islands relating to the nuclear testing programs was reached. Under the terms of this agreement, the U.S. Government reaffirmed its commitment to provide funds for the resettlement of Bikini Atoll by the people of Bikini, who were relocated during the first nuclear weapons tests in the Pacific, Operation Crossroads in 1946. Since then, studies that have focused on the eventual resettlement of Bikini have been and continue to be undertaken.

In July-August 1989 and April-May 1990, a team from the U.S. National Park Service traveled to Kwajalein and Bikini atolls to document ships sunk during the Operation Crossroads atomic bomb tests. The team was invited by the Bikini Council, the United States Department of Energy, Pacific Region, and Holmes and Narver, DOE's primary contractor in the Pacific and operator of DOE's Bikini Field Station.

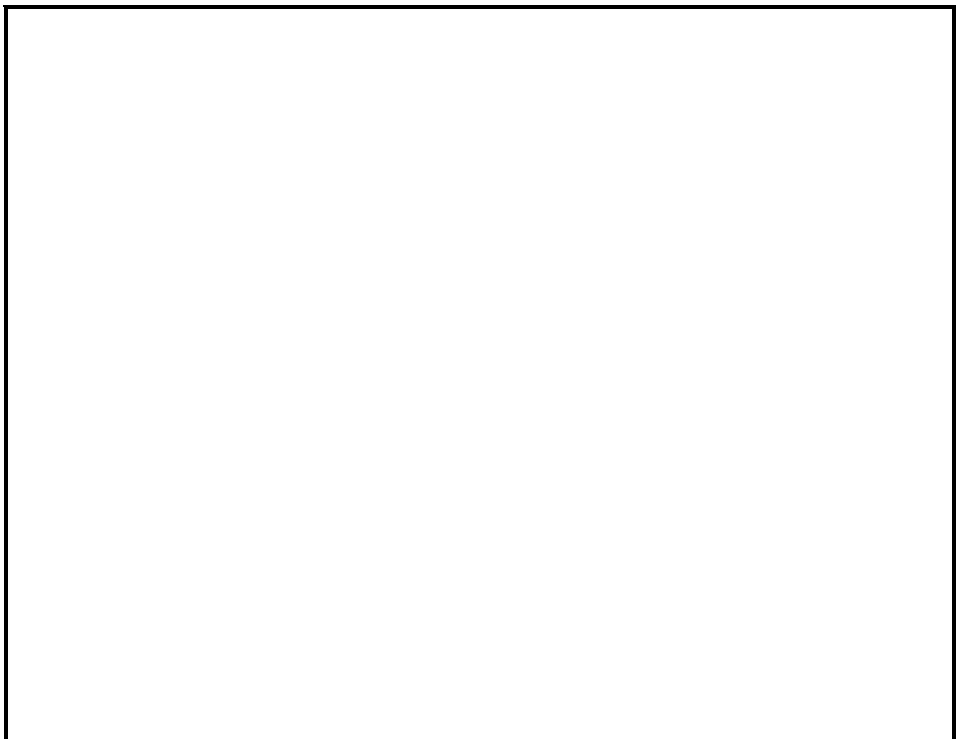
The sunken ships at Bikini are the property of the people of Bikini. Title was transferred in the U.S. Marshall Islands agreement in accord with Article 177 of the Compact of Free Association; according to Article VI, Section 2 of the agreement:

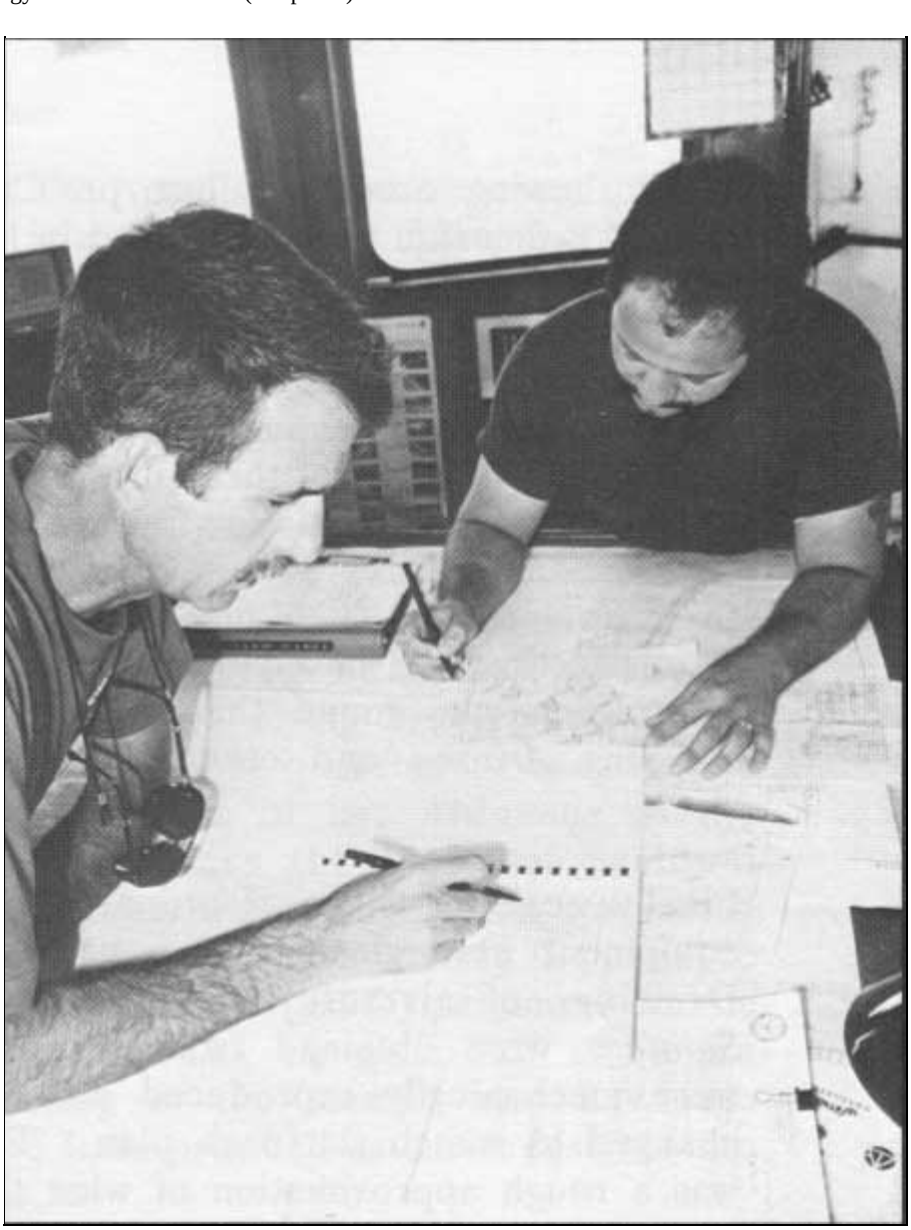
> Pursuant to Section 234 of the Compact, any rights, title and interest the Government of the United States may have to sunken vessels and cable situated in the Bikini lagoon as of the effective date of this Agreement is transferred to the Government of the Marshall Islands without reimbursement or transfer of funds. It is understood that unexpended ordnance and oil remains within the hulls

> of the sunken vessels, and that salvage or any other use of these vessels could be hazardous. By acceptance of such right, title and interest, the Government of the Marshall Islands shall hold harmless the Government of the United States from loss, damage and liability associated with such vessels, ordnance, oil and cable, including any loss, damage and liability that may result from salvage operations or other activity that the Government of the Marshall Islands or the people of Bikini take or cause to be taken concerning such vessels or cable. The Government of the Marshall Islands shall transfer, in accordance with its constitutional processes, title to such vessels and cable to the people of Bikini.

Under the Agreement, the U.S. Department of Energy conducted a study of the sunken ships in Bikini Atoll, in particular assessing leaking fuel and oil that may pose long-term environmental impacts that would result from the sudden rupture of tanks containing oil or fuel. Recommendations for the final disposition of the ships depended on assessments of their structural integrity and historic significance. The DOE requested the assistance of the U.S. Navy, Mobile Diving and Salvage Unit One, headquartered at Pearl Harbor, Hawaii, to (1) determine the geographic location (latitude and longitude) of each ship; (2) mark the bow, stern, and midships section of each ship with spar buoys; (3) make a preliminary description of the condition of each ship; and (4) determine if the condition of the ships warranted an assessment of historical significance.

The U.S. Navy deployed MDSU 1 at Bikini between August 5-17, 1988. This activity, as well as general footage of Bikini and the ships, was filmed by Scinon Productions, which produced a special for PBS and for KGO-TV, San Francisco. Following this exercise and the concurrence of the Bikini Council, on December 21, 1988, the Department of Energy requested the services of the National Park Service to conduct an evaluation of the historical significance, marine park potential, and diving hazards associated with the sunken fleet at Bikini. Because the ships and test equipment submerged in Bikini Lagoon are an immensely valuable cultural resource deserving thorough study, and the Service's Submerged Cultural Resource Unit is the only U.S. Government program with experience in this work, the National Park Service agreed to assist DOE. At the same time, MDSU 1 was redeployed at Bikini with EOD Mobile Unit One to continue marking wrecks and to assess and safe live ordnance in, on, and around the ships.





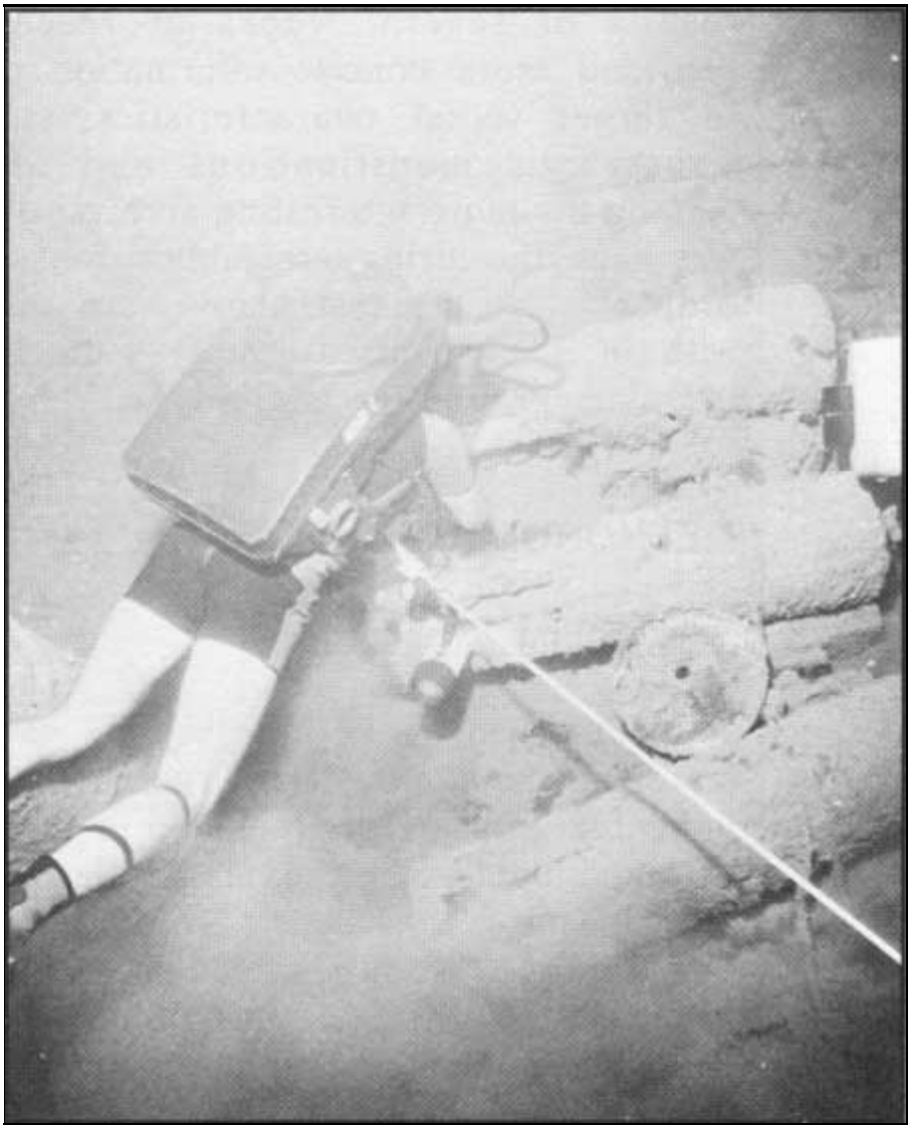
Commander David McCampbell, USN (left), led the Navy effort to locate and plot the wreck locations. *(NPS, Larry Murphy)*

The National Park Service team was led by Daniel J. Lenihan, Chief of the Submerged Cultural Resource Unit, and included as team members NPS Maritime Historian James P. Delgado, Head of the National Maritime Initiative; SCRU Archeologist Larry E. Murphy; Archaeologist Larry V. Nordby, Chief of the Branch of Cultural Research, Southwest Regional Office; and Scientific Illustrator Jerry L. Livingston of the Branch of Cultural Research. The same team assembled in Honolulu, Hawaii, in early August 1989 and from there traveled to Bikini by way of Kwajalein. The team returned for a second and final field season in late April-early May 1990.

Of the original array of target vessels, 21 ships (counting eight smaller landing craft) were sunk in Bikini Lagoon during the Able and Baker atomic bomb tests of July 1 and 25, 1946. A number of the remaining vessels, among them the former German heavy cruiser *Prinz Eugen* (IX-300), which "survived" the tests, were towed to Kwajalein Atoll for decontamination and offloading of munition. Progressive flooding from leaks, however, led to the capsizing and sinking of *Prinz Eugen* in shallow waters in Kwajalein Atoll Lagoon in 1946. Another target vessel, LCI-327, was stranded and "destroyed" on Bascombe (Mek)

Island in Kwajalein Atoll in 1947. These two vessels comprise a secondary deposition of Crossroads target ships that are accessible for study.

The NPS team was able to visit nine of these 23 vessels and document them to varying degrees. The team subsequently evaluated two other vessels utilizing the Navy's Remote Operated Vehicle (ROV) video coverage of them. The major focus of the documentation was the aircraft carrier *Saratoga* (CV-3) at Bikini; a lesser degree of documentation was achieved for the battleships *Nagato* and *Arkansas* (BB-33), the submarines *Pilotfish* (SS-386) and *Apogon* (SS-308), YO-160, LCT 1175, LCM-4, and the attack transports *Gilliam* (APA-57) and *Carlisle* (APA-69) at Bikini, as well as the cruiser *Prinz Eugen* at Kwajalein. In every case, the NPS found sufficient cause to determine that these vessels are indeed historically and archeologically significant.



The Navy's Explosive Ordnance Demolition Unit One safed a depth bomb by "gagging" its live fuse. *(NPS, Larry Murphy)*

This report documents the pre-sinking characteristics of each of the vessels, as well as an assessment of their careers and participation in Operation Crossroads. In the case of the nine vessels visited by the NPS team and the two ROV-dived vessels, a site description based on the assessment dives and documentation efforts is included. The report includes the results of several weeks of research that provided more concise information pertaining to target vessel

characteristics, specifically Crossroads modifications and outfitting. Among the more interesting archival discoveries was that the firing assemblies for some test ordnance on the test ships were incomplete, with inert elements (plaster) replacing either the main or booster charges.

METHODOLOGY

Background Research

In preparation for the project, background material on Operation Crossroads and the individual target ships included in the tests was obtained by historian James Delgado through several sources. Historical information about each vessel's characteristics, history, participation in the tests, and the circumstances of its sinking were obtained, as were materials pertaining to test planning, logistics, and results.

In preparation for field activities, the plans most likely to reflect the final configuration of armament and deck features present on *Saratoga* were sought. A set of microfilmed plans showing *Saratoga*'s last pre-Crossroads refit at Bremerton Naval Shipyard in May 1945 was obtained. From these and published plans of the ship, a deck plan and starboard elevation of the carrier as it was configured at the end of the Second World War were available. The scale of these drawings was too small to serve as a basis for field work, so they were expanded using a Map-O-Graph machine to a final scale of 1/8-inch per foot (1:96). This selection was based on the preference of illustrators, who found this scale ideal when mapping *Arizona* and other ships of similar size.

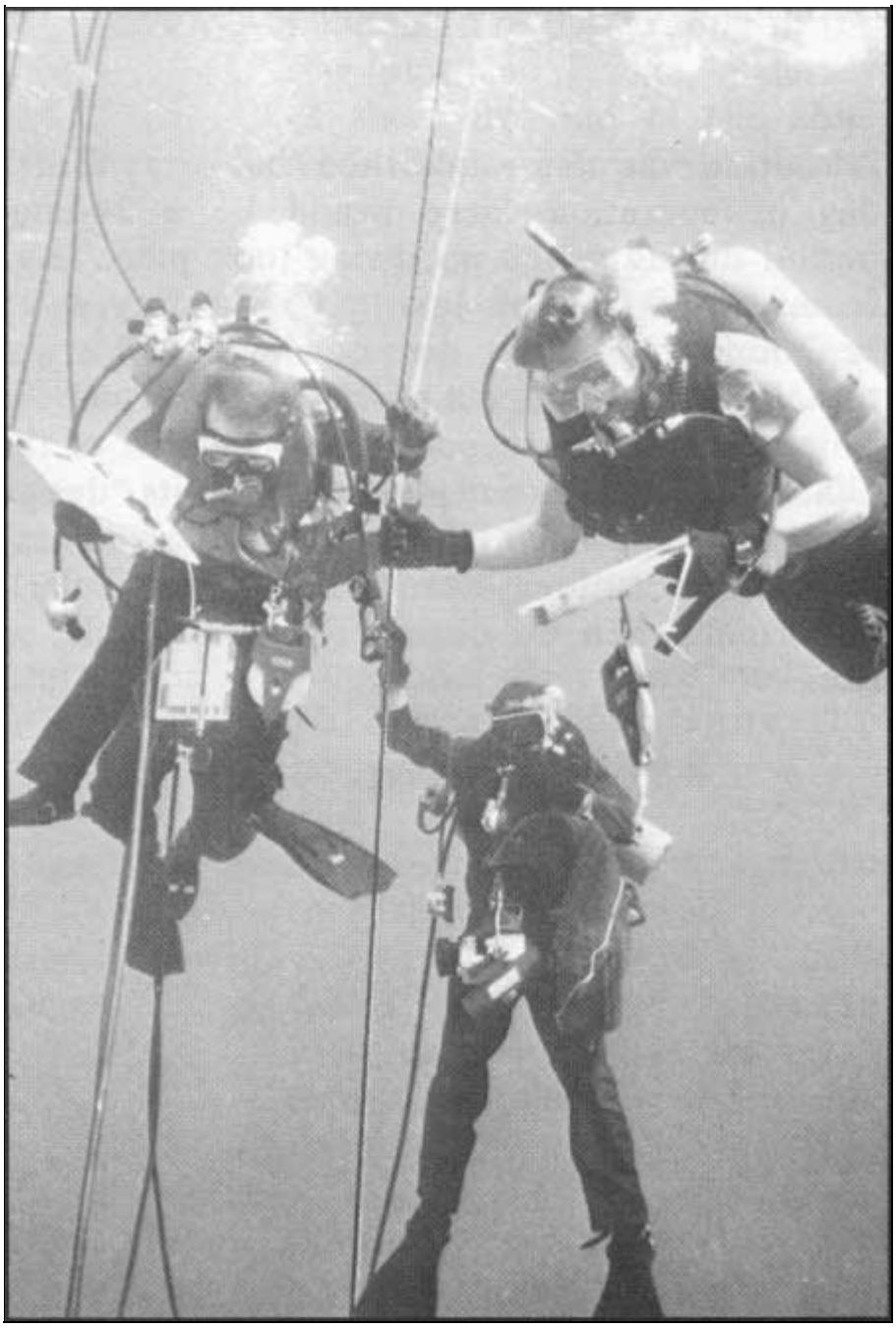
Finally, scale drawings of ordnance and radar equipment were gleaned from naval manuals. Drawings of aircraft known to be aboard *Saratoga* were obtained from books. These were mechanically reproduced and the scale changed to match the deck plan. The result was a rough approximation of what the vessel would have looked like on the eve of Operation Crossroads, expressed in drawings of the deck plan and starboard elevation, each more than nine feet long. Mylar tracings of small sections of their conjectural drawings were carried on each dive by the illustrators and altered to fit the archeological reality of the ship's present appearance.

Site Description and Analysis

To develop a narrative presentation of findings from the research, archeologists Dan Lenihan and Larry Murphy, and historian James Delgado, swam through each site and recorded observations or notes after the dive or on videotape during the dive. To permit filming, a special experimental hookup was designed before the project to connect a full face mask (AGA) to a small underwater video camera. The mask was installed with a microphone that permitted the diver to speak directly onto a videotape as he panned the site with the camera. This permitted onsite recording of field observations and also permitted much easier referencing of the viewer to the location of the image on the site. On large sites, recording the location of the camera image has been a consistent problem.

In addition to personal observation on the site, the Navy's Bureau of Ships 1946 description of some of the vessels helped separate primary deposition from later site formation processions. Information on biological communities now present on the site was obtained through video imaging for examination both at Bikini and on return to Santa Fe.





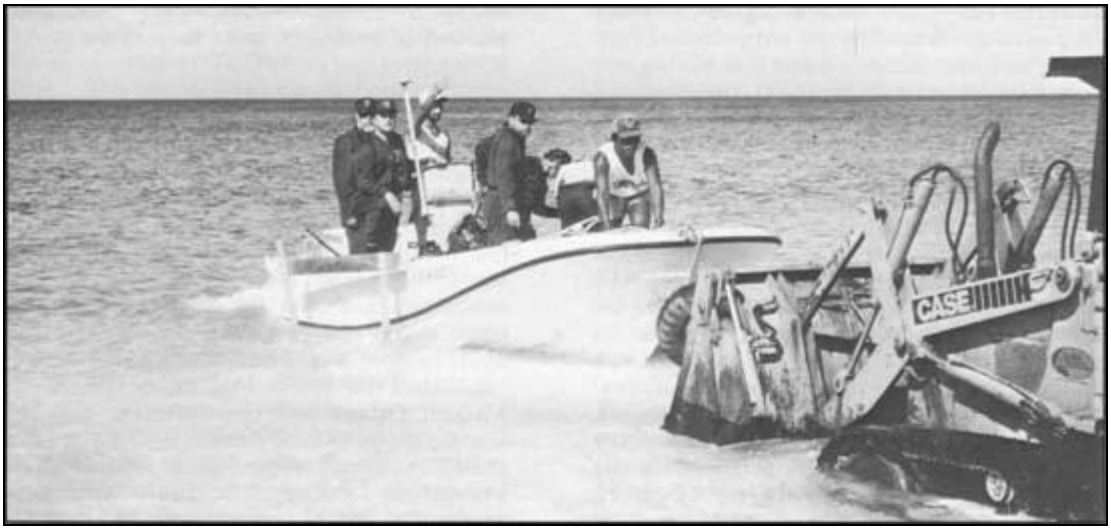
The depth at which the wrecks lie, and the amount of time required for meaningful observation and documentation compelled lengthy oxygen decompression stops. *(NPS, Larry Murphy)*

Information generated in this manner was also used for assessing recreational potential. Although the team was well equipped to assess normal sport diving hazards (given the extensive shipwreck diving backgrounds of the members), it was not qualified to evaluate the volatility or status of live ordnance in the vessels or address the issue of residual radiation hazards without help from specialists. Cooperation with U.S. Navy Explosive Ordnance Demolition (EOD) personnel on site was very useful in gaining such an understanding of the former, and Lawrence Livermore Labs provided extensive insights into the latter.

"Imaging the Ships"

Information for drawings that are part of the report was generated through sketching the sites

and comparing the results to plans obtained through the archival research. Some videotape obtained in the dives was taken primarily as an aid to illustration. Unlike most other situations in which physical baselines have been used by SCRU to map sites, there was enough integrity to the vessel fabric that features of the ships themselves could be used as integral reference points.



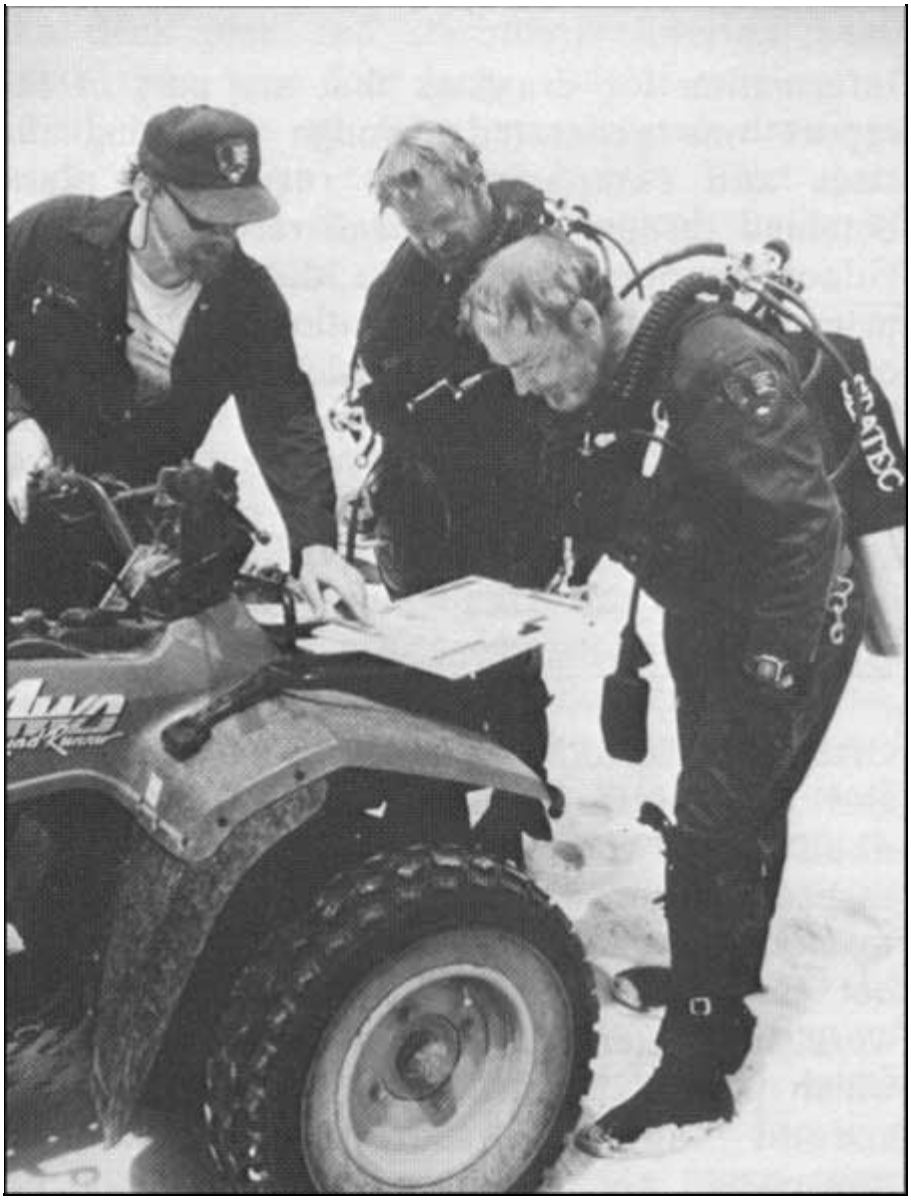
Boat launching by front-end loader. The NPS team prepares to depart for a day's diving. Eric Hanson is at the helm, while Edward Maddison prepares to release the boat.

Operational Diving Procedures

Given the 180-foot maximum depth of the ships and the intensity of the diving operations needed to accomplish the objectives of assessing and documenting the ships at a working depths usually well over 100 feet, if not deeper, certain deep diving procedures were implemented. Special dual manifolds which permitted total redundancy of first and second stages of breathing systems were transported to the job site from Santa Fe. These were used to arrange cylinders supplied by DOE into double tank configurations. The diving day was divided into two dives per team with staged decompression anticipated on both dives. The first dive of the day was always planned to be deeper or as deep as the second dive.

An in-water oxygen decompression system was also brought from Santa Fe to allow a large margin of safety in decompression profiles. Standard U.S. Navy air tables were used in decompression, but oxygen was substituted as the breathing gas for 30-, 20-, and 10-foot stops. Emergency evacuation procedures were established and after the Navy arrived on the scene during the first field session, a routine system for accident management was established that involved the use of their Diving Medical Officer and recompression chamber. During the 1990 field session no Navy medical facilities or chamber were available, so evacuation to Kwajalein would have been necessary.

A routine was also established that every fourth day of operation there would be a 24-hour period during which no diving took place, e.g., from "up" time of last dive on day 4 to beginning of the first dive on day 5. This was to help mitigate effects of "Safari Syndrome" in which the 12-hour decompression model of the U.S. Navy tables is pushed past its design limits for multi-day repetitive diving. These special precautions were deemed particularly important when no chamber was available on site.



After diving LCT-1175, Daniel Lenihan, Larry Nordby, and Jerry Livingston compare notes on the sketches and measurements made by the scientific illustrators. *(NPS, James P. Delgado)*

ACTIVITIES

1989 Field Season

August 8-10: The team traveled from their duty stations in Santa Fe, New Mexico, and Washington, D.C., to Kwajalein, Marshall Islands.

August 11: Layover in Kwajalein. Team traveled around Kwajalein with public affairs liaison officer visiting WWII sites.

August 12: Prepared for departure to Bikini, but Air Marshall Islands came in overbooked and would not take the team to Bikini. Obtained access to a boat during latter part of the day and snorkeled the wreck of *Prinz Eugen.*

August 13: The plane did not come, so the Holmes and Narver representative arranged for team to dive on *Prinz Eugen.* The team conducted a reconnaissance survey of the site, obtaining video footage, photographs, and a sketch. It was discovered that the description of the ship in *Jane's Fighting Ships* was incorrect in that it stated the ship had four screws rather than the three it has. On the basis of this dive, a section on *Prinz Eugen* was included in the results section of this report and specific management recommendations will be made for transmission to the Base Commander.

August 14: Once again Air Marshall Islands (AMI) decided not to fly. Kent Hiner, Holmes & Narver's project manager, radioed an AMI plane en route to Kwajalein from some other point and negotiated a flight to Bikini before they took their scheduled return flight to Majuro in the Marshall Islands. After lunch, a first assessment dive was made on the wreck of *Saratoga* to a maximum depth of 100 feet.

August 15: During the first full day of dive operations at Bikini, the team made an assessment dive on *Saratoga* and commenced taking observations for the site plan and starboard profile of the ship. The starboard side was reconnoitered at 140 feet; the elevator was entered and its immediate area investigated, as was the forward section of the ship, particularly the 5-inch gun mount.

August 16: Dives on *Saratoga* focused on assessments of the island, including the penetration of the flag plot and bridge, a survey of the port side of the ship, and the penetration of the hangar.

August 17: Mapping of the after area of the ship disclosed the first major damage to *Saratoga* from the tests. A reconnaissance of the bottom of the lagoon at the stern and additional penetration of the bridge were completed.

August 18: Additional dives were made on *Saratoga* to continue the mapping of the wreck.

August 19: *Saratoga*'s island was more thoroughly investigated.

August 20: Dives on *Saratoga* began to focus on mapping the starboard side of the ship for the profile drawing.

August 21: Dives completed the preliminary mapping of *Saratoga,* focusing on the forward section, midships area, and island.

August 22: Entire team dived on *Arkansas,* resulting in video and a sketch of the wreck. The dive assessed the more intact port side of the battleship at the 160-foot level and the keel at the 140-foot level.

August 23: A dive was made on *Pilotfish,* using for the first time the experimental AGA-video hookup. Delgado narrated his notes on the dive directly onto a tape at 150 feet, accompanied by Lenihan, while the other team members sketched and photographed the boat. The second dive of the day, with Delgado again in the AGA, visited *Nagato,* exploring the after section of the ship.

August 24: The only dive of the day was made to *Gilliam,* the accidental zeropoint ship for the Able Test bomb's detonation. The team swam the length of the ship, sketching and photographing it. Larry Murphy departed with the majority of the equipment to catch a Military Air Command (MAC) flight to Honolulu in order to assure loading of that equipment for another operation in the Aleutians.

August 25: The team made the last dive of 1989 on *Saratoga,* penetrating the hangar and more extensively documenting the aircraft inside. That afternoon, remaining equipment was packed for departure.

August 26: The team made an early afternoon departure from Bikini, flying via AMI to Kwajalein. From Kwajalein, the team members separated--Lenihan and Nordby to Santa Fe; Livingston and Delgado to Guam.

1990 Field Season

April 25-27: The team travelled from their duty stations in Santa Fe, and Washington, D.C., to Honolulu, and then to Kwajalein.

April 28: Layover in Kwajalein. The team made a dive on *Prinz Eugen* and obtained additional photos and information for a map of the wreck.

April 29: The team boarded the DOE research vessel *G. W. Pierce* and sailed from Kwajalein for Bikini.

April 30: At sea most of the day. Bikini was sighted at 4:00 p.m., and at 5:20 p.m., anchor was dropped off the island. The team was shuttled ashore.

May 1: First dives were made with team members working on the island and in the hangar of *Saratoga.*

May 2: Mapping *Saratoga* continued. Lenihan and Murphy penetrated the hangar to its aft bulkhead, locating additional torpedoes, rockets, and homing torpedoes (depth of 130 feet). Five-inch shells in the handling rooms and the open twin 5-inch/38 mount were explored aft of the stack by Delgado. Afternoon dives focused on the bow; the windlass and emergency radio compartments were penetrated. Delgado and National Geographic Society writer John Eliot dove on a shallow water inshore wreck, which proved to be LCT-1175.

May 3: Documentation of *Saratoga* continued. *Arkansas* was dived on and port casemate penetrated by Lenihan and Murphy at a depth of 170 feet. Wreck of LCM-4 snorkeled and identified near that of LCT-1175 by Delgado.

May 4: Lenihan, Delgado, and Murphy swam under *Nagato* from stern to the aft end of the bridge (depth of 170 feet). Nordby and Livingston continued mapping operations on *Saratoga,* and Lenihan and John Eliot dived on YO-160 in afternoon, videotaping deck machinery.

May 5: Lenihan, Murphy, and Delgado continued documentation of *Nagato,* videotaping and photographing upturned bridge, forward turrets, and stern. Livingston and Nordby continued mapping operations on *Saratoga*

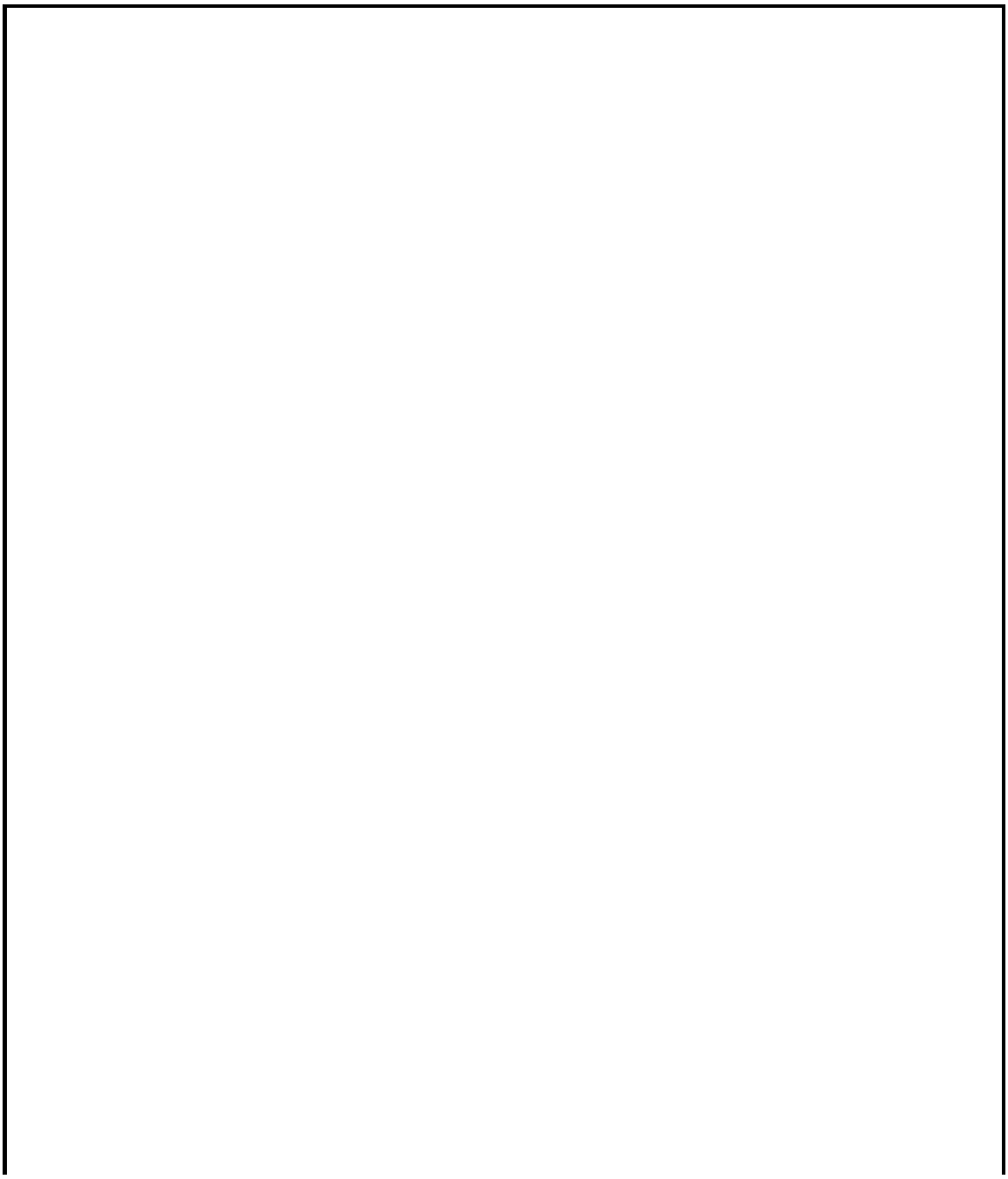
(portside). Entire team worked on *Saratoga* in afternoon.

May 6: Entire team worked on documentation of LCT-1175.

May 7: Lenihan and Murphy worked on *Nagato* bow; Delgado, Livingston, and Nordby worked on port bow of *Saratoga.*

May 8: Entire team conducted "blitz" dive on *Nagato* stern (depth of 170 feet) obtaining sketches, video, and photography. In afternoon, focus shifted back to completion of work on *Saratoga.*

May 9: Murphy conducted training dive for Bikinians, teaching them underwater oxyarc cutting techniques using car battery and oxygen. Lenihan was able to meet briefly with Bikinian elders and Jack Niedenthal (Bikini Liaison) during layover of AMI flight on Enyu. Some of the project results including drawings were reviewed.





The Bikini Council sent a dive team to participate in the documentation of the ships. Here, the team takes measurements to the corner of the blast gauge tower next to *Saratoga*'s elevator. *(NPS, Larry Murphy)*



The system of trilateration used to map the wrecks is being discussed by Edward Maddison, Wilma Riklon, and Larry Nordby. *(NPS, Larry Murphy)*

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National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER TWO: OPERATION CROSSROADS

James P. Delgado

The end of the Pacific War, and hence World War II, was brought about by the surrender of Japan following the dropping of atomic bombs on the cities of Hiroshima and Nagasaki. These were, respectively, the second and third nuclear detonations on the surface of the planet. The first bomb was detonated at Alamagordo, New Mexico, on July 16, 1945, at 5:30 a.m. The second bomb was detonated over Hiroshima on August 6, 1945, at 8:15 a.m. The third bomb was detonated over Nagasaki on August 9, 1945, at 10:58 a.m. The fourth and fifth bombs were detonated during the atomic tests at Bikini Atoll in the Marshall Islands.

The first large-scale atomic weapons effects tests conducted by the United States, the "Able" test detonation of July 1, 1946, at 9:00 a.m. local time at Bikini, and the "Baker" test detonation of July 25, 1946, at approximately 8:35 a.m. local time, were the first two of the three-part "Operation Crossroads" tests. (The third detonation, the "Charlie" test, was cancelled.) Formulated at the war's end and approved by President Harry S Truman on January 10, 1946, Operation Crossroads was not only the first of more than 850 publicly announced atomic weapons tests. It was a major demonstration of the power of the bomb and of the nation that had produced and used it, the United States. The name was selected because the atomic bomb represented a "crossroads"--from conventional to nuclear war.





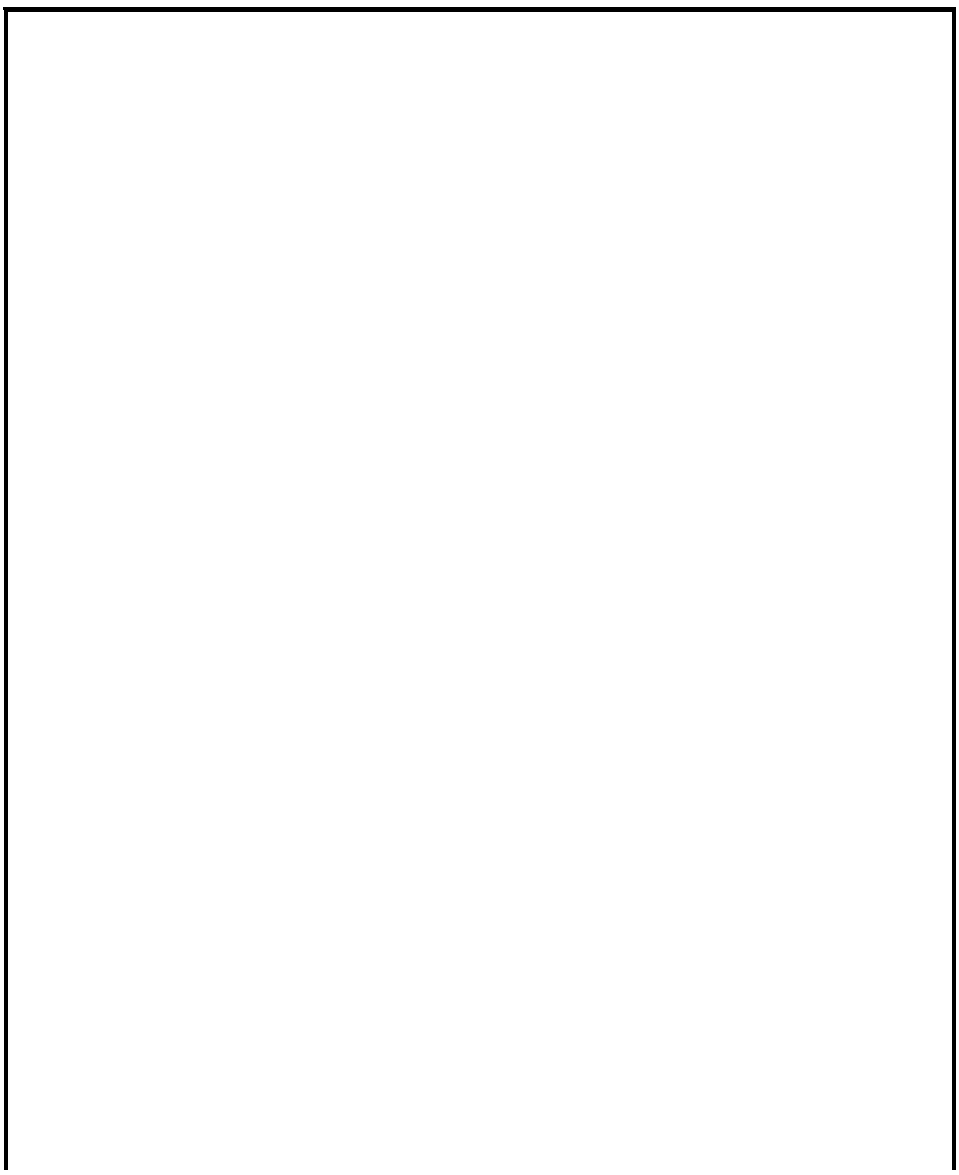
Joint Task Force One press release photo of the target area at Bikini, 1946. *(U.S. Naval Institute)*

The tests involved assembling a fleet of 242 ships, 42,000 men, 156 airplanes, and tens of thousands of tons of equipment, ordnance, and material at Bikini, as well as relocating the 162 residents of the atoll--beginning an odyssey that has earned for these displaced people the sobriquet of "nuclear nomads" of the Pacific. Observers from Congress, from other nations (including the Soviet Union), and representatives of "U.S. press, radio, pictorial services, magazines, etc." made these tests the most public and the most reported of any nuclear weapons tests. [1] The inherent message of nuclear weapons was underscored at Bikini, and has since become increasingly the subject of public debate and concern as the progeny of the Manhattan project multiplied until by 1986, according to one nonofficial estimate, the United States had manufactured 60,000 warheads of 71 types for 116 different weapons systems. [2]

Initially, the development and use of atomic weapons was welcomed and celebrated in the United States because the destruction of two Japanese cities had brought a fierce enemy to his knees through the fear of rapid annihilation. The toll of fighting at Palau, Iwo Jima, and Okinawa was still vividly recalled. Many thousands of American lives would have been lost in a bloody invasion of the Japanese home islands. Consciences were salved when the death toll at Hiroshima and Nagasaki, while terrible, was less than the number of Japanese civilians killed in the B-29 fire-bombing raids on Tokyo, Nagoya, and Kobe. Soon, however, as historian Paul Boyer has noted, a grim realization set in. Moral implications of the use of the atomic bomb troubled some observers. More pragmatically, many realized that the bomb was a world-threatening weapon. The spectre of nuclear armageddon overshadowed the globe, and in the United States, the understanding that the bomb could also someday be used against the United States brought the first chills to the Cold War. General H. H. "Hap" Arnold, head of the U.S. Army Air Forces, was the first to publicly prophesize that World War III would

not last as long as World War II; World War III would be over in hours, with no one left to determine who had won.

Widespread comprehension of the bomb's grim reality was not immediate. It took many years, the detonation of a nuclear bomb by the Soviet Union, and the development of vast arsenals of more potent nuclear weapons with the capacity to kill every living thing on earth several times over, for fear to set in. Yet until then, people accepted the bomb as a deadly and powerful beneficial force. At the very beginning, though, the message was clear. In 1946, a press report noted that while "a large number of scientists are looking forward to the forthcoming explosion...[the] least curious...are the atomic scientists. They take a poor view of the entire operation, maintaining that the explosions at Hiroshima and Nagasaki have perfectly well demonstrated the basic fact that the atomic bomb is too powerful a weapon to leave outside the confines of international control and that Operation Crossroads will simply underline this truth...." [3] The commander of Joint Task Force One which conducted Operation Crossroads was Vice Adm. William Henry Purnell Blandy. Blandy, writing in the foreword to *Bombs at Bikini,* the "official" public report on the tests, noted "the atomic bomb is definitely not 'just another weapon;' its destructive power dwarfs all previous weapons. Observers at Bikini saw the bomb sink great steel warships and, with its penetrating nuclear radiation, reach into ships' interiors to kill test animals. The explosions in air and underwater were very different spectacles, but their end results mean the same: death and destruction on an enormous scale." [4]





Admiral W. H. P. Blandy, commander of Joint Task Force One. *(National Archives)*

Operation Crossroads was interpreted as a defensive measure to the American public. Testing the effect of the atomic bomb on warships and their crews would specifically "improve our Navy." According to *Bombs at Bikini,*

> We want ships which are tough, even when threatened by atomic bombs; we want to keep the ships afloat, propellers turning, guns firing; we want to protect the crews so that, if fighting is necessary, they can fight well today and return home unharmed tomorrow....the unequalled importance of the atomic bomb....shakes the very foundations of military strategy. [5]

However, the concept of the bomb's deployment against ships was as an offensive weapon. Admiral Blandy told the Senate Committee on Atomic Energy on January 24, 1946, "The ultimate results of the tests, so far as the Navy is concerned, will be their translation into terms of United States sea power. Secondary purposes are to afford training for Army Air Forces personnel in attack with the atomic bomb against ships and to determine the effect of

the atomic bomb upon military installations and equipment." [6]

The history of the war, beginning with the surprise attack on the fleet at Pearl Harbor, and a hard four-year fight at a tremendous cost instilled a strong sense of the best defense being offense. The atomic bomb provided the strongest offensive capability available, and nuclear deterrence and the Cold War invocation of the necessity of nuclear capability were first aired for Operation Crossroads:

> The tests stand out clearly as a defensive measure. We are seeking to primarily learn what types of ships, tactical formations and strategic dispositions of our own naval forces will best survive attack by the atomic weapons of other nations, should we ever have to face them. By no stretch of the imagination can such steps of caution and economy be taken as a threat of aggression. If, because of such a false assumption, we failed to carry out these experiments, to learn the lessons which they can teach us, our designers of ships, aircraft and ground equipment, as well as our tacticians, strategists and medical officers would be groping their way along a dark road which might lead to another and worse Pearl Harbor. [7]

In April 1946, Admiral Blandy, reporting that "some of our leading scientists" agreed that "other nations with even a moderate degree of industrialization can manufacture atomic bombs in a few years....our Armed Forces must be kept modern, and one of the first steps in modernizing them is to learn the full capabilities of any new weapon which may be brought against them." [8] Among the more interesting aspects of Operation Crossroads was the inclusion of foreign observers from 11 countries, among them the Soviet Union, a rival for global influence.

THE CONCEPT OF A NAVAL TEST EVOLVES

The news of the atomic bombing of Hiroshima started discussions among naval circles as to the new weapon's effect on ships; this question was posed on the floor of the Senate on August 25, 1945, when Senator Brien McMahon of Connecticut stated:

> In order to test the destructive powers of the atomic bomb against naval vessels, I would like...Japanese naval ships taken to sea and an atomic bomb dropped on them. The resulting explosion should prove to us just how effective the atomic bomb is when used against the giant naval ships. I can think of no better use for these Jap ships. [9]

The idea of using the bomb against ships was not new; "even in 1944, Los Alamos scientists were looking into the possibilities of eventually atomic-bombing Japanese fleet concentrations," specifically the Japanese naval base at Truk Lagoon, but by that late date the Imperial Japanese Navy was already decimated by conventional warfare. [10] American submarines waged a terrible war of attrition: disastrous sea battles and bombing raids sank most Japanese capital ships, leaving a pitiful remnant of the once formidable fleet at war's end.

The destruction of the 48 surviving surface warships of the Imperial Japanese Navy surrendered at war's end was guaranteed regardless of whether or not the atomic bomb was used. [11] The new Japan would be demilitarized and its remaining vessels sunk or scrapped. On August 28, 1945, Fleet Adm. Ernest J. King, Commander in Chief of the U.S. Fleet, recommended that the remaining Japanese vessels be destroyed. Lt. Gen. B. M. Giles, on MacArthur's staff in Tokyo, followed Senator McMahon's lead and proposed on September 14, 1945, that atomic bombs be used to sink the Japanese ships. The proposal was supported

by Maj. Gen. Curtis LeMay, architect of the fire-bombing raids on Japan. Gen. H. H. "Hap" Arnold concurred, and asked the Navy on September 18 that "a number of the Japanese vessels be made available to the Army Air Forces for use in tests involving atomic bombs and other weapons." [12]

This proposal met with a positive response from the Navy. As early as June 1945, the Navy's Bureau of Ships (BuShips) and Bureau of Ordnance (BuOrd) had recommended a "comprehensive program for testing high explosives against merchant and warship hulks, captured enemy vessels, and United States Navy combatant ships about to be stricken from the active list." [13] The Underwater Explosion Program had been approved by the Chief of Naval Operations, but the deployment of the atomic bomb changed the scope of the effort. On August 28, the same day Admiral King recommended destroying the Japanese ships, the Chief of the Bureau of Ships, Vice Adm. E. L. Cochrane, informed the Underwater Explosion Program staff that they "must be prepared to undertake broad-scale experiments with the atomic bomb to clear up its major influence on naval warfare" as their first priority. The Chief of Naval Operations was notified by BuShips and BuOrd that "full-scale testing...both underwater and above water, against ships of various types" using the atomic bomb was imperative. [14] At the same time, the United States Navy, which had built a formidable fleet of more than 1,200 ships during the war, was scaling down.

At the end of August 1945, Secretary of the Navy James Forrestal suggested that the Navy would be reduced to a 400-ship force with 8,000 aircraft, with the remaining ships held in reserve. This situation provided the Navy with a large number of potentially expendable ships for weapons testing. Questioned about the atomic bomb, Forrestal strongly underscored the fact that the bomb would ultimately be put to use at sea, noting that "control of the sea by whatever weapons are necessary is the Navy's mission." The next day, *The New York Times*, reporting on the Navy's opposition to merging the War and Navy Departments, noted that the Navy was probably amenable to joint operations regarding "scientific developments," and prophesized that "it would not at all be surprising" within the next six months for a proposal "to test the effects of the new atomic bomb against warships. There has been speculation...whether the atomic bomb...might cause the bottoms of steel ships to disintegrate and thus sink the entire fleet...some Navy authorities say they would like to see such a test conducted against some of our old battleships, for, if the atomic bomb works this way, they want to know it." [15]

Given the Navy's strong interest in the bomb and its commitment to the Underwater Explosion Program and that program's priority being atomic testing, and with the Army Air Forces' proposal in hand, Admiral King agreed on October 16, 1945, to atomic bombing of the Japanese ships as a coordinated action of the Army and Navy under the control of the Joint Chiefs of Staff, with "a few of our own modern naval vessels...included in the target array" for air and underwater detonations, following the advice and plans of the Underwater Explosion Program staff. [16] On October 24, *The New York Times* reported that the Navy was to test the bomb to assess its effect on ships both dispersed and "massed at anchorage as in Pearl Harbor on Dec. 7, 1941." [17] It was not until December 10, 1945, however, that an official announcement of joint Army-Navy tests of the bomb was made. *The New York Times*, covering the announcement, stated that the details had yet to be worked out, specifically noting that the Army Air Forces "have been working aggressively to get a leading role in the experiment to make sure it would not be an all-Navy affair." [18] While hotly denied, the issue of Army-Navy competition was continually raised throughout the tests; a July 30, 1946, article in *The New York Times* quoted an unnamed Army officer's attacks on the "battleship mentality" of "die-hard" naval officers, noting "in the event of a future war...a Navy as we know it now will be utterly helpless on either side."

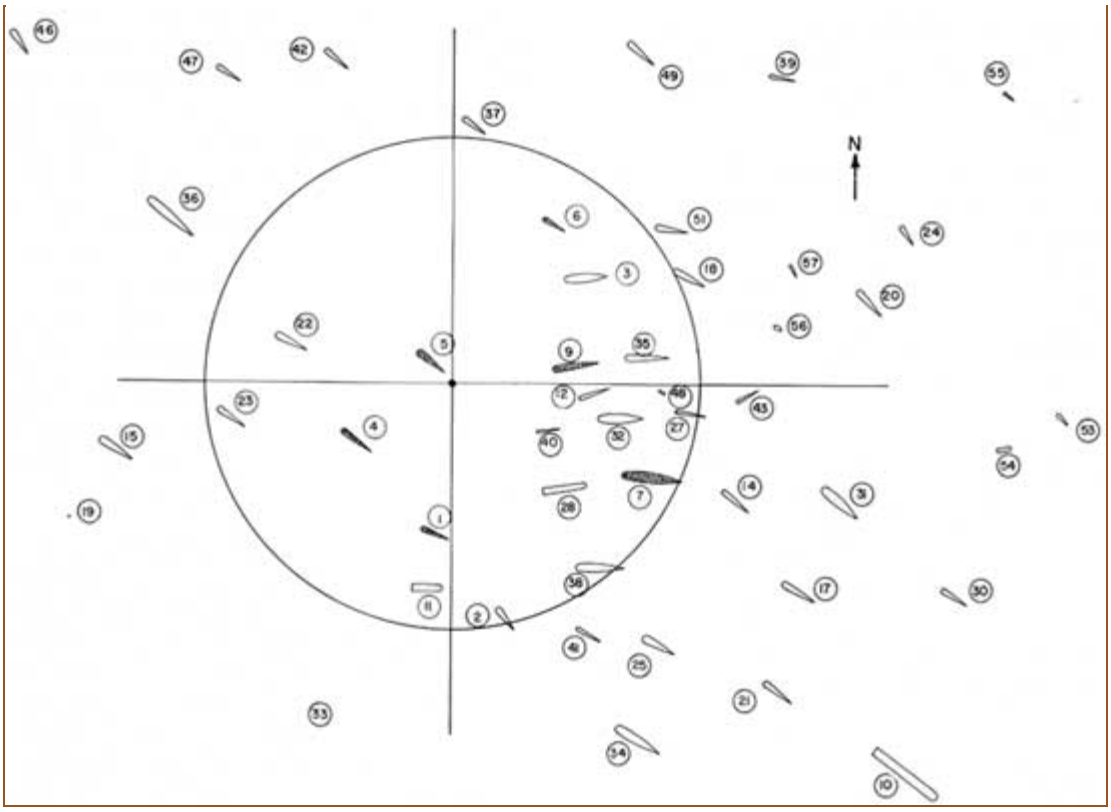
The concept of the tests was appealing for more than technical reasons; while "it is indeed

routine to test each new weapon in all major applications," including against naval targets, "the novelty of the proposed test of the atomic bomb against naval vessels would lie in the unprecedented scale and world-wide importance of the tests." [19] Even more attractive was the overt symbolism of the atomic bomb destroying the surviving capital ships of the Japanese Navy; one early 1946 newspaper account, accompanied by an Associated Press photograph of 24 battered-looking submarines and destroyers, crowed "Trapped Remnants of Jap Fleet Face Destruction in United States Navy Atom-Bomb Tests." Another symbolic and significant aspect of the tests was a demonstration that the United States was now the world leader; it alone possessed the secret of nuclear power, it had a stockpile of atomic bombs capable of being used again, and it was sufficiently wealthy to expend three (the original number of planned detonations) of these bombs and nearly a hundred ships in the most costly and elaborate weapons tests performed on earth up to that time.

Considerable interest in the tests by scientists assessing the weapon's effects was publicly touted. In July 1946, *Life* magazine reported that "a large number of scientists are looking forward to the forthcoming explosion....never having had a chance to test the effects of atomic energy in their own areas of knowledge," because they would have "a laboratory example of what may happen to the world and the animate and inanimate things on it in the event that war comes again." [20] Throughout Operation Crossroads, and well after, "scientific benefits" of the tests were stressed. These benefits were for the military, which learned from Crossroads and the hundreds of tests that followed to make stronger, deadlier nuclear weapons:

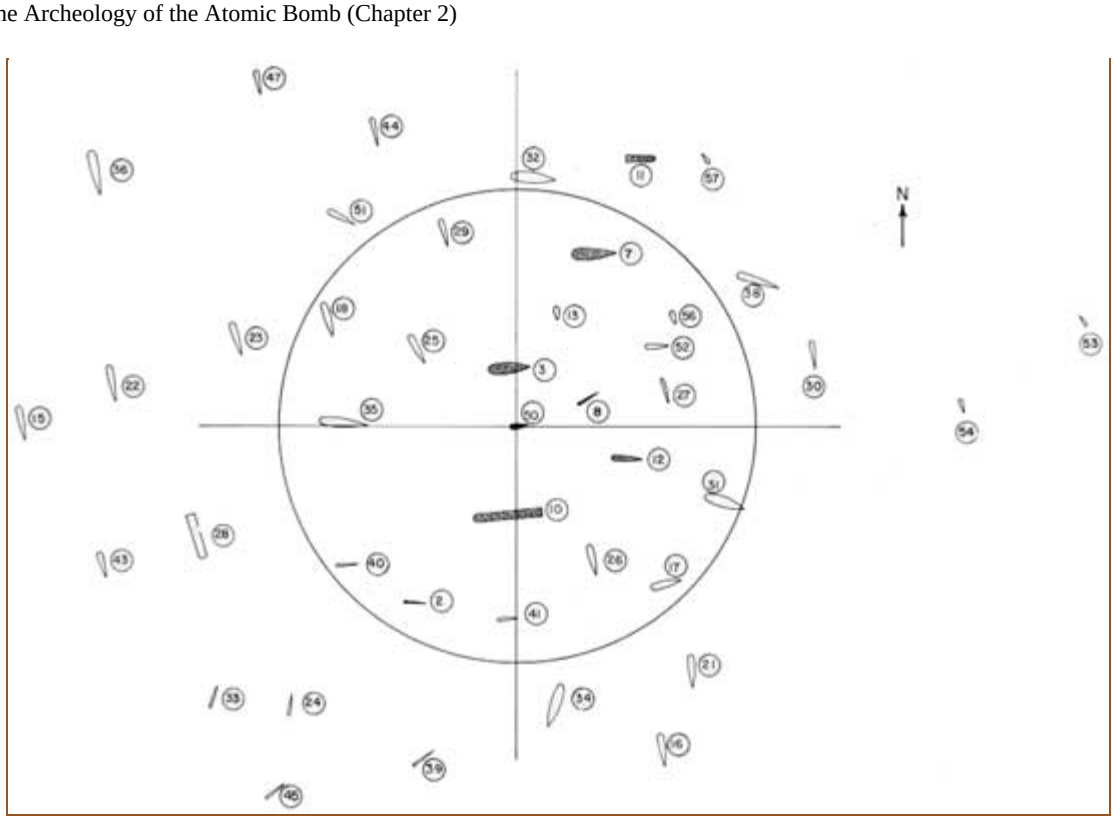
> At Hiroshima and Nagasaki a few photographs and pressure measurements were made of the explosions, but almost nothing of value to physicists was learned. Physicists wanted actual values of the following: pressure, impulse, accelerations, shock-wave velocity, ranges and intensities of gamma radiation, decrease of the gamma radiation during the first few hours. And medical men, arriving at the scene late, found it difficult to tell what the early symptoms of the injured persons had been, and whether the injuries resulted primarily from flash burn, gamma radiation, or from secondary factors such as fires, and floods, and lack of food, over-exertion, and lack of medical attention. [21]





(1) DD *Anderson*
(2) SS *Apogon*
(3) BB *Arkansas*
(4) APA *Carlisle*
(5) APA *Gilliam*
(6) DD *Lamson*
(7) BB *Nagato*
(8) SS *Pilotfish*
(9) CL *Sakawa*
(10) CV *Saratoga*
(11) ARDC-13
(12) YO-160
(13) LCT-1114
(14) APA *Banner*
(15) APA *Barrow*
(16) APA *Bracken*
(17) APA *Briscoe*
(18) APA *Brule*
(19) APA *Butte*
(20) APA *Carteret*
(21) APA *Catron*
(22) APA *Crittenden*
(23) APA *Dawson*
(24) SS *Dentuda*
(25) APA *Fallon*
(26) APA *Gasconade*
(27) DD *Holmes*
(28) CVL *Independence*
(29) DD *Mayrant*
(30) DD *Mustin*

The Able Target Array, showing the actual point of detonation. Shaded vessels sank as a result of the blast. *(click on image for a PDF version)*



(31) BB *New York*
(32) BB *Nevada*
(33) SS *Parche*
(34) BB *Pennsylvania*
(35) CA *Pensacola*
(36) IX *Prinz Eugen*
(37) DD *Rhind*
(38) CA *Salt Lake City*
(39) SS *Searaven*
(40) SS *Skate*
(41) SS *Skipjack*
(42) DD *Stack*
(43) DD *Talbot*
(44) DD *Trippe*
(45) SS *Tuna*
(46) DD *Wainwright*
(47) DD *Wilson*
(48) LCM-1
(49) LST-52
(50) LSM-60
(51) YOG-83
(52) LST-133
(53) LCT-327
(54) LCT-332
(55) LCT-674
(56) LCT-816
(57) LCT-818

The Baker Target Array, showing the actual point of detonation. Shaded vessels sank as a result of the blast. Both illustrations were redrawn by Robbyn Jackson of the NPS Historic American Engineering Record from JTF-1 sketches. *(click on image for a PDF version)*

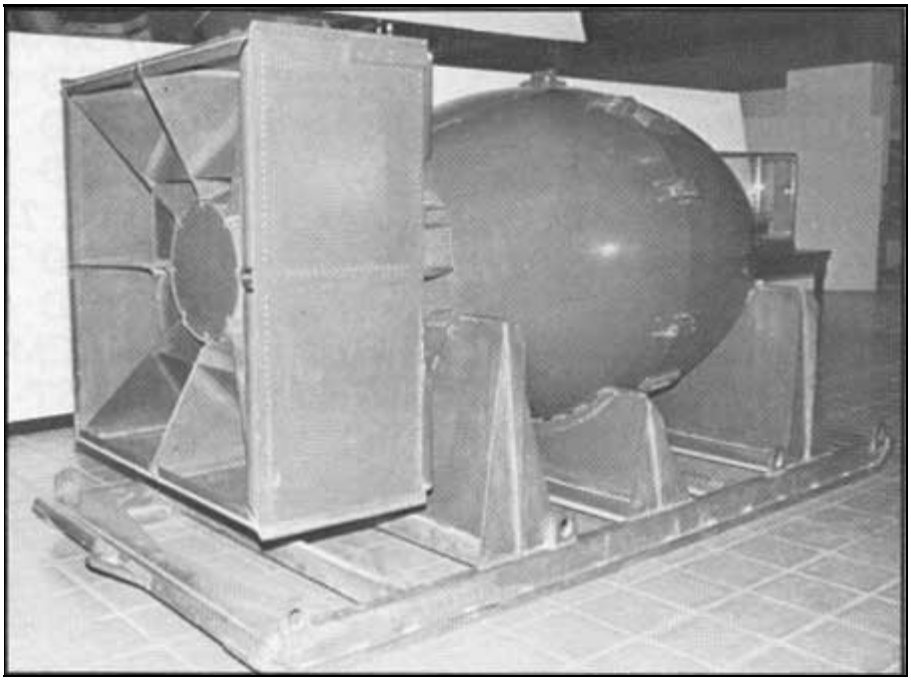
The Trinity detonation at the Alamagordo Air Base Range (now White Sands Missile Range) in July 1945 was a weapons proof shot; Hiroshima and Nagasaki were combat uses that had to be scrupulously analyzed after the fact for effect determinations. Operation Crossroads was of particular importance to the military; it was an opportunity for weapons scientists to assess, under a controlled environment, the effects of the bomb.

The bombs for Crossroads were delivered by the Los Alamos scientists who had also provided the bombs used for Trinity and against Japan. According to one report, the Crossroads bombs were drawn from the U.S. stockpile of nine implosion-type core devices; these weapons were nearly identical to the Mk III "Fat Man" bomb dropped on Nagasaki. [22] These weapons reportedly yielded a 23-kiloton effect, equal to 23,000 tons of TNT. ("Official" yield credited at the time was 20 kilotons.) The bombs "contained a proximity-fuze system of extremely great reliability, sensitivity, and absolute accuracy. The detonation system was set for an altitude of 515 feet." [23]

Initially three tests were planned in order to assess the effects of pressure, impulse, shock-

wave velocity, optical radiation, and nuclear radiation particular to the bomb. The air burst was reportedly to duplicate the conditions of the drop on Hiroshima, this time over water. The second shallow underwater blast was to simulate an attack on a fleet at anchor. The third test (cancelled) was to take place in the lee of Oruk Island, off the atoll, in 1,000 to 2,000 feet of water, with a small number of vessels moored above the blast solely to test the underwater effect of the bomb.

A variety of preparations were made to handle logistics, relocation of the Bikinians, and the various scientific studies and tests that were performed at the atoll. The 242 vessels involved in Operation Crossroads were the subject of the most preparation: organized in three groups--target ships (combatant), target ships (auxiliaries), and support ships. These vessels were placed "in the best possible material condition" at Pearl Harbor, Bremerton, Terminal Island, Hunter's Point, Philadelphia, and at Bikini. [24]



A Mark III "Fat Man" bomb casing. *(NPS, Candace Clifford)*

PREPARING FOR THE TESTS

Preparations for the tests involved surveys of structural and watertight integrity, installation of test equipment, stripping of armament and other items not required as test equipment, the removal of "certain items of historical interest or of a critical nature" from each ship--usually bells, nameplates, commemorative plaques, ship's silver sets--and their transfer to "the Curator of the Navy Department" in Washington, D.C. [25] The target ships were then loaded "with specified amounts of ammunition, fuel oil, gasoline, water....Ships were loaded as closely as possible to the battle or operating displacement of the ships. Varying percentages of the wartime allowance of ammunition and of the normal capacity of fuel oil and gasoline were carried in the ships' magazines and bunker tanks. All gasoline drums, airplanes loaded with gasoline, and similar items were placed in pans with coamings approximately 18 inches high to prevent dispersal of the gasoline." [26] In some cases emergency repairs were made to battle-damaged ships for the tests. USS *Pennsylvania* (BB-38), for example, had a cofferdam patch on the hull where a torpedo had holed the ship in August 1945. This patch was reinforced and tightened, and a special watertight box was built around a steam steering engine shaft which, if flooded, would be damaged if the shaft

bearings were immersed in salt water. [27] Other preparations included the establishment of vertical and horizontal reference lines for list and twist determination, installation of deck compression gauges, installation of special boarding ladders on the shell plating from waterline to deck edge, and painting of frame numbers on the hull and decks. A full photographic record was made of all "special installations." [28]

Factors involved in selecting the ships ranged from specific types and methods of construction to specific materials. In its enabling directive, Joint Task Force One was instructed to include not only captured enemy vessels in the target array but to also test vessels "representative of modern U.S. naval and merchant types...." However, "it was not feasible to include vessels of all U.S. naval types--especially the most modern types." A range of vessels were selected to include welded and riveted construction and the evolution of ship compartmentalization; "although the older vessels have extensive subdivision, recent ships have more complete transverse water-tightness to high-level decks and incorporate principles of longitudinal framing." [29] Therefore, the final target array included for the most part vessels that were "over-age or of obsolete design--which would otherwise have been decommissioned and sold for scrap. However, a modern aircraft carrier and several modern heavy-hulled submarines were included also." [30] Five battleships were selected, one being the Japanese *Nagato,* which was presumably included solely to sink it. The U.S. battleships, all of a type made obsolete by the newer classes, were included because "although not of most modern design [they] possessed great resistance to battle damage" because of heavy hulls, torpedo-protection systems of multiple longitudinal bulkheads, heavy armor, double or triple bottoms, and some 600 watertight compartments. [31]

Four cruisers--two U.S., one German *(Prinz Eugen),* and one Japanese *(Sakawa)*--were included. The American-built ships were "excellent examples of prewar riveted construction, with structure somewhat heavier than any cruisers up to the latest 8-in. cruisers built during the war." *Sakawa* and *Prinz Eugen* were selected because "they represented the latest in cruiser design of Germany and Japan." [32] *Sakawa* was intended to sink, as was *Nagato;* both vessels were moored within a 1,000-yard perimeter of the designated zeropoint for both tests, while *Prinz Eugen* was moored outside of the immediate blast area. *Saratoga* and *Independence,* the two carriers, were selected to include an old, pre-war carrier and a modern, but less than satisfactory light carrier. (The *Independence* class, a wartime necessity, were light, hastily constructed ships.) *Saratoga*'s selection was justified as follows:

> Subdivision of the *Saratoga* was unusually complete; she had approximately 1000 watertight compartments. There were 22 main transverse bulkheads and two continuous longitudinal bulkheads extended 70 percent of the length. Two watertight platforms extended fore and aft of the machinery spaces. The underwater protection was very similar in arrangement to that of modern battleships and large carriers. An inner bottom above the bottom shell was fitted between the innermost torpedo bulkheads for about 80 percent of the length. [33]

The 12 target destroyers selected represented three immediate prewar types--the *Mahan, Gridley,* and *Sims* classes. The attack transports were "typical of modern merchant-ship practice, with good transverse subdivision.... These vessels were designed and built during the war and were essentially of all-welded construction, with very few riveted joints." [34] Target landing craft were included "more for the purpose of determining the effects of wave action than for determining direct effects of pressure on the hulls." [35]

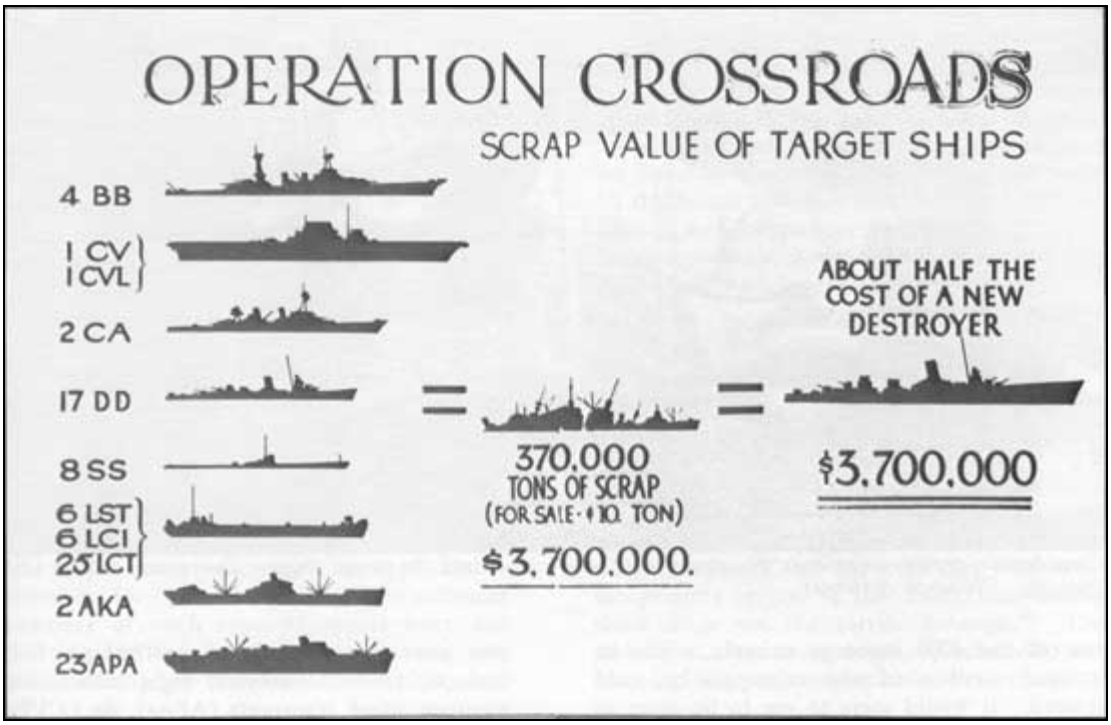
Three reinforced concrete vessels were used--ARDC-13, YO-160, and YOG-83. These three vessels were selected for dispersal within the target array from a group of craft scheduled for disposal to satisfy the Navy's Bureau of Yards and Docks' interest "in the damage to reinforced concrete structures at Hiroshima and Nagasaki....The lack of suitable land areas at

Bikini made construction of similar installations impractical, even if there had been time." [36] The eight target submarines were "selected from those scheduled for the reserve fleets or for disposal by scrapping. They represented the two major types [the *Gato* and *Balao* classes], light and heavy hull construction, built in recent years by [among others] the three submarine building yards of the Electric Boat Company and the naval shipyards at Portsmouth and Mare Island." [37] Some vessels were individually selected because of age, previous battle damage, and, occasionally, to replace ships selected but not available. LCT-705 and LCT-1013 were placed in the Able target array to serve as "catchers to collect samples of any fission products which might fall out of the atomic cloud." [38] The selection of 35 "major" vessels--from the battleships and carriers to the submarines--was publicly announced on January 24, 1946, at the first Crossroads press conference in Washington. [39]

Opposition to the tests surfaced for a variety of reasons, among them the destruction of the ships. One objection was to the cost of the various target ships: in March 1946, Admiral Blandy testified before the Senate Naval Affairs Committee that the construction costs for the target ships totaled $450 million, but noted that all the ships were obsolescent except for five submarines and the light carrier *Independence*. [40] Senator Scott Lucas of Illinois criticized the tests as a "grandiose display of atomic destruction" and argued that the target ships, if no longer useful for naval purposes, could be converted "into temporary homes for veterans." [41] One citizen, writing to protest the tests, was angry not over the loss of ships, but of valuable steel, and noted that airplane engineers tested models in wind tunnels and thus "do not need to destroy full size planes to see just what the planes will do under certain conditions....Scientists do not need to kill elephants to determine the reaction of chemicals and drugs. They use small mice." [42]

In response to criticism over the cost, Blandy responded on April 16 that the total costs of the tests would probably not exceed the total cost of "one large new ship," since the obsolete targets had been declared surplus and even if sunk "the cost for at least 90 percent would be only their scrap value," which the admiral estimated at $100 million. [43] In response to letters protesting the use of the target ships, Joint Task Force One's form letter response was that the ships were either obsolescent or "in excess of the number required to keep our post-war Navy at its proper strength." The letter emphasized that not all ships would be destroyed; even "those badly damaged...may be towed back to the United States and sold as scrap. Still others may be placed back into service...." [44] One letter writer wanted to place target ships in personal service: 11-year-old Max Ladewasser "and gang" wanted some of the ships presented to the children of the country; specifically "I would like to have a real P.T. boat which we could run on Lake Michigan." [45]

Some protests focused on the selection of individual ships as targets, specifically the battleships *New York* and *Pennsylvania.* When *New York* sailed from its namesake city in January 1946 for Bikini, the loss of the ship was lamented as veterans' groups and the state chamber of commerce lobbied to save it. "New York may lose forever its most useful and fitting war memorial unless something is done to prevent destruction of our century's Old Ironsides as an atom bomb target. This ship should be permanently on display in New York..." An unnamed officer stated that "I don't see why she couldn't have been given to the State, just as her sister ship, the Texas, was given to that State." [46] The response from Joint Task Force One was that while "it is regretted that such ships as the *New York* cannot be spared and exhibited as memorials, it is felt that this gallant battleship could perform no more valuable or distinguished service for our post-war Navy than it will render in the historic tests...." [47] It was also noted that "many other ships of the target group have equally glorious battle records and are similarly distinguished historically in their respective classes. It is sincerely regretted that such ships which have served with distinction in our Navy for so many years cannot be spared...." [48]



Joint Task Force One press release chart depicting "scrap" costs of Operation Crossroads. *(U.S. Naval Institute)*

The criticism by some nuclear scientists that the tests would add little or nothing to the understanding of the bomb was in part based on their assertion that ships, as mechanically stronger structures than buildings, would remain afloat and undamaged, lessening fear of the bomb by people who expected the total destruction of the fleet prophesized by the press, thus creating a "feeling of false security." Two explosive weapons had already been detonated--Able and Baker's bombs were identical to the Nagasaki weapon. The "greatest weakness" of the tests, however, was that as of early February 1946,

> no provisions are indicated for studying the effects of the bomb's radiation on ships' crews. What might happen in a real case, is that a large ship, about a mile away from the explosion, would escape sinking, but the crew would be killed by the deadly burst of radiations from the bomb, and only a ghost ship would remain, floating unattended on the vast waters of the ocean. If not killed outright, the crew may well suffer such strong radiation damage, as to become critically ill a few days later. [49]

This prescient comment's various implications were in part answered by the decision to place animals on the target ships to study the bomb's effects on them. Protests against the use of the animals were numerous; among the letters received were a few that grimly reflected on the use of enemy vessels as targets, with the addition of "Germans and Japanese who have been condemned to death by proper courts of jurisdiction." [50] One writer suggested that "in lieu of the 4000 innocent animals...a like or greater number of war criminals be used instead. It would seem to me to be more in keeping with the principles of justice and humanity to punish those responsible for the agonies the world was plunged into through their actions rather than to cause suffering to creatures whose only sin is existence at a lower biological level than our own." [51]



Considerable protest arose over the exposure Of animals aboard the target ships. Two goats aboard USS *Niagara. (National Archives)*

The target vessels were assembled at Bikini between May and June, 1946. They were moored at numbered berths, carefully arranged around the projected surface or ground zeropoint so that graduated scales of damage would be inflicted on the ships. A large number of vessels were required "in order to gain the greatest amount of useful information...and...determine the complete relationship between ship damage and distance from the explosion." The necessity of a large target fleet for Able test "was especially clear after it had been decided to drop the bomb from an airplane...it was clear that there would be uncertainty as to the point of detonation." [52] Ninety-five naval vessels, representing the products of U.S., Japanese, and German shipyards, were selected as the target fleet for Operation Crossroads. This fleet consisted of two aircraft carriers, five battleships, four cruisers, twelve destroyers, eight submarines, nineteen attack transports (APAs), six LCVPs, five LSTs, one LSM, sixteen LCTs, seven LCIs, six LCMs, and three auxiliary barges, namely one YO, one YOG, and one ARDC. [53] It is important to note that 88 vessels, not the full number of target ships, were deployed in the Able target array. The number of U.S. combatant vessels used as targets was limited to 33 ships by Congressional legislation (H. Res. 307) authorizing the tests; "considerable public feeling developed to the effect that valuable vessels were going to be destroyed; Congress reacted by putting an upper limit to the number of U.S. combatant ships." [54] Though the landing craft and auxiliaries were naval vessels, they were not commissioned and hence were not counted; nor were the attack transports, which arguably were also not "combatant" ships, making 28 American-built "combatant ships" counting only the carriers, cruisers, battleships, destroyers, and submarines. Disappointment not withstanding, the press proudly reported at Bikini that the target fleet formed the world's fifth or sixth largest navy, with only the navies of the U.S., Great Britain, the Soviet Union, France, "and perhaps Sweden" surpassing it. [55]



Nevada, the target ship for Able. *(Los Alamos National Laboratory)*

THE ABLE TEST

The target arrays were selected "to provide the best instrumentation possible, rather than be placed in a tactical formation. This policy was approved for both tests." [56] The vessels were closely grouped together near the center of the array "because of the...decrease of pressure with increase in distance from the zeropoint." [57] The test array for the Able test included 24 vessels within the 1,000-yard radius of *Nevada*, the designated zeropoint, while 21 vessels were placed within the 1,000-yard radius of the point of detonation for the Baker test.

Additionally, the Joint Chiefs of Staff required the target arrays to graduate the level of damage; "this involved dispersing the target fleet so that individual ships of each major type would be placed in positions ranging from close...for major damage...to appreciable distances...for light damage." [58] Since sufficient numbers of each type of vessel were not available, the best layout, geometric lines, bow and stern on, and broadside to the blast, was adhered to only for those ships that were present in large quantities--landing craft, destroyers, and attack transports. These ships were berthed at regular intervals along a single, curved (to keep one ship from partially shielding another) line extending radially from the designated zeropoint, which was 5,400 yards off the beach of Bikini Island. The battleship *Nevada* was selected as the zeropoint "target" for Able because it was "the most rugged ship available." [59]

The target arrays were different for each test. The Able target array consisted of 78 vessels; the Baker array consisted of 75. After the several vessels sank in the Able test, some of the ships in the "fringes" of the test area were shifted closer to the zeropoint to replace the lost vessels. Additionally, other vessels were placed farther out in the Able array to spare them from major damage since they were to be the primary targets in the Baker test; among these ships was the carrier *Saratoga*. [60] The Able test detonation, originally scheduled for May 15, was postponed six weeks to allow, according to some opinions, for Congressional observers to be on the scene. The Able test bomb, nicknamed "Gilda" for the recent Rita Hayworth motion picture of that name, and stencilled with the likeness of Miss Hayworth,

was dropped from the B-29, "Dave's Dream," on the morning of July 1, 1946. The bomb missed the designated zeropoint, *Nevada*, probably because of, according to some experts, poor aerodynamics caused by its high-drag tail fin structure, detonating instead 2,130 feet from the target and 518 feet directly above and 50 yards off the bow of the attack transport *Gilliam.* [61]

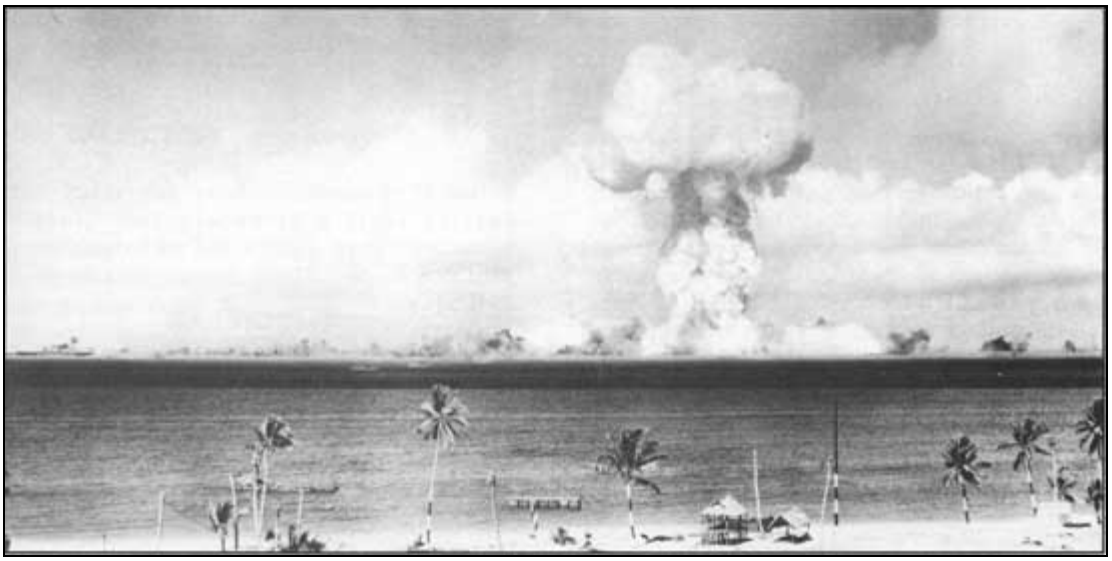


Journalists aboard LCT-52 inspect USS *Independence* after Able. *(National Archives)*

The Able burst sank five vessels: the attack transports *Gilliam* and *Carlisle*, closest to the detonation, sank almost immediately. Two nearby destroyers, *Anderson* and *Lamson*, were also severely damaged and sank within hours, followed by the Japanese light cruiser *Sakawa*, which sank on July 2. Other vessels were severely damaged, the most dramatic damage occurring to the light carrier *Independence* and the submarine *Skate*, both of which were for all intents and purposes wrecked. Six ships were immobilized, and 23 small fires were started on various ships. The badly damaged ships were all within a 1000-yard radius of the zeropoint along with *Hughes* (DD-410), which was among the more damaged destroyers and later required beaching to avoid its sinking, the battleships *Arkansas* and *Nagato*, ARDC-13, and YO-160, all badly burnt and battered. The fears of the physicists opposed to the tests--that contrary to expectations the results would be less than cataclysmic, thus creating a false sense of security--were realized. *The New York Times'* account of Able noted that while the bomb had exploded with a flash "ten times brighter than the sun" over the target ships, "only two were sunk, one was capsized, and eighteen were damaged." [62] The foreign observers were unimpressed, reported the press; the Russian observers shrugged their shoulders and the Brazilian observer said he felt "so so" about the blast. [63] Of the 114 press representatives at Bikini, only 75 stayed for the Baker test.



Able's mushroom cloud towers over Bikini Atoll. *(National Archives)*



Able, from Bikini Island. USS *Saratoga*'s deck burst into flame at the far left. *(National Archives)*



LSM-60 suspended the bomb detonated during Baker. *(U.S. Naval Institute)*

Following the Able detonation, Navy teams moved in to fight fires, reboard the ships, and tow sinking vessels to Enyu for beaching. As this work progressed, diving commenced on the sunken ships for "a full assessment of the damage done by the air blast." [64] The first dives were made on July 7, when *Gilliam* was dived on, followed by *Carlisle*, *Anderson*, and *Lamson.* Inspection of the ships, recovery of test gauges (particularly from *Gilliam*, which was the highest priority for instrumentation recovery because the ship was the accidental zeropoint for the blast), and underwater photography continued until July 14, when attention turned to the preparations for the Baker test. [65] Expectations for greater damage during the Baker test were high; Secretary of the Navy James Forrestal, touring the target ships after Able, when asked why the first detonation had not sunk the entire fleet, remarked that "heavily built and heavily armored ships are difficult to sink unless they sustain underwater damage." [66] News reports and military and public interest focused on blast effect. The effect of radiation was for the most part ignored; a short news item filed by the Associated Press on July 15 noted that the test animals were "dying like flies.... Animals that appear healthy and have a normal blood count one day, 'drop off the next day,' an officer said...." [67] This scarcely noted account was a harbinger of the future.



Baker blasts out of the lagoon a second after detonation. *Saratoga* is visible in the white blast slick as the column forms nearby. *(U.S. Naval Historical Center)*

THE BAKER TEST

The Baker test bomb, nicknamed "Helen of Bikini," was placed in a steel caisson manufactured by Los Alamos from the conning tower of USS *Salmon* (SS-182) which had been scrapped in April 1946. With "Made in New Mexico" chalked on its side by Carl Hatch, U.S. Senator from New Mexico and an observer at the tests, the caisson was suspended 90 feet below the well in the steel landing ship LSM-60. [68] The bomb was detonated on the morning of July 25, 1946. The blast displaced 2.2 million cubic yards and created a 25-foot deep crater with a maximum diameter of 1,100 yards and a minimum diameter of 600 yards; the segment of the crater deeper than 20 feet covered an area 250 to 700 yards in diameter. It was estimated that about 500,000 cubic yards of material fell back into the crater, with the remainder dispersed throughout the lagoon. "A layer of sand and mud several feet thick was deposited on the bottom..." and a diver working on the port side of *Arkansas* after the blast reportedly sank into soft, pulverized coral and mud up to his armpits. [69] The Baker blast--or the two million tons of displaced water from the cloud that fell back into the lagoon--sank an additional nine vessels, some almost immediately. LSM-60 was destroyed; except for a few fragments of the ship that fell on other vessels, no trace of the landing ship was ever found. The bomb's detonation point was within 500 yards of the location of the sunken *Lamson* and *Sakawa.* The failure to locate these vessels during subsequent dive surveys of the lagoon indicates the bomb, moored at a depth of 90 feet in a 180-foot deep lagoon, probably did considerable damage, or possibly completely destroyed them, depending on each wreck's exact location.

Arkansas, the submarines *Apogon*, *Pilotfish,* and *Skipjack,* and the auxiliaries YO-160 and ARDC-13 sank almost immediately. The badly damaged carrier *Saratoga,* listing but too radioactive to be boarded by salvage teams, sank within hours, followed by the Japanese battleship *Nagato,* and LCT-1114. Within the next few days, five other landing craft that were damaged in the Baker test were scuttled in Bikini lagoon; another was taken outside of

the atoll and sunk. The destroyer *Hughes* and the attack transport *Fallon,* badly damaged and sinking, were taken in tow and beached. The detonation effect of Baker was greater than Able; reports and interest were rekindled, although total destruction by the bomb had once more been averted. One reporter, William L. Laurence, the "dean" of atomic reporters who had witnessed the detonation of the Trinity test bomb, the Nagasaki bomb drop, and the two Bikini blasts, described a new public attitude as a result of Operation Crossroads. Returning to the United States, Laurence found that while "before Bikini the world stood in awe of this new cosmic force...since Bikini this feeling...has largely evaporated and has been supplanted by a sense of relief unrelated to the grim reality of the situation." Laurence felt this was because of the desire of the average citizen "to grasp the flimsiest means that would enable him to regain his peace of mind. He had expected one bomb to sink the entire Bikini fleet, kill all the animals...make a hole in the bottom of the ocean and create tidal waves. He had even been told that everyone participating in the test would die. Since none of these happened, he is only too eager to conclude that the atomic bomb is, after all, just another weapon." [70]

Laurence himself, as well as nearly everyone else involved in the tests, failed to realize or report the insidious effect of the bomb. Far deadlier than the actual blast, in that time of "limited yield" nuclear weapons, was the lasting effect of radiation, confirming once again the fears and prophecies of the nuclear scientists that even seemingly "undamaged" vessels could and would suffer from radioactive contamination. Decontamination by scrubbing the ships "clean" was only partially successful. The effort to decontaminate the target battleship *New York* was a case in point:

> The main deck forward had not been touched as yet....I made a careful survey of the deck, finding the intensity to vary a great deal in a matter of feet. One gets the impression that fission products have become most fixed in the tarry caulking of the planking and in rusty spots in the metal plates. When the survey was complete the Chief turned his booted, sweating, profane and laughing crew loose with brushes, water, and a barrel of lye. Yet when the hydraulics were done and the deck rinsed clean again, another survey showed the invisible emanations to be present.... The portly Chief stood watching the dial of my Geiger counter, completely bewildered. The deck was clean, anybody could see that, clean enough for the Admiral himself to eat his breakfast off of. So what was all this goddam radioactivity? [71]

While no extensive deposit of long-life radioactive materials were found on the target ships after the Able test, the Baker test detonation generated more radiation; even the salt in the water, for example, was transformed into a short-lived radioactive material. However, plutonium and other long-lived fission products that emitted beta and gamma rays were the major problem. The reboarding of ships after Able was undertaken after a few hours in some cases. After Baker, only five vessels at the extreme ends of two vessel strings could be boarded. Access to the rest of the target array was denied. By July 26 and 27, crews were able to beach *Hughes* and *Fallon,* which were sinking, "but both vessels were radioactive to the extent that taking them in tow...required fast work. The forecastle of *Hughes,* for example, had a tolerance time of about eight minutes." [72] By July 27 and 28, surveys of all remaining target vessels were made from distances of 50 to 100 feet.

DECONTAMINATION EFFORTS

Initial efforts to decontaminate the ships were hampered by the fact that no plans had been prepared for organized decontamination; "the nature and extent of the contamination of the targets was completely unexpected." [73] The first efforts, with the beached *Hughes,* employed Navy fireboats to wash down the exteriors of the ships because "water might take

up some of the radioactive materials in solution." Washing down reduced the radioactivity some fifty percent on *Hughes,* bringing the exposure Roentgens rates on it down to 9.6 R/day on the forecastle and 36 R/day at the stern! Subsequent washings had no measurable effect. Foamite, a water-mixed firefighting foam, was applied and washed off; two washings on *Hughes* reduced the radiation to levels varying between 2.0 to 8.5 R/day. [74]

Radioactive material adhered to the ships' wooden decks, paint, tar, canvas, rust, and grease; while some of it could be washed off, the only effective means of removal was sandblasting the ships to bare metal, stripping off every piece of planking, and bathing brass and copper with nitric acid. Washing, as the experience with *New York* demonstrated, did not significantly reduce radiation levels, particularly with crews limited to short periods of exposure. Only complete removal of the contaminated surface area reduced the radiation. The Navy discovered, too, that "painting over the surface produced no reduction in [beta gamma] activity...." [75] The problem of decontamination was serious; the Navy required a reduction of radiation intensity to allow reboarding for instrument recovery and inspection for periods of at least two hours. At the same time, it was hoped that in two-hour shifts crew members could "apply detailed scrubbing, abrasive, and paint removal action as necessary to reduce the radioactivity sufficiently to permit continuous habitation of the ships." [76] "Lightly" contaminated ships--*Conyngham, Wainwright, Carteret,* and *Salt Lake City*--were the first vessels subjected to "detailed decontamination" on July 30.



A Navy tug sprays down USS *New York* after Baker to decontaminate the battleship. *(U.S. Naval Institute)*

By August 5, several ships were being pumped out and "secondary decontamination" of others followed. On August 24, inspection efforts commenced on several target ships, including dives made on *Saratoga, Arkansas,* and *Pilotfish* that continued until August 30. The submarine *Skipjack* was successfully raised by divers on September 2, and some instruments were recovered from the sunken ships, but work time was limited by radiation hazards. On August 10, orders were issued to cease decontamination efforts at Bikini and prepare the target ships for towing to Kwajalein. The decision was reached when it was discovered that decontamination generally was not working and was extremely hazardous; the

final straw was "the discovery of alpha emitters from samples inside *Prinz Eugen"* which were not detectable with the monitoring instruments in use at Bikini. Further investigation showed "probable widespread presence of the alpha emitters... even in spaces not obviously contaminated. Since no alpha detectors for general field use were available and the alpha emitters are one of the most poisonous chemicals known, their presence was considered a serious and indeterminate menace...." [77] The priority of work shifted "toward recovery of instruments and clearance of those ships designated for use in Test Charlie." [78] This ten-vessel test (five submarines and five capital ships) at the southwestern end of the atoll and seaward of Oruk Island, scheduled for March 1947, was later cancelled by the President.



"The chief turned his booted, sweating, profane, and laughing crew loose with brushes, water, and a barrel of lye." Decontamination efforts aboard *Prinz Eugen. (National Archives)*

The "severe" contamination problem was kept as quiet as possible; according to an August 10 memorandum from the Manhattan Engineer District of the Army Corps of Engineers observer, Col. A. W. Betts, to his boss, Brig. Gen. Kenneth D. Nichols, "the classification of this memo can only be explained by the fact that the Navy considers this contamination business the toughest part of Test Baker. They had no idea it would be such a problem and they are breaking their necks out here to find some solution." [79] Gross decontamination efforts continued that enabled the Navy to complete the removal of test instruments and records, technical inspections, and salvage operations; however, the report on radiological decontamination concluded that these efforts, "although successful to a certain extent in the limited application they received, revealed conclusively that removal of radioactive contamination of the type encountered in the target vessels in Test Baker cannot be accomplished satisfactorily..." [80] On August 25, 1946, the Navy's Director of Ship Material, in charge of the inspections, "felt that all significant information had been recorded and reported that the technical inspection phase at Bikini was complete." That day he and his staff departed for Kwajalein "to establish facilities there for continued examination and radiological re-checks of the target ships." [81] Some of the vessels had departed as early as

August 19, and now the other ships followed; by August 29, only 19 target vessels--the destroyer *Mustin,* YOG-83, and 16 landing craft, were left at Bikini, along with 18 salvage vessels.

THE LEGACY OF CROSSROADS

Thirteen target ships were sent to Pearl Harbor or to the West Coast "for further study of damage and for development of radiological decontamination and safety techniques by the Navy....it is the policy of the Navy to carry out an aggressive active program of radiological and atomic defense research to apply the lessons of Crossroads." [82] The study of the ships led to certain modifications in the construction of new naval vessels, though after World War II the United States built few large vessels. Rounding of ship surfaces and wash-down systems to spray a vessel subjected to fallout and facilitate the rinsing off of the ship were the only Crossroads-induced changes for passive defense against nuclear weapons. The primary naval modifications after Crossroads were measures to take the bomb to sea as a weapon, leading to nuclear-capable carriers, guided missile cruisers, and submarines. Additionally, there was a demand for new designs of nuclear weapons suitable for carrying in these vessels. In an atmosphere of no adequate defense against nuclear deployment, the Navy, like the rest of the military, embraced nuclear deterrence through the adoption of and subsequent escalation of use of nuclear weapons at sea as a defense.

Decontamination efforts at Kwajalein ceased in September 1946; work after that focused on removing ammunition aboard the ships. On one such detail, the light carrier *Independence* was visited and described:

> The *Independence* is a ghost ship--its flight deck blown up, leaving the thick oak planks broken like so much boxwood; its hangar deck blasted down and only the skeleton of its sides remaining. Gun turrets and gangways, twisted, crushed, dangle oversides, grating and creaking with the roll of the ship. Doors are smashed in and jammed tight against the bulkheads, or blown out altogether, and the rusty water sloshes aimlessly back and forth across the rusty decks. For the most part the radiation is not particularly high, although sometimes these rusty pools will set your earphones singing and shoot your indicator needles off scale. [83]

A confidential memorandum from the Commander in Chief, Pacific Fleet, (CINCPAC), dated September 4, 1946, authorized the sinking of contaminated vessels at Kwajalein. [84] The same day, Admiral Blandy, back in Washington, reported that "only 9 of 92 ships escaped at Bikini," noting that "all but nine...were either sunk, damaged or contaminated by radioactivity," naming the submarines *Tuna, Searaven, Dentuda,* and *Parche,* and the transports *Cortland, Niagara, Bladen, Fillmore,* and *Geneva* as the nine undamaged ships. The report named 45 vessels that had been decommissioned after the tests. Blandy also reported he had sought and received permission to sink "a number of the small landing craft damaged in the experiments, pointing out the dangers of possible lingering radioactivity and also...the cost of repairs and movement from the Marshall Islands...." [85]



Pennsylvania, "too hot to handle," is scuttled off Kwajalein, February 10, 1948. *(National Archives)*

The target ships at Kwajalein remained there for two years in a caretaker status. Soon after the tests, on December 22, 1946, one vessel, the German cruiser *Prinz Eugen*, capsized and sank and was left in place. Another target vessel, LCI-327, stranded on Bascombe (Mek) Island in Kwajalein Atoll; it could not be freed and was "destroyed" in place on October 30, 1947. Some of the ships--the submarines, for the most part, and some of the landing craft--were sufficiently "cool" to return to duty as training vessels. The other vessels, contaminated by the tests, were subjected to additional analysis but for the most part were simply left as a ghost fleet that was literally too hot to handle. In June 1947, Chief of Naval Operations (CNO) established a policy for handling and control of "radiologically contaminated material from Crossroads." Noting the "real and ever present hazard," the CNO dictated that materials were to be removed only for carefully considered testing, that they be carefully controlled and handled, and they not be "retained indefinitely...but shall be disposed of, when the tests are completed, by sinking at sea or by replacement aboard the target vessel." [86]

Eventually, this policy was adhered to for the ships themselves. On August 30, 1947, the Chief of Naval Operations reiterated CINCPAC's September 1946 dictate that all ships "found radiologically unsafe" were to be sunk at sea in deep water. [87] By this time decisions had been made to separate the target ships, as well as some contaminated support vessels, into groups. The majority of ships, too hot to be decontaminated, were left at Kwajalein, while 13 others were taken to Pearl Harbor, Seattle, and San Francisco for decontamination studies; the three ships towed to San Francisco were *Independence, Crittenden,* and *Gasconade.* The six surviving submarines--*Dentuda, Tuna, Parche, Searaven, Skate,* and *Skipjack* were sent to Mare Island Naval Shipyard and the San Francisco Naval Shipyard at Hunter's Point. *Dentuda* and *Parche* were considered only "radiologically suspect" and were cleared for preservation and reuse. Four of the submarines could not be decontaminated; *Skipjack, Searaven, Skate,* and *Tuna* were sunk as targets off San Clemente, California, in 1948.

Pearl Harbor received the battleships *Nevada* and *New York.* Puget Sound Naval Shipyard received the destroyer *Hughes* and the cruisers *Pensacola* and *Salt Lake City.* In 1948 all three were towed to sea and sunk as targets in deep water. [88] Fifty of the target vessels were sunk as targets for conventional weapons (surface bombardment and aerial attack); 36 were sunk in the vicinity of Kwajalein. *New York* and *Nevada* were sunk off Hawaii in deep water; *Hughes* and *Pensacola* were sunk off the Pacific coast of Washington, and

Independence, Crittenden, Gasconade, Salt Lake City, and the four submarines previously mentioned were sunk off California. Nine ships are known to have escaped scuttling or sinking: two submarines, *Dentuda* and *Parche;* two LCIs were sold for scrap along with one LCM; and four attack transports--*Cortland, Fillmore, Geneva,* and *Niagara* were transferred to the Maritime Commission and ultimately scrapped by them. The fate of 13 landing craft (five LCIs, three LCMs, and five LCVPs) is unknown. [89] If they were scrapped later, this would raise the number of "survivors" of the target fleet to 22 vessels. Although a fourth of the total feet numerically, these ships included only two combatant ships and a small fraction of the total tonnage assembled at Bikini for the two blasts. The contaminated or "suspect" support vessels present better statistics; by the beginning of 1947, 80 of the 159 support ships were granted "final radiological clearance." By the end of the year, every one of the 159 was cleared, though some, like the destroyer *Laffey,* required drydocking in floating drydocks (to avoid contaminating permanent onshore facilities), sandblasting and repainting of all underwater surfaces, and acid washing and partial replacement of salt-water piping and evaporators in the ship. [90]

The message of Bikini, while not understood by the public at the time, and only grasped later in hindsight, was clear to the military, which had seen a fleet survive physically but nonetheless lost forever to radioactive contamination. Blast effect, while impressive, paled next to radiation effect: "From a military viewpoint, the atomic bomb's ability to kill human beings or to impair, through injury, their ability to make war is of paramount importance. Thus the overall result of a bomb's explosion upon the crew...is of greater interest...." Therefore, it followed that,

> If used in numbers, atomic bombs not only can nullify any nation's military effort, but can demolish its social and economic structure and prevent their re-establishment for long periods of time. With such weapons, especially if employed in conjunction with other weapons of mass destruction, as, for example, pathogenic bacteria, it is quite possible to depopulate vast areas of the earth's surface, leaving only vestigial remnants of man's material works. [91]

Ironically, the vestigial remnants of man's material works in the form of the target ships were the first tangible demonstrations of the power of the atomic bomb and the futility of defense against it; as Paul Boyer notes, an awakening slowly resulted from "the navy's determined, frustrating, and ultimately futile efforts to decontaminate the surviving ships by scrubbing, scraping, and sandblasting...the pariah feet of ghostly radioactive ships..." [92]

Public awareness and wariness began to surface in 1948. That year, David Bradley, M.D., a member of the radiological safety team at Bikini, published his diary, written during the tests as the book, *No Place to Hide,* which was syndicated in a pre-publication release by the *Atlantic Monthly,* condensed by *The Reader's Digest,* made into a Book-of-the-Month Club release, and stayed on *The New York Times* best sellers list for ten weeks. *No Place to Hide* was a forceful book that subtly told the real message of Bikini; Bradley felt that the Crossroads tests, "hastily planned and hastily carried out...may have only sketched in gross outlines...the real problem; nevertheless, these outlines show pretty clearly the shadow of the colossus which looms behind tomorrow." [93] Bradley also was drawn to the analogy of the target ships at Kwajalein, including "the beautiful *Prinz Eugen,* once the pride of the German feet and as sleek and cavalier a ship as ever sailed the seas," intact and unbroken by the blasts but "nevertheless dying of a malignant disease for which there is no help." [94] The cure was sinking the ships. In February 1949, *The Washington Post* published a column by Drew Pearson that termed the test results a "major naval disaster." Pearson reported that as of 1949, "of the 73 ships involved in the Bikini tests, more than 61 were sunk or destroyed. This is an enormous loss from only two bombs....The aircraft carrier *Independence*...is now anchored off San Francisco, permanently destroyed--usable only as a testing ground to

determine the possibility of removing radioactivity. This is still dangerous two years after the ship was attacked." [95]

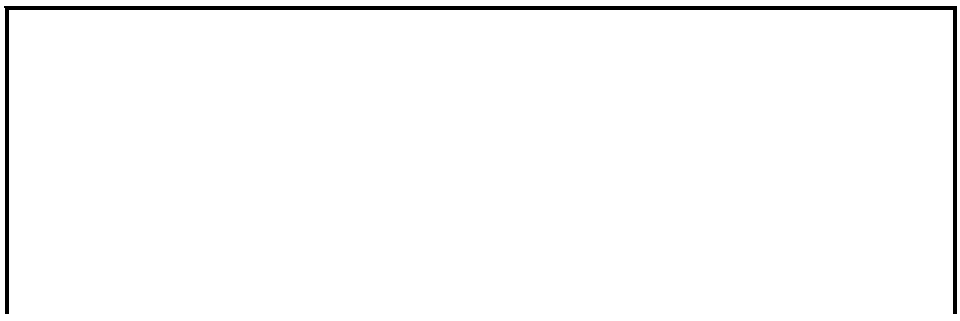
It is strangely prophetic that almost all of the target ships were ultimately taken to sea and scuttled in deep water, joining their sisters sunk in the more shallow waters of Bikini. Once too radioactive to visit, these vessels, with the beta or gamma activity reduced due to radionuclide decay are now the focus of a new look at them and at Crossroads.

Ironically, the "nuclear nomads" of the Pacific, presently the absentee owners and managers of many of the vessels from the sunken feet of Operation Crossroads, were, like the ships themselves, harbingers of a nuclear future. In 1948, David Bradley wrote of his 1946 visit to the displaced Bikinians on Rongerik Island. They "are not the first, nor will they be the last, to be left homeless and impoverished by the inexorable bomb. They have no choice in the matter, and very little understanding of it. But in this perhaps they are not so different from us all." [96] In 1978, Tomaki Juda, leader of the Bikinians, testified before Congress that his people had been relocated on the premise that the tests were for the good of mankind and that they were to be like "the Children of Israel, whom the Lord led into the Promised Land." Juda noted, sadly, that the Bikinians "were naive then.... We are, sadly, more akin to the Children of Israel when they left Egypt and wandered through the desert for 40 years." [97] Now, 44 years later, the Bikinians and the rest of the world more fully understand the meaning and legacy of Operation Crossroads, a legacy that is reflected in twenty-three vessels that lie accessible to divers at two Pacific atolls.

THE 1947 SCIENTIFIC RESURVEY

In early 1947, plans for a scientific resurvey of Bikini during that summer were drafted by the Joint Crossroads Committee. Adm. W. S. Parsons, the Navy's Director of Atomic Defense, forwarded a proposal to the Joint Chiefs of Staff on April 9, 1947. A program of biological study was necessary "in order to determine the long-term effects of Test Baker on fish and other marine organisms including corals and calcareous algae...and to obtain data on which to base a decision relative to possible resettlement of the native population." [98] At the same time, diving on some of the sunken target ships was proposed to "make additional diving observations" and retrieve test data from Crossroads instruments abandoned in 1946. Specifically mentioned as high priorities for reassessment were *Saratoga, Nagato, Pilotfish, Arkansas,* and *Apogon.* [99]

The plan was approved, and a group of scientists and technicians from the Navy, Army, the Smithsonian Institution, the U.S. Fish and Wildlife Service, and other unnamed institutions was placed under the command of Capt. Christian L. Engleman, USN, the Project Director at Bikini. Overall command of the resurvey ships was given to Capt. H. Henry Hederman, USN. Both men were Crossroads veterans. While a classified operation, the resurvey was publicly announced because of a strong desire by the Joint Chiefs to stress "the story of cooperation that exists between civilian and military agencies in the Bikini resurvey work. Proper handling of the Bikini Resurvey story can do much to acquaint the American public with the long-range value of Operation Crossroads." [100]





The Bikini Scientific Resurvey team lands at Bikini, 1947. *(U.S. Naval Institute)*

The Bikini Resurvey task group steamed from Pearl Harbor to Bikini on the transport USS *Chilton* (APA-38), the submarine rescue vessel USS *Coucal* (ASR-8), LSM-382, and LCI(L)-615 on July 1, 1947, arriving on July 15 and remaining until the first of September. The operations plan that they sailed under included an effort, directed by Lieut. Cmdr. F. B. Ewing, USN, to make detailed observations of *Saratoga, Nagato, Gilliam,* and *Apogon.* "Other vessels, including *Arkansas* and *Pilotfish* will be inspected if time permits." The inspection plans called for extensive underwater photography and structural inspections "in an effort to determine the exact cause of sinking." [101] The only specific instrument recovery noted was from *Nagato.* Four instruments, an ionization gage, two linear time pressure recorders, and a diaphragm gage, "the exact locations of which are known," were to be recovered at the discretion of Lieut. Cmdr. Ewing. Additionally, "it is believed that a portion of LSM-60 has been located. If time permits, an attempt will be made by divers to locate this portion and inspect it thoroughly for type of rupture, heat effects, and radioactivity. If practicable, an attempt will be made to raise this section for an inspection on the surface." [102]

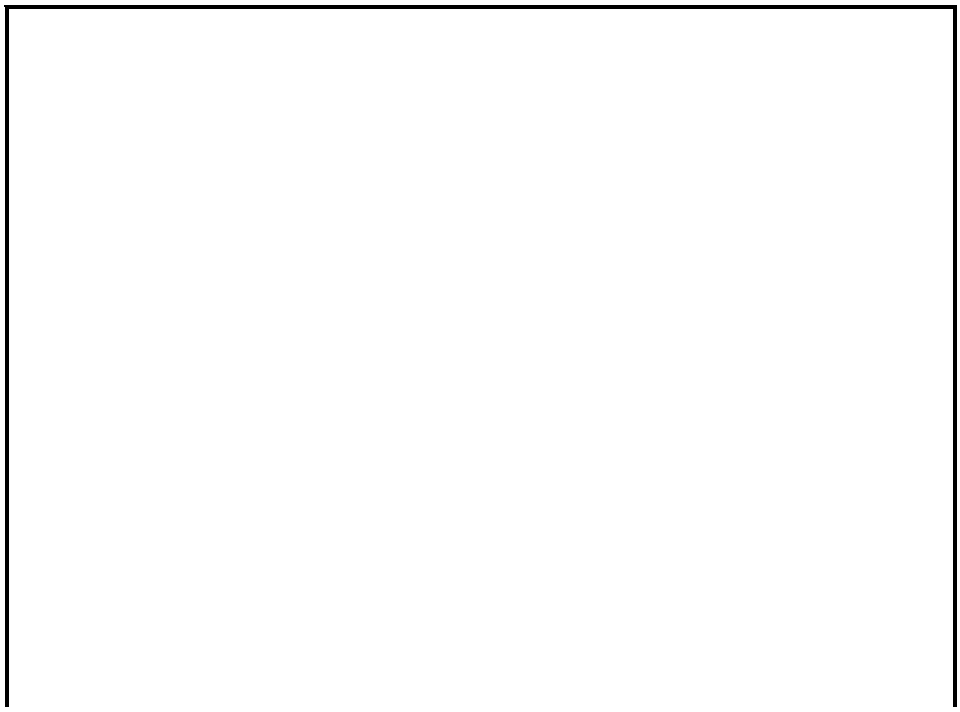
More than 600 dives were made to study blast effects and damage on the wrecks of *Saratoga, Apogon,* and *Pilotfish.* "In addition, a cursory inspection was made of the ex-Japanese battleship *Nagato."* [103] The first dives made were on *Saratoga* on July 17, two days after the resurvey team arrived. The Navy divers reported visibility to be from 15 to 30 feet on the wrecks. However, "divers on the bottom...did have difficulty in seeing clearly because of fogs of sand and mud which were easily stirred up...." [104] Radiation levels were carefully monitored. Divers wore pencil dosimeters and three film badges--on the chest, abdomen, and

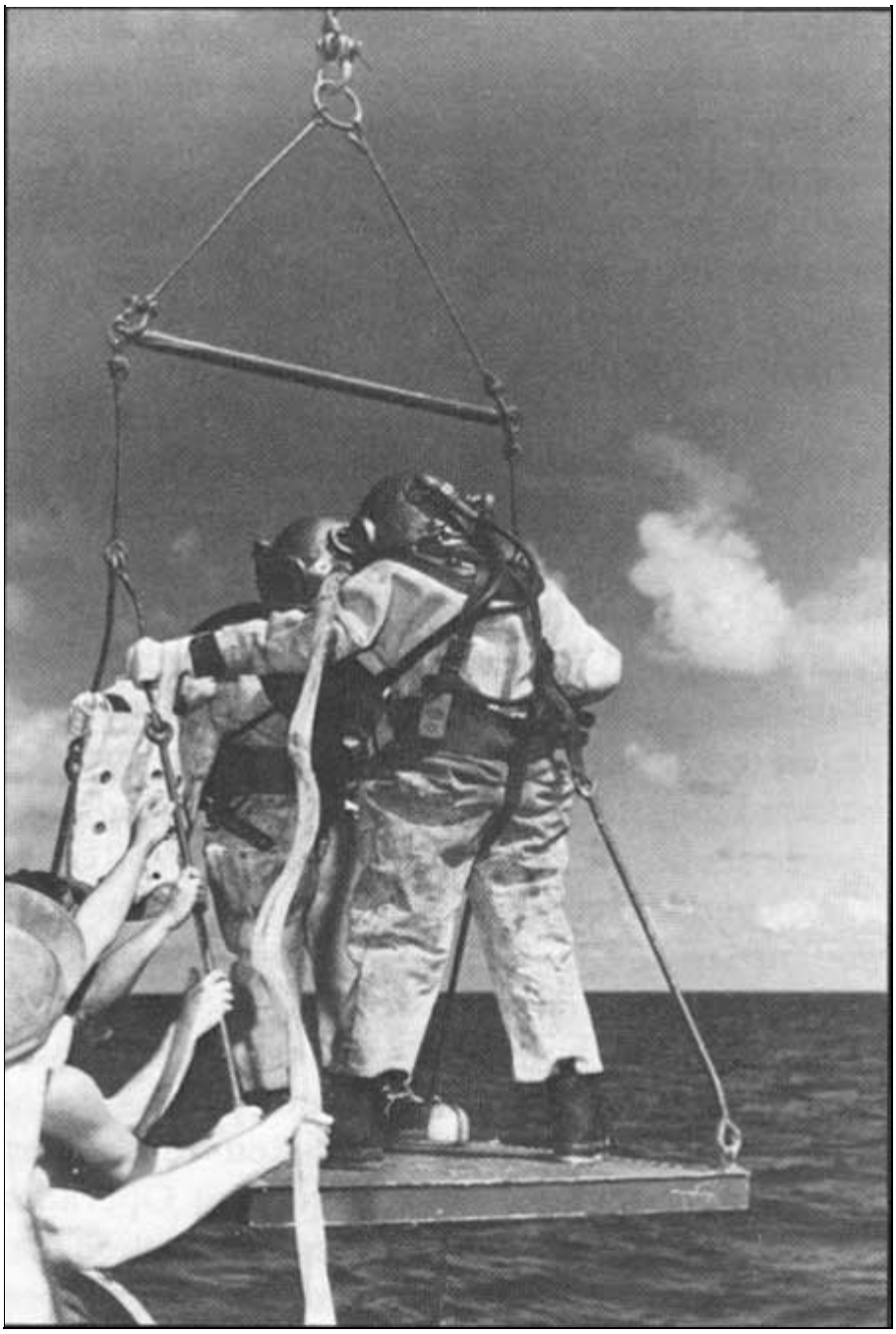
leg--and when hoisted from the water, each diver was "washed down by hose before being hoisted aboard ship." [105] Radiation levels recorded ranged from "two times background (gamma) to .1 R/24 hr. (gamma), and up to .6 R/24 hr. (beta and gamma)." [106] Dive equipment was found to be lightly contaminated; however, "some of the diving equipment was contaminated prior to the resurvey, which can be attributed to the fact that this equipment was used during Operation Crossroads." The source of contamination was found to be "due to contamination by coral powder from the sunken ships and sand from the lagoon bottom." [107]

Only observations were made of the ships at Bikini. Instrument recovery was not attempted since "after Baker day, recovery operations were carried on with unabated vigor and very considerable success, so that perhaps 80 percent of the instruments were recovered." [108] Instruments left behind were presumed buried on the bottom or were "by now [1947] so corroded that their readings would be useless...." A spring chronogram in the crew space, "port side, main deck, frame 16 [of *Nagato]* might contain a valid record on magnetic tape. It is believed, however, that recovery of this instrument would not add materially to the information at hand concerning the air blast in shot Baker." [109]

Other work accomplished by the resurvey team included detailed geological assessments of reef structures by drilling. Cores and samples were taken of the bottom of the lagoon. Scientists collected samples on the reefs to determine the "existing degree of radioactivity, or [conducted] studies concerned with habitats, food chains, and taxonomic relationships." Algae, sea urchins and other marine invertebrates, insects, birds, and mammals were collected and studied for "possible radiological or blast effects upon structure, physiological processes, fertility or normal processes of development." A radiological survey group made "a comprehensive survey of radioactivity on the reefs and islands...." [110]

At the end of August, packing of equipment began for departure. Laboratories ashore were closed and packed by August 27, and the buildings ashore were cleared and locked on August 29. A final inspection was made before the resurvey ships sailed on the 29th. The flagship of the group, USS *Chilton*, arrived at Pearl Harbor on September 3. The task group was dissolved on the 4th. [111] The production of the final reports was completed at the end of the year, and the three-volume *Technical Report, Bikini Scientific Survey* was published in December 1947 by the Armed Forces Special Weapons Project.





Divers prepare to descend on an unidentified sunken ship during the 1947 resurvey. *(U.S. Naval Institute)*

NOTES

[1]W. A. Shurcliff, *Bombs at Bikini: The Official Report of Operation Crossroads* (New York: Wm. H. Wise & Co., Inc., 1947) p. 36.

[2]Chuck Hansen, *U.S. Nuclear Weapons: The Secret History* (Arlington, Texas: AeroFax, Inc., 1988) p. 5.

[3]Eugene Kinkaid, "Bikini: The Forthcoming Atomic Bomb Test in the Marshalls Will Determine the Future ot Man, Animals, Birds, Fish, Plants, and Microorganisms," *Life*, XX (1), July 1, 1946, p. 41. Paul Boyer, in *By the Bomb's Early Light: American Thought and*

Culture at the Dawn of the Atomic Age (New York: Pantheon Books, 1985) analyzes the response to the bomb.

[4]Shurcliff, *Bombs at Bikini,* p. ix.

[5]*Ibid.,* p. 2.

[6]Director of Ship Material, Joint Task Force One, "Historical Report: Atomic Bomb Tests Able and Baker Operation Crossroads," (1947) Operational Archives, Naval Historical Center, Vol. 1, p. xiii. Hereafter cited as Director of Ship Material, "Historical Report."

[7]Vice Admiral W. H. P. Blandy, "Operation Crossroads Background Material," distributed to U.S. Naval Forces in Europe by the Public Information Section, JTF 1. Cited in Thomas N. Daly, "Crossroads at Bikini," U.S. Naval Institute *Proceedings,* Vol. 42, No. 7 (July 1986), p. 68.

[8]Blandy appeared on CBS radio youth forum broadcast sponsored by the New York *Herald-Tribune* on April 13, 1946. Cited in Daly, *Ibid.,* p. 70.

[9]Shurcliff, *Bombs at Bikini,* p. 10. Brian McMahon, junior senator from Connecticut, was chairman of the Senate's Special Committee on Atomic Energy. McMahon's committee held public hearings in Washington, and on December 20, 1945, McMahon introduced his Atomic Energy Act bill. Public hearings followed, and on April 19, 1946, the bill was reported to the Senate. Passed on June 1, 1946, the bill was sent to the House Military Affairs Committee, which referred it to the House on June 13. The House passed the bill with amendments on June 20; subsequently most changes were removed in a joint conference. The bill was signed into law by President Harry S. Truman on August 1, 1946, as the Atomic Energy Act of 1946 (Public Law 585, 79th Congress, 1st Session). The bill passed control of atomic energy from the Manhattan Engineer District, and hence the military, to the newly created Atomic Energy Commission, created a military liaison committee, and instituted security provisions to protect against the release of "classified" nuclear secrets. See Vincent C. Jones, *Manhattan: The Army and the Atomic Bomb: The United States Army in World War II, Special Studies* (Washington, D.C.: Center of Military History, 1985), pp. 576-578.

[10]Shurcliff, *Bombs at Bikini,* p. 9. A dispatch by Hanson W. Baldwin to *The New York Times,* published in the paper's July 25, 1946 edition, reported that the target array for Baker, a "tactical situation of the fleet in harbor...was frankly patterned after an opportunity in the past war that was never realized," namely an atomic bombing of Truk. Baldwin noted the bomb was not used because of the Japanese fleet's near destruction and "no concentration of enemy ships sufficiently large enough to warrant the use of the atomic bomb was ever detected." p. 2. Trinity, Hiroshima, and Nagasaki came as soon as active material and other components were ready--no earlier detonation was ever possible.

[11]According to Paul S. Dull, *A Battle History of the Imperial Japanese Navy (1941-1945)* (Annapolis: Naval Institute Press, 1978), Appendix A, "Name, Date of Completion, and Fate of Major Ships of the Imperial Japanese Navy," pp. 343-350. The remaining ships, some of them half-sunk at Kure or practically inoperable (such as *Nagato* at Yokosuka) were one battleship, two carriers, two light carriers (CVLs), two heavy cruisers, two light cruisers (CLs), and thirty-eight destroyers.

[12]Shurcliff, *Bombs at Bikini,* pp. 10-11.

[13]Director of Ship Material, "Historical Report," Volume 1, p. viii.

[14]*Ibid.*, pp. ix-x.

[15]*The New York Times*, August 25, 1945, p. 2.

[16]Shurcliff, *Bombs at Bikini*, p. 11.

[17]*The New York Times*, October 24, 1945, p. 4.

[18]*The New York Times*, December 11, 1946, pp. 1, 3.

[19]Shurcliff, *Bombs at Bikini*, p. 9.

[20]Kinkaid, "Bikini," p. 41.

[21]Shurcliff, *Bombs at Bikini*, p. 7.

[22]Hansen, *U.S. Nuclear Weapons*, p. 50.

[23]W. A. Shurcliff, "Technical History of Operation Crossroads," Vol. 1, (1946) copy on file at the National Technical Information Service, p. 5.3. Hereafter cited as Shurcliff, "Technical History."

[24]Director of Ship Material, "Historical Report," Vol. 1, pp. 68-69.

[25]*Ibid.*, p. 67.

[26]*Ibid.*, p. 68.

[27]*Ibid.*, p. 69. Also see Vice Admiral E. L. Cochrane, USN, "Crossroads and Ship Design," *Shipmate*, (September 1946) pp. 9-10.

[28]*Ibid.*, pp. 74-75.

[29]Shurcliff, "Technical History," p. 6.3.

[30]*Ibid.*, p. 6.4.

[31]*Ibid.*

[32]Shurcliff, "Technical History," p. 6.5.

[33]*Ibid.*

[34]Shurcliff, "Technical History," p. 6.6.

[35]*Ibid.*

[36]Director of Ship Material, "Historical Report," pp. 72-73.

[37]*Ibid.*, p. 71.

[38]*Ibid.*, p. 21.

[39]*The New York Times*, January 25, 1946, pp. 1, 4.

[40]*The New York Times*, March 20, 1946, p. 10. The Bureau of Ships, when totalling the costs of the target ships, was ordered *not* to include the cost of armament. Also untallied were modernization, modifications, and repair costs.

[41]*The New York Times*, March 24, 1946, p. 4.

[42]Letter, John P. Howe to the President, April 16, 1946, filed in Protest Answers, Joint Task Force One, Records of the Defense Atomic Support Agency, National Archives Record Group 374.

[43]*The New York Times*, April 17, 1946, p. 5.

[44]Letter, Brig. Gen. T. J. Betts, USA, to Alexander Wilde, April 2, 1946, filed in Protest Answers, National Archives Record Group 374.

[45]Letter, Max Ladewasser and Gang to the President, April 14, 1946, filed in Protest Letters, National Archives Record Group 374.

[46]*The New York Times*, January 26, 1946, p. 1.

[47]Letter, Brig. Gen. T. J. Betts, USA, to Peter Brambir, March 21, 1946, filed in Protest Answers, National Archives Record Group 374.

[48]Letter, Brig. Gen. T. J. Betts, USA, to Lt. Herbert B. Leopold, February 11, 1946, filed in Protest Answers, National Archives Record Group 374.

[49]"The Effect of the Atomic Bomb on Naval Power," *Bulletin of the Atomic Scientists of Chicago*, Vol. 1, No. 5 (February 15, 1946), p. 1.

[50]Letter, R. Lee Page to George Lyons, Commissioner of Atomic Research, Navy Department, March 15, 1946, filed in Protest Letters, National Archives Record Group 374.

[51]Letter, Jeanne Robinson to Adm. W. H. P. Blandy, May 1, 1946, filed in Protest Letters, National Archives Record Group 374.

[52]Shurcliff, "Technical History," p. 6.7.

[53]Shurcliff, "Technical History," p. 6.4 lists 94 vessels, but neglects to include LSM-60, the bomb-carrying ship for Baker, as well as one landing craft.

[54]*Ibid.*, p. 6.7.

[55]*The New York Times*, July 1, 1946, p. 3.

[56]Shurcliff, "Technical History," p. 6.7.

[57]*Ibid.*, p. 6.8.

[58]*Ibid.*

[59]Shurcliff, "Technical History," p. 6.10.

[60]*Ibid.*, p. 6.11.

[61]Hansen, *U.S. Nuclear Weapons,* p. 31, 38n.7. General Paul Tibbets, then commander of the Composite 509th Group, which dropped the bomb, blamed the Able miss on crew error. See Paul Tibbets, *The Tibbets Story* (New York: Stein and Day, 1978). In a telephone interview on December 20, 1990, the pilot, Woody P. Swancutt stressed the high level of training he and his crew had received, the considerable experience of the bombardier, Harold Wood, and post-Able tests with the same crew and bomb sight that consistently dropped "Fat Man" casings close to the target.

[62]*The New York Times,* July 1, 1946, p. 1.

[63]*Ibid.*, p. 3.

[64]Director of Ship Material, "Historical Report," Vol. 1, p. 44.

[65]*Ibid.*, pp. 44-45.

[66]*The New York Times,* July 2, 1946, p. 3.

[67]*The New York Times,* July 15, 1946, p. 3.

[68]See "Helen of Bikini," *Time* Magazine, August 5, 1946, p. 27. The naming of the two Bikini bombs is a further indication of the need to "humanize" the bomb through a mechanopomorphic process that began with the "Fat Man" and "Little Boy" weapons dropped on Japan. The female names for the Bikini bombs, particularly "Gilda" and its reference to Rita Hayworth, are part of what Paul Boyer terms the "complex psychological link between atomic destruction and Eros" that was evidenced by burlesque houses advertising "Atomic Bomb dancers" in August 1945, the "unveiling" by Hollywood of scantily-clad starlet Linda Christian at poolside as the anatomic bomb" in *Life* Magazine in September 1945, the French bathing suit "Atome" (quickly dubbed the "Bikini" when introduced in 1946) and the 1947 pop song "Atom Bomb Baby," which Boyer notes made the Bomb a metaphor for sexual arousal. See Boyer, *By the Bomb's Early Light,* pp. 11-12.

[69]Shurcliff, "Technical History," p. 28.7. Also see the *Washington Star,* August 22, 1946.

[70]*The New York Times,* August 4, 1946, p. 3.

[71]David J. Bradley, *No Place to Hide, 1946/1984* (Hanover and London: University Press of New England, 1983), pp. 109-110.

[72]Director of Ship Material, "Technical Inspection Report: Radiological Decontamination of Target and Non-Target Vessels," Vol. I, p. 4. Hereafter cited as "Radiological Decontamination of Target and Non-Target Vessels." For a summary of the radiological decontamination effort, also see C. Sharp Cook, "The Legacy of Crossroads," *Naval History,* Vol. II, No. 4, Fall 1988, p. 28.

[73]"Radiological Decontamination of Target and Non-Target Vessels," Vol. I, p. 4.

[74]*Ibid.*, p. 5.

[75]*Ibid.*, p. 6.

[76]*Ibid.*, p. 8.

[77]*Ibid.*, p. 13.

[78]Director of Ship Material, "Historical Report," p. 55.

[79]Memorandum, Col. A. W. Betts, USACOE, to Brig. Gen. K. D. Nichols, MED, USACOE, August 10, 1946. F-3-5, Test Baker Results, Box 26, National Archives Record Group 377, Records of the Manhattan Engineer District.

[80]"Radiological Decontamination of Target and Non-Target Vessels," Vol. I, p. 17.

[81]Director of Ship Material, "Historical Report," p. 57.

[82]Memorandum, CNO to CINCPAC, "Removal of Equipment and Supplies from Contaminated CROSSROADS Target Ships," February 18, 1947, Serial 034P36, Operational Archives, Naval Historical Center.

[83]Bradley, *No Place to Hide*, pp. 143-144.

[84]Cited in "Radiological Decontamination of Target and Non-Target Vessels," Vol. III, p. 14.

[85]*The New York Times*, September 5, 1946, p. 7.

[86]Memorandum, CNO to Chiefs of the Bureau of Ships, Bureau of Ordnance, Bureau of Aeronautics, Bureau of Medicine and Surgery, Bureau of Yards and Docks, Bureau of Supplies and Accounts, "Handling and Control of Radiologically Contaminated Material from CROSSROADS," June 10, 1947, Serial 0138P36, Operational Archives, Naval Historical Center.

[87]Cook, "The Legacy of Crossroads," p. 29.

[88]A. G. Nelson, Capt. USN, "Crossroads Target Ships," Memorandum, NNTPR #24-78, May 25, 1978, Department of the Navy, Office of the Chief of Naval Operations; NAVSEA Shipbuilding Support Office, "US Vessels Involved in Operation Crossroads," NAVSEASHPSO, Philadelphia, n.d.; and James L. Mooney, ed. *Dictionary of American Naval Fighting Ships*, eight volumes (Washington, D.C.: Government Printing Office, 1959-1981).

[89]See, for example, "Atom Bombed Ship Undergoes Study," in *The New York Times*, May 11, 1947, p. 19, which discusses the sinking of *New York* as a conventional weapons target as the battleship's probable fate. *Parche*'s conning tower is now on display at the Pacific Fleet Submarine Memorial Museum at Pearl Harbor.

[90]Cook, "The Legacy of Crossroads," pp. 31-32.

[91]"The Evaluation of the Atomic Bomb as a Military Weapon: The Final Report of the Joint Chiefs of Staff Evaluation Board for Operation Crossroads," (June 30, 1947), CCS 471.6, 10-15-46, Section 9, Part 1, p. 60, 73 (top quote). National Archives Record Group 218.

[92]Boyer, *By the Bomb's Early Light,* p. 92.

[93]Bradley, *No Place to Hide,* pp. 165-166.

[94]*Ibid.,* p. 147.

[95]Drew Pearson, "Bikini Naval Losses Disaster," *The Washington Post,* February 18, 1949.

[96]Bradley, *No Place to Hide,* p. 163.

[97]Cited in Jonathan M. Weisgall, "The Nuclear Nomads of Bikini," *Foreign Policy,* Vol. XXVIV (Summer 1980), p. 98. Also see William S. Ellis, "A Way of Life Lost: Bikini," *National Geographic* (June 1986), pp. 813-834.

[98]Memorandum to Op-36 from Op-33 and Op-38 (Parsons), April 9, 1947. Serial 106P36, Operational Archives, Naval Historical Center.

[99]*Ibid.,* attached draft memorandum from the Joint Crossroads Committee to the Joint Chiefs of Staff, the Secretary of the Navy, and the Secretary of War.

[100]"Bikini Resurvey Operation Plan 1-47, Annex L, Public Information Plan," National Archives Record Group 374, Entry 4B, Box 156, Folder A4.

[101]*Ibid.,* Annex D, "Sunken Ship Inspection Plan."

[102]*Ibid.*

[103]"Bikini Backtalk," 10 September 1947, Vol. I, No. 16. Copy on file in RG 374, Box 28, Folder 212.

[104]"Report of the Director Ship Material," in "Technical Report, Bikini Scientific Resurvey" (Washington, D.C.: Armed Forces Special Weapons Project, 1947) Vol. III, p. 1. Hereafter cited as "Report of Director of Ship Material."

[105]*Ibid.,* p. 2.

[106]*Ibid.*

[107]*Ibid.*

[108]Memorandum, Bureau of Ordnance to Chief of Naval Operations, 15 June 1947, Serial F141-6(49). Copy published in "Report of Director of Ship Material."

[109]*Ibid.*

[110]"Operations," in "Technical Report, Bikini Scientific Resurvey," Vol. I, p. 67.

111

Ibid., pp. 71-73.

TABLE ONE: SHIPS LOST DURING OPERATION CROSSROADS TESTING AT BIKINI ATOLL LAGOON

AIRCRAFT CARRIERS

BAKER TEST: **USS *Saratoga*** (CV-3), *Lexington* Class

BATTLESHIPS

BAKER TEST: **USS *Arkansas*** (BB-33), *New York* Class
HIJMS *Nagato,* *Nagato* Class

CRUISERS

ABLE TEST: HIJMS *Sakawa, Agano* Class*

DESTROYERS

ABLE TEST: USS *Anderson* (DD-411), *Sims* Class*
USS *Lamson* (DD-367), *Mahan* Class*

SUBMARINES

BAKER TEST:

USS *Apogon* (SS-308), *Balao* Class
USS *Pilotfish* (SS-386), *Balao* Class

TRANSPORTS

ABLE TEST: ***Gilliam*** (APA-57), *Gilliam* Class
Carlisle (APA-69), *Gilliam* Class

AUXILIARIES AND LANDING CRAFT

BAKER TEST:

ARDC-13
LCM-4
LCT-414 (scuttled after)
LCT-812 (scuttled after)
LCT-1114
LCT-1175
LCT-1187 (scuttled after)
LCT-1237 (scuttled after)
LCVP-10
LSM-60 (completely destroyed)
YO-160

TABLE TWO: VESSELS LOST INSIDE KWAJALEIN ATOLL LAGOON IMMEDIATELY AFTER THE CROSSROADS TESTS CURRENTLY AT DEPTHS ACCESSIBLE TO SCUBA

CRUISERS

USS *Prinz Eugen* (IX-300), ex-KMS *Prinz Eugen*

LANDING CRAFT

LCI-327

Boldface indicates this vessel was documented by NPS SCRU during August 1989 and/or May 1990 Survey (includes analysis of USN ROV Survey).

*At the time this report went to press, the remains of three additional vessels were discovered at Bikini. They have not been evaluated but it is probable based on descriptions that they are the two destroyers and *Sakawa*.

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National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER THREE: SHIP'S HISTORIES OR THE SUNKEN VESSELS

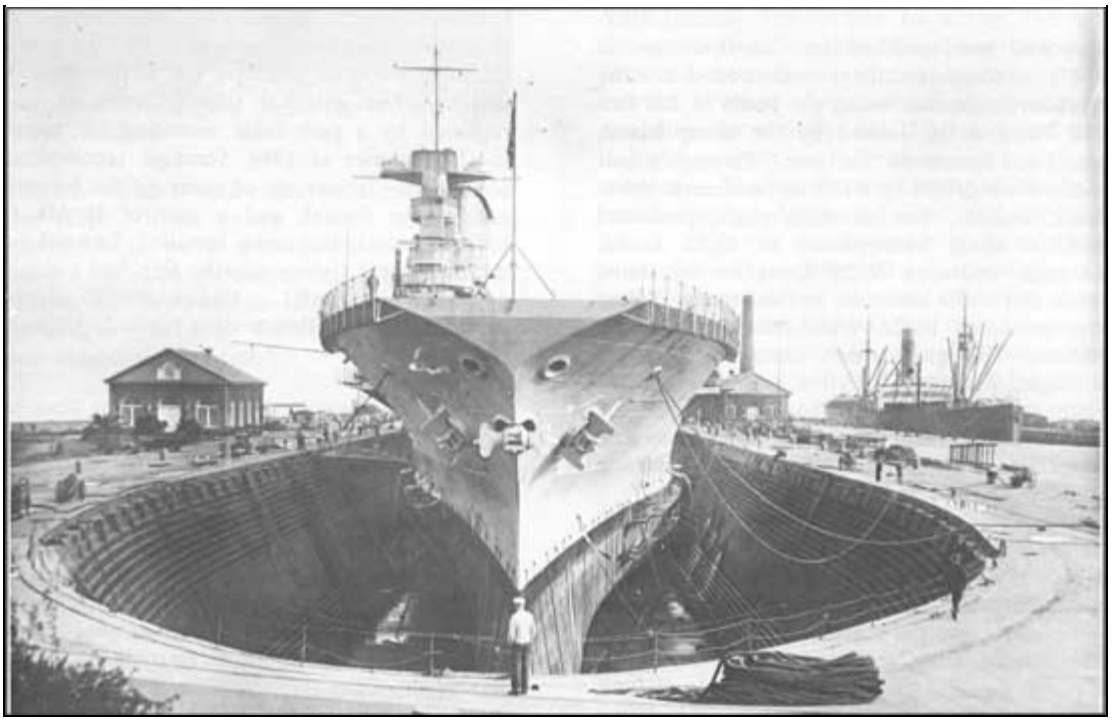
James P. Delgado

Twenty-one target vessels and small craft sank at Bikini as a result of Operation Crossroads. The characteristics, histories, and Crossroads role of each vessel sunk at Bikini, as well as *Prinz Eugen,* are discussed here.

USS *SARATOGA* (CV-3)

Characteristics

USS *Saratoga* (CV-3) was a steel-hulled vessel with a waterline length of 830 feet. The cruiser hull of *Saratoga* was wedded to the flight deck, which as built was 874 feet long (later extended to 888 feet) and overhung the hull forward and aft. "Above the water line the hull shape was determined by the requirements for as wide a flying deck as possible. This has given a very pronounced flare both forward and aft." [1] From keel to flight deck, the depth of the hull was 74-1/2 feet. The hangar deck below was built to accommodate 90 aircraft maximum; *Saratoga* usually carried 81 to 83 planes. *Saratoga*'s maximum beam was 105-1/2 feet, with a mean draft of 31 feet. *Saratoga* "officially" displaced 33,000 standard tons in compliance with the Washington Naval Treaty. The vessel actually displaced (full combat load) 43,500 tons--later alluded to by "official" tonnage upgrades to 36,000, later increased to 40,000, tons. The ship's trial displacement was 38,957 tons. [2] *Saratoga*'s characteristics as an aircraft carrier were influenced by the ship's original design as a cruiser. Partially completed as cruisers when the order was given to convert *Saratoga* and its sister *Lexington* to carriers, they could not be economically torn apart and rebuilt. "The principal dimensions of the hull, the primary features of protection against gunfire and underwater explosion, and the design of the propelling machinery were thus determined before the plans for conversion to airplane carriers was undertaken. This situation...forced the acceptance of elements which in a new design might have been changed. The development of the machinery and ammunition handling spaces was practically complete, and the airplane carrier development took place almost entirely above the protective deck." [3]



Saratoga in drydock at Hunter's Point, San Francisco, 1928. *(San Francisco Maritime National Historical Park)*

The hull was modified for the first time in 1942; a torpedo blister was added to the starboard side, increasing the beam to 108 feet and fixing a list caused by the heavy island, guns, and funnel on that side. *Saratoga*'s four shafts were driven by a GE turbo-electric drive. Eight engines, two on each shaft, produced 180,000 shaft horsepower at 32.25 knots. *Saratoga* delivered 32.28 knots on its initial trials and 34.99 knots on its final trials. Steam was produced by 16 White-Foster oil-burning boilers. The uptakes were swept together into a single, flat-sided, 105-foot long, 80-foot tall (later cut down some 15 feet) funnel abaft the island. The flight deck, 47 feet above the waterline, was covered with wood planking, caulked and painted. [4]

Saratoga's main gun armament consisted of twin 8-inch/55 caliber guns in four gun houses, with an antiaircraft array of twelve 5-inch/25 caliber guns and eight .50 caliber machine guns; the latter were later replaced with quad-mount 1.1-inch machine guns. [5] In January-April 1942, following the carrier's return to the Puget Sound Navy Yard after being torpedoed, *Saratoga* underwent its first major wartime refit. The 8-inch guns were replaced by twin mounted 5-inch/38 caliber guns in four houses; single 5-inch guns of the same caliber were added to the sponsons, replacing the original 5-inch/25 caliber weapons. Thirty 20mm Oerlikon antiaircraft guns were added, and four quad 40mm Bofors guns were installed.

Torpedoed in August 1942, *Saratoga* after repairs was again modified; the 1.1-inch guns were removed and replaced with 40mm Bofors, making nine such mounts, and twenty-two additional 20mm guns were installed, making 52 of these single-barrel weapons on board. In another refit in December 1943, *Saratoga* received 16 more Bofors mounts; two in new portside sponsons abeam the island, seven in the boat recesses to port, two in the boat recess to starboard, three outboard of the flight deck off the island, and two in the bow machine gun galleries. [6] Other modifications included reducing the island structure, cutting it down to an open bridge for air operations, with the original flag plot one deck below, followed by the pilothouse and navigating bridge, conning tower, and at flight deck level, the meteorological

platform and air intelligence office. The original tripod foremast was replaced by a pole mast mounting SK radar. In the summer of 1944, *Saratoga* received an SM fighter-director set of radar on the forward end of the funnel, and a pair of H Mk II hydraulic catapults were installed forward on the flight deck (previously the ship had a single hydraulic catapult). Other modifications included the installation of a portside torpedo blister. [7]

Saratoga was heavily damaged off Iwo Jima by Japanese bomb hits on February 21, 1945, which holed the flight deck and the starboard hull near the bow, starting fires on the hangar deck. Repairs at Puget Sound hastily patched the hull and deck, removed the after elevator, fitted a new 44-foot square elevator forward, and filled the aft end of the hangar deck with two decks of berths. *Saratoga* was again modified for Operation Crossroads. Nearly two-thirds of the ship's armament was stripped, including two of the houses with the twin 5-inch guns. Other fixtures, including compasses and the ship's bell (now at the Washington Navy Yard), were taken off, and aircraft, vehicles, and radar were mounted on the ship. Blast gauge towers and other instruments were mounted on *Saratoga.* Loaded with 700 gallons of fuel oil, 15 tons of diesel, and two-thirds of its ammunition, *Saratoga* was sent to the bottom in a near-combat-ready state. [8]



Bow view of *Saratoga* at Puget Sound Navy Yard, Bremerton, Washington, September 1944. *(U.S. Naval Institute)*

History

The aircraft carrier *Saratoga* was originally planned as (CC-3), the second cruiser of a six-vessel *Lexington* class authorized and appropriated for on August 29, 1916, as part of a three-year program of naval construction. [9] Laid down on September 25, 1920, at the Camden, New Jersey, yard of the New York Shipbuilding Company, *Saratoga* was completed as a result of a post-WWI naval arms race with Britain, Japan, France, and Italy in which construction efforts focused on capital ships--namely battleships and battle cruisers.

This arms race, as well as growing interest in naval aviation, conspired to redesign *Saratoga* before its launch. Despite Congressional insistence that all *new* ship construction focus on capital ships, the U.S. Navy received funds to convert the collier *Jupiter* (AC-3) into an aircraft carrier. Conversion of the hybrid ship at Norfolk Navy Yard took two years before USS *Langley* (CV-1) emerged as the U.S. Navy's first aircraft carrier on March 22, 1922. By that time, however, plans were already being considered for the conversion of the cruisers *Lexington* and *Saratoga* into fully functional fleet carriers.

The post-war naval arms race led to several conferences, conventions, and treaties. The Washington Naval Conference of 1921-1922 led to international agreement to limit the numbers, sizes, and armament of naval vessels. Under the treaty, many of the battleships and cruisers then under construction could either be scrapped or converted to aircraft carriers. Anticipating the order to scrap the six *Lexington* class cruisers, the Navy prepared plans to convert one of the cruisers into a carrier. When the conference agreed to scrapping the cruisers, the U.S. converted two ships, *Lexington* and *Saratoga*, into aircraft carriers. The incomplete hulls of the two cruisers were redesignated CV-2 and CV-3 on July 1, 1922, the day Congress approved their conversion. Japan followed suit, converting the battle cruiser *Akagi* and the battleship *Kaga* into fleet carriers. [10] At that time, work on *Saratoga* had progressed to the point where the cruiser hull had received its armored barbettes and decks were being laid. All of this work had to be torn out to reconstruct *Saratoga* as a carrier.

Under provision of the Washington Naval treaty, carrier conversions were limited to 33,000 tons *maximum* standard displacement, and no more than ten low-angle guns with a maximum caliber of eight inches. Both the United States and Japan interpreted a clause in the Treaty to permit adding 3,000 tons of antiaircraft and torpedo defenses to capital ships, to apply to their carrier conversions. As a result, while listed "officially" at 33,000 tons, *Lexington* and *Saratoga* carried weight in excess of the treaty limit, even after sacrificing some of their cruiser armor. *Saratoga* was the first launched, sliding down the ways into the Delaware River on April 7, 1925. The first of the two *Lexington*-class carriers, *Saratoga*'s launch was the heaviest warship launch on record and in the top dozen heaviest launches for merchant and naval vessels up to that time. [11] The launching program noted that "the new *Saratoga*, aircraft carrier, when completed and commissioned...will be the largest and fastest craft of its kind in the world." [12] Fitting out *Saratoga* took two years; the carrier was commissioned on November 16, 1927, at the Philadelphia Navy Yard. Departing Philadelphia on a shakedown cruise on January 6, 1928, *Saratoga*'s first aircraft landed on board on January 11. [13]

The Navy considered *Saratoga* and *Lexington* as major successes. The most powerful carriers in the U.S. fleet, as well as their first fleet carriers, the two ships were, according to historian Norman Friedman,

> as remarkable in their way as the first British Dreadnought battleship launched only 25 years before, outclassing every other carrier in existence. *Saratoga* and *Lexington* were faster than their Japanese rivals, they could operate more aircraft, and their design was so sound that they went to war...without major reconstruction since their completion. [14]

Just prior to its launching, *Saratoga* was hailed by the Philadelphia *Evening Star* because "there is no counterpart for this first American first-line carrier in any other navy...." [15] Naval officers appreciated the vessels. Capt. Marc Mitscher, naval aviation pioneer, captain of USS *Hornet* (CV-8), the carrier that launched Col. "Jimmy" Doolittle's strike at Japan, later commander of the fast carrier task force, and, incidently, the first man to land a plane aboard *Saratoga*, testified in 1940 that

> we have always felt, a good many of us, that the *Lexington* and *Saratoga* were the best ships we have ever built for all purpose ships, carrying the protection and armor of a cruiser. We will have twelve carriers that need cruiser protection and that cannot be sent out on independent missions unless they have cruiser protection. I feel that we have two carriers, the *Lexington* and *Saratoga* that can be sent out on independent missions and if they lose their cruiser protection they can still protect themselves with their aircraft and armament. Therefore we feel we should look into that field for future carriers.... [16]

However, the *Lexington*-class carriers had one major design flaw--the inclusion of their four twin 8-inch gun mounts, which could only be fired in starboard broadsides. The 8-inch guns, intended to battle a surface enemy, were also out of place on a carrier. This was corrected after the outbreak of war, when the 8-inch guns were replaced with 5-inch/38 caliber guns, "the correct weapon against the carrier's true foe: enemy carrier aircraft." [17] Despite Captain Mitscher's sentiments, *"Lexington* and *Saratoga* were never envisaged as prototypes for a heavyweight carrier fleet. They remained one-offs, a unique double product of the Washington Treaty...." [18]

Saratoga's prewar career was spent engaged in fleet training exercises that defined a strong role for aircraft carriers in naval warfare. This included "attacks" on the Panama Canal and Pearl Harbor, usually operating in tandem with *Lexington,* then in later years with the carriers that followed these pioneers. Based out of San Pedro or San Diego, *Saratoga* operated in annual fleet "problem" exercises. According to the ship's official Navy history, "in the fleet problems, *Saratoga* continued to assist in the development of fast carrier tactics, and her importance was recognized by the fact that she was always a high priority target for the opposing forces." [19]





Saratoga's most trying hour, off Iwo Jima, February 21, 1945, as the flight deck forward burns after a kamikaze attack. *(U.S. Naval Institute)*

According to Friedman, "it was with *Lexington* and *Saratoga*--the matched giants, the biggest carriers in the world--that the U.S. Navy learned the rudiments of carrier task force operations between 1927 and 1941." [20] Fleet Admiral W. F. "Bull" Halsey noted in his 1947 autobiography:

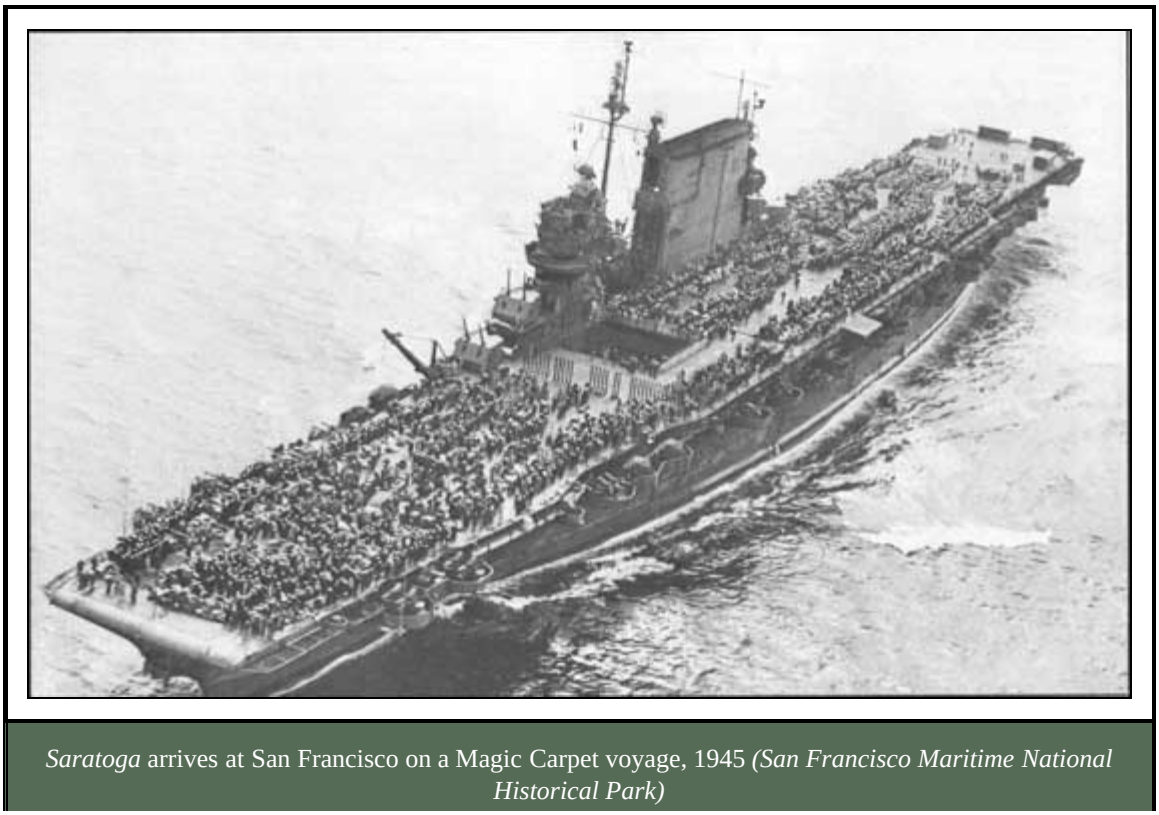
> the *Sara* is a queen and that is why she will always have a secure place in my heart. First, I loved her as a home; I commanded her for two years and flew my rear admiral's flag on her for two more, which means that I lived on board her longer than I ever lived anywhere else. Second, I loved her as a ship; she helped me make my debut in the carrier Navy, and she initiated me into the marvels of fleet aviation. [21]

When the United States Pacific Fleet was attacked at Pearl Harbor on December 7, 1941, *Saratoga* was in California, entering San Diego harbor after an overhaul at the Puget Sound Navy Yard at Bremerton, Washington. Within 24 hours, the carrier was on its way into the Pacific. [22] During WWII, *Saratoga* participated in several campaigns. *Saratoga* was involved in the aborted effort to relieve the beleaguered Marine garrison of Wake Island, and opened the American attack on Guadalcanal. *Saratoga* pounded Japanese bases in the Gilbert and Marshall Islands, providing support for the landings at Tarawa and flying combat air patrols over Eniwetok and Wotje. *Saratoga*'s aircraft struck the heavily defended Japanese port of Rabaul and airfields at Buka, neutralizing effective Japanese counterstrikes at Bougainville in "perhaps her most brilliant strike of the war," according to the Navy. [23] Admiral Halsey, going aboard the carrier at Espiritu, Santo, praised *Saratoga:* "Your strike," he stated, "was another shot heard round the world...the *Saratoga,* when given the chance, can be deadly." [24] Operating with a British carrier and a French battleship, *Saratoga* struck Japanese-occupied Sumatra and Java, damaging port and oil production facilities. In another important wartime assignment, the carrier spent several months training fliers to operate at night. *Saratoga* then participated in night strikes against the Japanese home islands as diversionary aids during the Iwo Jima operation, also flying patrols over Chichi Jima. [25]

Considered a "lucky" vessel by its crew despite two torpedoings, *Saratoga* was hit hard off Iwo Jima when five kamikazes struck the ship on February 21, 1945, killing 123 men, wounding another 192, and tearing a huge hole in the ship's side. In June 1945, the Navy announced the damage to the by then repaired carrier:

> Fires broke out and burning planes and fuel scattered over great areas of the ship. The forward part of the flight deck was battered beyond use. One enemy suicider penetrated the side of the ship into the hangar deck where he exploded to cause a great fire. The crane forward of the bridge, the catapults and many guns were battered by the crashing planes and exploding bombs. [26]

At the war's end *Saratoga* was steaming toward Japan to strike the home islands. Sent to the West Coast for decommissioning, *Saratoga* was instead ordered to "Magic Carpet" service in November 1945. *Saratoga* ferried naval veterans back to the United States as part of Operation "Magic Carpet." Within 28 hours "after her last plane was launched *Sara* was en route from Pearl Harbor to Alameda, California, with 3,800 grinning, happy, overseas warriors. Her hangar deck had been made into the world's largest dormitory with endless rows of 4-tiered bunks for passengers. Recreation facilities replaced planes on her flight deck." [27] By the end of "Magic Carpet," *Saratoga* had carried 29,204 veterans home, more than any other vessel. By the end of its career, *Saratoga* also held the record for the greatest number of aircraft landed on a carrier, with a lifetime total of 98,549 landings in 17 years. [28] On January 22, 1946, *Saratoga* was attached to Task Unit 1.2.2, the aircraft carrier unit of the target ship task group being assembled by Joint Task Force One for Operation Crossroads. Designated as a replacement for the carrier *Ranger* (CV-4) which had originally been designated as a target vessel, *Saratoga* was then prepared for the atomic bomb tests in early 1946 at Hunter's Point Naval Shipyard in San Francisco. [29] A January 25, 1946, news release showed the "gallant carrier" in dock as two 5-inch gun houses and the majority of the lighter antiaircraft weapons were stripped from the ship. Sent to Pearl Harbor "after stripping" and reduction of personnel on April 30, 1946, *Saratoga* arrived there on May 7. From there, the carrier was ordered to proceed to Bikini Atoll, steaming from Pearl on May 23 in the company of the destroyer *Anderson* and arriving at Bikini on May 31.



Saratoga arrives at San Francisco on a Magic Carpet voyage, 1945 *(San Francisco Maritime National Historical Park)*

Saratoga was selected as a test ship for Operation Crossroads because it, as a sole representative of a now obsolete class, had been replaced by the large number of wartime-built *Essex*-class carriers now available for future fleet use. Additionally, the carrier's compartmentation was "unusually complete" with more than 1,000 watertight compartments and its "underwater protection was very similar in arrangement to that of modern battleships and large carriers." [30] *Lexington* had not survived the war (it was sunk in May 1942 at the Battle of Coral Sea). *Saratoga* was moored 2,260 yards off the actual zeropoint for the Able test blast of July 1, 1946; intentionally located at some distance to save the carrier for the Baker test. *Saratoga* was lightly damaged, with a fire on deck that was extinguished. [31] Initial array plans for Baker placed *Saratoga* within a 300-yard radius of the detonation point. Because this position was deemed likely to sink the carrier so quickly that "no photographs could be made of the behavior of her flight deck under the severe hull pressure and wave action expected," *Saratoga* was changed to a 500-yard distant mooring, within the 500- to 700-yard "lethal radius" of the blast. Because of slack moorings and a wind change, the carrier drifted closer in, perhaps to within 300 yards of the bomb location before the detonation. [32] The ship was blown out to a position 800 yards distant before drifting back in and sinking 600 yards from the detonation point. [33]



Saratoga being prepared for Operation Crossroads at Hunter's Point. Note the two 5-inch/38 caliber gun houses landed on the dock off the carrier's stern. *(San Francisco Maritime National Historical Park)*

New York Times correspondent Hanson W. Baldwin, watching nearby as *Saratoga* slowly sank nearly eight hours after the blast, penned an epitaph:

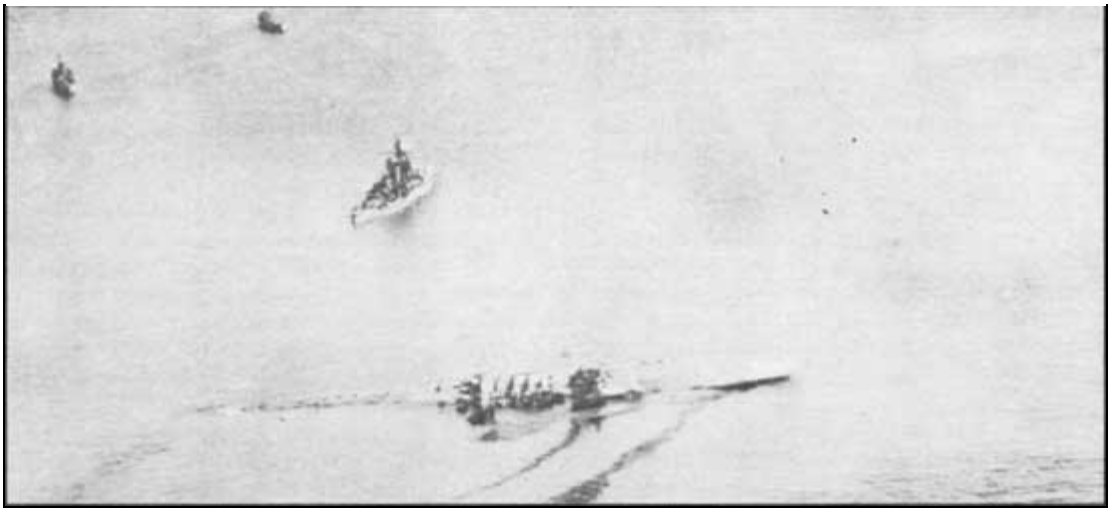
> There were many who had served her in the observing fleet and they fought with her through the long hot hours as the sun mounted.... Outside the reef--a safe distance from the radioactive waters in the lagoon--the observing ships cruised, while the *Sara* slowly died. There were scores who wanted to save her--and perhaps she might have been saved, had there been a crew aboard. But she died a lonely death, with no man upon the decks once teeming with life, with pumps idle and boilers dead.... From three o'clock on she sank fast, her buoyancy gone, as the fleet kept the death watch for a "fighting lady." The...*Sara* settled--the air soughing from her compartments like the breath from exhausted lungs. At 3:45 p.m. the starboard after corner of her flight deck was awash; then the loud speakers blared: "The water is up to her island now; the bow is high in the air." She died like a queen--proudly. The bow slowly reared high; the stern sank deep,

> and, as if striving for immortality, the *Sara* lifted her white numeral "3"...high into the sun before her bow slipped slowly under. Her last minutes were slow and tortured; she fought and would not sink, but slowly the "3" was engulfed by the reaching waters....the tip of her mast was the last bit of the *Sara* seen by man.... [34]

The carrier was decommissioned on August 15, 1946, and stricken from the Navy Register. [35]



Saratoga sails for Bikini, modified for Operation Crossroads, May 1946. *(San Francisco Maritime National Historical Park)*



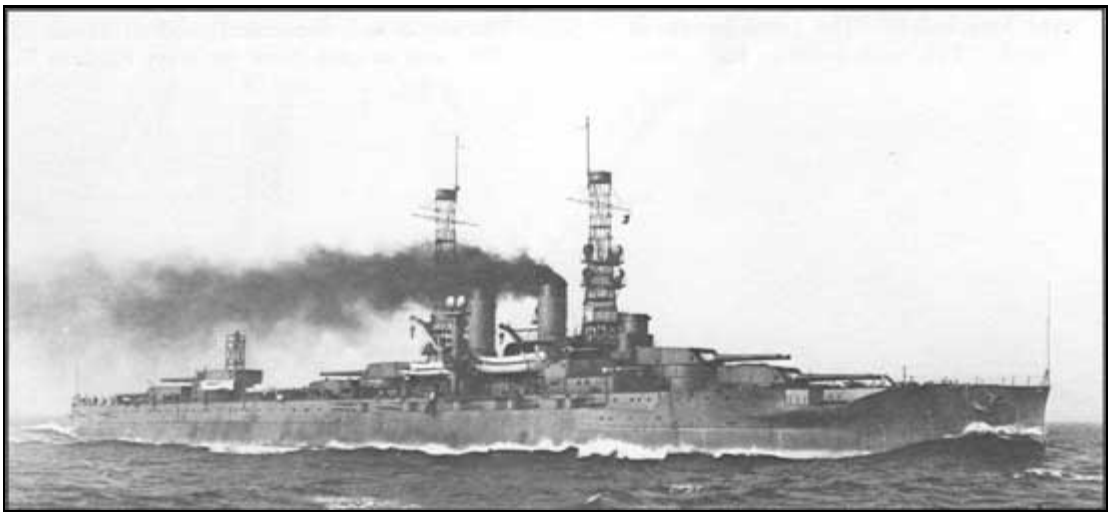
Saratoga sinks, bow in the air, at Bikini on July 25. *(National Archives)*

USS *ARKANSAS* (BB-33)

Characteristics

USS *Arkansas* (BB-33) was a riveted steel vessel 562 feet long overall, with a waterline length of 555-1/2 feet, a maximum beam of 106 feet, and a draft of 29 feet, 11-1/2 inches. *Arkansas* originally displaced 23,066 tons standard; the addition of deck armor and torpedo blisters between 1925-1927 increased the battleship to 26,100 tons standard displacement. The ship had 1,448 crew and was fitted as a flagship. [36]

Arkansas was heavily armored above the waterline; an 9-to-11-inch armor belt protected the ship amidships. The turrets were covered by 9 to 12 inches of armor plate. The hull was double-bottomed except in the machinery spaces, where three bottoms were fitted. The battleship received additional deck armor between 1925-1927; 3.5 inches of armor covered the top of the armor belt. This increased the displacement by 3,000 tons.

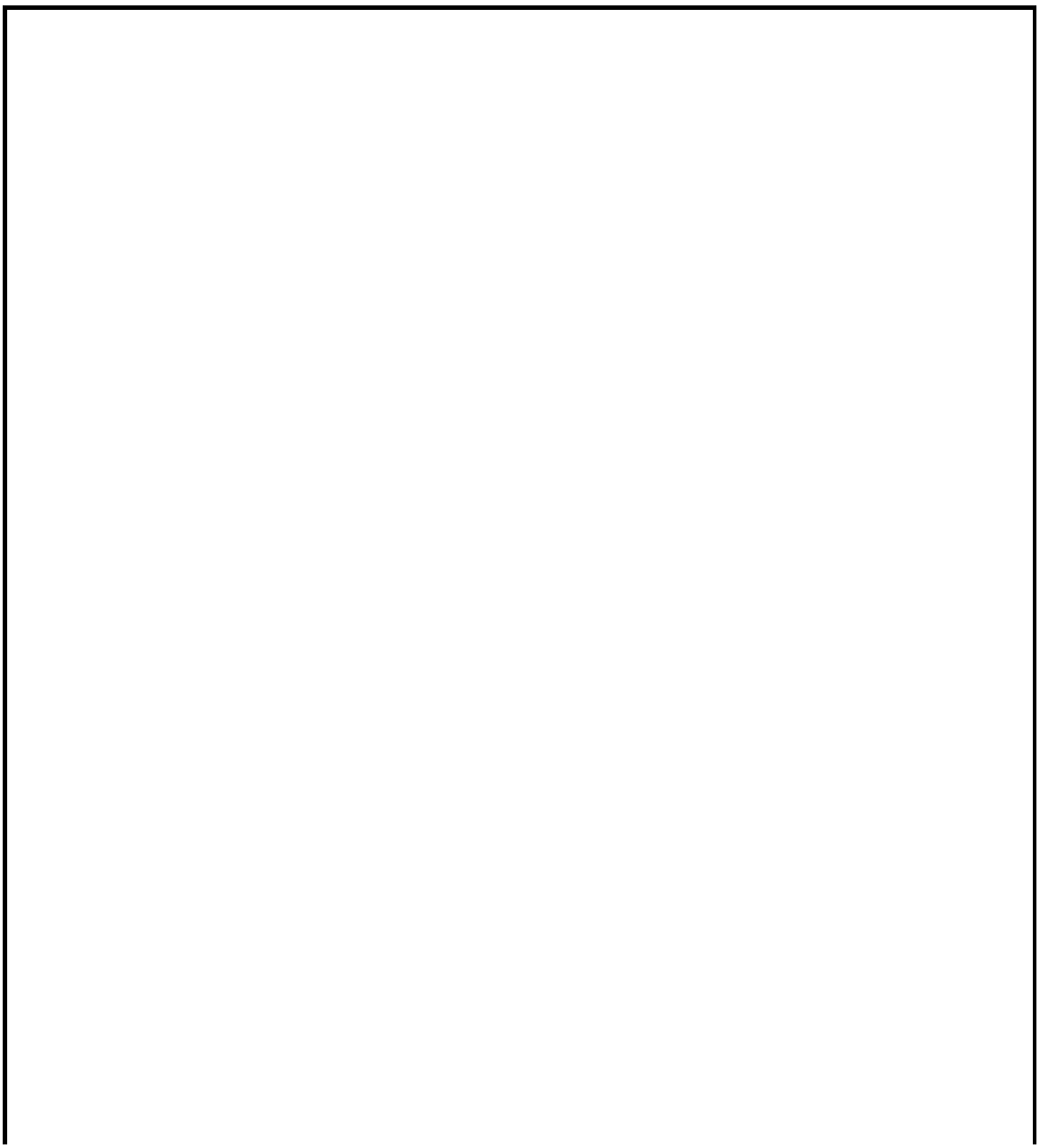


Arkansas on its trials, 1912. *(Philadelphia Maritime Museum)*

The main battery consisted of twelve 12-inch/50 caliber guns, twin mounted in six turrets--

two forward, two amidships, and two aft. The secondary battery consisted of sixteen 5-inch/51 caliber guns in casemates. [37] Between 1925-1927 some of these latter positions, which were wet in a seaway, were moved up to the main deck, and in 1942, ten of the 5-inch guns were removed, leaving three 5-inch guns in midships casemates (known aboard ship as the air castles) on each beam of the ship. *Arkansas* mounted two 21-inch torpedo tubes, which were later removed. The battleship's original antiaircraft battery comprised eight 3-inch/50 caliber guns. In 1942 additional AA guns were added; as of 1945, *Arkansas* mounted nine quad 40mm Bofors guns and 28 single-mount 20mm Oerlikon guns. In its 1925-1927 refit, *Arkansas* also received an airplane catapult atop turret No. 3 and three spotter aircraft. [38]

Arkansas' four screws were driven by Parsons turbines and four White-Forster boilers which developed 28,000 shaft horsepower at 20.5 knots. The boilers vented into two stacks; between 1925-1927 when *Arkansas* was reboilered, a single stack replaced the original two. The coal-burning boilers installed in 1912 were replaced at that time with oil-burners; *Arkansas'* bunkers carried 5,425 tons of fuel oil. Other topside changes included replacing the cage mast with a low tripod between No. 4 and No. 5 turrets. In 1942, the ship was fitted with a tripod foremast aft of the bridge; the bridge itself was reconstructed at the same time. Fire control stations were located atop each mast in the enlarged tops. [39]





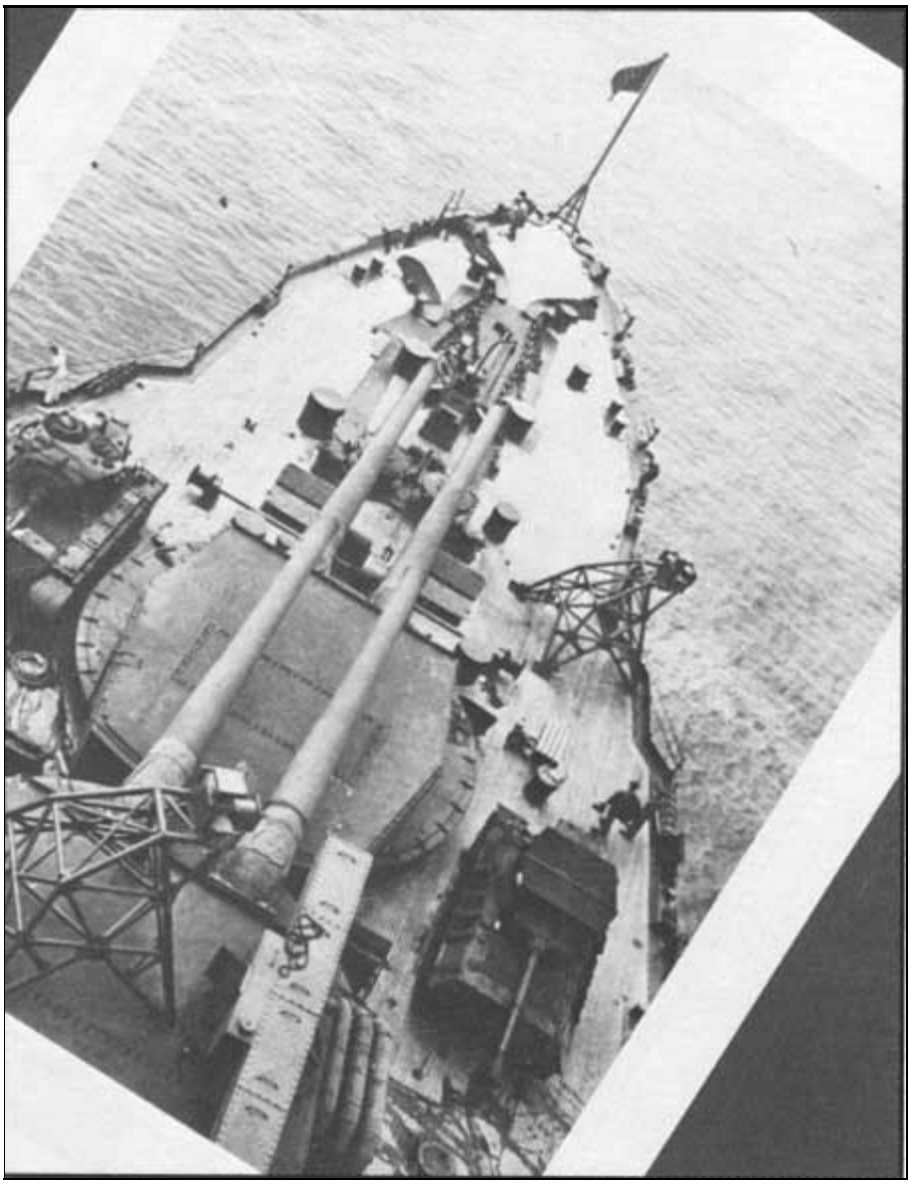
Stern view of *Arkansas*, 1945. *(U.S. Naval Institute)*

History

USS *Arkansas* (BB-33), second of two *Wyoming*-class battleships, was a near-sister of four *Florida*- and *Texas*-class battleships, which included the before-mentioned vessels as well as USS *Utah* and USS *New York*. *Arkansas* and its near-sisters represented the first "modern" class of U.S. battleships. The American "dreadnoughts" were designed to win sea battles through superior fire power and speed. *Arkansas* mounted six turrets with 12-inch guns, and was powered by newly developed steam turbines operating at then unheard-of speeds. *Arkansas* was built at the Camden, New Jersey, yard of the New York Shipbuilding Corporation. The battleship was laid down on January 25, 1910, just weeks after its near

sister *Utah* was launched from the same yard. As *Utah* was fitted out, *Arkansas* rose on the ways. Launched into the Delaware River on January 14, 1911, the new battleship was fitted out in 20 months' time, and was commissioned as USS *Arkansas* at the Philadelphia Navy Yard on September 17, 1912. [40]

Prior to the First World War, *Arkansas* spent its career on the Atlantic coast and in the Caribbean, with one voyage to the Mediterranean. *Arkansas* carried President William H. Taft to Panama in December 1912 to inspect work on the Canal. [41] In 1914 *Arkansas* played an important role in the American landings at Veracruz, Mexico. In late April, *Arkansas* joined other ships in an attempt to contravene the landing of German arms to Mexican President Victoriano Huerta, who had succeeded the assassinated elected President Francisco I. Madero. U.S. President Woodrow Wilson, supporting Madero backers and anti-Huerta revolutionaries as part of his international campaign for human rights, and seeking to stabilize war-torn Mexico (by force of arms if necessary), sent in troops. [42] Marines and bluejackets landed from U.S. vessels off Veracruz, took the city, and prevented the landing of German weapons. After this maneuver, between 1914 and 1917 *Arkansas* trained along the Atlantic seaboard and in the Caribbean.



Arkansas' bow, showing two blast gauge towers and tanks placed on the battleship for the test. *(National Archives)*

Following the United States entry into World War I in April 1917, *Arkansas* spent the first year patrolling the eastern seaboard before sailing to Europe in July 1918. Attached to the 6th Battle Squadron of the British Grand Fleet, *Arkansas*, along with near-sister *Texas* was present when the German High Seas Fleet surrendered at Scapa Flow on November 20, 1918. *Arkansas* served as one of the honor escorts for *George Washington* when that vessel carried President Wilson to France. Returning to the United States at the end of 1918, *Arkansas* resumed training and cruising; this time, however, the battleship operated in the Pacific. Between 1919 and 1938, *Arkansas* alternated in service between both coasts, spending several years in each ocean before being attached to Battleship Division 5 of the Atlantic Squadron in October 1938. *Arkansas* served on the Neutrality Patrol in the North Atlantic in 1941, prior to the U.S. entry in World War II. Following the Japanese attack on Pearl Harbor and Germany's declaration of war against the United States, *Arkansas* served on convoy duty, escorting vessels to Ireland, Scotland, Iceland, and French Morocco. In June 1944, *Arkansas* participated in the invasion of Normandy, providing fire support on Omaha Beach. It also was used in the bombardment of Cherbourg, and later assisted in the invasion of Southern France in mid-August of the same year. Returning to the United States in September 1944, *Arkansas* was modernized at the Boston Navy Yard in Boston and sent into the Pacific. [43]

When *Arkansas* arrived in the Pacific in late 1944, it was the oldest and smallest of the then-existing American capital ships, as well as the last American battleship to mount 12-inch guns. Replaced as a first-line ship by the new battleship *North Carolina*, *Arkansas* nonetheless played a major role in the Pacific war. *Arkansas* provided pre-invasion bombardment at both Iwo Jima (February 1945) and Okinawa (March 1945) as well as ongoing fire support for both operations. The battleship fired 1,262 rounds of 12-inch ammunition at Iwo Jima and 2,564 rounds at Okinawa. Through the war *Arkansas'* 12-inch guns fired 5,255 rounds in all; the 5-inch guns of the secondary battery fired 5,123 rounds, and the ship's lighter antiaircraft battery fired 8,422 rounds, while the battleship steamed 134,141 miles. Returning to the United States in October 1945, *Arkansas* was readied for participation in Operation "Magic Carpet"; the veteran battleship then made three voyages transporting returning servicemen to Pearl Harbor. *Arkansas* was selected as a target vessel for Operation Crossroads and was prepared for the bomb tests at Terminal Island, California, before steaming from Pearl Harbor on May 8, 1946. *Arkansas* left Pearl on May 20 and arrived at Bikini on May 29, 1946.

Arkansas was moored off the port beam of USS *Nevada*, the target ship for the Able test on July 1, 1946. The battleship was "one of the three major combatant ships within one half mile of the zeropoint." [44] The ship was the site of the maximum measured radioactive contamination from the Able test; a pool of water on *Arkansas* was measured at eight roentgens per eight hours. *Arkansas* was moored within 500 feet of the detonation point for the Baker Test of July 25, 1946; it was the closest of the target vessels with the exception of the vessel that suspended the bomb, LSM-60. The detonation is popularly believed to have lifted the battleship vertically out of the water within the blast column. Careful analysis of the sequence of movie photographs, however, shows what appears to be the battleship's foremast in the blast column, with the dark "hole" thought to be the up-ended battleship caused by the mass of the ship blocking the uplifted water column rising above it. *Arkansas* sank almost immediately; the Navy technical inspection report for *Arkansas* notes it disappeared within 19 seconds after the blast. According to *Bombs at Bikini*, "in sinking, she carried with her the dubious honor of being the first battleship to be sunk by an atomic bomb, and the first battleship to be sunk by a bomb that never touched her." [45]

HIJMS *NAGATO*

Characteristics

The Japanese battleship *Nagato* was a steel-hulled vessel 708 feet in length overall, with a 95-foot beam and a 30-foot draft. *Nagato* displaced 38,500 tons standard. The ship was armored with a 3.9-to-11.8-inch belt; the turrets were protected by 14-inch thick armor. *Nagato*'s armament consisted of eight 16.1-inch/45 caliber guns, twenty 5.5-inch/50 caliber guns, four 3.1-inch antiaircraft guns, three machine guns, and eight 21-inch torpedo tubes, four above and four below the waterline. Between 1934-1936, *Nagato* was reconstructed: torpedo bulges were added and the superstructure was raised and modified. In June 1944, *Nagato* had sixty-eight 25mm Hotchkiss antiaircraft guns; by October of the same year, the number of antiaircraft guns had increased to include ninety-eight 20mm guns. At that time, *Nagato* retained eighteen 5.5-inch guns; *Nagato*'s full load displacement at that time was 43,581 tons. [46]

Nagato's four screws were driven by Gihon steam turbines that developed 80,000 shaft horsepower at 26.7 knots. By October 1944, the rated speed of the vessel was 24.98 knots. [47] Steam was provided by 21 Kanpon boilers. The battleship was originally coal-fired; between 1934-1936 the ship's machinery was replaced with new oil-burning boilers. This led to the removal of *Nagato*'s forward stack. During the reconstruction, in addition to new machinery and torpedo bulges, *Nagato* received a triple bottom, additional deck armor, and increased elevation for the 16-inch guns. *Nagato* carried three observation planes launched by catapult forward of the "C" turret. According to the U.S. Navy's confidential report on the Japanese Navy, ONI-221-J, issued in June 1945, "the most outstanding outboard feature of *Nagato* is the large heptapodal foremast with its numerous tops and bridges for fire and ship control purposes. The central vertical leg is thick enough to accommodate an electric lift running between the foretop and main deck." [48] *Nagato*'s hull was reportedly divided into 560 separate watertight compartments; its rated complement was 1,333 men. [49]



Nagato underway in the 1920s. *(U.S. Naval Institute)*

History

The battleship *Nagato* was built by Kure Navy Yard for the Imperial Japanese Navy under provision of the 1916-1917 Programme of Naval Construction by that nation. Laid down in 1917, *Nagato* was launched on November 9, 1919. The first of two *Nagato*-class battleships *(Nagato* and *Mutsu), Nagato* was the first battleship in the world armed with 16-inch guns. [50] Completed on November 25, 1920, *Nagato* served in its most famous role as flagship for Adm. Isoroku Yamamoto, Commander in Chief for the Combined Fleet. *Nagato,* "its entire crew manning the sides," led the combined fleet in its last official public display on October 11, 1940, during an Imperial review off Yokohama in ceremonies celebrating the 2,600th anniversary of the accession of Jimmu, Japan's first emperor. [51]

Nagato was the scene of Yamamoto and his staff as many meetings by plans to attack the U.S. Pacific Fleet at Pearl Harbor were first broached, discussed, and refined. Final preparations for the war were made aboard *Nagato,* and Yamamoto stood aboard *Nagato* with the battleship's crew as the Pearl Harbor strike force vessels sortied. With them the Japanese aircraft carriers brought specially modified 16-inch shells from *Nagato* and its sister *Mutsu* that would be dropped on the American ships at Pearl Harbor as bombs. One of these shells would be credited with sinking the battleship *Arizona. Nagato* was the scene of nervous waiting by Yamamoto and his staff. They first heard of Japan's overwhelming success at Pearl Harbor when *Nagato*'s radio operator received the famous "to, to, to" signal for a successful attack's commencement--crystal-clear reception from the skies over Oahu thousands of miles away. [52]



View aft from bow, trig *Nagato*'s A and B turrets and distinctive superstructure, at Bikini, May 1946. *(National Archives)*

Nagato served as flagship for Yamamoto until replaced by the 63,700-ton super battleship *Yamato* in February 1942. [53] Yamamoto, when he shifted his flag to *Yamato,* released the older battleship for operational duty; thus, *Nagato* as part of the Japanese Main Force steamed with the striking force that attempted to take Midway and the Aleutians in late May

1942. *Nagato,* however, was not engaged in combat in the disastrous engagement off Midway in June in which four carriers were sunk by American carrier aircraft. [54]

Nagato next sortied with the fleet in the Marianas in June 1944. This disastrous battle, Japan's last opportunity to win a decisive naval engagement, ended in defeat and the withdrawal of the fleet to Japanese home waters. [55] The fleet, with *Nagato,* again sailed in October 1944 to engage the American fleet at the Battle of Leyte Gulf. *Nagato,* in formation with the super battleships *Musashi* (sunk in this engagement) and *Yamato,* was hit by two torpedoes but survived, assisting *Yamato* off Samar. In retreat *Nagato* took a heavy pounding from carrier bombers; it was hit by four bombs and was damaged by nine near-misses. [56] Upon reaching Japan, *Nagato* was left at anchor at Yokosuka, awaiting repairs that never came. Thus, the crippled *Nagato,* tied up at Yokosuka, missed the last sortie of the Imperial Japanese Navy in April 1945. In that special *kikusui* (battle of certain death) *Yamato* was sunk, effectively destroying the Imperial Japanese Navy as a fighting force. [57]

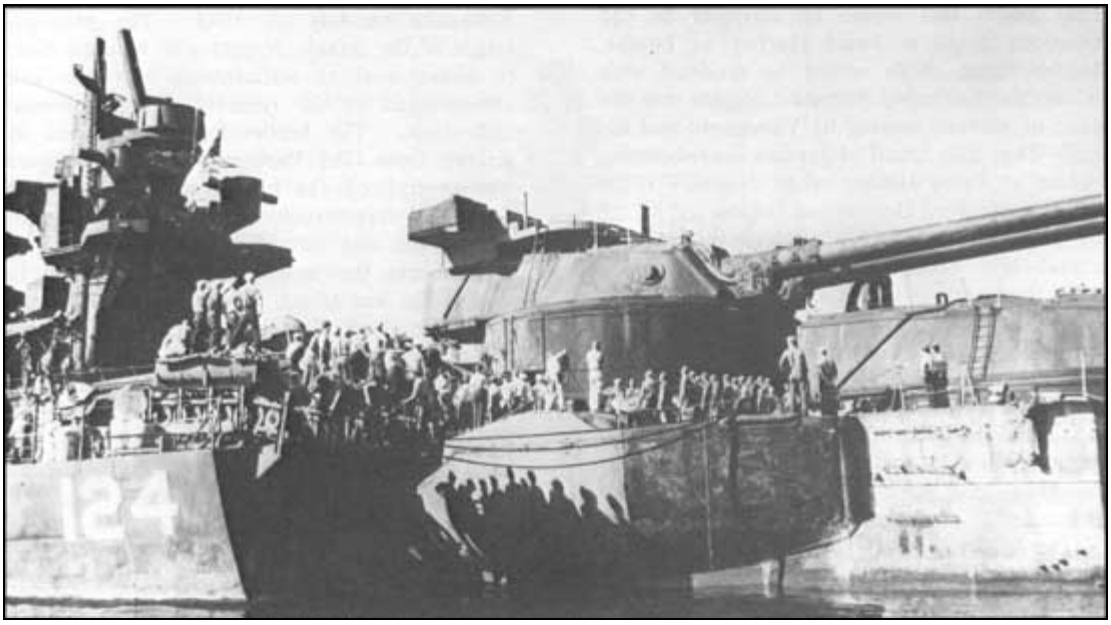
Nagato, already badly damaged, was again mauled by aerial attack while at anchor at Yokosuka on July 18, 1945. The principal target of the attack, *Nagato* was moored close to shore next to antiaircraft batteries and camouflaged by the removal of its mainmast and stack. The battleship was pounded by aircraft from USS *Yorktown* (CV-10). *Nagato* was neutralized--the bridge wrecked, and the decks and superstructure holed and damaged. [58] Ending the war out of action in Tokyo Bay, *Nagato* was the only Japanese battleship to survive the war afloat. Following the Japanese surrender, Task Force Thirty-One (the Tokyo Bay occupation force) landed and occupied the Tokyo Bay area. Navy Underwater Demolition Team 18 was assigned to "capture" *Nagato* on August 30, 1945. This act, according to the U.S. Navy, "symbolized the unconditional and complete surrender of the Japanese Navy." [59] Unlike some other captured vessels, *Nagato* was not brought into the U.S. Navy as a special auxiliary, as was the case with the German battle cruiser *Prinz Eugen.* This may have been because *Nagato* was heavily damaged and was of no use to the United States as a capital ship. The vessel was also a symbolically laden ship, being the "flagship" of the *kido butai* or "strike force," as well as the genesis point of the plan for the attack on Pearl Harbor, which Americans perceived as a vicious sneak attack, and onetime quarters of Yamamoto, who, while a villain in the United States was still very much a hero to the Japanese. *Nagato,* not surprisingly, was selected as a target vessel for Operation Crossroads. In early 1946 the ship was prepared at the Yokosuka Naval Base and steamed under its own power close to Bikini Atoll in the company of the captured cruiser HIJMS *Sakawa.*

Nagato's imminent arrival was noted in "Crossroads," the semi-official newsletter of the tests, on April 27, 1946:

> Once the lofty pride of the Japanese fleet, the battleship *Nagato* will strike an ironic contrast as she enters the atoll shortly. Flying the American ensign and manned by an American crew, she will be the first of the 'guinea' ships to take her position for what may well be her last mooring. Then, humbly, she will await the fateful day when the blow, mightier than the greatest salvo ever produced by man, will descend.

After its arrival at the end of April, *Nagato,* "the one-time pride of the Japanese Navy," was eagerly explored by sightseeing sailors. According to the May 4 edition of "Crossroads," "this huge battleship appears to have already undergone the blast. Visitors will find that she is pretty-well shattered, her decks and bulkheads rusty, and her equipment highly picked over. An LST alongside supplies all her water and electricity." The vessel was prepared by a repair ship for the tests at Bikini, and then moored 400 yards to the starboard of *Nevada,* target ship for the Able test. When the bomb missed *Nevada, Nagato* was only moderately damaged by the Able blast; light plating on the superstructure was wrinkled and light non-watertight doors

were blown off their hinges; paint was scorched. The report on the ship concluded that "the *Nagato* is structurally sound.... The poor condition of the ship and her equipment is due to lack of preventive maintenance and overhaul, and to the fact that her engineering plant sat idle for over a year." [60]



The "capture" of *Nagato* and the symbolic surrender of the Imperial Japanese Navy at Yokasuka, August 30, 1945. *(U.S. Naval Institute)*

The end came for *Nagato* when the Baker test bomb detonated nearby on July 25, 1946. [61] The passing of the battleship under these circumstances made a profound impression on the Japanese. Naval historian Masanori Ito wrote:

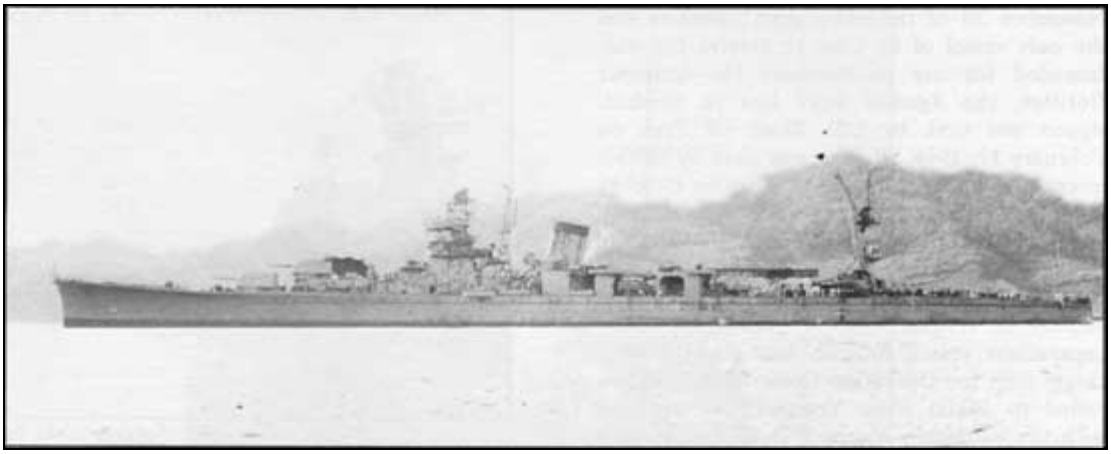
> When World War II began, the Japanese Navy--the third most powerful in the world--included some of the mightiest ships in naval history and was a force worthy of the pride and trust of the Japanese people. Then, in less than four years, this great war machine fell from glory to oblivion. Of ten battleships riding in Hiroshima Bay in December 1941, nine were sunk. The lone survivor, *Nagato,* died at Bikini Island as a target in an atomic bomb test. [62]

HIJMS *SAKAWA*

Characteristics

Sakawa was a welded steel cruiser of the *Agano* class. Particulars of the ship are not fully documented since Japanese records were destroyed at the time of the surrender. The U.S. Navy's official report on the Japanese Navy, ONI-221-J, issued in June 1945, cites a length of 550 feet overall and a beam of 49.6 feet. The vessel's length is not cited in other sources; its sister ship *Yahagi,* built at the same yard at roughly the same time, had a length of 531 feet between perpendiculars. *Sakawa* displaced 6,652 tons. The ship had a flush deck, "with marked sheer to the forecastle." The *Agano* class cruisers were also fitted with bulbous bows. The four shafts were driven by steam turbines; steam was provided by six Kanpon boilers. *Agano* was rated at 10,000 shaft horsepower at 35 knots; *Sakawa* probably had the same rating. The vessels were reportedly armed with six 6-inch/50 caliber guns, paired in three turrets, two forward and one aft. *Sakawa* had an antiaircraft battery of four 3.1-inch/65

caliber guns, and thirty-two 25mm/65 caliber Hotchkiss guns. *Sakawa* also mounted eight 24-inch torpedo tubes above water and carried 16 depth charges. Each *Agano* class cruiser also carried two floatplanes for observation, launched from a single catapult. [63]



A captured Japanese photograph of *Sakawa*, circa 1945. *(U.S. Naval Historical Center)*

History

The cruiser *Sakawa* was built at Sasebo Navy Yard for the Imperial Japanese Navy as part of that nation's 1939 Programme of Naval Construction. Fourth and last of the *Agano* class cruisers, *Sakawa* and its sisters were the first regular light cruisers to be added to the Imperial Japanese Navy in more than ten years. [64] Laid down in 1942, *Sakawa* was launched on April 9, 1944, and completed on November 30 of the same year. *Sakawa* was the only vessel of its class to survive the war. Intended for use as flagships for destroyer flotillas, the *Aganos* were lost in combat. *Agano* was sunk by USS *Skate* off Truk on February 17, 1944; *Noshiro* was sunk by carrier aircraft from USS *Hornet* and *Wasp* on October 26, 1944; *Yahagi* was sunk while sortying with the battleship *Yamato* on April 7, 1945. [65] The undamaged *Sakawa* was at the Japanese naval base at Maizaru (on the coastline of the Sea of Japan) in August 1945. [66] After use as a reparations vessel, *Sakawa* was selected as a target ship for Operation Crossroads. *Sakawa* sailed to Bikini from Yokosuka in company with the battleship *Nagato.* Both vessels were readied for the tests at Bikini by a U.S. Navy repair ship. This work included removing the airplane catapults, torpedo tubes, 6-inch guns, and smaller gun mounts from the cruiser. [67]



Mangled by the Able detonation, *Sakawa* sinks by the stern on July 1. *(National Archives)*

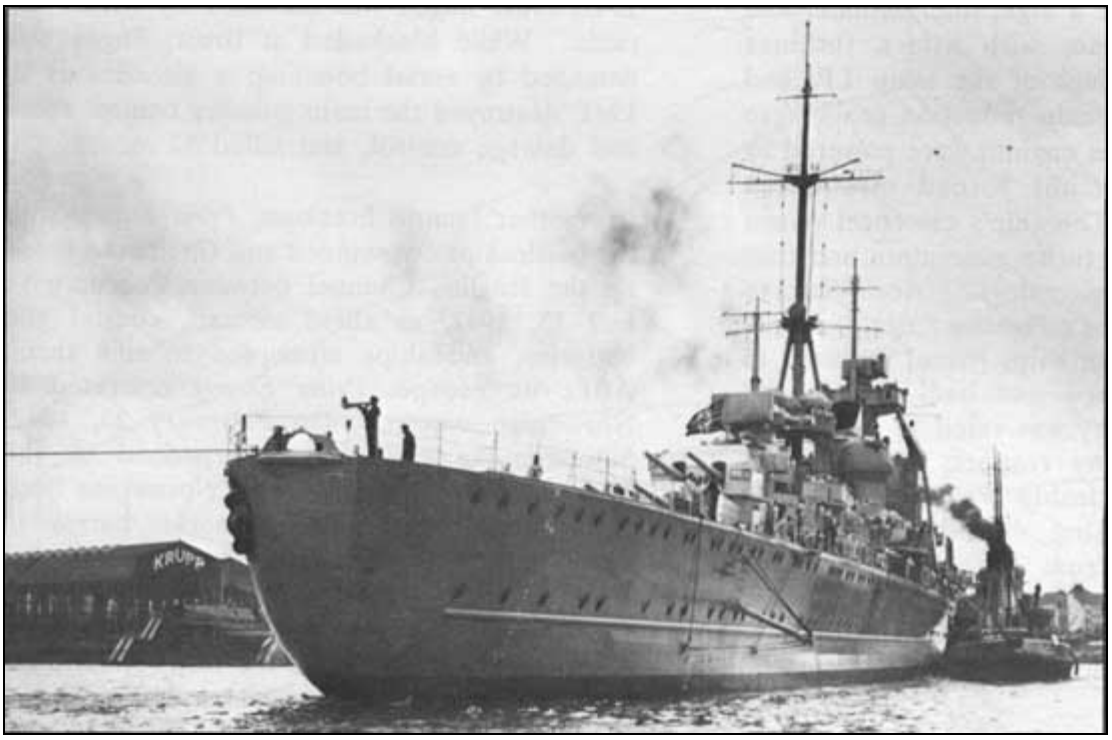
Sakawa was moored off the port quarter of *Nevada*. The actual detonation of the Able bomb took place some 490 yards above and slightly to starboard of *Sakawa*'s stern. Following the blast, observers noted that *Sakawa*'s superstructure and hull had suffered major damage. The superstructure aft of the bridge was smashed down, as was the stack, which collapsed forward. The mainmast toppled forward and to port until it overhung the side by one-third of its length. Reports also noted that "the tops of the after mounts were crushed. The tops of the forward mounts were dished in a fore and aft V having a two-foot maximum depression." [68] The worse damage, however, was to the hull. "The stern was most badly damaged.... Its deck plating was crushed inward and shell plating about the counter was twisted and torn open in several places. Shell plating on the starboard side...was badly wrinkled from approximately frame 145 aft." [69] Other damage included the dislodging of deck fittings, the smashing of the lifeboats, and a fire that broke out on the stern and raged for two hours. [70]

Immediately after the test *Sakawa*'s stern sank two feet. Through the night the stern continued to settle as the cruiser listed to port. Some 24 hours after the test, the ship lay on its port beam, half submerged, with the stern on the lagoon bottom. *Sakawa*'s bow sank beneath the lagoon surface at 10:43 a.m. on July 2. According to the U.S. Navy, "flooding unquestionably started when the *Sakawa*'s stern was ripped open to the sea by the blast....Poor watertight integrity...permitted progressive flooding. After 24.5 hours the main deck was awash. In the next hour rapid progressive flooding, probably due to poorly fitted and damaged hatches, vent trunks, and other fittings in the main deck, sent the *Sakawa* to the bottom." [71] At the time of sinking, the Navy tug *Achomawi* (ATT-148) had a line aboard *Sakawa* and was attempting to pull the ship from astern to shore; the cruiser was moved astern about 150 feet when it finally sank. The Navy was able to board and inspect the cruiser prior to sinking; "diving operations on this vessel were assigned low priority and eventually limited by a time factor to recovery of instruments. Hence no diver's report is available..." [72]

USS *PRINZ EUGEN* (IX-300)

Characteristics

Prinz Eugen was a welded-steel vessel incorporating substantial aluminum internal construction. It was 692 feet in length, with a 71.2-foot beam and a 24.8-foot draft, and displaced 19,553 tons standard. The vessel carried a complement of 830 crew. The armament consisted of eight 8-inch/55 caliber guns in four turrets; twelve 4.1-inch antiaircraft guns; twelve 21-inch torpedo tubes in triple deck mounts; six 40mm Bofors AA guns; eight .30 caliber guns in four twin mounts; and twenty-eight 20mm flak guns mounted as two quads and ten twins. *Prinz Eugen* carried three AR-196 spotter aircraft in a hangar between the stack and mainmast. The planes were launched from a single catapult and recovered by cranes on either side of the hangar. The ship was armored with 3.15-inch-thick vertical nickel steel side armor, with 2-inch armor on the bridge and 20mm of armor on the rangefinder positions. The turret barbettes were protected by 3.5-inch-thick steel armor; the turrets themselves were covered by two to six inches of armor. The vessel's three shafts were powered by geared steam turbines reportedly rated at 80,000 shaft horsepower at 32 knots. The three complete sets of main turbines consisted of a high, intermediate, and low pressure turbine, with astern turbines installed in the casings of the main I.P. and L.P. turbines. The main reduction gears were single reduction. The engines were powered by high pressure, Lamont forced circulation watertube boilers. The ship's electrical power was provided by six turbo generators and four diesel emergency generators. According to wartime issues of *Jane's Fighting Ships*, "internal arrangements of these ships [were] reported to be decidedly cramped and badly ventilated." *Prinz Eugen*'s capacity was rated at 1,049 crew by *Jane's*. In many respects, *Prinz Eugen* resembled the battleship *Bismarck*, its "big brother" and running mate: according to German officers from both, even trained observers had difficulty telling the two ships apart at a distance when their relative size could not be assessed. [73]



Prinz Eugen at the Krupp Yard in Kiel, circa 1939-1940. *(U.S. Naval Institute)*

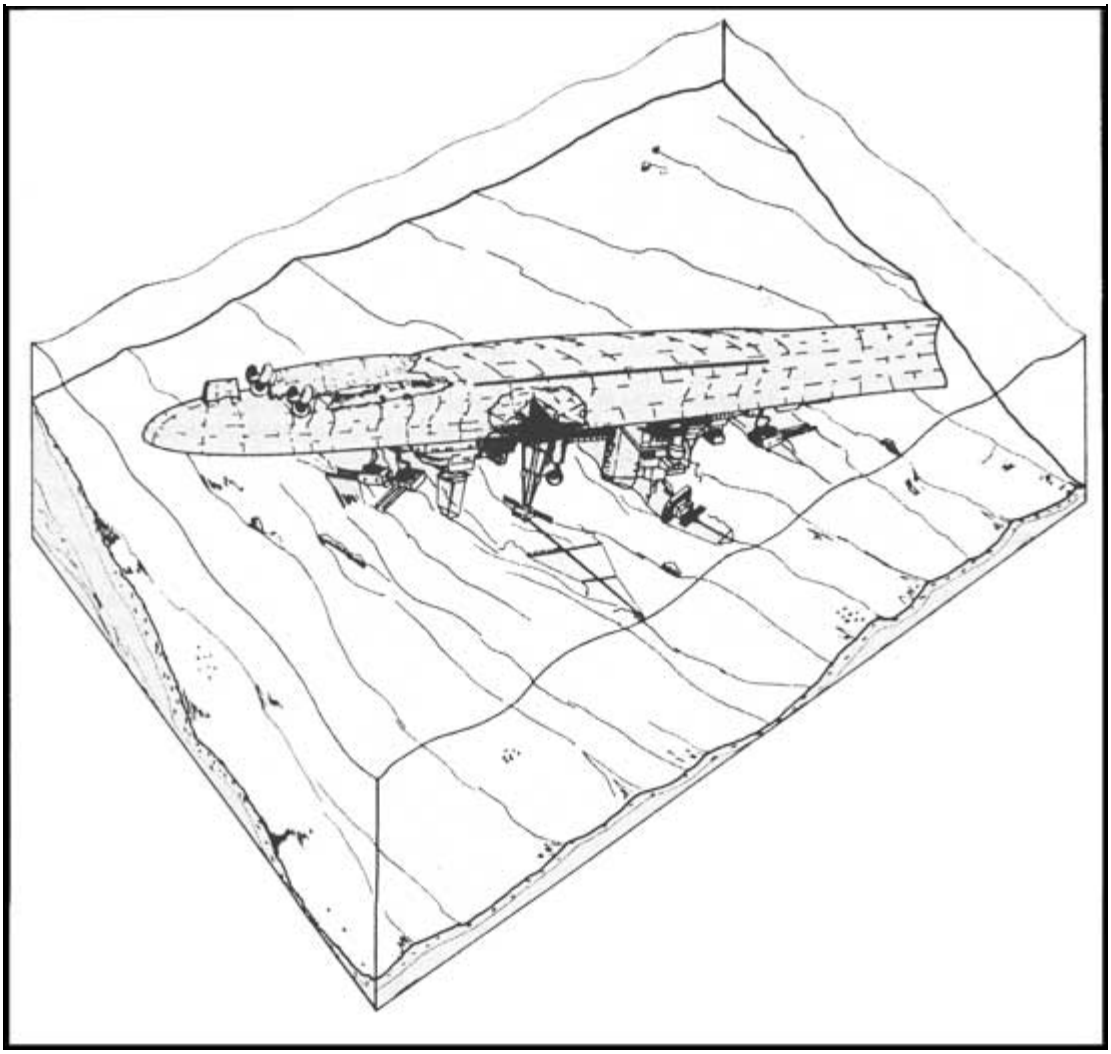
History

The heavy cruiser *Prinz Eugen* was built by Krupp at their Germania Werft shipyard in Kiel for the German Navy under the 1936 naval construction program. Laid down in 1936, *Prinz Eugen* was launched on August 20, 1938, in the presence of Adolf Hitler and Grossadmiral Erich Rader. The cruiser was christened by Madame Horthy, wife of the Hungarian dictator, Admiral Nicholas Horthy. [74] Second of four *Hipper* class heavy cruisers *(Admiral Hipper, Prinz Eugen, Seydlitz,* and *Lutzow), Eugen* was completed in 1940 and commissioned on August 1 of that year. Constructed principally for high seas commerce raiding, *Prinz Eugen* spent most of WWII blockaded in port. After shakedown exercises in the Baltic, the cruiser joined KMS *Bismarck* in Norway in May 1941. *Prinz Eugen* and the battleship made their famous breakout into the North Atlantic, where they engaged and sank the battle cruiser *Hood* on May 24; *Prinz Eugen*'s shells were credited with setting the British ship afire before a hit from *Bismarck* detonated *Hood*'s magazines. Prior to being met by a superior British task force that sank *Bismarck* after a running sea battle, *Prinz Eugen* escaped the battleship's fate by slipping away to the Azores. [75] Arriving at Brest, France, for sanctuary and an overhaul in June 1941, *Prinz Eugen* was harassed by British air raids. While blockaded at Brest, *Eugen* was damaged by aerial bombing; a hit on July 2, 1941, destroyed the main gunnery control room and damage control, and killed 52 men. [76]



Prinz Eugen at Philadelphia, March 1946. *(Floating Drydock)*

In another famous breakout, *Prinz Eugen,* with the battleships *Scharnhorst* and *Gneisenau* raced up the English Channel between February 11 and 13, 1942, as allied aircraft, coastal gun batteries, and ships attempted to sink them. After its escape, *Prinz Eugen* operated in Norwegian waters. On February 23, 1942, however, the cruiser was torpedoed by the British submarine *Trident* in a Norwegian fjord and lost its counter. After another harrowing run to Germany under attack by British planes, the ship was repaired and returned to service as a training ship on the Baltic in the summer of 1942. In October 1943 the ship rejoined the fleet as flagship of the German Baltic forces. In this capacity, the cruiser provided fire support for German troops and panzers in Lithuania and Latvia in 1944; *Prinz Eugen* spent the last months of the war on the Baltic coast, supporting ground forces retreating from the Russian advance, firing more than 5,000 rounds. Surrendered at the end of the European war on May 7, 1945, at Copenhagen, *Prinz Eugen* was taken by the United States as a prize of war. [77] Designated IX-300 as a special auxiliary, *Prinz Eugen* was taken to the United States for tests and analysis in January 1946, arriving at Boston on the 24th of the month. [78]



Artist's perspective of *Prinz Eugen* at Kwajalein, 1973. *(U.S. Navy, Supervisor of Salvage)*

Selected as a target vessel for Operation Crossroads, *Prinz Eugen* was readied at the Philadelphia Navy Yard in February-March 1946. This work involved removing two 8-inch gun barrels from turret "A" for additional evaluation. A fire control tower was also taken from the ship at this time. *Prinz Eugen* then proceeded to Bikini, arriving on June 11, 1946. There it was moored between two U.S. destroyers off the port quarter of USS *Arkansas*, 1,200 yards from the zeropoint. The vessel was not appreciably damaged in the Able test of July 1, 1946, nor in the Baker test three weeks later, when it was moored one mile off the detonation point, but was contaminated with radioactive fallout. The cruiser was towed to Kwajalein for decontamination along with several other vessels after the tests. The ship had a slight, but progressive leak, and on the morning of December 21, 1946, it was found listing and down by the stern. Boarding parties found the ship flooding rapidly from what was believed to be a failed sea valve. An attempt was made to beach the ship on Enubuj Island, but underpowered tugs and strong winds swung *Prinz Eugen* broadside to the beach, portside to shore, where the ship grounded offshore on a coral ledge at 5:00 p.m. During the night the flooding continued, with the list gradually reaching 35 degrees to starboard. At 12:43 in the morning of December 22, 1946, *Prinz Eugen* capsized and sank. [79] Subsequent dives on the ship found that technically the cruiser could be raised, but radiation hazards prohibited this action being practical. In 1973, the Department of the Interior requested that the Navy relinquish title to *Prinz Eugen* to allow scrapping of the ship to commence. A Navy team dove and documented the wreck, and reported in June 1974 that beta and gamma radiation could no longer be detected on *Eugen*, but that the vessel had suffered severe hull damage

amidships, was partially imbedded in the lagoon bottom, and required removal of residual fuel oil and ordnance before salvage operations could commence. [80] As a consequence, no action to remove the ship was taken.

USS *ANDERSON* (DD-411)

Characteristics

The *Sims*-class destroyer *Anderson* was a welded steel vessel with an overall length of 348.3 feet, a waterline length of 341.4 feet, a 36.1-foot beam, a 19.8-foot depth, and a 17.4-foot draft. *Anderson* displaced 1,720 tons standard. [81] The *Sims*-class destroyers were supposed to have been 1,570 tons; lack of communication between the Navy's Bureau of Construction and Repair and the Bureau of Engineering led to the overweight problem of the *Sims*-class. As a result of this and other problems, the two Bureaus were merged into a single organization, the Bureau of Ships, in 1940. [82] *Anderson*'s twin screws were driven by Westinghouse steam turbines and three oil-fired Babcock and Wilcox boilers, rated at 50,000 shaft horsepower at 35 knots. The Navy experimented with streamlining these vessels in an effort to improve speed and fuel consumption; a rounded bridge structure on the *Sims*-class produced less wind resistance and turbulence than previous classes. *Anderson*'s main battery comprised five 5-inch/38 caliber guns in single mounts. The ship carried twelve triple-mounted 21-inch torpedo tubes on deck. In mid-1941, four .50 caliber machine guns for AA use were installed. *Anderson* also mounted two depth charge racks aft. [83]

USS *Anderson*'s superstructure was badly damaged by the Able test burst; the stack toppled, and a fire started abaft the bridge. The fire subsided in a minute's time, then flared up as *Anderson* capsized to port. Once capsized, *Anderson* sank by the stern. Shortly after the Able event, Navy divers found the destroyer in 176 feet of water, lying on its port side, with the bow imbedded in the bottom and the stern lying 15 feet off the bottom. The damage that sank the ship was presumed to be on the port side; the starboard hull was wrinkled and "several seams...were leaking oil and air." [84] The worst damage noted was topside; the mainmast was stripped of fittings and the yardarm was snapped in half. Radar antenna and the stack were missing. The deckhouses were crumpled, the No. 2 gun shield split open, bulwarks on several superstructure decks were torn away, the torpedo crane was bent at a 90-degree angle, and the starboard "Y" depth charge launchers were ripped off the deck. [85] The Navy determined that blast damage and a post-blast fire and explosion sank *Anderson.* This was the only occasion during the tests that shipboard munitions detonated.

History

USS *Anderson* was the third of twelve *Sims*-class destroyers. The last of the American "single stackers," these vessels were the result of a 1935 request by the Chief of Naval Operations for a new design for destroyers. The U.S. Navy's General Board forwarded a proposal in May 1936 for a 1,570-ton ship with five 5-inch guns and twelve 21-inch torpedo tubes. [86] Twelve destroyers were built to the design, commencing with USS *Sims* (DD-409). Authorized in fiscal year 1937, the destroyers were built by different yards to a design by the noted New York firm of Gibbs and Cox. The *Sims*-class had robust hulls and were heavily armed; more significantly, these destroyers were the first to carry the newly developed Mark 37 fire control system, which introduced for the first time in a destroyer a computer room below decks--an innovation that proved highly successful in combat in WWII and was fitted to all major U.S. combatant vessels by 1945. [87]

Anderson was laid down in late 1938 at the Kearny, New Jersey, yard of the Federal Shipbuilding and Drydock Corporation (a subsidiary of U.S. Steel). The destroyer was

launched on February 4, 1939, and fitted out over the next few months. [88] *Anderson* was commissioned on May 19, 1939, and began a year-long program of tests and trials. Sent into the Pacific in 1940, *Anderson* spent a year as flagship of Destroyer Division 3 until sent back to the Atlantic in June 1941. There, the destroyer joined the other *Sims*-class vessels in Neutrality Patrol and convoy duties between Canada and Iceland. *Anderson* was part of the escort force for three convoys. Following the Japanese attack on the U.S. fleet at Pearl Harbor, *Anderson* returned to the Pacific in December 1941. The remainder of the ship's career was spent in the Pacific. [89]



Anderson, shown in a popular view that epitomized the prewar destroyer force. *(U.S. Naval Historical Center)*

Anderson served as part of the screening force for the Navy's carriers during the early, decisive battles in the Pacific. In May 1942, *Anderson* operated with Task Group 17 in the Coral Sea. This force moved against the Japanese, with *Anderson* screening the carrier *Lexington* (CV-2), sister of *Saratoga.* In the battle, the Japanese light carrier *Shoho* was sunk, along with *Lexington*, which succumbed to ruptured gasoline lines. Accumulating gasoline fumes ignited, setting off internal explosions that spread flames throughout the ship.

Anderson stood by to render assistance and rescued 377 men from the carrier, which was then sunk with a torpedo from the destroyer *Phelps* (DD-360). *Anderson* was recalled to Pearl Harbor, arriving on May 23, 1942, where it sortied with Task Force 17 for the Battle of Midway. TF 17 was grouped around the carrier *Yorktown* (CV-5), which had been damaged during and quickly repaired after the Battle of the Coral Sea. At Midway, *Yorktown* was the only American carrier located by the Japanese, who struck Task Force 17, bombing *Yorktown.* A second wave of planes again attacked as *Yorktown*'s crew got the fires under control; *Anderson* shot down one torpedo plane, but others got through and *Yorktown* was again hit, this time by two torpedoes. The destroyer managed to destroy four planes in the two attacks. *Anderson* moved in to pick up survivors as *Yorktown* was abandoned; 204 men were taken off by the destroyer. Damage control crews on *Yorktown* managed once again to keep the carrier afloat; however, a Japanese submarine launched two torpedoes that sank the carrier and the destroyer *Hammann* (DD-412), a sister ship of *Anderson*, which was

alongside. [90]

Always in the front lines, *Anderson* screened USS *Wasp* (CV-7), which was sunk by torpedo attack on September 15, 1942. The destroyer next screened USS *Hornet* (CV-8) at the Battles of the Eastern Solomons and Santa Cruz; in the latter battle (October 25-26, 1942) *Hornet* was lost. In both cases *Anderson* again moved towards the stricken carriers and rescued men; in all, the destroyer saved more than 1,000 crew members from the four carriers. The destroyer was shifted from screening duty to invasion support in November 1942; *Anderson* screened transports carrying reinforcements to Guadalcanal and shelled Japanese troops on the island. It then went on escort duty and anti-submarine patrols in the New Hebrides. In July-September 1943 *Anderson* served in the Aleutians, participating in the bombardment of the Japanese garrison on occupied Kiska. The destroyer then screened transports and provided fire support for troops invading Tarawa. *Anderson* then steamed to the Marshalls for the invasion of those heavily defended islands. The destroyer bombarded Wotje and screened vessels shelling Kwajalein. *Anderson* was hit by an enemy 155mm shell off Wotje, which killed the captain and five other officers and wounded 18 men. While transferring the wounded off ship, *Anderson* struck an uncharted pinnacle that badly damaged the destroyer, which was then towed to Pearl Harbor for repairs. [91]

After repairs, *Anderson* was deployed to assist the Sansapor, Morotai, and Leyte operations; at Leyte on November 1, 1944, the ship was again badly damaged when a kamikaze struck the deck, killing 18 and wounding 21 members of the crew. *Anderson* steamed to San Francisco for repairs at Hunter's Point. After these repairs and an overhaul, *Anderson* joined the 9th Fleet operating off the Kuriles on anti-submarine patrols and shore bombardment. *Anderson* ended the war by participating in the occupation of northern Honshu after the Japanese surrender. [92] The ship was ordered to the Atlantic for decommissioning. *Anderson* arrived at San Diego on November 8, en route to Philadelphia. On November 14, 1945, however, *Anderson* was ordered retained in the Pacific "in an inactive status in view of experimental tests." Selected as a target vessel for Operation Crossroads *Anderson* was "stripped in preparation for use as a target..." at Pearl Harbor between January and May 1946. [93]

Arriving at Bikini on May 30, 1946, in the company of the carrier *Saratoga*, *Anderson* was moored close to the actual zeropoint for the Able test on July 1, 1946. Following the burst, *Anderson* suffered two explosions within nine seconds' time. The ship capsized, while burning, onto its port side, and sank within seven minutes. [94] Ironically, the destroyer that had stood by and rendered assistance when *Lexington* went down, sank at Bikini with *Saratoga*, sister of the lost carrier.

Of 12 *Sims*-class destroyers, none survived past 1948; five were lost during the war, *Anderson* was sunk at Bikini in 1946, three were broken up in 1947, and three were sunk as targets in 1948. [95] *Anderson* was stricken from the Navy register on September 25, 1946. The ship's bell and nameplate were presented to the city of Anderson, South Carolina, by Congressional request. These had apparently been removed at Bikini and given to an Anderson, South Carolina, press representative on board USS *Appalachian.* [96]

USS *LAMSON* (DD-367)

Characteristics

USS *Lamson* was a welded steel destroyer of the *Mahan* class. *Lamson* was 341.3 feet long overall, with a waterline length of 334 feet, a 34.8-foot beam, a 9.9-foot draft, and a 1,726-ton displacement. [97] *Lamson*'s twin screws were driven by General Electric geared

turbines, which were powered by four Babcock and Wilcox, oil-burning, Express boilers. The ship's plant was rated at 46,000 shaft horsepower at 37 knots. Armament consisted of a main battery of five 5-inch/38 caliber guns and three quad 21-inch torpedo tubes mounted on deck. *Lamson* additionally carried four .50 caliber machine guns, two depth charge tracks, and "K"-type depth charge projectors. [98]

Loaded with 50 percent of its fuel and ammunition, *Lamson* was badly damaged by the Able test burst, which tore off the light topside superstructure, stacks, and mainmast, and badly smashed the bridge. The vessel capsized to starboard and sank (after floating bottom up) sometime between 2:00 p.m. and 5:00 p.m., five to eight hours after the blast. Divers found the ship resting on its starboard side; "the stern was lying in a hole which makes it appear that the ship went down stern first, pivoted around and ended up heading southwest on the bottom." [99] Navy reports made just after Able indicate that "the portion of the stern aft of frame 178 has twisted counterclockwise until the sheer strakes are separated about three feet. This rotation appears to pivot about the centerline of the deck." [100] A "large dent" was noted in the bottom shell plating extending from the port propeller guard to the centerline, with an 18-inch-deep "wrinkle" in the main deck plating at the stern, with another wrinkle "of varying depth and width in the port side shell plating. It is 2.5 feet deep and 18 inches wide at frame 170 and tapers to nothing at frame 130. The sheer strake appears crushed between frame 70 and 80." [101] The starboard side was not examined because the destroyer was lying on it.

Damage topside included the missing stacks and mainmast, "badly damaged" light superstructure, and the foremast, which was bent aft at a 90-degree angle. "At frame 70 a Z door and frame are blown out. The port side of the deckhouse aft of mount 2 is opened up top and bottom for a short distance fore and aft." [102] The guns remained in their mounts, "at maximum elevation," and the quad 21-inch torpedo tubes "are apparently intact. Only one torpedo is in the tubes and it is broken and hanging there." The depth charge racks "are twisted and torn almost beyond recognition," with "a large number of depth charges around the bottom aft. The special weapon NORD 5130 was not in its chocks on the stern and could not be located." [103]

History

Prior to World War II the United States focused considerable attention on destroyer design and construction; in 1922 it possessed the largest destroyer fleet in the world. [104] The basic pattern for prewar destroyers was set with the *Farragut* class destroyers of 1934; they were followed by larger "leader" destroyers of the *Porter* class of 1935-1936. The next class, and the first to introduce "extreme steam conditions" was the *Mahan* class. The *Mahan* destroyers incorporated prototypes of a new generation of destroyer machinery, which combined increases in pressure and steam temperature with a new type of lightweight, fast-running turbine." [105]





Lamson off Yorktown, Virginia, in April 1939. *(The Mariners Museum, Ted Stone Collection)*

Thus was introduced a class "whose long endurance was so important for Pacific warfare." [106] The *Mahan* class was also important in that additional above-the-waterline 21-inch torpedo tubes were added and gun crew shelters were built for the superimposed weapons fore and aft for the first time. [107] The *Mahan* destroyers were the first destroyers fitted with emergency diesel generators. Eighteen of these destroyers were built between 1935 and 1936, among them, *Lamson.*

Lamson was laid down on March 20, 1934, at the Bath Iron Works Corporation, Bath, Maine. The ship was launched on June 17, 1936, and was commissioned on October 21, 1936, at the Boston Navy Yard. After a shakedown cruise to South America, the destroyer proceeded through the Panama Canal on July 1 for the Pacific. For the entire month of July, *Lamson* searched the Marshall and Gilbert Islands for missing aviatrix Amelia Earhart. Returning to the United States, *Lamson* was based at San Diego for the next four years except for a one-month deployment on the East Coast in 1938. Ordered to Pearl Harbor in October 1941, *Lamson* was deployed with other vessels in an unsuccessful search for the Japanese Task Force on December 7-8, 1941. The destroyer was then detached and sent to Johnston Island to rescue civilians from the advancing Japanese. With refugees aboard, *Lamson* arrived at Pearl Harbor on January 3, 1942. [108]

In February 1942, *Lamson* was sent south to join the ANZAC squadron in Fiji. This six-vessel squadron (USS *Chicago,* USS *Perkins,* HMAS *Australia,* HMZNS *Achilles,* HMZNS *Leander,* and *Lamson),* was formed to keep South Pacific supply lines open. The destroyer was sent back to Pearl Harbor on June 1 to serve in the reserve line for the Battle of Midway. Detached from this unit on June 13, *Lamson* was sent to Mare Island Navy Yard for an overhaul before being deployed again to the South Pacific. On October 22, 1942, *Lamson* and sister ship *Mahan* raided Japanese picket boats between the Gilbert and Ellice Islands; together they sank a 7,000-ton armed auxiliary. After a month-long duty patrolling Guadalcanal, *Lamson* joined Task Force 67 and fought in the Battle of Tassafaranga and then patrolled the Solomon Islands as part of an antisubmarine warfare screen until April 1943. [109]

Returning to Pearl Harbor on May 6, 1943, *Lamson* was soon dispatched to Australia. The destroyer participated in the bombardment of New Britain and was one of four destroyers that penetrated Japanese lines some 160 miles to bombard the main Japanese naval base at Madang in New Guinea on November 29, 1943. As part of the U.S. Fifth Fleet, *Lamson* served off New Guinea and in the Marshall Islands through much of 1944. On October 20,

1944, *Lamson* was ordered to join the Seventh Fleet and proceeded to the Philippines. In December 1944, *Lamson* was deployed off Leyte as fighter director ship for small convoys going through the Surigao Straits to reinforce troops ashore. Attacked by kamikazes, these convoys were badly mauled. On December 6, 1944, *Lamson*'s sister ship *Mahan* was sunk at 11:00 a.m.; at 3:00 p.m., the convoy was again attacked. A kamikaze came in low from astern and hit *Lamson*'s after stack with its right wing before cartwheeling into the superstructure:

> The flame of the explosion reached to the top of the mast and flashed from stem to stern. 21 enlisted men and 4 officers were either killed instantly or died of wounds received, 1 man was missing and 54 men wounded. The superstructure from the forecastle deck up and both stacks were completely destroyed. The forward fireroom was flooded. A tug...attempted to put out the fires but it appeared hopeless, all remaining men aboard the *Lamson* were put aboard the tug. Just as the USS *Flusser*, which was standing by, prepared to sink the *Lamson* with torpedoes, the tug reported making headway against the fires and the ship was saved. [110]

Towed to safety, the destroyer received rudimentary repairs and proceeded under its own power to Pearl Harbor and then to Bremerton for repairs. *Lamson* made the trip with its torpedo tubes loaded "with enough torpedoes to sink a battleship" but jammed by the kamikaze attack. [111]



Marine Corps artist Grant Powers depicts the destruction of *Lamson* during Able. *(Naval Historical Center)*

After arriving at Bremerton on January 16, 1945, 90 percent of the ship's superstructure was removed and a new deckhouse was installed; "electrical repairs on the *Lamson* required four times more work than usually is required for a complete electrical overhaul.... Bomb fragmentation had pierced cables in remote places. More than 200 major circuits had to be

installed and 25 percent of the total battle damage repair fell to the electrical shop." [112] The destroyer steamed from Bremerton on April 15 for San Diego, and then quickly proceeded back to the Pacific. Stationed off Iwo Jima, *Lamson* spent the remainder of the war rescuing downed aviators who ditched while returning from striking the Japanese home islands. At the war's end, the destroyer was sent to Sasebo as part of the occupation force, departing for Pearl Harbor on October 29, and arriving there on November 9, 1945. *Lamson* was ordered retained in inactive status on November 15 "in view of experimental tests" and was sent to San Diego on November 29. [113] At year's end, the destroyer returned to Pearl Harbor, where it was prepared for Operation Crossroads.



The stern of the sunken *Lamson* after Able. *(U.S. Naval Institute)*

Lamson steamed from Pearl on May 21, 1946, for Bikini. The destroyer sailed with Submarine Division 111, made up of *Skipjack, Tuna, Skate,* and *Searaven,* also bound for Crossroads. On the afternoon of Thursday, May 30, 1946, *Lamson* arrived at Bikini and was anchored at "Berth 142" in 21 fathoms of water. According to the ship's log for June 30, 1946, the main engines were secured on 12 hours notice, the gyro was secured, and boiler No. 4 alone was lit for auxiliary purposes. That morning the crew was mustered, evacuated to USS *Henrico* (APA-45), and the last inspection of the ship was made. In the afternoon the fires were allowed to die under the No. 4 boiler, the engineering plant was secured, and condition "affirm" was set: "ship is secured throughout" before the last of the crew departed. The log reported on Monday, July 1, "Anchored as before. 0902 Bomb for Test 'ABLE' was detonated. 0930 *Lamson* was reported as capsized, with her keel in the air, as a result of the atom bomb detonation. In the early afternoon the *Lamson* rolled onto her port side and sank

stern first in 21 fathoms of water." [114]

Lamson was anchored approximately 700 yards abeam and slightly aft of the actual zeropoint for the Able bomb's detonation. Photos taken 12 seconds after the burst show the destroyer upright, but with heavy superstructure damage; a second photograph, taken nearly six minutes after the burst, shows the same. At 9:40 a.m. a reconnaissance plane, PBM Charlie, noted the destroyer was on its beam ends, "on her starboard side with her bridge structure underwater, and the port side of her bottom above the surface. A large oil slick...trailing to leeward." [115] *Lamson* remained afloat at least until 2:00 p.m., when PBM Charlie departed the lagoon; at 5:00 p.m., USS *Reclaimer* (ARS-42) made a quick tour of the lagoon and found "no trace of the *Lamson.*" [116] *Lamson* was decommissioned on July 29 and stricken from the Navy Register on August 15, 1946.

USS *APOGON* (SS-308)

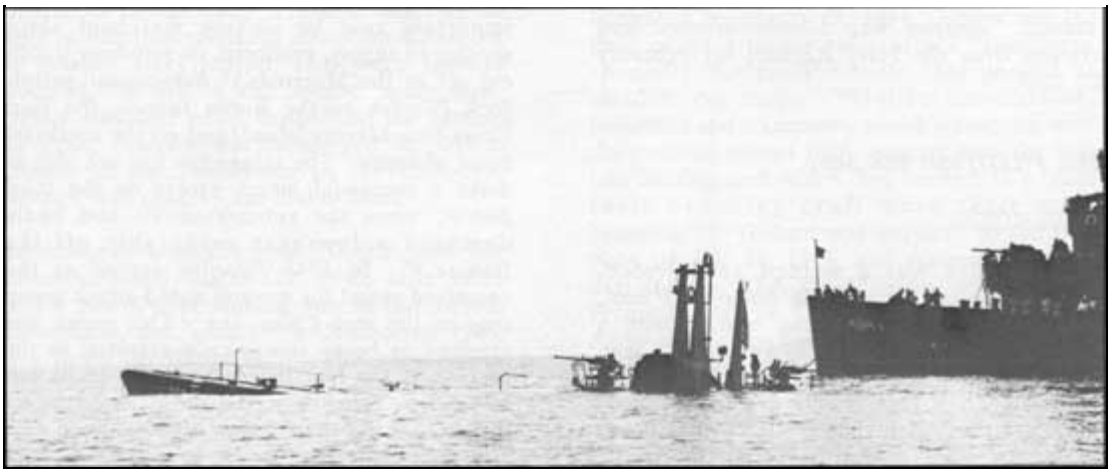
Characteristics

USS *Apogon* was a welded, riveted, and high-tensile *Balao*-class steel submarine--311.8 feet long overall, with a 27.3-foot extreme beam, a height of 47.2 feet, and a 15.3-foot draft at surface trim. *Apogon* displaced 1,525 tons standard surfaced and 2,424 tons submerged. [117] The boat's two shafts were driven by twin Elliot electric motors, each rated at 2,740 shaft horsepower for a total of 5,480 SHP. While surfaced, electricity was provided by four Fairbanks-Morse diesel engines, each rated at 5,400 brake horsepower. While submerged, *Apogon*'s motors were powered by 252 Exide battery cells. *Apogon* was capable of 20.25 knots surfaced and 8.75 knots submerged. [118] The boat's primary armament consisted of ten 21-inch torpedo tubes--six located forward and four aft. *Apogon* carried 24 Mark torpedoes. The boat also mounted a single 5-inch/25 caliber gun on deck; lighter AA guns were also fitted.

History

The United States Navy built hundreds of "fleet boat" submarines during the Second World War. One hundred thirty-two of the *Balao* class, the most common U.S. submarine of the war, were constructed at shipyards throughout the country. As part of this effort, beginning in 1940, an order was placed for 73 Gato-class vessels, "in response to the realization that the U.S. would probably become involved in the current war." [119] Longer, tougher, and with more endurance, the *Gatos* were supplemented after Pearl Harbor by an order for 132 near-identical *Balao*-class submarines. The *Balaos* were slightly reconfigured for prefabrication and were built with a higher tensile steel that extended their diving depth 100 feet beyond the *Gato* boats' 300-foot operating limit.





Apogon surfaces after a test submergence at Bikini, 1946 *(U.S. Naval Institute)*

Of these submarines, all 73 *Gato* and 101 of the *Balao* boats saw combat, all of it in the Pacific. [120] These boats waged a terrible war of attrition against Japan's navy and merchant marine, particularly the latter. U.S. submarines sank most of Japan's merchant fleet, crippling the industrial capabilities of the empire and forcing the abandonment of far-flung outposts.

USS *Abadejo* (SS-308) was laid down at the Portsmouth Navy Yard in 1942. Renamed *Apogon* on September 24 of the same year, the submarine was launched March 10, 1943. After fitting out, *Apogon* was commissioned on July 16, 1943, and proceeded to the Pacific. [121] The boat made eight war patrols, sinking three Japanese vessels totalling 7,575 tons. *Apogon*'s first patrol was out of Pearl Harbor on November 3, 1943. In later patrols, the submarine sortied from Majuro and Midway. *Apogon* was one of ten submarines deployed for Operation Galvanic in November 1943. In this coordinated action, a carrier task force, amphibious landing force, and the submarines worked together to invade Tarawa and the Gilbert Islands and prevent a Japanese counterstrike. *Apogon* and two additional submarines were stationed at the entrance to Truk, the Japanese naval stronghold, in order to attack Japanese ships attempting a sortie to the Gilberts. One of the boats, USS *Corvina* (SS-226), was lost in the operation, but *Apogon* escaped without harm. [122] Not long after this, the sub scored its first kill on December 4, 1943, when *Daido Maru,* a former gunboat of 889 tons, was sunk north of the Marshalls. [123] In February 1944, U.S. carrier aircraft pounded the Japanese fleet anchored in Truk Lagoon as part of Operation Hailstone. Following this highly successful action, a second strike at Saipan was orchestrated with a pack of four submarines, including *Apogon,* surrounding the area. The raid was a success, and submarines sank six ships escaping from Saipan. In June 1944, *Apogon* sailed with three other boats, *Guardfish* (SS-217), *Piranha (SS-389),* and *Thresher* (SS-200) in a wolf-pack known as the "Mickey Finns." Working off Formosa, the wolf-pack sank 41,000 tons of Japanese shipping, but *Apogon* did not get a kill. [124] The boat's next sinking was on September 27, 1944, when the 1,999-ton freighter *Hachirogata Maru* was torpedoed. [125]

Apogon played an important role in coordinating attack information with the other boats as had been done when the sub was a member of the "Mickey Finns." [126] *Apogon*'s last kill came in June 1945 as the submarines blockaded Japanese ports and commenced finishing off the rapidly diminishing merchant marine of the nearly defeated nation. North of the Kuriles, *Apogon* ambushed the 2,614-ton transport *Hakuai Maru* on June 18, sending it to the bottom. [127] *Apogon* returned from its last patrol on September 2, 1945.

Consigned to the Operation Crossroads tests, *Apogon* arrived at San Diego on September 11, 1945. There the boat was readied for the tests. One of eight submarines selected for

Crossroads, *Apogon* was modified to submerge and surface without a crew on board. According to *Bombs at Bikini*, "never before had there been occasion to submerge a submarine without crew aboard. The method used was to fill part of the ballast tanks with water, then suspend heavy weights from the bow and stern by cables of carefully chosen length. These weights overcame the submarine's residual buoyancy and drew her down to the desired depth. She could be surfaced again by pumping air back into her ballast tanks." [128]

Lightly damaged during Able, *Apogon* sank during Baker. Shortly after sinking, Navy divers located the submarine in 180 feet of water, entered the boat, and began salvage operations, which included blowing air into the flooded hulk. The salvage efforts were abandoned, however, before the boat was brought to the surface. *Apogon* was decommissioned and stricken from the Navy Register on February 25, 1947. [129]

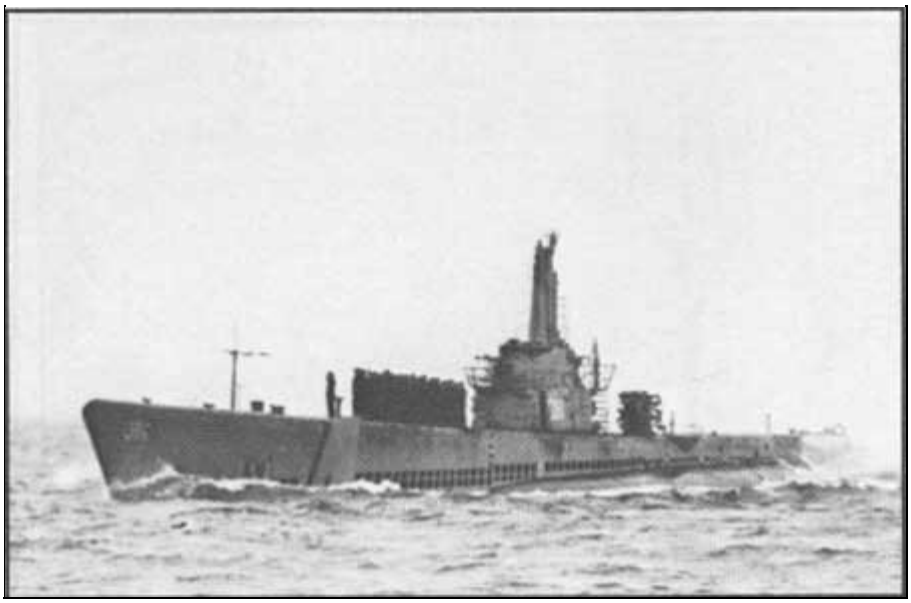
USS *PILOTFISH* (SS-386)

Characteristics

USS *Pilotfish* was a welded and riveted, high-tensile-steel submersible *Balao*-class boat. *Pilotfish* was 311.8 feet long overall, with a 27.3-foot extreme beam, a height of 47.2 feet, and a 15.3-foot draft at surface trim. *Pilotfish* displaced 1,525 tons standard when surfaced and 2,424 tons when submerged. [130] The boat's two shafts were driven by twin GE electric motors, each rated at 2,740 shaft horsepower, for a total of 5,480 SHP. While submerged, *Pilotfish*'s motors were powered by 252 Exide battery cells. *Pilotfish* was capable of 20.25 knots surfaced and 8.75 knots submerged. [131] The boat's primary armament consisted of ten 21-inch torpedo tubes; six tubes were located forward and four tubes aft. *Pilotfish* carried 24 Mark 14 torpedoes. As built, the boat carried a 5-inch/25 caliber gun on the deck aft of the sail and a single 40mm Bofors antiaircraft gun forward of the sail. When sunk at Operation Crossroads, *Pilotfish* had been modified to a late-war configuration; the 5-inch gun had been removed, and twin 20mm Oerlikon AA guns had been mounted aft of the periscope shears on the sail.

History

USS *Pilotfish* (SS-386) was laid down at the Portsmouth Navy Yard, New Hampshire, on March 15, 1943. The submarine was launched August 30, 1943. After fitting out, *Pilotfish* was commissioned December 16, 1943, and proceeded to the Pacific after training on March 29, 1944, arriving at Pearl Harbor on April 26. [132] At this time submarines were deployed in wolf-packs, and on its first patrol, *Pilotfish* was sent out with the pack known as "Blair's Blasters," which included *Pintado* and *Shark* under tactical command of Capt. L. N. Blair of *Pintado*. [133] The boat made five war patrols, beginning the first, to the Marianas, in May 1944. (By this time, the Pacific war had turned against Japan. Submarines played an important role by sinking merchant ships seeking to supply, reinforce, or withdraw troops cut off in the Marianas.) Subsequent patrols took *Pilotfish* to the Bonin Islands, the East China Sea, Marcus Island, and off the southeast coast of Japan. The submarine was not able to make a successful attack except on the third patrol, when the submarine hit and badly damaged a Japanese cargo ship off the Bonins. [134] In 1945 *Pilotfish* served as the command vessel for a coordinated-attack group sent to the east China Sea. This group was credited as being strategically essential to the success of the Iwo Jima assault. [135] In its last war patrol, *Pilotfish* served on lifeguard picket duty off the Japanese home islands, armed with AA guns and standing by to rescue downed airmen returning from the bombing of Japan. [136]



Pilotfish enters San Francisco Bay in November 1945. *(U.S. Naval Institute)*

After provisioning at Guam, *Pilotfish* departed for its sixth war patrol on August 9, 1945. Taking up position off Japan, the submarine was ordered to cease hostile action on August 15 when the Japanese surrendered. After cruising off Kii Suido on lifeguard duty and neutrality patrol, *Pilotfish* was ordered to stand in to Tokyo Bay as part of the fleet making the formal occupation of Japan. With 11 other submarines, *Pilotfish* was present, moored alongside the submarine tender *Proteus* (AS-19), during the formal surrender ceremonies on September 2, 1945. [137] Departing Japan on September 3, *Pilotfish* arrived at Pearl Harbor on the 12th. From there the sub was sent to San Francisco for lay-up after 18 months' duty in the Pacific, with 313 days and 75,075 miles of war patrols. [138] After arrival in the United States, the submarine was consigned to Operation Crossroads. *Pilotfish* was one of eight submarines originally slated for scrapping or reserve fleet lay-up, that were instead modified for use in the atomic bomb tests. Lightly scorched while moored on the surface for Able, *Pilotfish* was submerged for Baker. Closest of the submarines to the zeropoint, *Pilotfish* was sunk by the Baker blast.

According to some accounts, *Pilotfish*, although decommissioned August 29, 1946, little more than a month after sinking, was in fact raised, towed away, and "resunk" on October 16, 1948, as a target off Eniwetok. [139] This report is in error; Navy records indicate the ship was "expended" at Bikini on July 25, 1946, decommissioned on August 29, 1946, and stricken from the Navy list on February 28, 1947. [140] *Pilotfish* lies on the bottom of the lagoon at its mooring for the Baker test.

USS *GILLIAM* (APA-57)

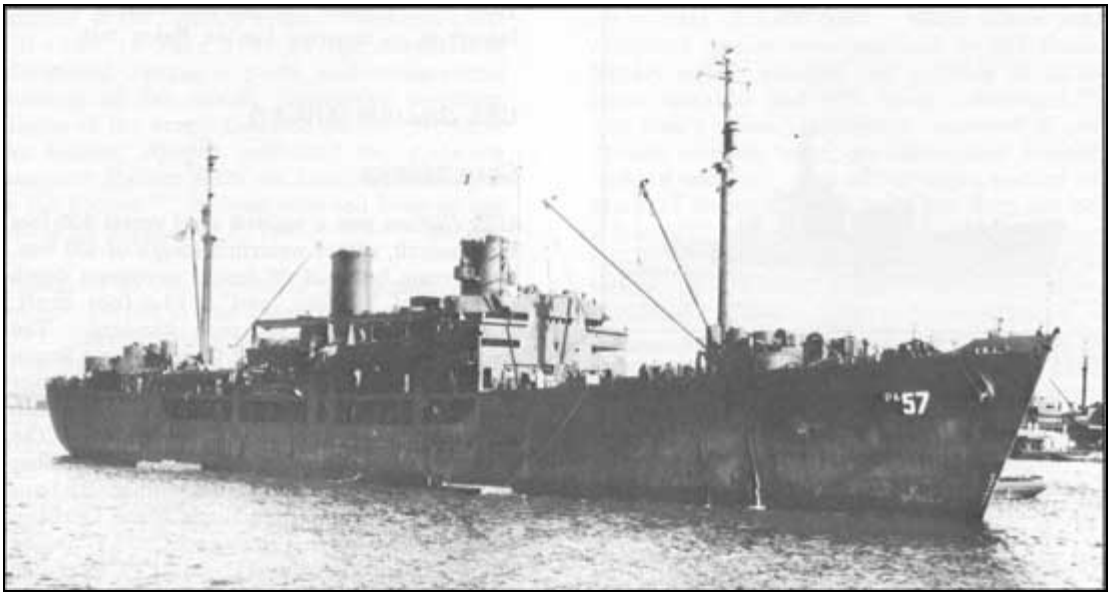
Characteristics

USS *Gilliam* was a welded steel vessel 426 feet long overall, with a waterline length of 400 feet, an extreme beam of 58 feet, a maximum depth of hold of 37 feet, and a 15.6-foot draft. *Gilliam* displaced 6,800 tons standard. The twin screws were driven by Westinghouse Steam Turbines that developed 6,000 shaft horsepower at 18 knots. Steam was provided by two oil-burning Babcock and Wilcox boilers. The vessel was armed with a single 5-inch/38 caliber gun, four twin-mounted 40mm Bofors antiaircraft guns, and ten single 20mm Oerlikon guns. *Gilliam* carried thirteen LCVPs (Landing Craft Vehicles, Personnel), one LCPL (Landing

Craft Personnel, Large), and 1,032 tons of cargo or 849 troops. [141] The superstructure was located in the center of the ship; two masts, one forward and one aft, were fitted with booms and steam winches that handled cargo and the ship's landing craft.

History

USS *Gilliam*, a type S4-SE2-BU1 transport, was built under a U.S. Maritime Commission contract in 1944 by the Consolidated Steel Corporation of Wilmington, California. [142] Launched on March 28, 1944, *Gilliam* was the first of 32 *Gilliam*-class attack transports, specially designed vessels that served as amphibious ships. "Unlike conventional freighters and transports, attack transports were designed to unload their cargoes over the side into landing craft which they carried; in a sense their beaching craft were their main batteries." [143] *Gilliam* was acquired by the U.S. Navy on July 31, 1944, and commissioned the next day as APA-57. *Gilliam* departed San Francisco Bay on October 16, 1944, with 750 Army troops bound for New Guinea. *Gilliam* ferried troops to the Philippines in support of the reconquest of those islands and served as a receiving ship for crews and injured personnel of damaged or lost warships during the Battle of Leyte Gulf. *Gilliam* also participated in the assault on Okinawa. At the war's end the transport carried occupation troops to Sasebo, Japan, and ferried returning troops home as part of Operation "Magic Carpet." [144]



Gilliam in 1946. The transport was identical to the 31 other ships of the *Gilliam* class, including *Carlisle*. *(U.S. Naval Institute)*

Gilliam was selected as a target vessel for Operation Crossroads. Arriving at Pearl Harbor on February 16, 1946, the ship was readied for the tests. [145] *Gilliam* was moored aft of *Nevada*, the projected target for the Able test detonation. The bomb instead detonated off *Nevada* and close to *Gilliam*, "the *only* ship located within 1,000 feet of the projected zeropoint." [146] The vessel sank in less than two minutes.

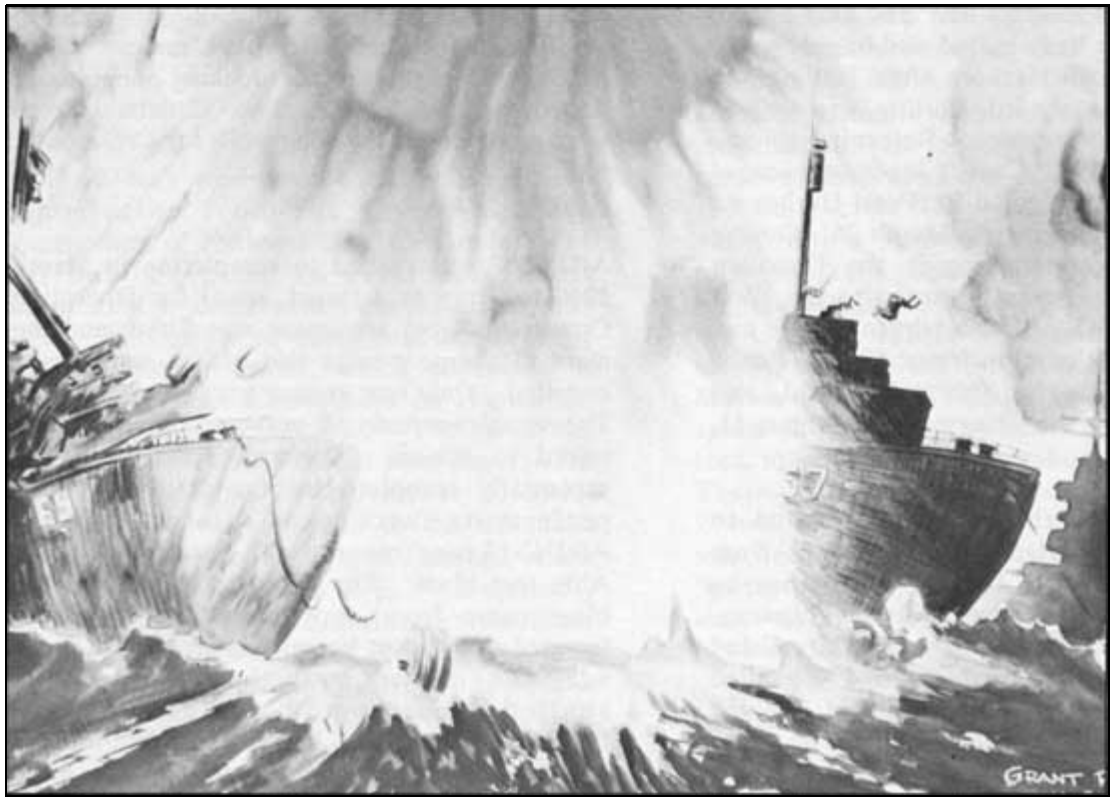
USS *CARLISLE* (APA-69)

Characteristics

USS *Carlisle* was a welded steel vessel 426 feet long overall, with a waterline length of 400 feet, an extreme beam of 58 feet, a maximum depth of hold of 37 feet, and a 15.6-foot draft.

Carlisle displaced 6,800 tons standard. The twin screws were driven by two Westinghouse steam turbines that developed 6,000 shaft horsepower at 18 knots. Steam was provided by two oil-burning Babcock and Wilcox boilers.

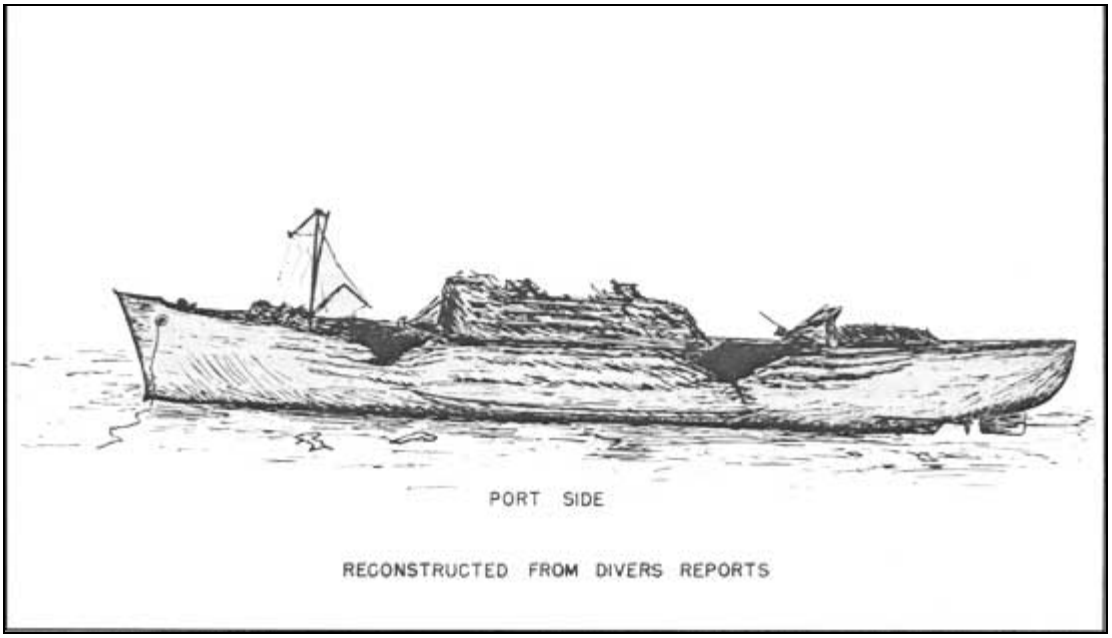
The vessel was armed with a single 5-inch/38 caliber gun, four twin-mounted 40mm Bofors antiaircraft guns, and ten single 20mm Oerlikon guns. *Carlisle* carried thirteen LCVPs, one LCPL, and 1,032 tons of cargo or 849 troops. [147] The ship's superstructure was located amidships; two masts, fore and aft, were fitted with booms and steam winches to handle landing craft and cargo.



Grant Powers' depiction of Able's detonation over *Gilliam* and *Carlisle*. *(U.S. Naval Historical Center)*

History

USS *Carlisle*, a type S4-SE2-BU1 transport, was built under a U.S. Maritime Commission contract by the Consolidated Steel Corporation of Wilmington, California. [148] *Carlisle* was one of 32 *Gilliam*-class attack transports. [149] The keel was laid on May 12, 1944; *Carlisle* was launched little more than two months later on July 30. Named for Carlisle County, Kentucky, the vessel was completed and acquired by the U.S. Navy on November 28, 1944. [150] It was commissioned the next day at Terminal Island, Los Angeles. After provisioning, outfitting, and some alterations at San Pedro, the ship underwent a shakedown cruise in December 1944. First sent to San Diego for amphibious landing training, the transport was finally ordered to Pearl Harbor on January 23, 1945, arriving there on January 31. The ship's main propulsion motor had shorted and burned while underway to Pearl Harbor; after landing the troops and cargo aboard, *Carlisle* was sent to San Francisco for repairs. Returning to San Diego in March 1945, *Carlisle* loaded personnel and cargo and again sailed for Pearl Harbor on March 17, 1945, arriving on March 26. *Carlisle* was used for crew training in the Hawaiian Islands before the vessel returned to the West Coast in June 1945. After a trip to Seattle and San Francisco, the ship returned to Pearl, where it was sent to Eniwetok, Ulithi, and Samar, arriving at the latter port on August 11, 1945. [151]



Artist's 1946 drawing of the sunken *Carlisle. (National Archives)*>

At the war's end the ship was detailed to "Magic Carpet" service, carrying troops from the Philippines, Pearl Harbor, and Japan to Seattle and San Francisco. In this capacity, *Carlisle* had loaded 44 officers and 92 enlisted men at Tokyo, and on January 26, 1946, sailed for Seattle. Four days later, while at sea, the ship was ordered to Pearl Harbor for assignment to Joint Task Force One for Operation Crossroads. Arriving at Pearl on February 4, the ship was "stripped" during that month before sailing to Bikini Atoll as one of eighteen attack transports slated for the tests. [152] Moored close to *Gilliam*, *Carlisle* was sunk by the Able test burst on July 1, 1946. USS *Carlisle* was stricken from the Navy Register on August 15, 1946.

ARDC-13

Characteristics

The floating drydock ARDC-13 (Auxiliary Repair Drydock, Concrete) was built of steel-reinforced concrete with a lift capacity of 2,800 tons. The dock's overall length was 389 feet, with an 84-foot width, and a height of 40 feet. The dock floated with a 9-foot, 6-inch draft. The dock was built of three sections; (1) the 5-3/4-inch to 6-inch thick slabs that formed the hull, which consisted of the side, bottom, and dock floor; (2) the 5-1/2-inch-thick port; and (3) the starboard wing walls, each containing a 5-inch-thick intermediate and 6-1/2-inch-thick top deck. The vessel was further reinforced by concrete transverse frames every six feet. The hull was divided into eight watertight compartments, four on each side, in addition to fore and after peak tanks. [153] The ARDC was capable of drydocking submarines, destroyers, and LSTs. Two Christmas trees were mounted on the wing walls for Crossroads.

History

ARDC-13 was rushed to completion in March 1946 to serve as a target vessel for Operation Crossroads. No armament was fitted, and the main discharge pumps and cranes were never installed. Only one anchor windlass was fitted. The vessel was only 60 percent complete

when towed to Bikini. "Otherwise, the dock was essentially complete insofar as required to perform its function as a target ship." [154] ARDC-13 was moored off *Saratoga* for the Able test blast. The pressure wave from the blast came from approximately 12 degrees forward of the port beam; this cracked the port wingwall, carried away the control house, spalled concrete and strained the hull "sufficiently to open hairline cracks, for the most part, throughout the length of the dock. A few of the cracks are well defined." [155] Beached on Enyu where temporary repairs were effected, ARDC-13 was remoored in the array for Baker. Refloated and moored in the target array for Baker, ARDC-13 was damaged by the detonation, but remained afloat. It was not inspected until eight days after Baker. At that time, "slow leakage was observed through cracks in the underwater body which had resulted from Test A. The rate of flooding was calculated to be approximately 30 percent of that which was observed before temporary repairs.... Two days later the dock capsized as a result of progressive flooding of the port side compartments." [156] After capsizing, ARDC-13 remained afloat, with its starboard side up, until sunk by demolition charges on August 6, 1946.

YO-160

Characteristics

YO-160 (Yard Oiler) was a steel-reinforced concrete barge, 375-feet long overall, with a 56-foot beam and a 28.6-foot draft. The barge displaced 6,422 tons, and was registered at 5,426 tons gross and 5,295 tons net. The barge's capacity was 62,900 cubic barrels of fuel oil. [157]

History

YO-160 was ordered by the Maritime Commission from the Concrete Ship Constructors of National City, California. The hull was converted to naval use almost immediately as construction proceeded in May 1943. The completed barge was acquired by the 11th Naval District, which purchased it from the Maritime Commission on August 31, 1943, at a cost of $2,900,000. [158] The barge was towed to Pearl Harbor by the fleet tug *Tawasa* (ATF-92), arriving on November 5, 1943. There YO-160 was assigned to the advanced bases in the Pacific, arriving at Funafuti in the Ellice Islands in December 1943. [159] Presumably the barge spent its entire wartime career there before being ordered to Bikini Atoll to participate in Operation Crossroads in March 1946.

Heavily damaged during Able, YO-160 was sunk by the Baker test blast; Navy reports credit the descending water column as the probable cause. Photographs of the blast taken from Enyu show the barge's bow lifted some 36 feet by the blast wave. [160] Subsequent photographs show the water column covering the vessel. When the air cleared, YO-160 was no longer afloat. No dives were made. The vessel was stricken from the Navy Register on August 15, 1946. [161]

LCT-414, 812, 1114, 1175, 1187, and 1237

Characteristics

The LCT (Landing Craft, Tank) was a welded steel "light but extremely rugged vessel designed for direct 'on-the-beach' loading and unloading....Equipped with a bow ramp...the bottom is especially designed for 'beaching'....docking facilities are not required." [162] These standardized craft were 117.5 feet long overall, with a beam of 32 feet, and a light draft of 1.5 feet forward. The loaded draft was 3.75 feet forward. LCTs displaced 134 tons

light and 286 tons loaded and could carry 150 tons of cargo; this could be four medium or three heavy tanks. The LCT came in several models: the target LCTs were Mark 5 and Mark 6 versions. The latter was an improved design that permitted stern loading and had increased living accommodations. One purpose of the Mark 6 modification was to serve as links in floating causeways between LSTs (Landing Ships, Tank) and the shore. They had a detachable stern plate, "with a lip beneath it for the LST ramp to engage;...the superstructure was split in half to permit vehicles to run the entire length of the craft." [163] LCTs were propelled by three screws, each driven by a single 225 HP Gray Marine diesel engine that developed a maximum speed of 9 knots. The fuel capacity was 11.12 tons in addition to 140 gallons of lube oil. [164] These craft were usually armed with two single 20mm antiaircraft guns. According to a wartime manual, the LCT was often seen "transported on LSTs or in sections on APAs and AKAs. They are the largest of the U.S. open-deck, bow-ramp types." [165]

History

The LCT was the largest of all U.S. shipborne amphibious warfare craft and the smallest U.S. landing craft to receive numbers in their own right. [166] LCTs were the result of a November 1941 British request for a U.S. version of a tank lighter for a projected European invasion. The first LCT was completed on June 29, 1942; the last wartime-built LCT was finished on December 22, 1944. In all, five hundred LCTs, Mark 5 models were built, along with 965 Mark 6 LCTs. [167]

LCT-1114 was a late-model Mark 6 unit. The vessel was one of ten LCTs requisitioned for Operation Crossroads and placed in the target array. LCT-1114 capsized as a result of the Baker test detonation and the resulting wave of water. After the blast, it was observed floating bottom up, bow ramp secured, with the "stern awash and the bow four feet out of the water" next to ARDC-13. [168] LCT-1114 remained afloat for four days, gradually drifting in a westerly direction "until it was finally sunk off Amen Island with a demolition charge to prevent it from becoming a menace to navigation." [169]

Similarly, the other LCTs were sunk in the days after the Baker test as hazards to navigation. A total of 18 vessels were beached off Bikini Island during the Baker test; among them were six LCTs: the Mark 5 LCT-412, and five Mark 6 LCTs--Nos. 812, 1175, 1187, and 1237, which were beached between the high and low tide mark on the lagoon side of the island. LCT-1187 and LCT-1237 "suffered major flooding as a result of apparent bottom damage due to pounding against coral ledges and working in the surf." [170] They were also displaced by wave action. LCT-812 suffered major damage, with its bow ramp torn free and missing after the test; both it and LCT-412 became waterborne "as a direct result of the waves which immediately followed the test...." [171]

Post-Baker inspection of LCT-1187 found that

> the tanks from about midships aft were completely flooded. The manhole cover plate to the void below the forward starboard wing tank deckhouse was not secured in place. This void was flooded. The galley was flooded to a depth of two feet from water coming in over the stern.... This craft was slightly above radiological tolerance when boarded on 1 August 1946. [172]

After the Baker detonation, LCT-1237 was displaced about 20 feet along the beach and swung around parallel to the water's edge.

> This craft was leaking badly before the test and by Baker day the engine room were completely flooded. The tanks just forward of the crew's quarters was completely flooded. The tanks just aft of the forward stowage compartments

contained about one foot of water. The after end of the galley contained 1-1/2 feet of water. The sounding hole covers were missing from the flooded tanks. Indications are that much of the tank flooding was due to waves washing over the vehicle deck, but leaky propeller shaft glands probably caused flooding of the engine space. [173]

NOTES

[1]Rear Admiral George R. Rock, USN, "Some Observations on the Design of Airplane Carriers and Notes on the *Saratoga* and *Lexington," Transactions of the Society of Naval Architects and Marine Engineers,* Vol. XXXVIII (New York: Society of Naval Architects and Marine Engineers, 1928), p. 64.

[2]Roger Chesnau, ed. *Conway's All the World's Fighting Ships, 1922-1946* (New York: Mayflower Books, 1980), p. 101. Also see the specifications for *Saratoga* in the contract book, contract No. 199, *Saratoga,* in the New York Shipbuilding Corporation Collection, Philadelphia Maritime Museum, Philadelphia, and the official ship's characteristics card on file at the Ships History Branch, Naval Historical Center.

[3]Rock, "Some Observations on the Design of Airplane Carriers," p. 64.

[4]*Ibid.,* p. 69. Also see Lieut. Commander J. T. Alexander, USN, "Trial Trip Data of the USS. *Saratoga," Transactions of the Society of Naval Architects and Marine Engineers,* Vol. XXXVII (New York: Society of Naval Architects and Marine Engineers, 1929), p. 201.

[5]Norman Friedman, *U.S. Aircraft Carriers: An Illustrated Design History* (Annapolis: Naval Institute Press, 1983), p. 48. Hereafter cited as Friedman, *Aircraft Carriers.*

[6]*Ibid.,* p. 51. Also see *Saratoga,* War Damage Report, Final report, Torpedo Damage, 11 January 1942, no serial, Box 615, and *Saratoga,* War Damage Report, 21 September 1942, serial 0120, World War II Action Reports, Operational Archives, Naval Historical Center.

[7]Friedman, *Aircraft Carriers,* pp. 53-54.

[8]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group Technical Inspection Report, USS *Saratoga* (CV3), Test Able, Operation Crossroads," p. 14. National Archives Record Group 374, Records of the Defense Atomic Support Agency, National Archives. Hereafter cited as "Technical Inspection Report, *Saratoga,* Test Able;" the identical report, from Test Baker, will be similarly cited.

[9]Navy Department Press Release, March 20, 1925. On file at Ships History Branch, U.S. Naval Historical Center. Also see Chesnau, *Conway's All the World's Fighting Ships,* p. 101.

[10]Richard Humble, *U.S. Fleet Carriers of World War II,* (Poole: Blanford Press, 1984), pp. 18-19. Hereafter cited as Humble, *Fleet Carriers.* Also see Harold and Margaret Sprout, *Toward a New Order of Sea Power: American Naval Policy and the World Scene, 1918-1922* (Princeton, New Jersey: Princeton University Press, 1940), pp. 230-235.

[11]E. H. Rigg, "The Launch of the Airplane Carrier USS. *Saratoga," Transactions of the Society of Naval Architects and Marine Engineers,* Vol. XXXIII (New York: Society of Naval Architects and Marine Engineers, 1925), p. 148.

[12]Launch program, USS *Saratoga,* April 7, 1925. Original copy on file, Ships History Branch, Naval Historical Center. The same quote may also be found in the Philadelphia *Evening Star,* March 21, 1925.

[13]Mooney, *Dictionary of American Naval Fighting Ships,* Vol. VI, p. 339.

[14]Humble, *Fleet Carriers,* p. 21.

[15]Philadelphia *Evening Star,* March 21, 1921.

[16]As quoted in Friedman, *Aircraft Carriers,* p. 49.

[17]Humble, *Fleet Carriers,* p. 21.

[18]*Ibid.,* p. 27.

[19]Mooney, *Dictionary of American Naval Fighting Ships,* Vol. VI, p. 340.

[20]Humble, *Fleet Carriers,* p. 27.

[21]William F. Halsey and Joseph Bryan III, *Admiral Halsey's Story* (New York: McGraw-Hill, 1947), p. 62.

[22]Mooney, *Dictionary of American Naval Fighting Ships,* Vol. VI, p. 340.

[23]*Ibid.,* pp. 340-341.

[24]Cited in Ships Section, Office of Public Information, Navy Department, "History of USS *Saratoga* (CV-3)," (August 29, 1946), p. 5. Copy on file in Ships History Branch, Naval Historical Center. Hereafter cited as Ship Section, "History of USS *Saratoga."*

[25]Mooney, *Dictionary of American Naval Fighting Ships,* Vol. VI, p. 341.

[26]*Ibid.,* p. 341. Also see Navy Department Press Release, June 15, 1945, "The 'SARA's' Luck Runs Out," on file at Ships' History Branch, Naval Historical Center. Also see a reminiscent account by an officer, Irwin Patch, Jr., "USS *Saratoga* at Iwo Jima," *Shipmate,* Volume LII, No. 5 (June 1989), pp. 20-22. *Shipmate* is the magazine of the United States Naval Academy Alumni Association. A detailed report on the action and the damage suffered is found in *Saratoga* report, serial 007 of 21 February 1945, Box 616, World War II Action Reports, Operational Archives, Naval Historical Center.

[27]Ships Section, "History of USS *Saratoga,"* p. 10.

[28]*Ibid.*

[29]Commander, Joint Task Force One, "Report on Atomic Bomb Tests Able and Baker (Operation Crossroads) Conducted at Bikini Atoll, Marshall Islands, 1 July 1946 and 25 July 1946," Vol. 1, Chapter VII, p. 7. Copy on file at Operational Archives, Naval Historical Center.

[30]Shurcliff, "Technical History," Vol. II, p. 6.5.

[31]Director of Ship Material, "Technical Inspection Report, *Saratoga*, Test Able," p. 7.

[32]Shurcliff, "Technical History," p. 6.12.

[33]Director of Ship Material, "Technical Inspection Report, *Saratoga*, Test Baker," p. 8.

[34]Hanson W. Baldwin, dispatch of 22:02 to *The New York Times*, July 25, 1946, from on board USS *Appalachian.* Press Dispatches, July 25, 1946, from nos. 2534 to 2644, National Archives Record Group 374, Records of the Defense Atomic Support Agency.

[35]Ship's characteristics card, Ships History Branch, Naval Historical Center.

[36]Chesnau, *Conway's All the World's Fighting Ships,* p. 91 and *Jane's Fighting Ships, 1920* (London: Sampson Low, Marston & Co., Ltd., 1920), p. 187. Also see the original contract specifications for Contract No. 97, *Arkansas*, in the New York Shipbuilding Corporation Collection, Philadelphia Maritime Museum, Philadelphia, and the ship's characteristics card, Ships History Branch, Naval Historical Center, Washington, D.C.

[37]*Jane's Fighting Ships, 1935* (New York: D. Van Nostrand Company, Inc., 1935), p. 492, and Chesnau, *Conway's All the World's Fighting Ships,* p. 91.

[38]*Jane's Fighting Ships, 1944-45,* Corrected to April 1946 (New York: The MacMillan Company, 1947), p. 458, and Chesnau, *Conway's All the World's Fighting Ships,* p. 91.

[39]*Ibid.*

[40]Contract Data, USS *Arkansas* (BB-33), New York Shipbuilding Corporation Collection, Philadelphia Maritime Museum; also see James L. Mooney, *Dictionary of American Naval Fighting Ships,* p. 62.

[41]*Ibid.*

[42]*Ibid.*

[43]*Ibid.*

[44]Shurcliff, *Bombs at Bikini,* p. 134.

[45]*Ibid.*, p. 164. I am indebted to Charles Haberlein, Curator of Photographs, Naval Historical Center, who conducted a detailed analysis of the Baker Blast photographs and spotted the mast in the blast column.

[46]Hansgeorg Jentschura, Dieter Jung, and Peter Mickel, *Warships of the Imperial Japanese Navy, 1869-1945* (Annapolis: Naval Institute Press, 1986), p. 28.

[47]*Ibid.*

[48]U.S. Division of Naval Intelligence, ONI-221-J (June 1945).

[49]*Janes Fighting Ships,* 1945, n.p.

[50]Jentschura, Jung and Mickel, *Warships of the Imperial Japanese Navy,* p. 28; also see Stephen Howarth, *The Fighting Ships of the Rising Sun: The Drama of the Imperial Japanese Navy, 1895-1945* (New York: Atheneum, 1983), p. 134.

[51]Hiroyuki Agawa, *The Reluctant Admiral: Yamamoto and the Imperial Navy,* trans. John Bester (Tokyo and New York: Kodansha International Ltd., 1979), pp. 200-201.

[52]Gordon W. Prange, Donald M. Goldstein, and Katherine V. Dillon, *At Dawn We Slept; The Untold Story of Pearl Harbor* (New York: McGraw-Hill Book Company, 1982), pp. 503-504.

[53]Agawa, *The Reluctant Admiral: Yamamoto and the Imperial Navy,* pp. 269-270.

[54]Gordon W. Prange, Donald M. Goldstein, and Katherine V. Dillon, *Miracle at Midway* (New York: McGraw-Hill Book Company, 1983); also see Mitsuo Fuchida and Masatake Okumiya, *Midway: The Battle that Doomed Japan, The Japanese Navy's Story* (Annapolis, Maryland: United States Naval Institute Press, 1955).

[55]Masanori Ito and Roger Pineau, *The End of the Imperial Japanese Navy* (New York: Jove Books, 1986), pp. 93-110, *passim.*

[56]*Ibid.,* p. 181.

[57]*Ibid.,* pp. 198-205, *passim.*

[58]Samuel Eliot Morison, *History of United States Naval Operations in World War II,* Volume XIV: Victory in the Pacific, 1945 (Boston: Little, Brown and Company, 1975), p. 316.

[59]Certificate of Commendation on file at the USS *Arizona* Memorial, Honolulu, Hawaii.

[60]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group, Technical Inspection Report, *Nagato* (Ex-Jap BB), Test Able, Operation Crossroads," pp. 105-106. National Archives Record Group 374.

[61]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group, Technical Inspection Report, *Nagato* (Ex-Jap BB), Test Baker, Operation Crossroads," p. 6.

[62]Ito and Pineau, *The End of the Imperial Japanese Navy,* p. 1.

[63]Jentschura, Jung, and Mickel, *Warships of the Imperial Japanese Navy, 1869-1945,* p. 111. Also see ONI-221-J and *Jane's Fighting Ships, 1944-45,* Corrected to April, 1946 (New York: The MacMillan Company, 1947), p. 307.

[64]*Ibid.*

[65]Jentschura, Jung, and Mickel, *Warships of the Imperial Japanese Navy,* p. 112.

[66]*Ibid.*

[67]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group, Technical Inspection Report, *Sakawa* (Ex-Jap CL), Test Able," p. 9. National Archives Record Group 374.

[68]*Ibid.*, p. 6.

[69]*Ibid.*, pp. 5-6.

[70]*Ibid.*, pp. 6-7.

[71]*Ibid.*, p. 5.

[72]*Ibid.*, p. 8.

[73]The ship's specifications are found in a circa January 1946 document, "A Short Historical Sketch of the *Prinz Eugen'* IX-300," with "General Statements Involving the Ship's Characteristics," Serial 10-00C, Operational Archives, U.S. Naval Historical Center. Additionally, statements regarding the ship are found in *Jane's Fighting Ships* for 1941-1946, though these entries are not completely reliable. Also Director of Ship Material, Joint Task Force One, "Bureau of Ships Group, Technical Inspection Report, *Prinz Eugen* (Ex-German CA), Test Able," p. 3. National Archives Record Group 374.

[74]Paul S. Schmalenbach and Commander James E. Wise, Jr., USN, *Prinz Eugen* Album," U.S. Naval Institute *Proceedings* (August 1969). Also see "A Short Historical Sketch..." Mr. Schmalenbach was a member of *Prinz Eugen*'s German crew throughout its career and accompanied the vessel to the United States. He and the other German members of the crew left the ship at San Diego before it steamed for Pearl Harbor and Bikini.

[75]*Ibid.*

[76]*Ibid.*

[77]*Ibid.;* also see *"Prinz Eugen," Our Navy,* July 1969, p. 7.

[78]Schmalenbach and Wise, *Prinz Eugen* Album;" also see Mooney, *Dictionary of American Naval Fighting Ships,* p. 388.

[79]Captain George L. Dickey, Jr. USN, "The End of the *Prinz,"* U.S. Naval Institute *Proceedings,* August 1969, pp. 149-151. Capt. Dickey, then a young officer, was in charge of the attempt to beach *Prinz Eugen* at Kwajalein.

[80]Battelle, Inc. "Summary Report on Salvage Survey of *Prinz Eugen,* Supsalv Report No. 6-74, to US Navy, Supervisor of Salvage, Naval Ships System Command," (June 1974), manuscript on file in the ship's history file, Ships History Branch, Naval Historical Center.

[81]Chesnau, *Conway's All the World's Fighting Ships,* p. 127. Also see the ship's characteristics card, Ships History Branch, Naval Historical Center, p. 127.

[82]*Ibid.* Also see Norman Friedman, U.S. *Destroyers: An Illustrated History* (Annapolis: Naval Institute Press, 1983), p. 93. Hereafter cited as Friedman, *Destroyers.*

[83]Chesnau, *Conway's All the World's Fighting Ships,* p. 127.

[84]Director of Ship Material, Joint Task Force One, "Bureau of Ships Report, Technical Inspection Report, USS *Anderson* (DD411), Test Able," pp. 5, 9. National Archives Record

Group 374.

[85]*Ibid.*, pp. 5-6.

[86]Chesnau, *Conway's All the World's Fighting Ships*, p. 127.

[87]Friedman, *Destroyers*, p. 93.

[88]"History of USS *Anderson* (DD 411)," (May 26, 1948), Ships History Branch, Naval Historical Center.

[89]*Ibid.*

[90]*Ibid.;* also see *Anderson*, Action Report, Battle of Midway, June 5, 1942, Serial 0109, Operational Archives, Naval Historical Center; and Robert Cressman, *That Gallant Ship: USS Yorktown (CV-5)* (Missoula, Montana: Pictorial Histories, 1985), pp. 158-160.

[91]"History of USS *Anderson."*

[92]*Ibid.*

[93]Ship's service record, Ships History Branch, Naval Historical Center.

[94]Director of Ship Material, "Technical Inspection Report, USS *Anderson*, Test Able," pp. 8-9. Also see Shurcliff, *Bombs at Bikini*, p. 131.

[95]Chesnau, *Conway's All the World's Fighting Ships*, p. 127.

[96]Memorandum, H. C. Bruton, Administrative Aide to CNO to Vice Admiral Carpender, June 17, 1946. On file in *Anderson*'s jacket, Ships History Branch, Naval Historical Center.

[97]Ship's characteristics card, Ships History Branch, U.S. Naval Historical Center.

[98]*Ibid.* Also see Friedman, *Destroyers*, p. 405.

[99]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group, Technical Inspection Report, USS *Lamson* (DD367), Test Able, Operation Crossroads," pp. 8-9. National Archives Record Group 374.

[100]*Ibid.*, p. 5.

[101]*Ibid.*, p. 6.

[102]*Ibid.*

[103]*Ibid.*

[104]Chesnau, *Conway's All the World's Fighting Ships*, p. 125.

[105]Friedman, *Destroyers*, p. 88.

106

Chesnau, *Conway's All the World's Fighting Ships,* p. 126.

[107]*Ibid.*

[108]"Battle History of the USS *Lamson* (DD367), 21 October 1936 till 1 October 1945," (October 1945), typescript, Ships History Branch, Naval Historical Center.

[109]*Ibid.*

[110]*Ibid.*, also see "Commander John V. Noel, Jr, USN, Awarded Bronze Star Medal," (October 31, 1945), press release, Navy Department, *Lamson* file, Ships History Branch, Naval Historical Center, and Capt. John V. Noel, Jr. USN (Ret.) "Homeward Bound," *Shipmate,* May 1984, pp. 17-18.

[111]Seattle *Star,* June 19, 1945 and Baltimore *Sun,* June 19, 1945.

[112]"The USS *Haraden* and USS *Lamson* Go Back to War," (June 18, 1945) press release, Navy Department, *Lamson* file, Ships History Branch, Naval Historical Center.

[113]Ship's service record, USS *Lamson,* Ships History Branch.

[114]Log Book, USS *Lamson,* entries for May 30, June 30, and July 1, 1946. National Archives Record Group 45.

[115]Director of Ship Material, "Technical Inspection Report, USS *Lamson,* p. 8.

[116]*Ibid.*

[117]Ship's characteristics card, Ships History Branch, Naval Historical Center.

[118]*Ibid.*

[119]Robert C. Stern, *U.S. Subs in Action* (Carrollton, Texas: Squadron/Signal Publications, 1983), p. 34.

[120]*Ibid.*

[121]"History of USS *Apogon* (SS-308), (1945), Ships History Branch, Naval Historical Center. Also see ship's service record, also on file at Ships History Branch.

[122]Theodore Roscoe, *United States Submarine Operations in World War II* (Annapolis: United States Naval Institute, 1949), pp. 285-286, 288.

[123]*Ibid.*, p. 527; also see "History of USS *Apogon."*

[124]Roscoe, *United States Submarine Operations in World War II,* p. 343.

[125]*Ibid.*, p. 527.

[126]*Ibid.*, p. 364.

127

Ibid., pp. 478, 527.

[128]Shurcliff, *Bombs at Bikini,* p. 147; also see plate 17, caption, between pp. 118-119.

[129]John D. Alden, *The Fleet Submarine in the U.S. Navy: A Design and Construction History* (Annapolis: Naval Institute Press, 1979), p. 260.

[130]Chesnau, *Conway's All the World's Fighting Ships,* p. 145. Also see the ship's characteristics card on file at the Ships History Branch, Naval Historical Center.

[131]*Ibid.*

[132]Mooney, *Dictionary of American Naval Fighting Ships,* Vol. V, p. 308.

[133]Roscoe, *United States Submarine Operations in World War II,* p. 341.

[134]Mooney, *Dictionary of American Naval Fighting Ships,* p. 309.

[135]*Ibid.*

[136]*Ibid.*

[137]Roscoe, *United States Submarine Operations in World War II,* p. 491.

[138]Mooney, *Dictionary of American Fighting Ships,* Vol. 5, p. 308-309.

[139]Alden, *The Fleet Submarine in the US. Navy,* p. 268. Also see Chesnau, *Conway's All the World's Fighting Ships,* p. 145; and Mooney, *Dictionary of American Fighting Ships,* Vol. V, p. 308.

[140]Characteristics card for USS *Pilotfish,* Naval Historical Center.

[141]Chesnau, *Conway's All the World's Fighting Ships,* p. 160.

[142]Mooney, *Dictionary of American Fighting Ships,* Vol. V, p. 308.

[143]Chesnau, *Conway's All the World's Fighting Ships,* p. 160.

[144]Mooney, *Dictionary of American Fighting Ships,* Vol III, p. 97.

[145]*Ibid.*, p. 97.

[146]Shurcliff, *Bombs at Bikini,* p. 130.

[147]Chesnau, *Conway's All the World's Fighting Ships,* p. 160.

[148]Ship's characteristics card, Ships History Branch, U.S. Naval Historical Center, Washington, D.C.

[149]Chesnau, *Conway's All the World's Fighting Ships,* p. 160.

[150]Ship's service record, USS *Carlisle*, Ships History Branch, Naval Historical Center. Also see "Ship's History: USS *Carlisle* (APA-69)," (April 1, 1946) Ships History Branch, Naval Historical Center, and Mooney, *Dictionary of American Naval Fighting Ships*, Vol. 1, p. 36.

[151]*Ibid.*

[152]*Ibid.*

[153]Director of Ship Material, Joint Task Force One, "Bureau of Ships Group. Technical Inspection Report, USS ARDC-13, Test Able, Operation Crossroads," p. 13, National Archives Record Group 374.

[154]*Ibid.*

[155]*Ibid.*, p. 7.

[156]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS ARDC-13, Test Baker, Operation Crossroads," p. 3, National Archives Record Group 374.

[157]Ship's characteristics card and service record, Ships Histories Branch, Naval Historical Center.

[158]*Ibid.*

[159]*Ibid.* Funafuti is the capitol of Tuvalu (formerly the Ellice Islands), and lies at 8.30 S - 179.12 E between the Gilberts and Samoa in the South Pacific.

[160]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS YO-160, Test Baker, Operation Crossroads," p. 5, National Archives Record Group 374.

[161]Ship's characteristics card and service record, Ships History Branch, Naval Historical Center.

[162]War Shipping Administration and Maritime Commission, *U.S. Army and U.S. Navy Floating Equipment, Landing Craft and Misc. Vessels, For Sale* (Washington, D.C.: War Shipping Administration, n.d. [ca. 1955]) n.p. entry for LCTs.

[163]Chesnau, *Conway's All the World's Fighting Ships*, p. 163.

[164]War Shipping Administration, *U.S. Army and U.S. Navy Floating Equipment*, n.p.

[165]U.S. Division of Naval Intelligence, *ONI-54 Series: U.S. Naval Vessels* (Washington, D.C.: U.S. Navy, 1943) n.p., section on landing craft. This work has now been reprinted, with an introduction by A. D. Baker III, as *US Naval Vessels, 1943* (Annapolis: Naval Institute Press, 1986).

[166]Chesnau, *Conway's All the World's Fighting Ships*, p. 163.

[167]*Ibid.* Also see Major L. F. Ellis, C. R. G. Allen, A. E. Warhurst, and Sir James Robb, *Victory in the West: Volume I: The Battle of Normandy* (London: Her Majesty's Stationary

Office, 1962), pp. 511-512 for a discussion on the development of the LCT.

[168]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS LCTs 705, 816, 818, 874, 1013, 1078, 1112, 1113, 1114, 1115, Test Baker, Operation Crossroads," p. 170, National Archives Record Group 374.

[169]*Ibid.*, p. 172.

[170]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, Beached Landing Craft, Test Baker, Operation Crossroads," p. 3, National Archives Record Group 374.

[171]*Ibid.*, p. 4.

[172]*Ibid.*, pp. 10-11.

[173]*Ibid.*, p. 11.

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National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER FOUR: SITE DESCRIPTIONS

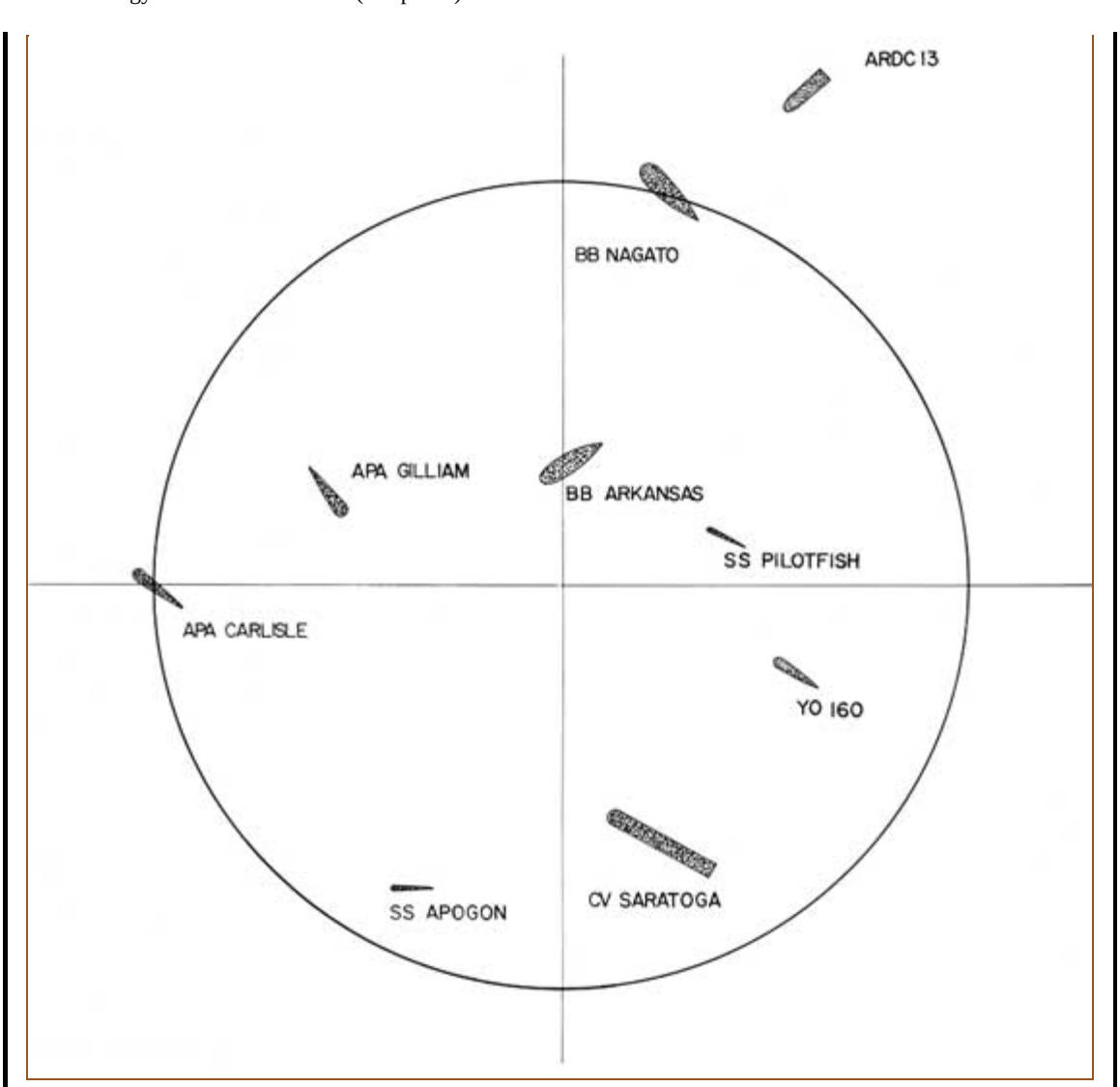
James P. Delgado and Larry E. Murphy

INTRODUCTION

During two field sessions at Bikini and Kwajalein, eleven shipwrecks from the Able and Baker tests were surveyed. The results include graphics, photographs, and narrative site descriptions included in this report, as well as several hours of video footage. Time spent underwater on each site was limited by both field session lengths and diving constraints. Most dives were decompression dives between 100 and 180 feet in depth. Typically, two dives were done each day, and in the two sessions which cumulatively totalled four weeks, there were 24 diving days.

In addition to site descriptions, which are the principal archeological fieldwork products, we evaluated the Bikini wrecks in terms of site formation processes. Rather than emphasizing the unique nature of wreck events caused by an atomic blast, we take the position that whatever the agency of destruction, ships are damaged and sunk by forces governed by physical processes that are repetitive, often quantifiable, and that ultimately may be predictable. In addition to describing the target ships and evaluating their current condition as the result of a unique set of historical circumstances that may never be repeated, we present the analysis in terms that may be useful for comparisons with other wreck processes. A comparative approach is taken for those ships sunk by the same blast, between categories of ships and between ships sunk by the two blasts. The site descriptions pay particular attention to variables of ship class, proximity, and orientation to the blast, pre-blast vessel condition and alterations. We have also included contemporary observations from immediate post-blast vessel evaluations as a control for natural deterioration resulting from submersion for nearly 45 years.





Actual positions of the sunken ships at Bikini, as plotted by the U.S. Navy, 1989. *(Redrawn by Robbyn Jackson, HABS/HAER) (click on image for a PDF version)*

This particular approach incorporates into the site description some of the remarkable amount of quantified data collected by the numerous test-instrument arrays. The Able test included 5,000 pressure gauges, 25,000 radiation-measuring instruments, 750 cameras, and four television transmitters within and around the target array. [1] Eighty percent of the instruments were recovered after each test from the sunken test ships. [2] These data, recently declassified, offer a rare chance to observe structural hull damage that can be attributed to measured peak-pressure waves of known duration. These observations provide a comparison against which other wreck processes, whether conventional explosives or natural effects, can be measured for steel-hulled shipwrecks.

The discussions in this chapter follow the categorical sequence of Pre-Test Alterations, Immediate Post-Blast Observations, and 1989/90 Site Descriptions. Pre-Test Alterations includes the recorded changes to each vessel in preparation for Operation Crossroads. In order to make the atomic test reliable, the vessels had to be in good repair. Most test vessels were recent combat veterans and required some repairs. Post-Blast Observations, like Pre-Test Alterations, are derived from historical records. This section presents both surface observations of each ship's sinking and underwater observations made by divers examining the wrecks shortly after each blast. Apparently there were two diving evaluations made by the Navy, one soon after the blast and another a year later. Unfortunately, with the exception of

Saratoga, most of the detailed descriptions of the 1947 dives on these vessels are not available; only general descriptions were microfiched, the rest are missing from the archival record.

Two target vessels were lost in shallow water inside Kwajalein Atoll lagoon. The German cruiser *Prinz Eugen* and an infantry landing craft, LCI-327, were lost to capsizing or grounding and left in place. All but nine of the other target vessels not sunk in Bikini Lagoon were scuttled in deep water. This leaves a group of 21 wrecks associated with Operation Crossroads accessible to divers at Bikini and Kwajalein atolls. Nine were dived and assessed during two field seasons by the NPS; two others were ROV dived by the Navy and subsequently assessed by the NPS.

This Site Descriptions section contains the 1989 and 1990 fieldwork observations as well as observations made by divers and through use of surface-monitored Remote Operated Vehicles. Each site discussion is a composite drawn from direct observations, video, photographic and field illustrations. The amount of time spent on each site was variable, which is reflected in the amount of detail in each site discussion.

RECONSTRUCTING THE NUCLEAR DETONATIONS

The "nominal yield" of the two plutonium, implosion-core Mk III "Fat Man" bombs detonated during Operation Crossroads has been variously estimated in secondary source histories to have been between 20 to 23 kilotons, or a force equal to 20,000 to 23,000 tons of TNT. The formerly classified official analysis of the "Able" detonation of July 1, 1946, noted that one measuring technique indicated that the bomb's yield was 19.1 kilotons. [3] The "Baker" detonation of July 25, 1946, was noted to have yielded approximately 20.3 kilotons, described as a "normal" yield for "an atomic bomb of the Nagasaki type." [4]

The Able Detonation

The proximity (VT) fuze of the "Able" bomb was set for an altitude of 515 feet over the ocean surface. Even though the bomb missed the intended target ship, USS *Nevada*, by 710 yards, it detonated close to the set altitude, at 518 feet, 50 yards off, and slightly to starboard, of USS *Gilliam.* [5]

The firing of the weapon caused the fissionable material in the bomb to become supercritical, and a self-sustaining chain reaction was initiated. The fission process released the energy equivalent to approximately 20 kilotons of TNT before the bomb was quickly blown apart and fission was no longer possible. A luminous mass known as the "ball of fire" was formed. The ball of fire emitted thermal radiation that started fires as far away as 3,700 yards. [6] The thermal radiation accounted for 35 percent of the total energy released in the detonation. The ball of fire continued to expand, touching the water, as vapor from the detonation formed a reddish-brown cloud rich in nitrous acid and nitrogen oxide, which climbed at a rate of 200 miles per hour. At 0.5 seconds after the detonation, the fireball was nearly 1,500 feet in diameter.

Immediately after detonation, a high-pressure wave was created that swept about 750 feet ahead of the fireball. This "blast wave" with its shock front, accounted for 50 percent of the total energy released by the bomb. At 1.25 seconds, the shock front had moved out more than a third of a mile, and had struck the lagoon surface. This created a reflected shock wave that travelled up to collide with the initial shock wave, fusing with it to form a single, reinforced "mach effect" front that generated up to 16-pounds-per-square-inch peak overpressure. [7] The mach front continued to grow, so that three seconds after detonation, it was nearly a mile

from the zeropoint and 185 feet high, creating winds at the front of 165 miles per hour. [8]

Ten seconds after detonation, the mach front was 2.5 miles from the zeropoint, moving at 40 mph with a peak overpressure of one psi. The blast effect of the bomb at this time was effectively over, as the hot, gaseous ball of fire rose, drawing up air and producing strong air currents, or "afterwinds" that sucked up water and debris to form the stem of the characteristic "mushroom cloud." [9] Only 30 seconds after detonation, the cloud was about a mile and a half high. Ten minutes after detonation, the water sucked up into the cloud or vaporized by the ball of fire was released when a light, radioactive rain fell.

Apart from the initial release of nuclear radiation, which accounted for five percent of the total energy expended, residual radiation near the point of detonation was reported to be minimal, which was attributed to the carrying up by the afterwinds of the radioactive materials into the cloud and their distribution into a diffuse, light fallout that did not, for the most part, land on the target fleet.

1946 "Able" Damage Assessments

A summary of damage to the target ships was prepared by Joint Task Force One. The following discussion is drawn from that document and not from the archeological record prepared by the NPS.

The worse damage was done to ships within a thousand-yard radius of the zeropoint. Five ships were sunk: *Gilliam* (50 yards from the zeropoint); *Sakawa* (420 yards); *Carlisle* (430 yards); *Anderson* (600 yards); and *Lamson* (760 yards). Additionally, six other target vessels were "immobilized" by blast damage, and another eight suffered "short- or long-term serious loss of military efficiency" by having their boilers, radio, or radar and fire control systems disabled. These were *Skate* (400 yards); YO-160 (520 yards); *Independence* (560 yards); *Crittenden* (595 yards); *Nevada* (615 yards); *Arkansas* (620 yards); *Pensacola* (710 yards); ARDC-13 (825 yards); *Dawson* (855 yards); *Salt Lake City* (895 yards); *Hughes* (920 yards); *Rhind* (1,012 yards); LST-52 (1,530 yards); and *Saratoga* (2,265 yards). Additionally, four ships suffered "short- or long-term moderate loss of military efficiency": *Talbot* (1,165 yards); *Barrow* (1,335 yards); *Pennsylvania* (1,540 yards); and *New York* (1,545 yards). Based on these reports, Joint Task Force One concluded after plotting the actual damage and determining its relationship to the structural strength of the specific ship types and methods of construction, that the range of damage was "very serious" to 900 yards, "serious" to 1,000 yards, "moderate" to 1,300 yards, and "slight" to 1,500 yards. [10]

The worse damage from the blast was that suffered by vessel superstructures. Hull damage, including decks, sides, and bottoms, was next in severity, followed by damage to masts and stacks. The worse hull damage was that done to *Gilliam*, which was described as "badly ruptured, crumpled, and twisted almost beyond recognition." [11] *Gilliam* sank within a minute. The other attack transport, *Carlisle*, sunk, was dished, and had hull breaks. However, the transport *Crittenden*, 165 yards farther out from the zeropoint than *Carlisle*, survived sinking, although it suffered "severe dishing and deflection of the deck." *Carlisle*'s sinking was attributed more to its beam-on orientation; hence *Crittenden*'s "bow-on orientation may have saved her from being sunk." [12]

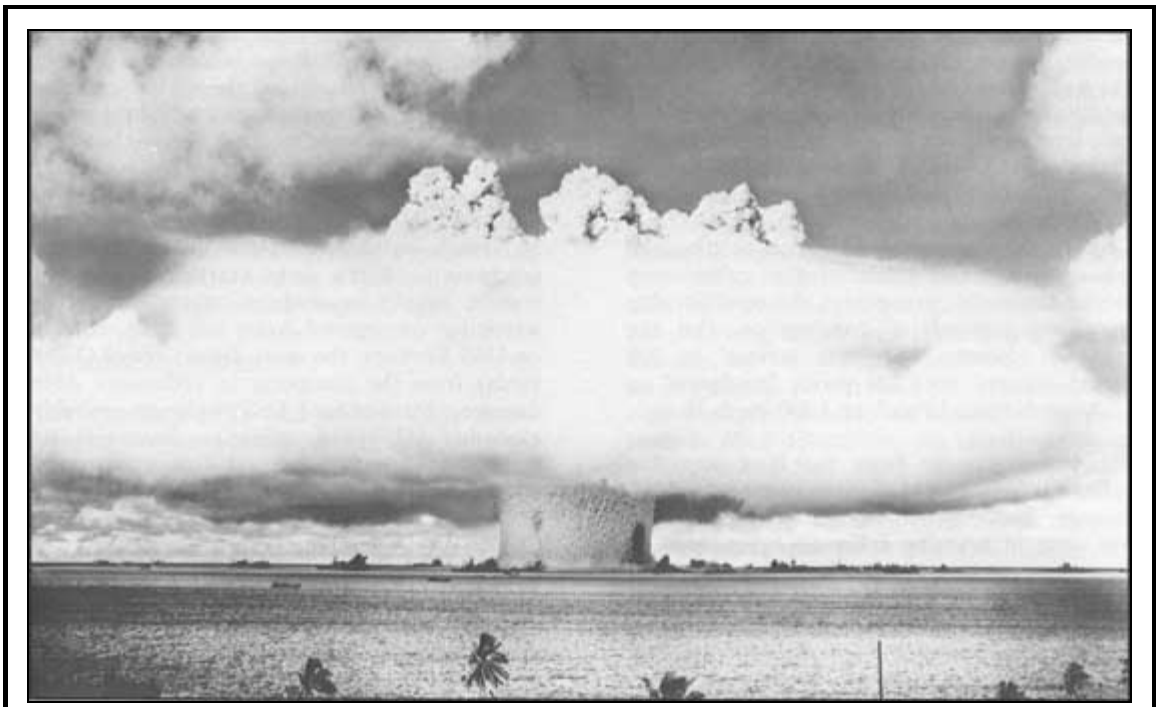
The loss of *Sakawa*, which sank in 25 hours from tears in the stern plating, was attributed to its "considerably lighter construction," as opposed to the two U.S. cruisers moored nearby, which suffered dished decks and stacks and superstructure damage. [13] The destroyers *Anderson* and *Lamson*, two of three destroyers anchored within the thousand-yard radius of the zeropoint, sank because of extensive hull damage. USS *Hughes*, at 920 yards, was dished but survived. Three other vessels suffered major damage without sinking. The light carrier

Independence's hull was "blown in and there was buckling of bulkheads." Additionally, the flight deck was "badly warped and buckled, and the sides enclosing the hangar deck were blown through." [14] USS *Skate* suffered serious damage which prevented the submarine from submerging, including a bent conning tower and a "badly stripped and crumpled superstructure." YO-160's concrete hull was broken and spalled, exposing bent reinforcing bars, its concrete deckhouses were smashed, and all of the wood in the vessel was burned by a thermal-radiation-induced shipboard fire. [15]

Flash scorching on painted surfaces was found on vessels up to 3,700 yards distant from the zeropoint. Fires were started on several vessels, usually in cordage, canvas, or burlap wrappings on exposed Army test items, notably on USS *Saratoga,* the most distant vessel (2,265 yards) from the zeropoint to suffer any Able damage. Fires aboard USS *Anderson* probably exploded shipboard ordnance, hastening its sinking. The only fuel oil fire was started aboard *Sakawa.*

The Baker Detonation

The Baker bomb was detonated by Los Alamos scientists inside its steel and concrete caisson, suspended 90 feet beneath LSM-60, and approximately 90 feet above the lagoon bottom. [16] Energy release was similar to the Able shot. A fireball was formed that illuminated the water with an orange-white light for a few millionths of a second before the high-pressure gases of the ball erupted to the surface. The shock wave formed a "blast slick" of white water on the surface, emanating out from the zeropoint in a "rapidly advancing circle" formed by the hurtling of small water droplets short distances into the air. [17] Immediately, within four millionths of a second, the gas bubble burst into the air, throwing up a mound of super-heated steam and water called the "spray dome," at a rate of 2,500 feet per second. [18] The spray dome climbed into a column in which the water in the center moved faster than the water farther out, at a rate estimated at 11,000 feet per second. This formed a hollow center in the column that acted as a chimney for the hot gases and superheated steam from the now nearly exhausted fireball to climb, carrying excavated lagoon bottom and radioactive products up to form, with water vapor, a cauliflower-shaped mushroom cloud. [19] At the same time, the condensation of the water formed a vast "Wilson Cloud" around the column 18 seconds after detonation, which dispersed into a dissipating ring of clouds that vanished after 30 seconds.



The most famous photograph of Baker. The dark spot in the column marks the position of the capsizing *Arkansas*. Crossroads mythology mistakenly insists this photo shows the upended form of the battleship. *(U.S. Naval Institute)*

The height of the column and cloud, containing some 2,000,000 tons of vaporized and boiling water (estimated at four cubic feet of water per thousand cubic feet of column and weighing at least two million tons), was 4,100 feet at 10 seconds after detonation, and 7,600 feet at 60 seconds. [20] At that time the stem radius was 975 feet in diameter, formed by 300-foot-thick walls of water with a 75-foot-diameter hollow stem. [21] The column also contained approximately 2,000,000 tons of lagoon bottom from a crater nearly 700 yards in diameter and 20 feet deep. The blast generated a seismic effect equal to an earthquake measuring 5.5 on the Richter scale. Ten percent of the energy released by the bomb was represented in the formation of the column and crater. [22]

The peak pressure wave lasted two milliseconds. The peak overpressures, recorded at a 90-foot depth, were considerable. At 835 feet from the zeropoint, the peak overpressure was 7,000 psi. Other readings were 5,900 psi (928 feet); 5,200 psi (996 feet); 4,400 psi (1,084 feet); 3,200 psi (1,278 feet); 2,300 psi (1,554 feet); 1,400 psi (2,060 feet); 800 psi (3,040 feet); 560 psi (3,700 feet); and 330 psi (5,000 feet). [23] It was later found that the ships shielded some of the blast. The underwater pressure on the remote sides of hulls was measured at 40 percent of those on the exposed sides. [24] Peak pressures were also recorded in the air that were equal to a 4-kiloton air or surface burst. The pressures measured in the air were 16 psi at 550 yards, diminishing rapidly to 9.6 psi at 650 yards, 6.6 psi at 800 yards, 4.8 psi at 100 yards, 3.8 psi at 1,200 yards, and 2.8 psi at 1,500 yards. [25]

The velocity of the pressure wave was the same in the water and in the air: at two seconds the shock front had travelled two miles from the zeropoint. Another effect of the shock front and the eruption of the fireball was the creation of a series of waves that moved at 45 knots. At seven seconds after detonation, a 94-foot-high wave passed the thousand-yard mark. It was followed by a 47-foot wave at 2,000 feet at 20.5 seconds, and a 24-foot wave at 4,000 feet at 47.5 seconds. These were the only three waves of height. Four lesser waves followed, diminishing to a nine-foot wave at 12,000 feet 156 seconds after detonation. The nearby islands of the atoll, notably Bikini, were washed by 15-foot breakers. [26] The creation of these waves accounted for one percent of the bomb's total energy.

A "base surge" also emanated out from the column as it collapsed. "This doughnut-shaped cloud moving rapidly out from the column...is essentially a dense cloud of water droplets, much like the spray at the base of Niagara Falls...but having the property of flowing almost as if it were a homogeneous fluid." [27] Moving at 45 mph, the base surge was 800 yards distant from the zeropoint and a thousand feet high. The base surge contained many of the bomb material's radionuclides as well as radionuclides produced because of activation of the sea water, lagoon sand, etc. It has been estimated by one expert that as much as 50 percent, and no less than 10 percent of the radioactive material remained trapped in the seawater. [28] Radiation levels were measured near the point of detonation at the surface of the water at more than 10,000 Roentgens, or at an amount variously estimated to have been equal to placing 2,500 to 8,300 tons of radium at the zeropoint. [29]

A fatal dose of radiation is generally assumed to be 400 Roentgens per 24 hours. Personnel on ships within 700 yards of the zeropoint would have received that fatal dose in 30 to 60 seconds. A dose 20 times fatal--8,000 Roentgens--would have been received in the first hour. At 7,000 yards, the fatal dose was administered in seven minutes, while at 2,500 yards, a fatal dose would have been accumulated in three hours. Radiation levels on the ship's decks fell to 65 Roentgens per 24 hours four hours after the blast, and to .1 Roentgens per 24 hours by five

days after the blast, in large part because of radioactive decay and the diffusion of radioactive materials by convection and current. [30] Yet four- to eight-inch-thick contaminated sediments from the 50,000 cubic yards of bottom excavated from the crater that were estimated to have fallen back in the lagoon demonstrated "high" readings six days after the blast. Similarly, "a number of vessels were covered with contaminated coral sand which had been sucked from the bottom of the lagoon" and deposited by the base surge. [31]

1946 "Baker" Damage Assessments

The "Baker" detonation sank nine vessels and badly damaged another eleven within a thousand-yard radius of the zeropoint. Joint Task Force One, tallying the results, determined that 700 yards was a "serious if not fatal" damage zone, with serious damage at 900 yards, moderate damage at 1,000 yards, and slight damage at 1,500 yards. The majority of damage was caused by two factors--underwater shock, and the violent motion caused by it, as well as the impact with and violent motion from the blast-induced waves. [32] Five of the vessels not sunk within the 1000-yard radius were "immobilized." USS *Pensacola* suffered moderate hull dishing, damage to bulkheads, stanchions, and machinery foundations, holding down clips on turrets and battery mounts. USS *Hughes* was the closest destroyer to the zeropoint. It suffered major structural damage, including ruptured pipes and sea connections which flooded the ship, dished plating, and a badly damaged rudder and skeg. [33] A nearby ship had worse damage. USS *Gasconade* suffered a complete loss of longitudinal strength, the wrinkling of the bottom and shell plating, and partial flooding. The difference in damage was attributed to *Hughes'* broadside mooring and *Gasconade*'s stern-to mooring. *Gasconade* rode the waves perpendicularly and hogged and sagged, while *Hughes* rode them parallel and consequently had its bottom and keel constantly supported by water. [34]

The transport *Fallon* was flooded to the waterline, with "severe structural damage to ship girders," buckled decks and plates, and a permanent "transverse-curvature twist in her hull." LST-133 had minor hull damage and cracked ballast tanks. Damaged but not immobilized were the destroyer *Mayrant,* with bulkhead, stanchion, and weather deck damage and minor flooding from ruptured pipes, the battleship *New York,* the transports *Briscoe* and *Brule,* the already wrecked submarine *Skate,* and LCT-816. [35]

SITE DESCRIPTIONS: VESSELS LOST DURING THE ABLE TEST

USS *GILLIAM*

USS *Gilliam* is the only Able test vessel dived and assessed. It is the most important Able vessel, given its accidental role as surface zero for the test.

Pre-Test Alterations

Documented pre-test alterations to *Gilliam* apparently were limited to addition of various exposure test instruments and military equipment. These included a bulldozer, searchlight and generator, fire-fighting equipment, radiation monitors, water-distilling equipment, and a VF aircraft secured to the aft upper deck.





Wreckage of midships house, *Gilliam. (NPS, Larry Murphy)*

Post-Blast Observations

Because the bomb detonated much closer to *Gilliam* than originally planned, the blast effects were greater than anticipated. Test instruments placed had been designed only for recording the expected pressures and failed to give good data. Hence the blast effects on *Gilliam* were difficult for the Navy to quantify.

Gilliam sank in 79 seconds, going down bow first at an estimated 70-degree angle according to the Navy's interpretation of post-blast photo sequences. [36] Navy divers assessing *Gilliam*'s damage soon after the Able test found it nearly upright in 180 feet of water, with the stem, one bulkhead, and side shell-plating compressed a depth of six to ten feet and pushed to port: "the forward part of the ship is mashed down as though the blast acted like the hammer and the water an anvil." [37] The forward main deck was pushed down to within about five feet of the hull bottom, and starboard side shell-plating was stripped off as far back as frame 30--about 90 feet.

The flattened superstructure was pushed off the deck to port. According to Navy survey

reports, "the weather deck from frame 60 forward was stripped of all deck machinery, deckhouse, hatch coamings, foremast, and other fittings. The sole fixed object noted on this deck was a port 40mm gun, with its round welded steel shield (gun tub) stripped off. The deck openings for hatches and trunks were plainly seen by the Navy divers." [38] The blast also opened up the chain locker, exposing the chain and tearing hawsepipes, with the chain still passing through them out of the hull. Portions of the vessel were blown overboard by the blast and littered the lagoon bottom. Navy divers noted bitts, which were retrieved for radiological testing, a 40mm gun, a blast gauge tower, and twisted shell plating lying on the lagoon bottom.



Gas cylinders in No. 1 hold of *Gilliam. (NPS, Video Freeze Frame)*

Navy divers recorded the wreckage with 60 underwater photographs. Unfortunately, we found these photographs to be mostly uninformative. Made from 4x5-inch negatives, the photographs show small areas or individual wreckage pieces, such as bitts and the twisted bulldozer blade. Poor visibility hampered the clarity of the photographs; it appears to have been less than six feet. The bulldozer, stowed on the weather deck, would be unrecognizable in the photograph without the label. The poor visibility probably resulted from blast-displaced sediment still suspended in the water column, indicating the photographs were taken shortly after the blast. Another indication of how soon the underwater photographs were made is that each is over-exposed, which may be a result of the high radiation levels noted in the Navy survey dive reports. The Navy divers also prepared a plan view and profile sketch of *Gilliam*'s shattered hulk.

Site Description

One documentation dive was made on *Gilliam.* The full five-member NPS team swam over the deck, at 150 feet below the surface, from stern to bow. Water visibility was 50-100 feet vertically. The basically intact hulk of *Gilliam* was found to be upright on the bottom of the lagoon in 180 feet of water. Hull damage now appears to be more severe than 1946 diver reports indicated. It is possible that additional damage was inflicted on the submerged hull by the nearby Baker test detonation, and that what is seen, is cumulative damage.

The overall impression is that the hull has taken an enormous downward compressive force.

The barely recognizable ship has the appearance of being smashed down into itself, with the successive deck levels pancaked down into the hold. These decks were originally supported by longitudinal bulkheads, stanchions, and rider frames of welded steel with 1-1/2-inch-thick steel gusset plates on lower hull beams. The hull sides above the waterline are bent inward, in some cases more than ten feet. The hull area below the waterline appears to have the least distortion.

It should be noted that *Gilliam* was not a lightly built vessel, even though not a combat ship. The Victory-type ships were built to correct some of the weaknesses observed in earlier Liberty ships. *Gilliam* was welded steel and very strongly built for heavy service. *Gilliam*'s hull had transverse frames on 36-inch centers and a double bottom. There were numerous watertight compartments that were strongly built, contributing directly to hull girder strength.

The majority of damage, as the 1946 reports indicated, is forward. The bow appears crumpled and folded. A square frame, possibly a skylight, lies on the deck. The shell plating is peeled back and missing in places; the deckhouse stripped off and in part smashed down and to port. The impression upon viewing the hull is one of chaos--ship parts crumbled, torn, and scattered.

There were no deck fittings observed forward except a 20mm gun mount near remains of the aft bulkhead of the forecastlehead. This is the only bulkhead that seems to be in its original position. It is bent in an "s" shape that has a correspondingly distorted door in it.

Forward of the bulkhead is the 20mm gun mount. The remains of the forward hold, which contained railroad iron as test cargo and gas cylinders, is aft the bulkhead. Numerous gas cylinders and angle iron can be seen among the jumble of what was once the forward hold. The deck seems to have been ripped off, exposing the hold's contents. A kingpost lies off the starboard side. To port is the bulldozer, with its blade bent inward.

Within the jumbled wreckage, hatch coamings can be discerned as rectangular interruptions of ship scatter. The coamings appear to have been torn out of the deck. A perimeter of broken deck plate adheres to the hatch coaming margin.

Gilliam is the most damaged of the vessels the team examined in Bikini Lagoon. It is unforgettable.

USS *CARLISLE*

USS *Carlisle* was dived by the Navy ROV in August 1989. Videotapes of the ROV dive were assessed by us for comparison with *Gilliam.*

Pre-Test Alterations

Carlisle was loaded to 95 percent of its capacity with fuel and diesel oil. This ship was also loaded with 100 percent of its wartime allowance of ammunition "plus several loaded but plugged bombs, rocket heads and incendiary clusters throughout the ship. The Bureau of Aeronautics secured a VF airplane aft on the upper deck." [39]

Post-Blast Observations

Carlisle was moored close to and athwart *Gilliam,* the accidental zeropoint of the Able test detonation. *Carlisle* was 430 yards from surface zero. *Carlisle*'s port side faced the blast. The blast displaced *Carlisle* approximately 150 feet, toppled the stacks and mainmast, displaced the superstructure to starboard, and damaged the foremast. The ship was first seen in photographs less than three minutes after the burst; "at that time she was smoking heavily

amidships...she continued to burn and by burst plus 5 minutes 33 seconds she had assumed a 10 degree list to starboard." [40] The ship sank unobserved approximately one-half hour after detonation. In 1946 Navy divers located the wreck of *Carlisle* lying in 170 feet of water, "with a small list of about 5 degrees to port." [41]

Site Description

One ROV dive was made by Navy operators in 1989 on *Carlisle*, commencing on the port side near the bow and heading aft to the fantail, then running back along the port side to the hatch leading into the aft cargo hold. The ROV then headed across the deck, descended into the hold, and then came out, dropped to the starboard side, and ran aft along it for a short distance before ending the dive.

Comparing the identical, sister ships *Gilliam* and *Carlisle* offers a comparison of the Able bomb's damage to this type of vessel as observed at the different positions of 50 and 430 yards from surface zero. *Gilliam* was heavily mangled, as previously discussed. While *Carlisle* is more substantially intact, the ship suffered considerable and fatal damage at eight times the distance of its sistership, which the Navy attributed to *Carlisle*'s beam-on orientation to the blast. Damage observed in the ROV dive would confirm this. The port shell plating is buckled, dented, and dished considerably, with a major failure forward. The superstructure, while more or less intact, has separated from the hull at the port side, and is pushed to starboard, as indicated in 1946 reports.

The most interesting damage to *Carlisle* is that done to the decks, which evidence the same compressive downward force of the blast that *Gilliam*'s decks do, although not as severely. The port side of the deck around the aft hold's hatch has separated from the bulwark and the hull, and the deck seams have parted. The hatch coaming is bent and twisted, but remains attached to the deck plates except in its after portions, where it has pulled free. The deck has partially collapsed into the hold, and stanchions have buckled inside the hold, so that the subsequent deck levels are also deformed. A jumble of broken plate lies in the hold.

The after deckhouse is pushed down completely. A buckled bulkhead, with the turnbuckles for the wire rope rigging of the mainmast welded to it, is twisted down to the weather deck level. The formerly elevated port gun tub for a 40mm gun is now lying on the deck, without a weapon. Moving aft, bitts and fairleads remain attached to the deck, and two strands of anchor chain run from the fantail down into the silt on the lagoon bottom. These chains moored the ship's stern to a 10-ton mooring clump. Moving forward along the port side, a cargo boom from the mainmast slopes down from the deck to the lagoon floor. On the starboard side, the superstructure leans slightly over the starboard hull, which exhibits minor dishing. A gun mount on the aft port quarter of the superstructure is missing both its gun and the armored steel tub that surrounded it. Scattered artifacts, including a ship's running light and ammunition boxes, presumably from the gun tubs on the superstructure, lie off the starboard side on the bottom.





Stern of *Carlisle,* showing smashed aft deckhouse and bitts. *(U.S. Navy, ROV)*

SITE DESCRIPTIONS: VESSELS LOST DURING THE BAKER TEST

USS *ARKANSAS*

In addition to the Navy dives of 1946 and 1947, USS *Arkansas* was dived twice by the Navy ROV in 1989 and three times by the NPS team in 1989 and 1990.

Pre-Test Alterations

Arkansas' modifications for Operation Crossroads included blast gauge towers and test equipment installation. Also aboard was test ordnance. One photograph of *Arkansas'* deck shows a howitzer and a 90mm antiaircraft gun secured by turnbuckles and wooden chocks held by angle iron bolted to the teak deck.



Stern of *Arkansas* showing the two surviving port shafts with screws and the deformed stern plating. *(NPS, Larry Murphy)*

Able Post-Blast Observations

Arkansas was part of the Able test array, and was heavily damaged by the aerial burst. According to *Operation Crossroads: The Official Pictorial Record*, "although little damage was done to her hull and turrets, her wrecked superstructure showed the hammer-like effect of the bomb. Amidships she was a shambles." [42] *Arkansas'* damage was further described in *Bombs at Bikini:*

> When the lagoon was first re-entered, she was still sending up clouds of smoke from smoldering fires on her decks. But the shock wave did the worst damage. Stacks, masts, and mast supporting structures suffered, as well as pipe rails, bulwarks, stowage spaces. Much dishing occurred. Many doors, stanchions, and bulkheads were badly damaged. [43]

If any alterations were made to the ship prior to the Baker test, they were not recorded in the documents reviewed.

Baker Post-Blast Observations

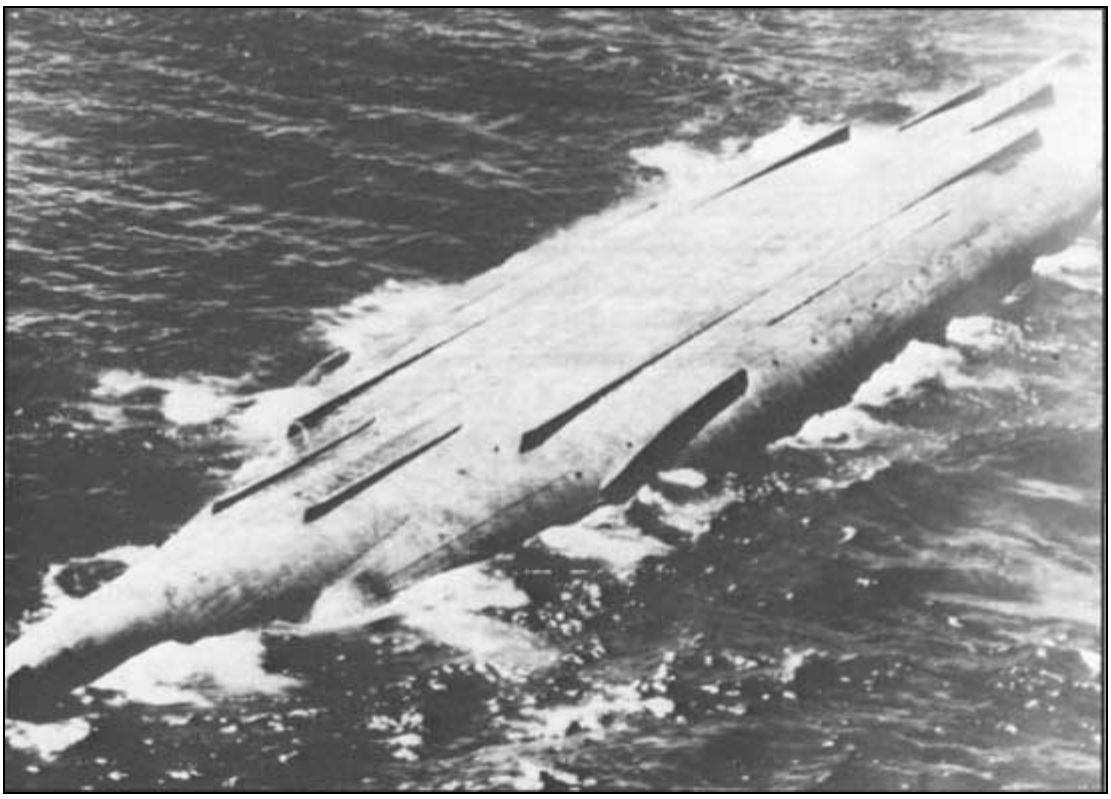
In 1946, after Baker, Navy divers found the wreck "lying buried in the silt, bottom side up.... Most of the superstructure, including stacks, boat cranes and mast is not visible and is presumed to have been driven into the coral silt on the lagoon bottom." [44] They observed major hull damage:

> Little is left of the shafting and the rudder has not been found. Only the port

> forward shaft without the screw has been found, and it is seriously out of line. No struts have been sighted and two large holes aft indicate the after two shafts have been completely torn out, stern tubes and all, leaving the surrounding area badly distorted and broken. [45]

The hull's shell plating either dished in (in some cases as much as six feet), tore, bent, or dented around the frames, parting butts and plate seams. In some cases the transverse framing failed. The torpedo blisters dented, bulged, and separated from the hull in several areas. Rivets failed throughout the hull, and near the No. 2 turret, a 15-to-20-foot wide dent of undetermined depth ran from the bottom up to the turn of the starboard side bilge.

The Navy determined that the upsurging blast water "acted on *Arkansas* from below and to starboard at a point approximately one-third of her length from the bow." [46] This mass of upsurging water capsized the ship to port. The Navy concluded, "The many holes and rivets seams which were opened throughout the entire length of the shell plating by the underwater explosion were the probable sources of flooding. A water wave which smashed over the *Arkansas*...may have partially aided in swamping the ship." [47]



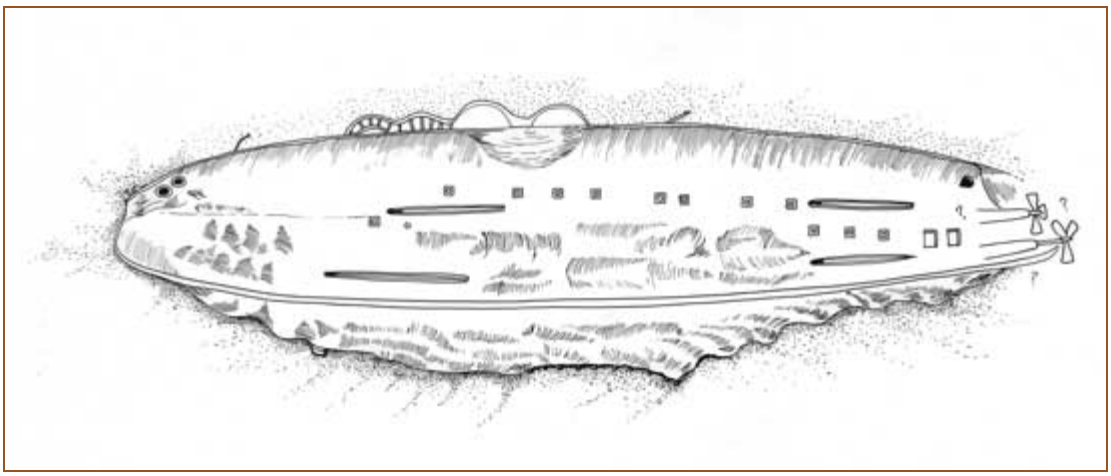
This 1948 photo of the capsized battleship *New York*'s intact bottom offers a stark contrast to the mangled *Arkansas. (U.S. Naval Institute)*

Site Description

The 1989 and 1990 surveys found that the seriously damaged *Arkansas* lies inverted on the bottom of Bikini Lagoon in 180 feet of water roughly aligned east-west, bow to the east. The battleship was aligned close to this position for the test. The former weather deck level is located at approximately 160 feet below the water surface; the port casemate, or aircastle, is located at 170 feet, while the deformed keel is at the 100 to 120-foot level.

Arkansas has a slight list to starboard. The port side is more or less intact, while the starboard

side is crushed and flattens out onto the lagoon bottom. The forward hull area is heavily damaged; the bow structure twists and is bent down and to starboard.



Perspective sketch of *Arkansas. (NPS, Jerry Livingston and Larry Nordby) (click on image for a PDF version)*

The hull bottom is markedly dented and rippled along the series of longitudinal supports, creating a series of "steps" that gradually slope down from the port bilge keels, past the deformed keel to the smashed starboard side, where frames splay out from the shell plating on the lagoon bottom. The shell plating has parted in some areas. Some pieces of wreckage containing frames, identifiable by their lightening holes, lie off the side.

In the stern, the propeller shafts have been torn away. The forward port shaft, with its three-bladed screw, is intact but deformed and bent outward. The shaft struts are missing. The after port shaft is bent to port. There is no trace of the starboard shafts or screws; it is possible that the entire 142-foot shaft lengths were torn free of the hull. The rudder and stern are missing. Broken hull fragments lie off the starboard side.

At the bow, the only identifiable features are the bulbous stem, which normally protrudes forward below the waterline, a chock on the port bow, and the two hawsepipes for *Arkansas'* two port anchors. This battleship carried three anchors, two to port and one to starboard. Two anchor chains extend from the forward hawses into the sand. The hull is cracked just below the gunwale forward of the No. 1 turret.

The chains, which are still attached to the deck by stoppers, hang down below the inverted deck. The ship is raised on the port side, allowing access to the deck. The vessel appears to be supported on the forward turret, the two 12-inch gun barrels of which can be seen pointing forward and slightly to port.

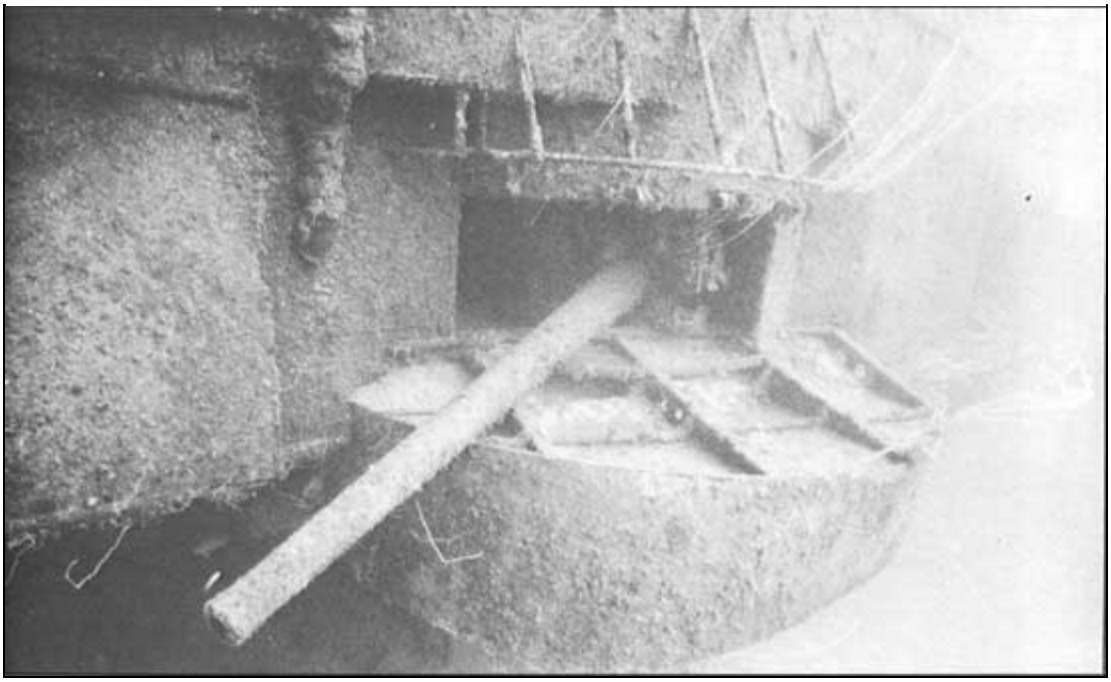
The ship's superstructure was not observed by Navy divers in 1946 because of a heavy silt layer that lay over and around the wreck. This silt layer, created by the blast, has now been scoured away, exposing the hard coral and sand of the lagoon floor. The lagoon bottom is less than six feet below the weather deck in most locations observed forward. This spacing accommodates the turrets and a smashed superstructure reported in the Able post-blast assessment.



Daniel Lenihan swims forward past the bilge keel of *Arkansas.* Longitudinal failure of the shell plating resulted in the long dents in the hull. *(NPS, Larry Murphy)*

The 1946 Navy reports suggest the ship was smashed nearly straight down into the lagoon floor. This observation is supported by the ship's nearly level position on the bottom, with only a slight starboard list. The flattened hull bottom and the superstructure being directly beneath the hull also reflect a straight down pressure on the hull. Superstructure elements would be expected to be visible on one side or the other if the vessel had rolled. Apparently, the hull was capsized by the uplifting water and smashed straight downward by the millions of tons of collapsing water column.

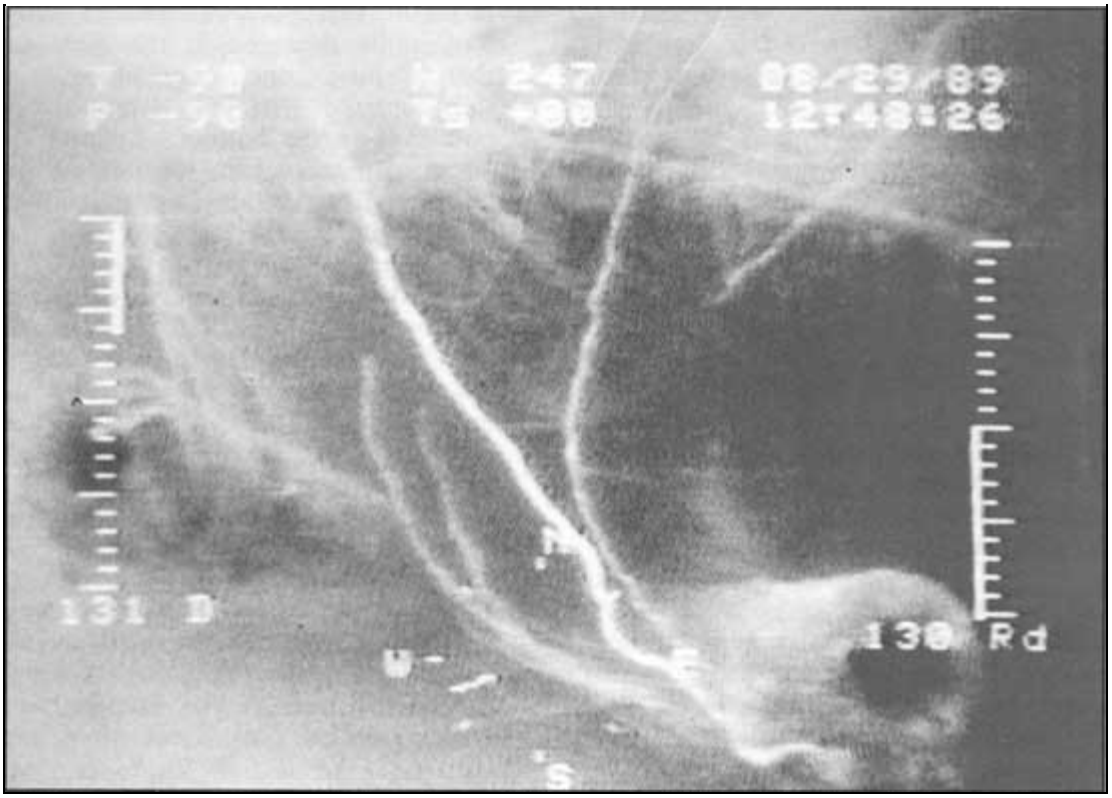
The portside casemates, known as "air castles," built of 6-inch-thick steel armor plate, are intact. Three 5-inch/51 caliber Mk13 guns on single mounts are visible. These 11-1/2-ton, 22-foot-long weapons were manually operated, fired a 50-lb. projectile with an eight-milerange at a 20 degree elevation. The guns are slightly elevated and have swung to port.

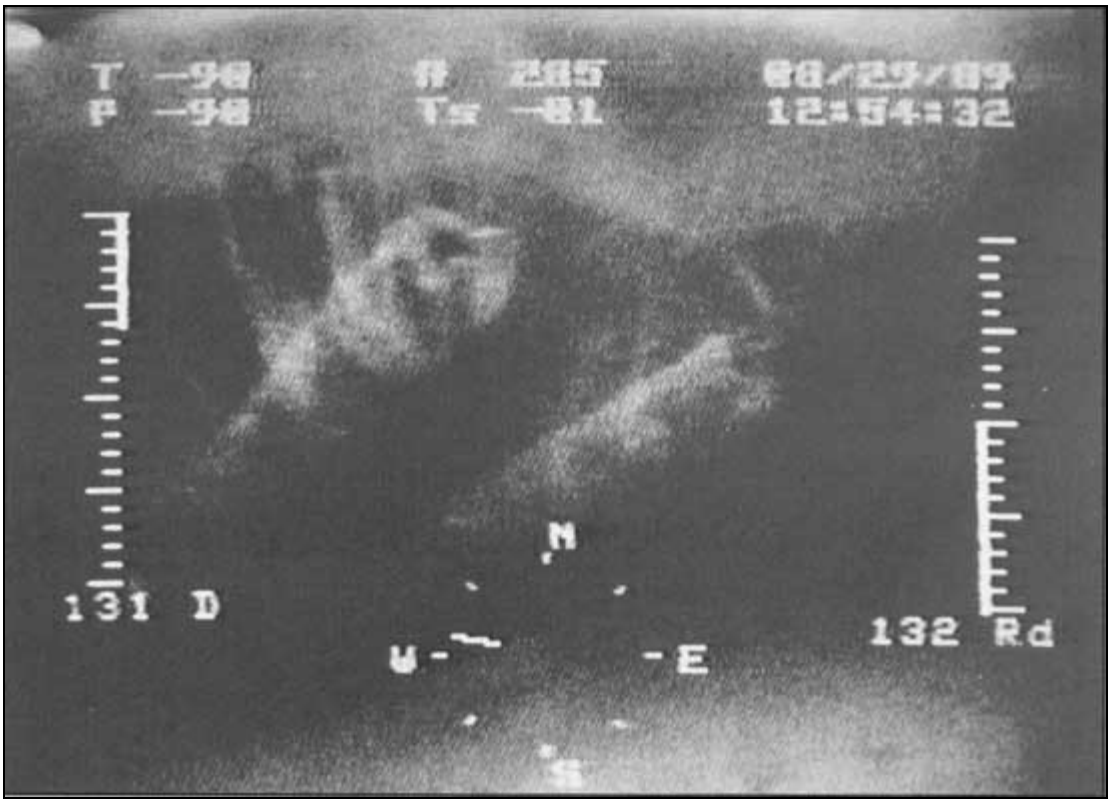


Port aircastle of the capsized *Arkansas*. The barrel of a single 5-inch/51 caliber gun protrudes. *(NPS, Larry Murphy)*

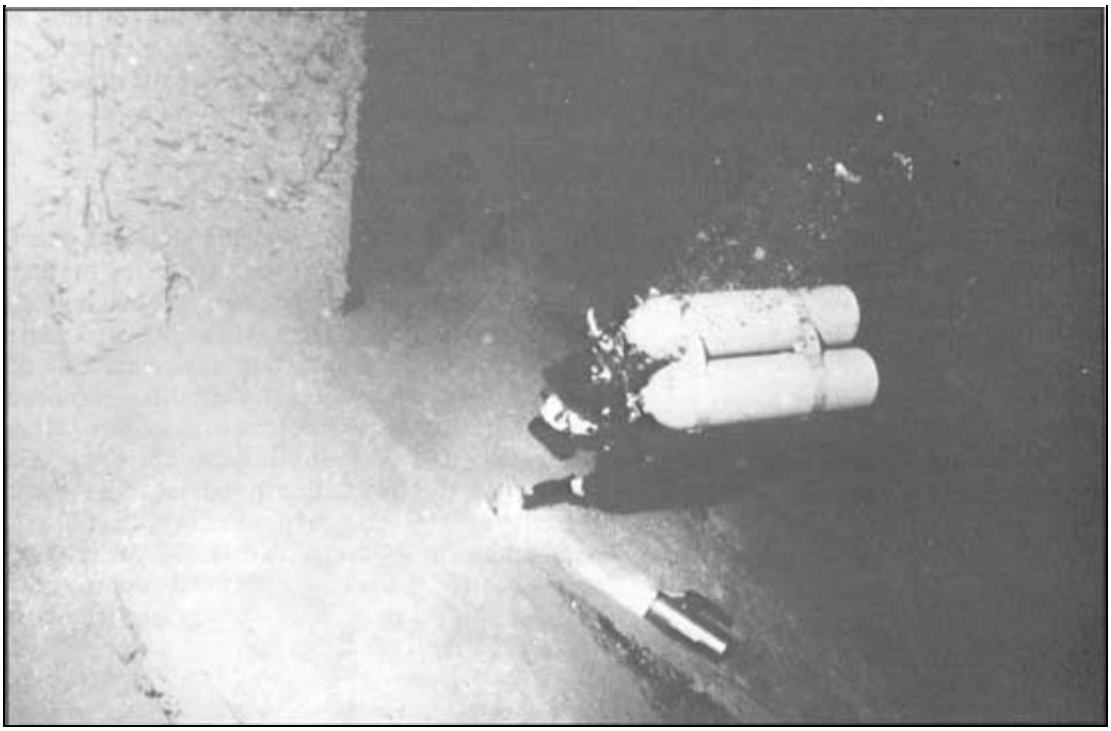
Most of the gunport shutters are missing. Reportedly damaged in the Able test, these shutters have fallen away, probably when the ship capsized. At least two lie beneath the port side on the bottom. Splinter shields for 40mm antiaircraft guns were noted beneath the inverted aircastle; the weapons themselves were removed before the test.

Inside the casemate, two 5-inch rounds remain in the ready rack. The guns still have rangefinders and sights. In the casemate messing and berthing spaces, stanchions, which once provided support for the gun crew hammocks, remain in place but slightly bent from compressive forces. Remarkably, the glass cover and bulb for a battle light was located undamaged on the inverted ceiling. Overhead, the teak deck is missing, presumably consumed by marine organisms, leaving only metal deck fasteners attached to the steel underdeck. A wire-cable reel for the port paravane is stowed at the aft end of the compartment. An ammunition hoist hangs open from the deck.

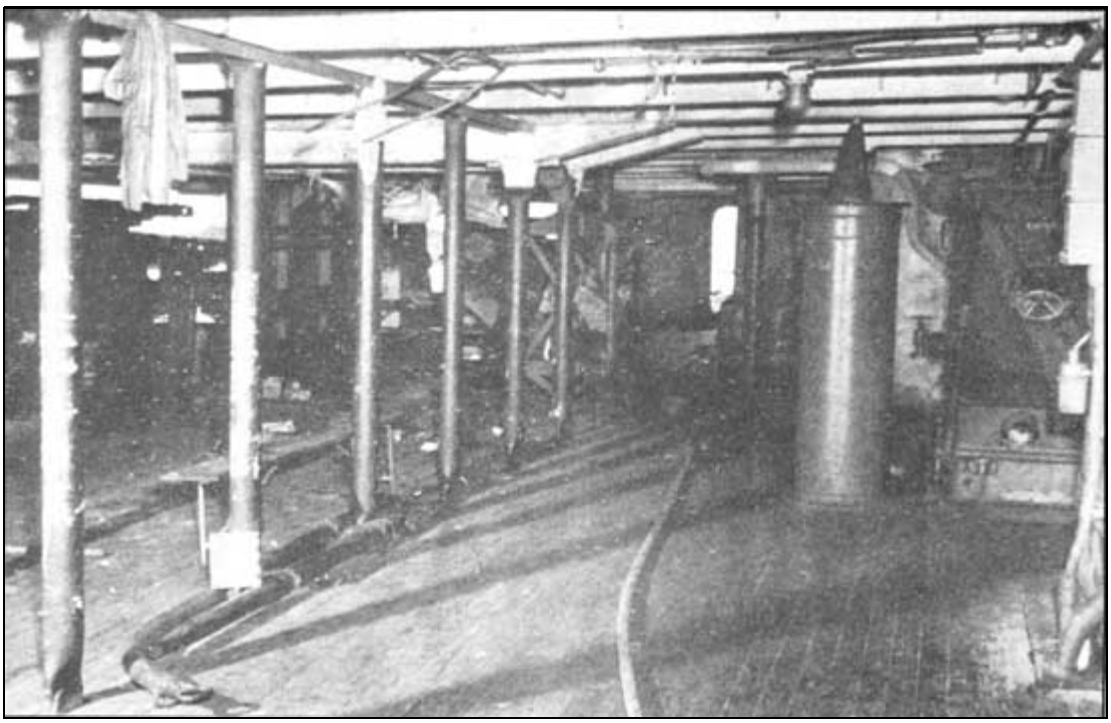




Two ROV views, taken at slightly different angles, of the barrels of the 14-inch guns of *Arkansas'* No. 1 turret. *(U.S. Navy, ROV)*



Inside *Arkansas'* port aircastle, Dan Lenihan inspects an unbroken light inside its wire and glass safety cage. *(NPS, Larry Murphy)*



Looking forward in the port aircastle of *Arkansas,* at Bikini in 1946. The light that Lenihan investigated in 1990 is visible in the upper right corner of the photograph. *(National Archives)*

This 21-foot-wide compartment was entered through a seven-foot wide longitudinal passageway that runs from port to starboard. The passageway leading to the starboard air castle was not entered. The port air castle included the entrance to the admiral's cabin; *Arkansas* was fitted as a flagship. This cabin was not entered. There was also a 32-foot-wide

space between each passageway that contained boiler uptakes, evaporators, and the ship's enlisted cafeteria with steam tables opening into each passageway. These passageways were not entered.

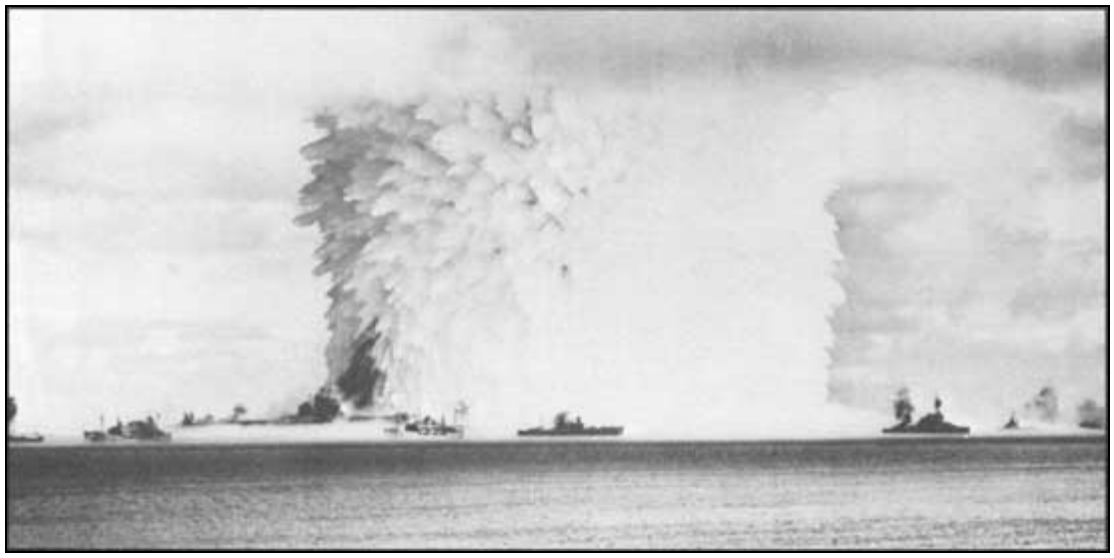
USS *SARATOGA*

USS *Saratoga* was the principal focus of assessment and documentation during the Bikini field seasons. The vessel is one of the most accessible to divers, and consequently of primary interest for evaluation as a dive site.

Pre-Test Alterations

Saratoga was modified for Operation Crossroads. Nearly two-thirds of the ship's armament was stripped, including two of the houses with the twin 5-inch guns. Other fixtures, including compasses and the ship's bell (now at the Washington Navy Yard), were removed. To measure the effects of the bombs, aircraft, vehicles, and radar were placed on *Saratoga.* Blast gauge towers and other instruments were mounted at desired locations.

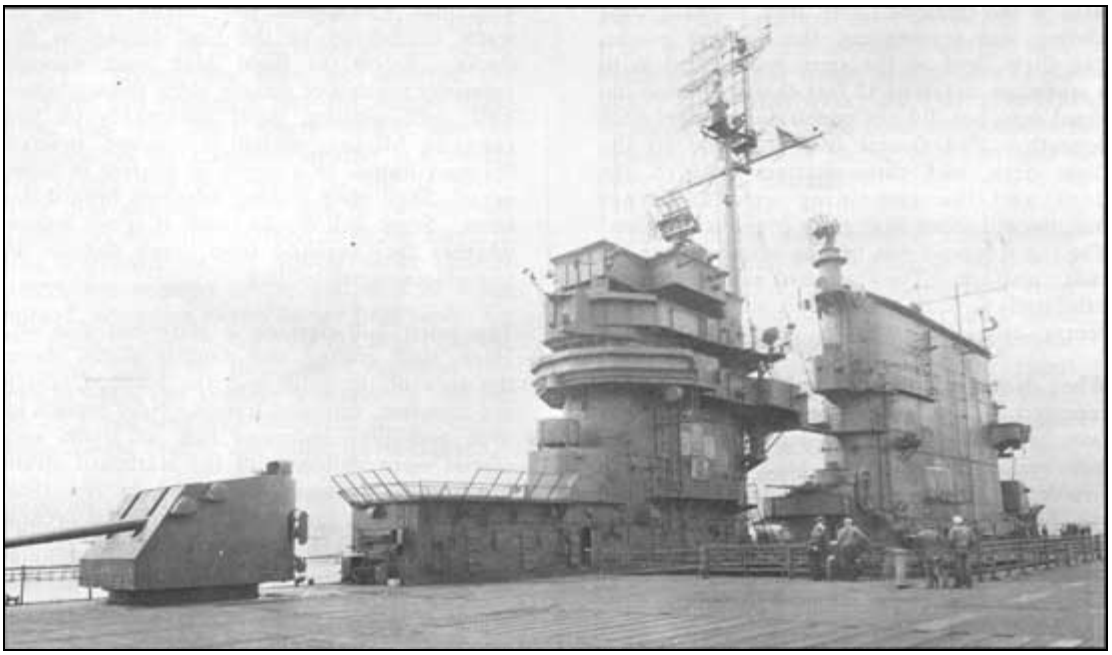
Loaded with 700 gallons of fuel oil, 15 tons of diesel, and 66-2/3 percent of its ammunition, *Saratoga* was sent to the bottom in a near-combat-ready state. [48]



Saratoga, hit by the first blast-generated wave, rises 43 feet and lists to port, 10 seconds after detonation, in this view from Enyu Island. *(U.S. Naval Institute)*

Baker Post-Blast Observations

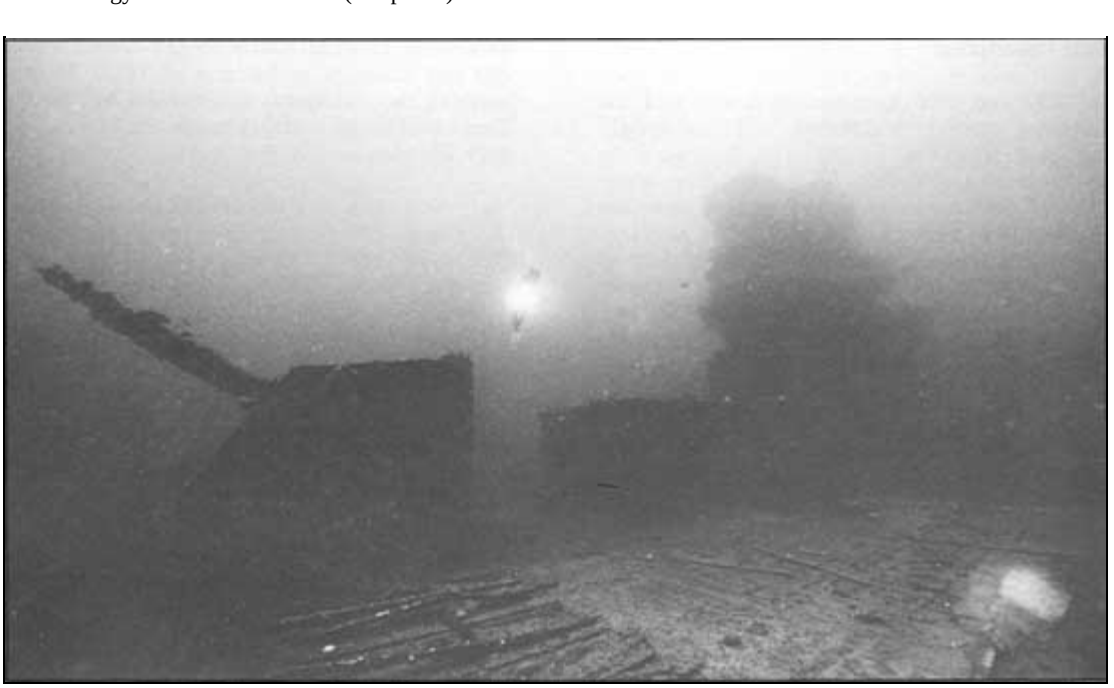
After the Baker detonation, the ship was blown to a position 800 yards out from its original position before drifting back in and sinking 600 yards from the detonation point. The detonation of the Baker test device on July 25 created a blast wave crest that lifted *Saratoga* out of the water. Eleven seconds after detonation, the 94-foot-tall wave crest was 330 yards from the detonation point; at 23 seconds, it was 660 yards off and 47 feet tall, diminishing to 24 feet tall at 1,330 yards at 48 seconds after detonation. Official reports state that *Saratoga*'s stern rose 43 feet and the bow at least 29 feet. A large wave of water washed over the ship, sweeping away five TBM-3E and SBF-4E aircraft stowed on deck, as well as vehicles and equipment placed there for the test. According to test data analysis, "it appears highly probable that shortly after the rise on the first wave crest, the *Saratoga* fell into the succeeding trough and was bodily hit by the second wave crest...." [49]



Saratoga's island, stack, and No. 1, 5-inch mount after stripping the ship for Crossroads. This photograph was taken at Naval Air Station, Alameda, California, February 27, 1946. *(Floating Drydock)*

In 1946, Navy divers made limited dives on the wreck and reported that the forward starboard strut in the stern had torn free, buckling shell plating and tearing out the doubler plates. The flight deck at the stern was dished in to a maximum depth of 12 feet that splintered the wood deck but did not penetrate the steel deck beneath. The funnel had collapsed to the flight deck, with three-quarters lying on the deck and the remaining quarter "erect but...twisted about 20 degrees counterclockwise." The top foremast was broken off above the SK radar platform. The starboard side of the hull exhibited a three-to-six-inch dishing in the central area of the ship. [50]

When Navy divers inspected the wreck, they reported it lying in 180 feet of water on the port bilge at a 10- to 15-degree angle. The bow reportedly tilted up at an approximate five-degree angle. The ship had settled into the bottom, to the shaft level, leaving the screws exposed. The starboard bilge was about seven to eight feet above the bottom. The Navy determined from oil leaks that the bottom shell plating had ruptured. This, they concluded, along with a tear in the hull near the starboard quarter, and the failure of sea chests and valves, had sunk *Saratoga.* [51]



The same view today. The stack, mast, and radar antennae are conspicuous in their absence. *(National Geographic Society, Bill Curtsinger)*

Site Description

In 1989 and 1990 dive surveys found that the virtually intact USS *Saratoga* still lies upright on the bottom of Bikini Lagoon in approximately 180 feet of water. The vessel rises to within 40 feet of the surface, with the island and mast visible from the surface. Numerous hatches and the elevator bay stand open. The vessel strongly retains its integrity as a ship and is easily identifiable as *Saratoga.* Although the carrier's entire exterior was surveyed, emphasis was upon the starboard side (which faced the blast) and the flight deck. Few interior spaces were examined other than the hangar deck amidships, as well as the island, the flag plot, navigation bridge, and aerological office. Additionally the auxiliary radio room and windlass area was entered through a hole in the flight deck.

Saratoga readily evidences the effects of the Baker test bomb's detonation. More precisely, the ship shows the aftermath of a nearby nuclear detonation's pressure wave, the effects of being lifted 29 to 43 feet, being hit by enormous waves, and the results of tons of water thrown up by the blast falling on the decks. Below the flight deck level, damage primarily consists of dishing along the starboard hull shell plating, most noticeably on the torpedo blister, which is pushed inward between frames to a depth of six feet in some areas. Shell plate dishing increases toward the stern. Some hull cracks show; it is not known whether they resulted from bomb damage or post-depositional settling.

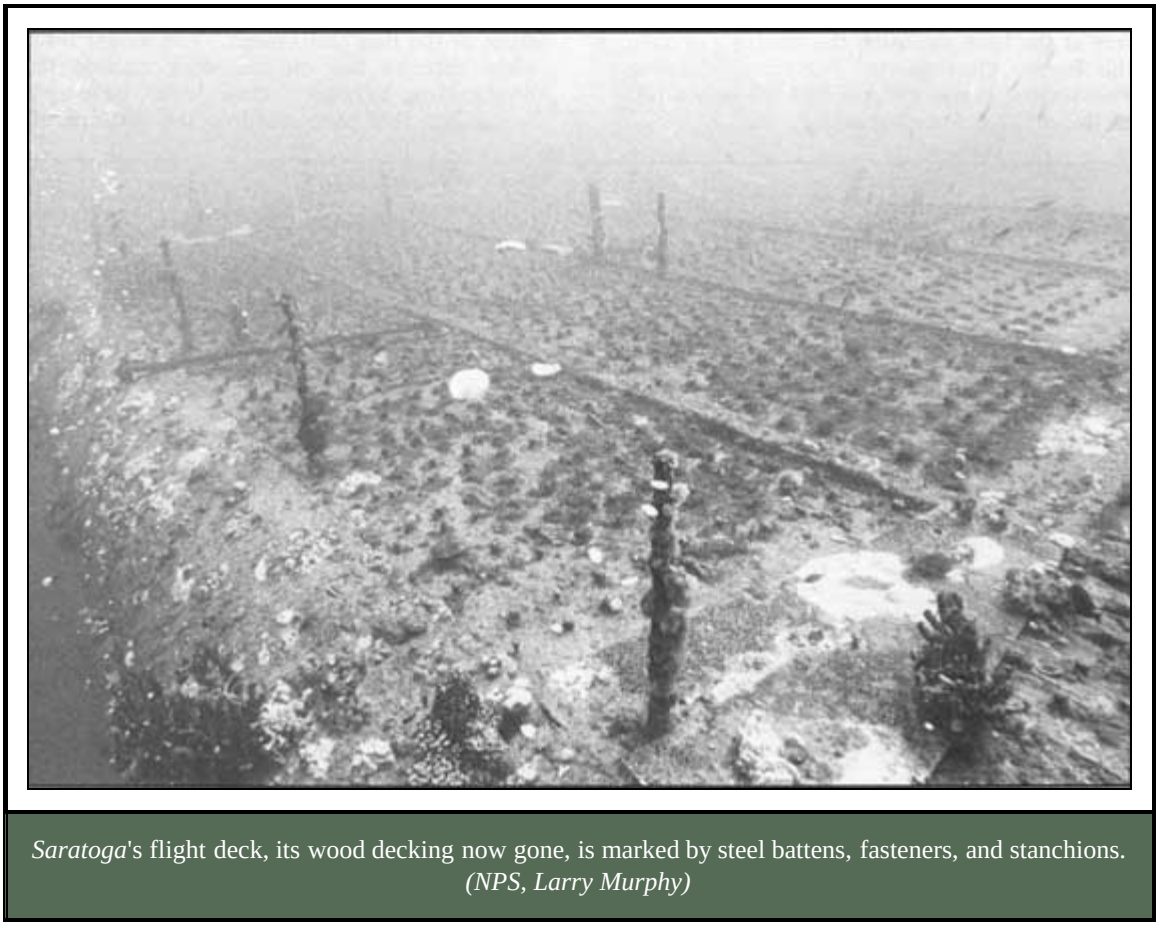
The worst hull damage is starboard side aft. Here, shell plating and doubler plates above the turn of the bilge and the torpedo blister are torn free, exposing frames. Navy reports in 1946 and 1947 indicated that all shafts and screws were visible, with the starboard struts broken. This was also noted in the 1989 survey, with the forward starboard strut broken violently enough to damage the shell plating around it.

Flight Deck. The flight deck shows extensive damage. A combination of blast wave and thousands of tons of water falling from the blast column collapsed and compressed the aft flight deck, beginning close to the stern and continuing forward nearly to the funnel about 200 feet down to a distance of 12 to 20 feet between the outermost longitudinal bulkheads.

These bulkheads, which provide the main flight deck support, are 70 feet apart.

Navy reports in 1946 noted "the indentation [of the flight deck] is gradual with no abrupt breaks or bends. There is no indication that the steel deck has ruptured but the wood decking has been splintered and broken... [52] The steel deck is now ruptured. It could have been ruptured in 1946, with splintered wood obscuring the break to observers. A large break about 100 feet aft of the stack is clearly visible and another open deck crack can be seen on the starboard side near the boat bay.

The major flight deck failure is near the funnel. A partial deck break beneath the collapsed funnel is probably attributable to the latter crashing down on it. A roughly square depression aft roughly conforms to the No. 2 elevator position, which was sealed off in early 1945 during *Saratoga*'s last pre-Crossroads refit. The platform that covered the elevator was reported missing in 1946: "This platform was reported found on the starboard quarter of the ship." [53] During our dives we observed the platform had collapsed into the hangar deck. What the 1946 Navy divers thought was the platform on the starboard quarter is probably the fantail drip pan, which is still in place. This drip pan was under one of two SBF-4E Helldivers mounted on the fantail for the test. The starboard aircraft, BuAer serial number 31859, was secured to the pan with its wings spread; according to the BuAer final report for the plane, it was "blown over the side from the *Saratoga* before the ship sank. The steel drip pan in which the airplane was secured was left on deck and sank with the *Saratoga."* [54] A brief unsuccessful search was made for this plane.

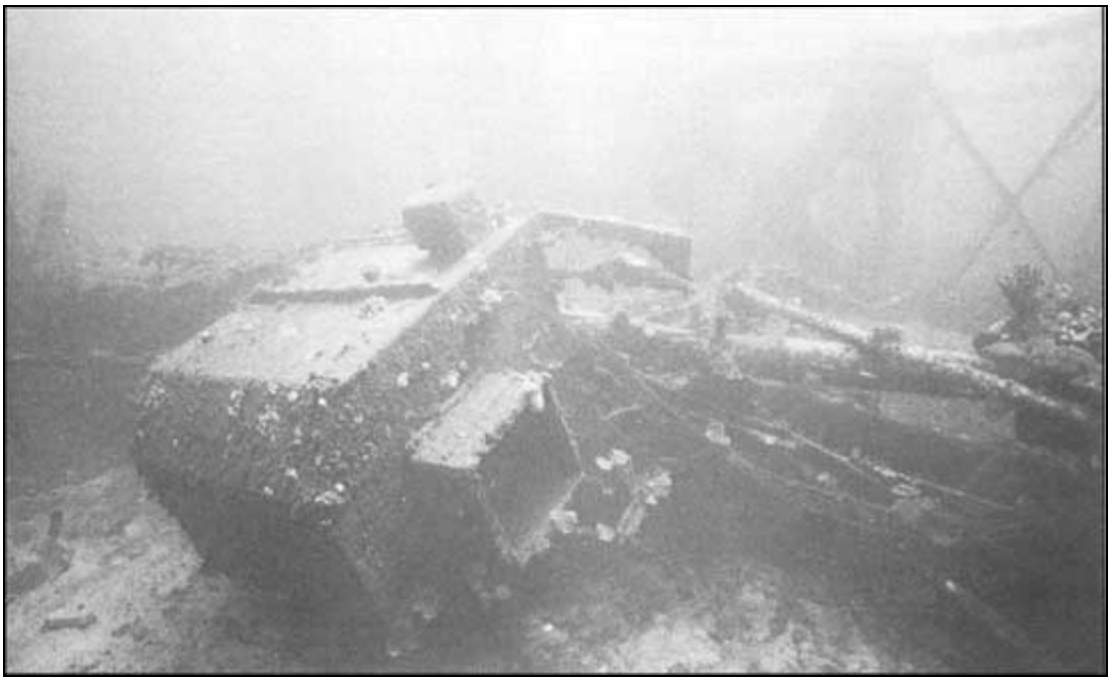


Saratoga's flight deck, its wood decking now gone, is marked by steel battens, fasteners, and stanchions. *(NPS, Larry Murphy)*

Saratoga's main flight elevator, forward the funnel, lies at the bottom of the shaft, diagonally bent nearly 90 degrees. The elevator was stowed in the "locked up" position for the test, as it had been for Able. In that test, it had dished down "slightly," with "a number of broken welds, in a number of places below the platform, on the structural members." [55] The Baker blast compounded this damage; 1946 aerial photographic analysis and diver's reports showed

> the platform was dished in considerably in the center and slightly to port, to a depth of...four to six feet probably from the effect of falling water and blast effect....The port side of the elevator had been depressed downward about three feet and the whole platform tilted to starboard, so that the starboard side of the platform extended above the flight deck level about one foot. [56]

The elevator platform's location at the bottom of the shaft in its current position is attributed to post-depositional settling.



The secondary conning position on the forward edge of *Saratoga*'s collapsed stack. *(NPS, Larry Murphy)*

Near the bow, the flight deck is partially collapsed. This collapse generally conforms to an area damaged by kamikaze attack off Iwo Jima on February 21, 1945, and subsequently repaired for quick return to service. Diver reports in 1946 noted that "the flight deck forward appeared to be intact" and that "the flight deck in the area of the catapults was undamaged by the blast." [57] The deck collapse in this area may also be postdepositional and attributable to a twice-damaged area weakening with corrosion and finally collapsing after the sinking.

Superstructure. Above the flight deck level, the most apparent damage is to the ship's funnel. The funnel split at the 04 level and fell to port across the flight deck, slightly angling toward the bow, indicating a lateral twisting probably from the angle of the 90-foot wave that hit it. The blast wave or the water column's falling mass likely contributed to the present distortions. The funnel completely tore free at the base, exposing the intakes. In 1946, the funnel after-quarter remained standing. Post-sinking funnel collapse has left only a fifth of the original funnel standing.

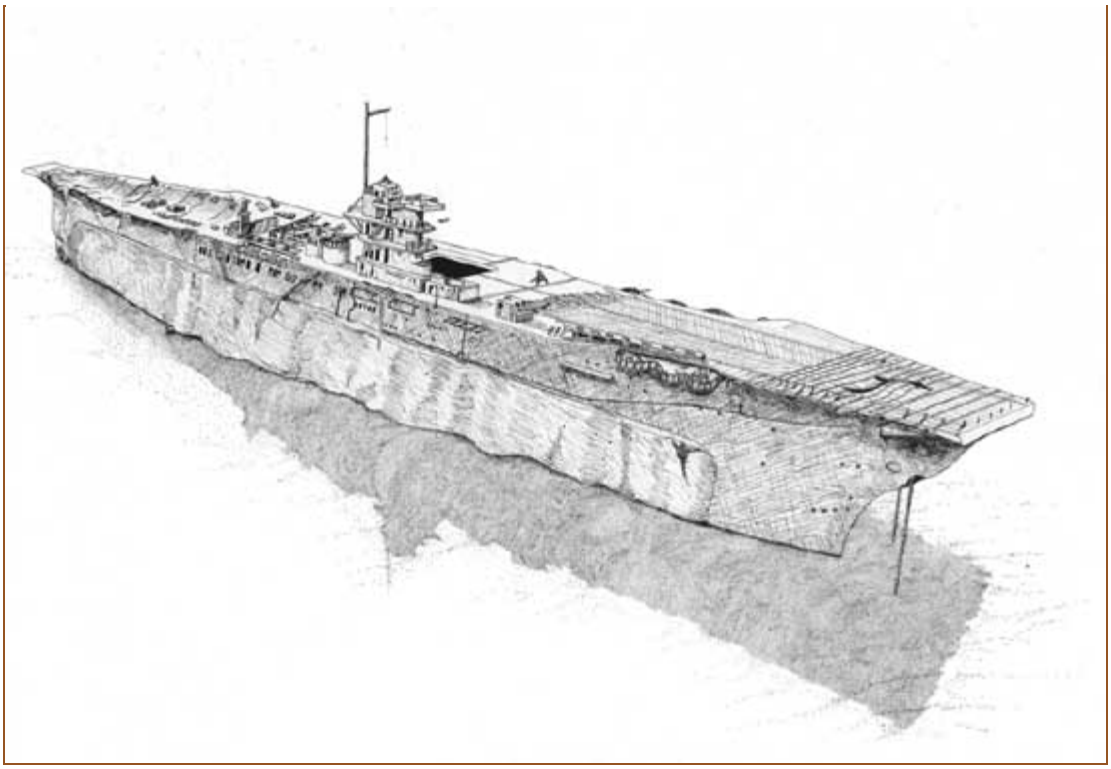
The funnel has completely collapsed into itself, with only the major longitudinal and transverse framing left intact. The plating lies broken and scattered inside the frames on the deck. Blast and wave effects have bent the funnel's horizontal framing to port, in some cases more than six feet. The forward end of the toppled funnel is intact. The secondary conning position and the broken SM fighter-director radar mounted atop the funnel's forward end are recognizable. Diver reports in 1946 noted that this "radar equipment...on the forward portion

of the stack was damaged." [58]

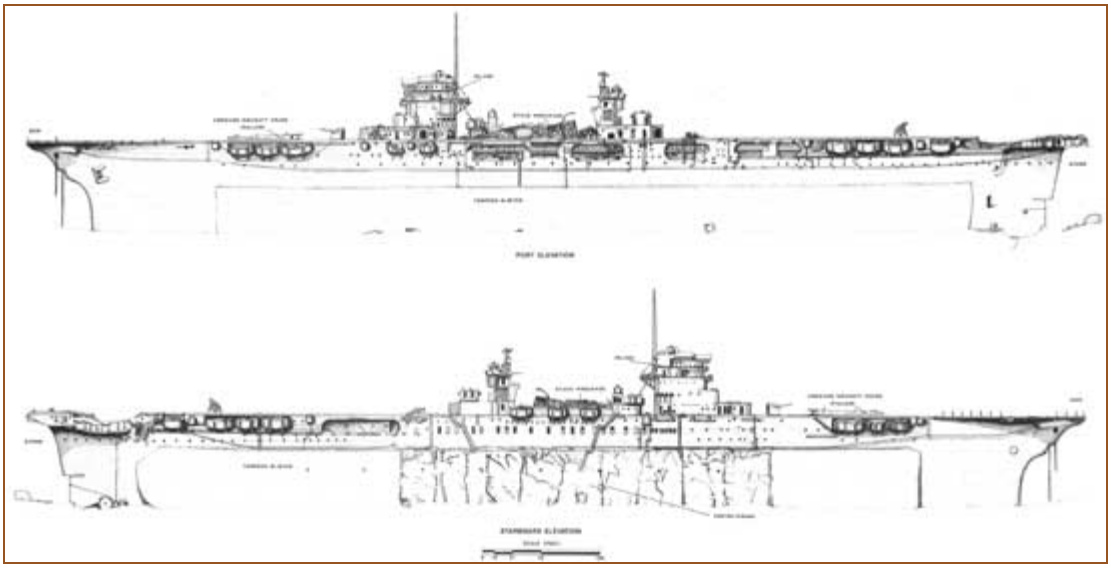
Damage to *Saratoga*'s island and mast includes shattered deadlights, hatches and doors blown off their hinges, toppled Pelorus stands, and sheared antennae. The single-pole mast aft the island was blown off at its crosstree; the wire rope that rigged the mast lies festooned on the after area of the island. The SK radar antenna atop the mast fell forward; pieces of the antenna lie tangled and broken on the island in front of the flag plot bridge. The mount for a whip antenna lies on the deck outside the navigation bridge. One level below, a searchlight that once stood on the platform aft of the mast lies face down on the deck. The stub mast that projected aft the pole mast is now bent 90 degrees to port and broken. A spar from the mast lies on the flight deck outboard the funnel; a cable runs from it over the starboard side. From this cable a whip antenna mount is suspended. Other antenna, such the Mark 12-22 array atop the MK 37 director on the air operations bridge, as well as all other observed director locations, are missing. This conforms to 1946 Navy reports: "the SK, YE, and Mk 12-22 antennae are missing. The whip antenna installed forward, at the starboard side of the flight deck, were missing after the blast." [59]



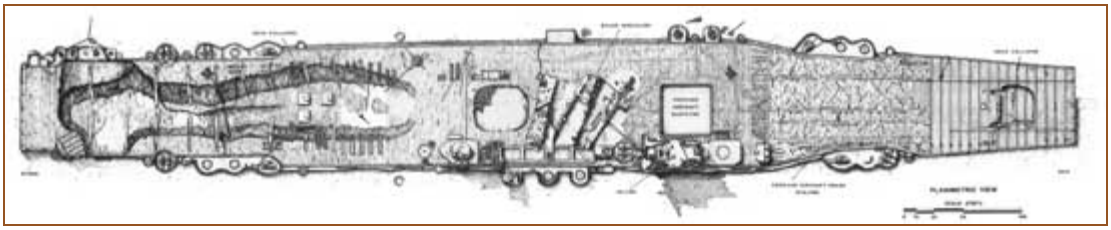
Perspective painting of *Saratoga. (Tom Freeman) (click on image for a PDF version)*



Perspective drawing of *Saratoga. (NPS, Jerry Livingston and Larry Nordby) (click on image for a PDF version)*



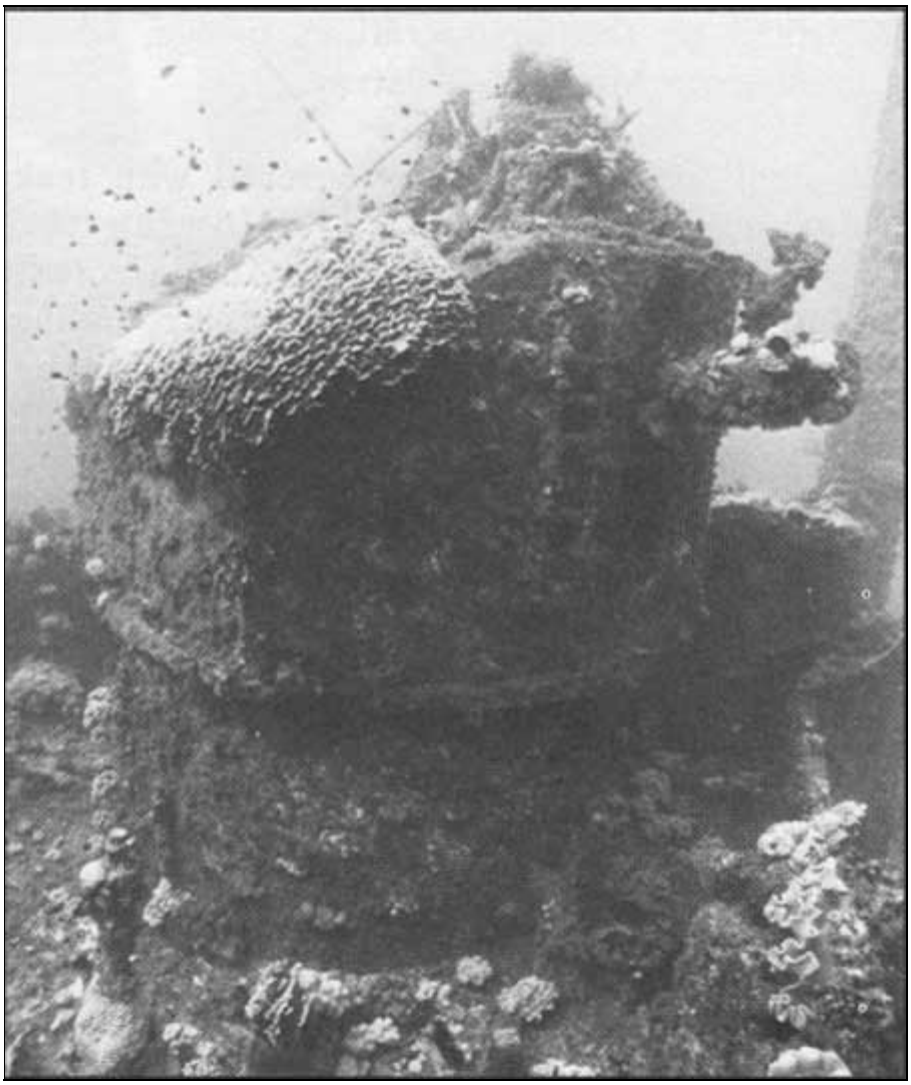
Profile views of *Saratoga. (NPS, Larry Nordby and Jerry Livingston) (click on image for a PDF version)*



Plan view of *Saratoga. (NPS, Larry Nordby and Jerry Livinston) (click on image for a PDF version)*

The various starboard hatches are mostly blown in, partially collapsed, or altogether missing. All porthole deadlight blast covers are closed; the glass in every porthole observed was missing. Wire-rope life nets, once strung above the sponson deck, are missing with the exception of some loose netting hanging forward of the starboard boat bay and near the stern.

Armament. *Saratoga*'s primary armament was the 81 to 83 aircraft aboard. When subjected to the Baker test blast, *Saratoga* had five aircraft secured to the flight deck; all were swept off the ship by the blast or waves. In 1988 Holmes and Narver and U.S. Navy divers reported an airplane on the bottom off the starboard hull. This aircraft was not observed in 1989. The four aircraft stowed for the Baker test--three "Helldiver" Navy single-engine dive-bombers and an Avenger single-engine torpedo bomber--were observed in the hangar. A more detailed discussion of these planes will be found in the section detailing *Saratoga*'s interior.



Mark 37 director at the air defense level of *Saratoga*'s island. *(NPS, Larry Murphy)*



No. 1, 5-inch/38 caliber mount on *Saratoga.* The island is faintly visible in the background. *(National Geographic Society, Bill Curtsinger)*

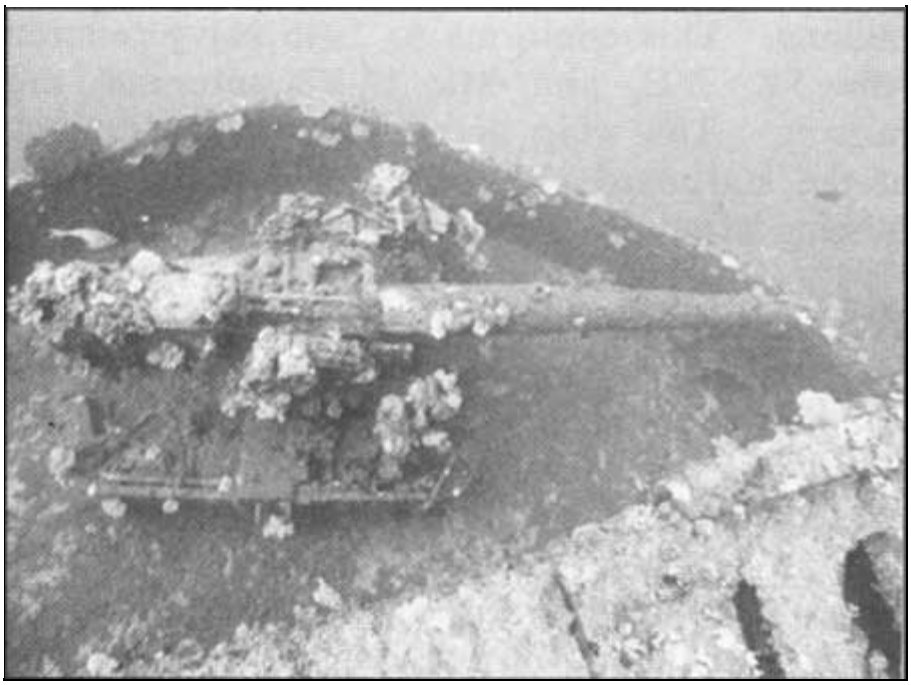
Saratoga also carried eight paired 5-inch/38 caliber guns in four houses--two forward, two aft. Before Crossroads, during the ship's 1946 stripping at Hunter's Point, two of the houses were removed: the No. 2 gun position forward the island (though its barbette remains atop the handling room) and the No. 4 gun position abaft the funnel. The remaining two guns in the No. 1 position are elevated 20 degrees and trained forward, whereas the two guns in the No. 3 position are level and pointed to starboard.



Gun tub, with quad 40mm mount, aft of *Saratoga*'s island. Abaft the 40mm mount is a Mark 51 gun director; further aft is stack wreckage. *(NPS, Larry Murphy)*

Other weapons were also removed for the tests, but a representative sample was left to assess the blast effect. For Baker *Saratoga* carried in addition to the paired guns, 12 single 5-inch/38 caliber guns; four were noted in the 1989-1990 dives. Six of the original twenty-four quad Bofors antiaircraft 40mm guns were also located. The carrier also mounted 52 Oerlikon antiaircraft 20mm guns on the sponson deck; five of these were located, two lying on the lagoon bottom aft close to the sheared off stern sponson gun platform on which they were mounted. The sponsons were torn off either by huge bomb-generated waves or falling water from the collapsing column. Twelve sponson-mounted Mk 51 gun fire-control directors were noted next to the antiaircraft guns.

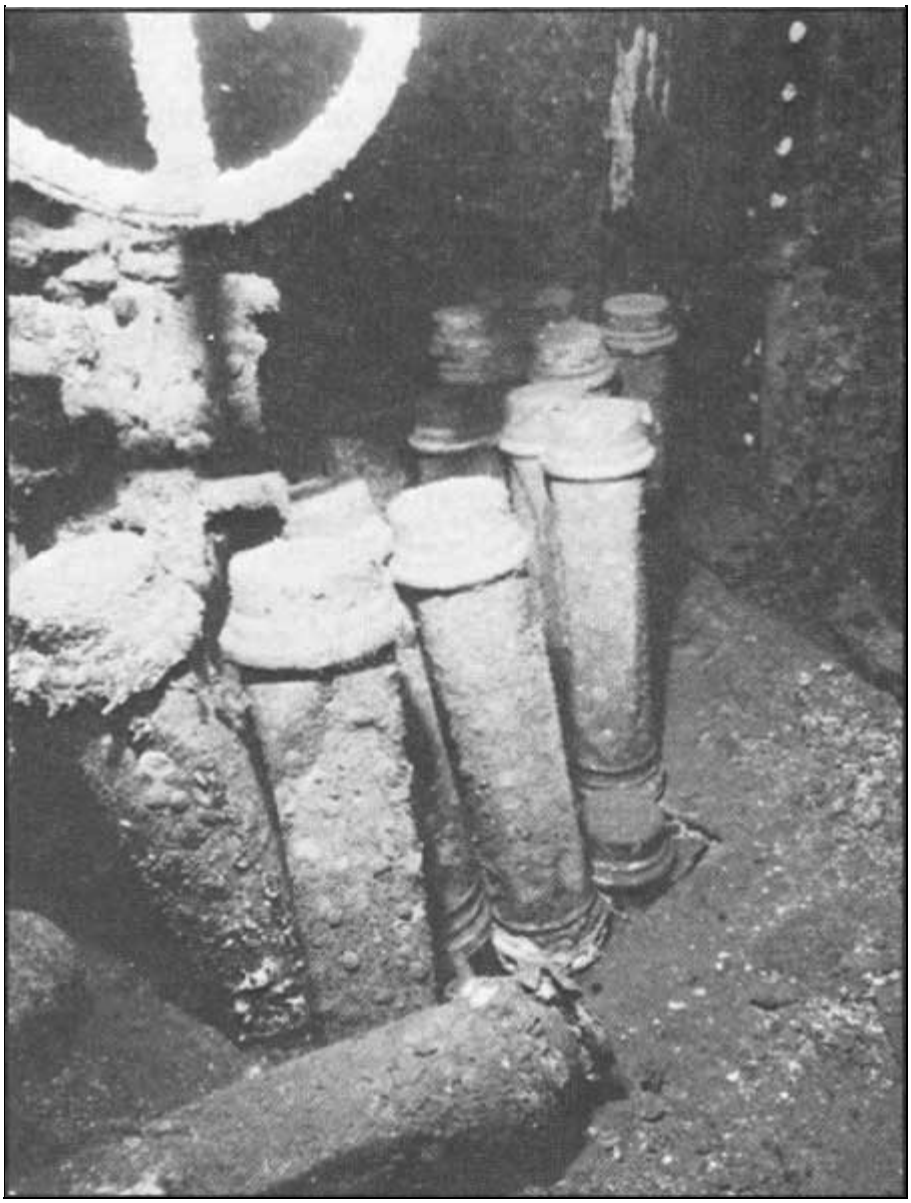
Saratoga carried 66-2/3 percent of its normal ammunition complement for the tests. Presumably live five-inch/38 caliber shells were actually found inside the 5-inch gun turrets. Aerial bombs and torpedoes were found in the hangar and will be discussed later.



Single 5-inch/30 caliber AA gun on *Saratoga*'s starboard bow gallery or sponson. *(NPS, Larry Murphy)*

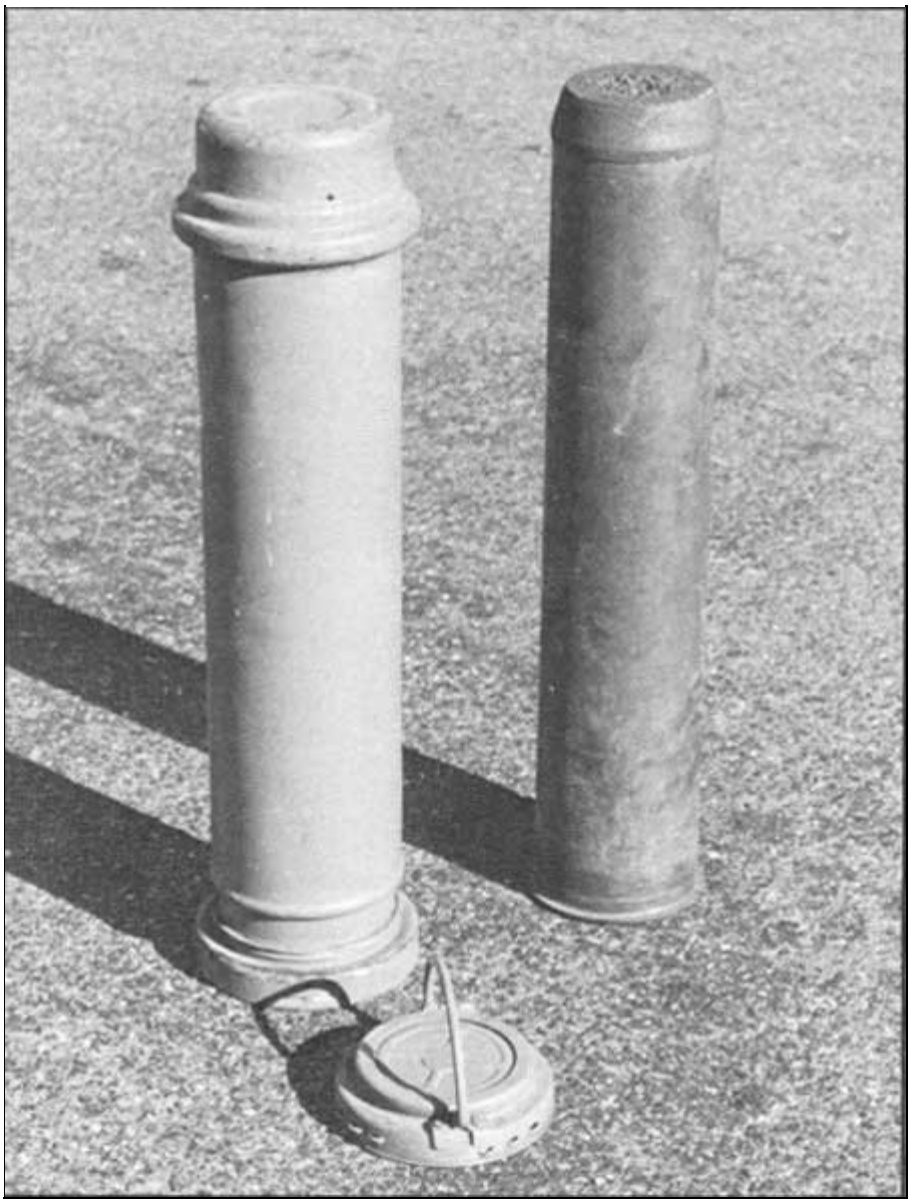
Various fire-control radars were also noted; the only types specifically identified were the SK and SM, as well as the Mark 37 director atop the island on the air-operations bridge, which is missing its Mark 12-22 array.

The steel flight deck, once covered with teak decking, is now exposed, allowing the observation of battens used for aircraft tie-downs, with small wood pieces surrounding the iron deck pieces. The area of the palisades is discernible, as are the tracks for *Saratoga*'s Mk II hydraulic catapults forward. Aft, 21-inch bitts and other arresting gear, with wire rope attached and running athwartship, are still in place. Other extant deck furniture includes the forward aircraft crane, which has dropped and lies on the deck. The crane was noted in 1946 reports as not appearing "to be damaged by the blast." [60] It was, however, lying on the deck when observed by Navy Divers in 1947. The collapse of the crane may be depositional. The airplane jettisoning ramp, which lies portside abeam the island, and various valves and fittings as well as fueling booms lie to starboard outboard the funnel. Both the bomb and torpedo elevators were seen. The bomb elevator hatch is open; the torpedo elevator is secured.



Live 5-inch/38 caliber cartridges, without warheads, in aluminum cartridge cases in *Saratoga*'s handling room for the No. 3, 5-inch mount. *(NPS, Larry Murphy)*

Ground tackle aboard includes an anchor stowed in a port bow hawsepipe and an anchor chain that runs from the bow to the seabed. The chains run into the sand but are no longer attached to a mooring. *Saratoga* was moored by 10-ton "clumps" made of anchors and concrete; one of these clumps is off the starboard side of the ship. Others were separated by the blast effect, which lifted the carrier and displaced it several hundred yards. A Navy stockless anchor, attached with wire cable to a bitt, lies on the flight deck aft the funnel to starboard. It may have been a mooring that was displaced by the blast and dumped on the ship by the falling water column; it lies in the indentation of the flight deck.

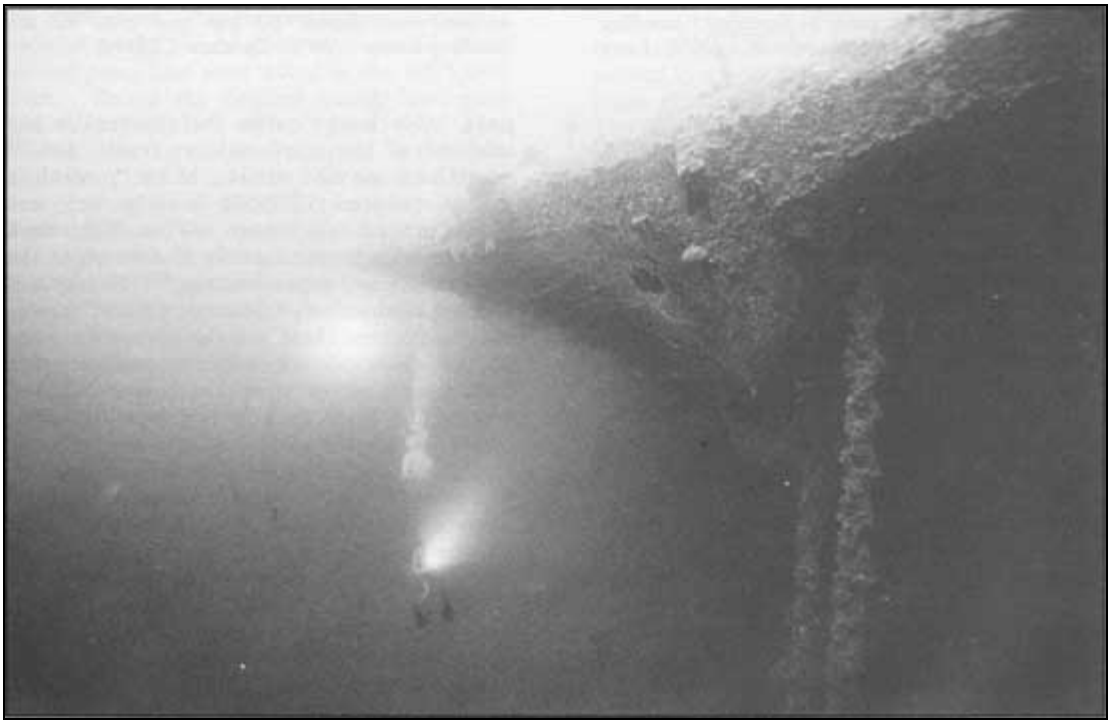


Five-inch cartridge case, showing the cartridge. The warhead was added by the gun crew in the handling room. *(NPS, Candace Clifford)*

Test Equipment. As part of the tests, military teams and scientists placed recording equipment and gauges aboard *Saratoga.* Much of this equipment remains, in some cases as traces of badly damaged instruments or mounts. Mounting brackets and pallets for military field equipment lie aft the funnel; on one of these pallets, on the port side flight deck near the after elevator, around frame 120, stands the remains of Army Signal Corps test equipment. On the pallet are the remains of the packing case and "safety trough" for an SCR-399 radio set and an air-cooled diesel power unit that were mounted to the deck "by means of ring pads, 1/2-inch wire cables and turnbuckles just inboard of the port rail...at frame 120." [61] Another power unit, M7A1, with a trailer-mounted SCR-584-B radar set, was placed aft of this set-up on the flight deck weather edge "approximately 50 feet aft of the main stacks and superstructure." [62] Nearby was a "shock-mounted" trailered PE-237 power unit. [63] Perhaps these are the source for some of the observed wreckage; a portion of a trailer, with rubber tires, lies in the indented area of the flight deck in this area. Another trailer lies on the seabed off the port side.

The most obvious piece of test equipment is an Army long antiaircraft gun bolted to the deck

on the port side abaft the funnel. It is reported that the Army Ordnance Task Unit 1.4.3 placed six items on the carrier for Baker: 1) a light tank, 2) a heavy tank, 3) an M1 cable system, 4) a 90mm GMC, Mark 36, 5) a 155mm Mark 2 gun, and 6) a 90mm Mark 2 antiaircraft gun. The weapon on the deck is probably the 155mm. [64]



Divers illuminate the bow and mooring cables of *Saratoga. (National Geographic Society, Bill Curtsinger)*

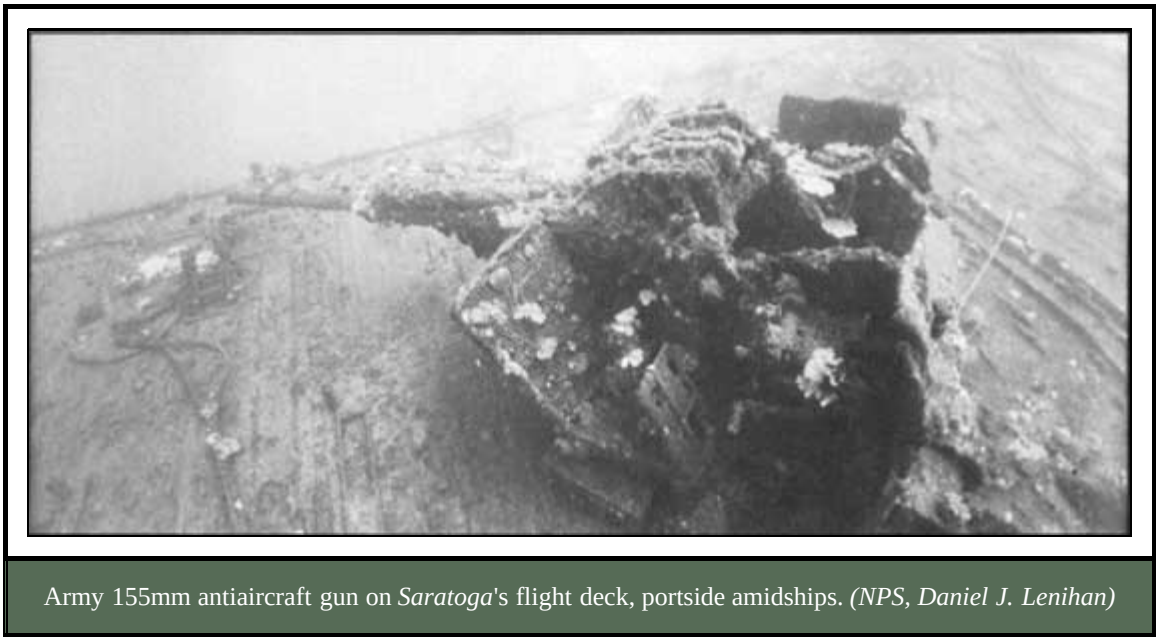
Also on deck are two blast gauge towers, one forward and one aft. The forward tower lies off the port forward corner of the elevator; the after tower is set about 50 feet abaft the funnel. These roughly pyramidical towers were known as "Christmas trees" and served as mounts for peak-pressure measurement gauges. To mount the gauges in proper position, test accounts state "typically, they [the gauges] were bolted to 'Christmas trees,' sturdy 9-foot-high structures of heavy steel pipes. The Christmas trees were ordinarily welded to the upper decks of the target vessels." [65] The pressure gauges were made of 1/4-inch-thick brass plates with round holes of various diameters up to two inches bored through them. Tin foil was sandwiched between two plates, which were then enclosed at the rear by a "sturdy air-tight cover, to prevent instantaneous equalization of pressure." [66] Blast effect in the range of 0 to 50 psi was measured by foil rupture; a greater blast effect ruptured smaller diameter foil, while a lesser blast only ruptured the more exposed foil in the larger diameter holes.

Another instrument mount type was observed on the flight deck aft. Welded to the deck on the centerline, but arranged in a nearly square pattern are three plate-steel boxes, each with a differently shaped bracket atop it. These are probably mounts and housings for delicate gauges and recording devices. The primary requirement for most instruments used in the Operation Crossroads tests was that they be

> really rugged. Despite the need for using ingenious recording systems, the gauges and their mounts must survive the terrific overpressure. It is pointless to use a precision gauge which is promptly flattened or blown overboard. Hence delicacy was not a characteristic of the instrument cases taken to Bikini; on the contrary, many of the designers encased their instruments' delicate works in

cases built of 2-inch-thick steel which could withstand the pressure. [67]

A large number of 1-inch-thick lead plates, some with large square holes cut in their middles, were observed lying atop the No. 3 gun house, and on the flight deck near the radio set pallets and inboard the 155mm gun. Nearly all lay bent or crumpled. These lead plates are probably the remains of indentation peak-pressure gauges used to measure pressure in the range of 20 to 1,000 psi or 100 to 6,000 psi, depending on the thickness of the lead. [68] One report notes "pressure is recorded in terms of indentation produced by a small steel ball forced against a sheet of lead. The greater the pressure, the deeper the indentation." [69] The last type of test equipment seen on the ship were two parabolic chromed, polished metal dishes. A 12-inch dish lies in a rubble pile at the after starboard corner of the deck outside the navigation bridge chartroom. A 24-inch dish lies in a rubble pile at the after port corner of the same deck. These are the remains of a "pendulum type inclinometer" developed by the material laboratory of the New York Naval Shipyard for the tests. The inclinometers were used to automatically record angles of rolls and pitch of target ships. Mounted on steel plate with a weighted arm designed to remain vertical at all times, the discs were scratched by the arm which left its record on the "shiny discs provided." [70]



Army 155mm antiaircraft gun on *Saratoga*'s flight deck, portside amidships. *(NPS, Daniel J. Lenihan)*

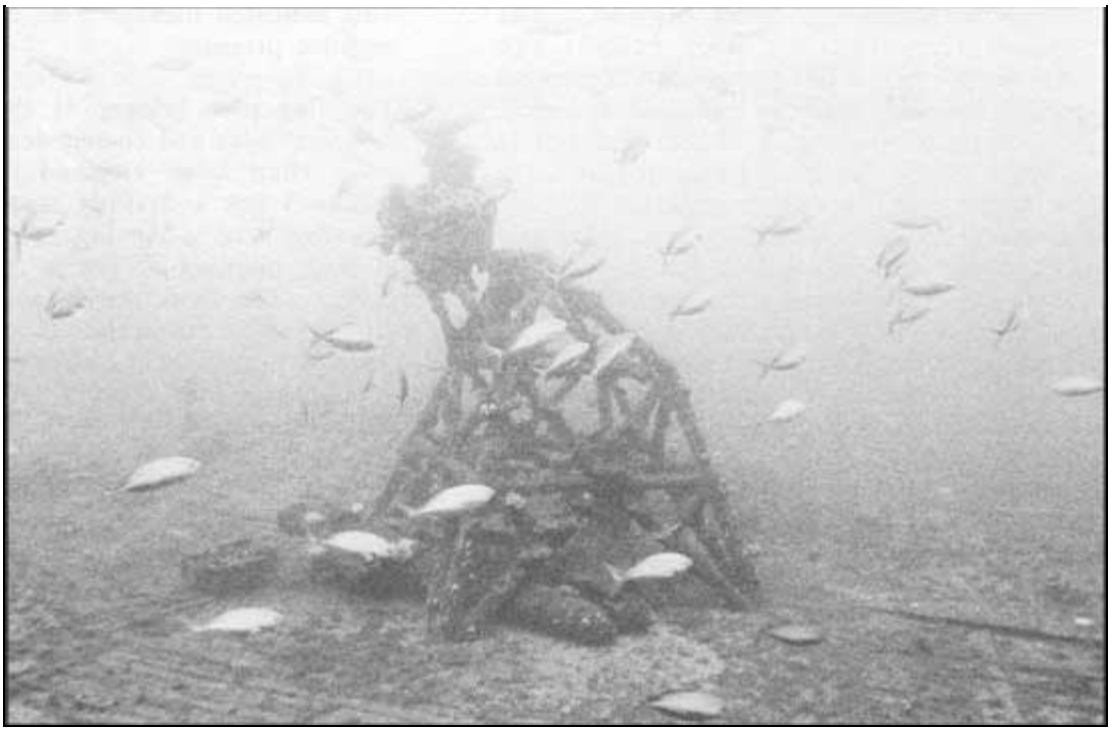
Island. Because of the time limitations caused by the depth of the dives and the need to focus effort on documenting the ship's exterior, only a few compartments were entered. Most were on the island. The compartments entered on the island were the flag plot, navigation bridge pilothouse, and the aerological office. All hatches and doors that enter the flag plot stand open--most blown off their hinges--with the exception of a closed hatch on the after starboard corner. Navy divers noted in 1947, that most of the hatches were distorted or blown down. Some inward and others outward. This indicated damage from both positive and negative pressure.

The flag plot bridge, at the forward end, contains radar and communications equipment; on a chart table attached to the starboard bulkhead lies a drafting machine, missing its drawing arm. Moving aft, bulkheads are missing, allowing access to the admiral's day cabin. The bunk, head, and a small white porcelain sink are in the cabin, which is largely open to the sea because the exterior bulkhead is missing in several areas. A hatch leads out to the starboard side of the flag plot bridge; on the deck outside, a ladder, with traces of lashings on the handrail, leads below to the navigation bridge. Forward the ladder and matched by another to port is a Pelorus.

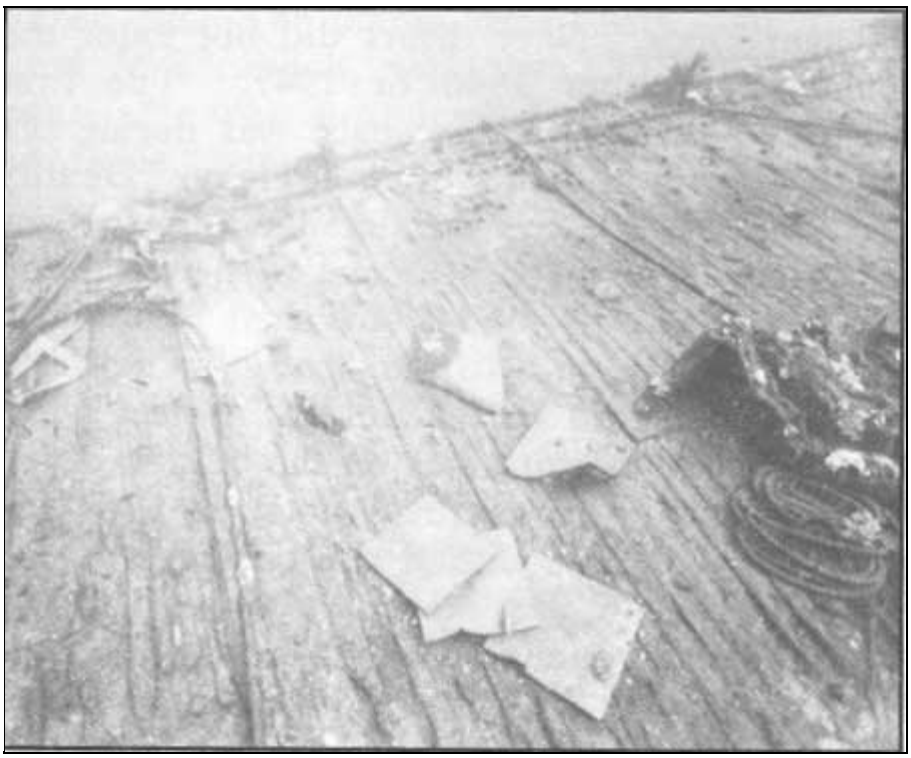
The navigation bridge portholes are missing their deadlights. External blast covers with viewing slits cover all portholes with the exception of the last porthole aft on the starboard side. That blast cover hangs down on its hinge. Outside the bridge are the mounts for two Pelorus; lying on the deck on the starboard side are a battle light, an air-raid siren, and an inclinometer gauge. A non-watertight interior door, probably from the hatch leading into the pilothouse, lies on the deck. Badly corroded, it retains a rubber gasket. Aft of it lies the watertight hatch for the chartroom. The watertight pilothouse door is open and hangs on its hinges. Through this hatch is an open companionway. The corresponding hatch on the port side is closed and dogged.



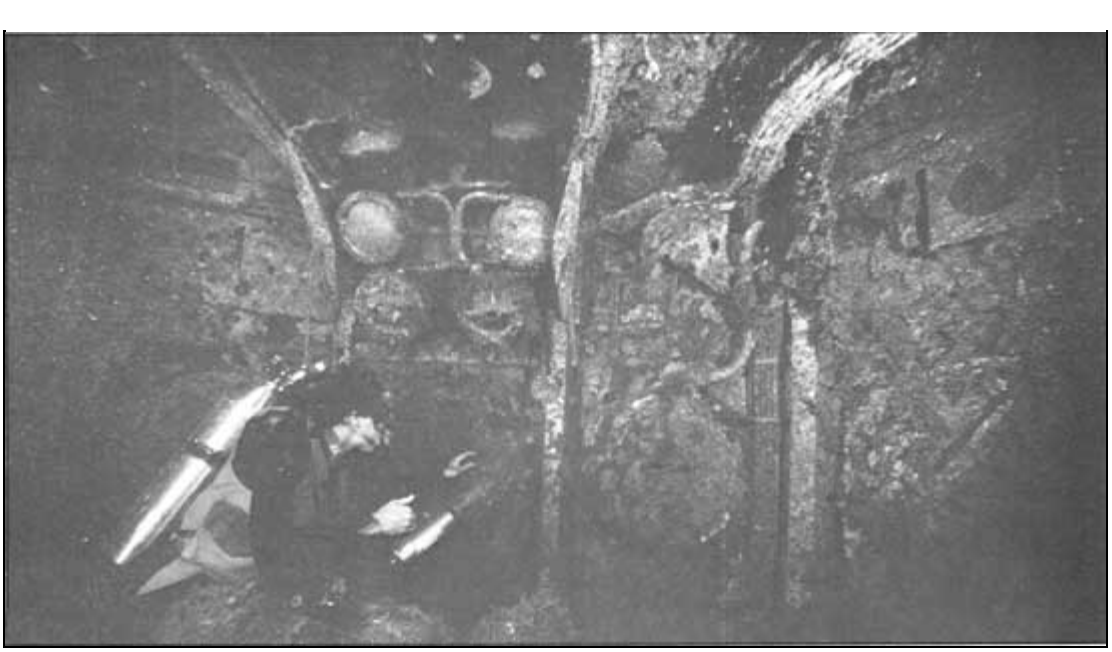
Installing a ruptured foil peak pressure gauge on a "Christmas Tree," in 1946. *(U.S. Naval Institute)*



Aft "Christmas Tree" blast-gauge tower on *Saratoga. (NPS, Larry Murphy)*

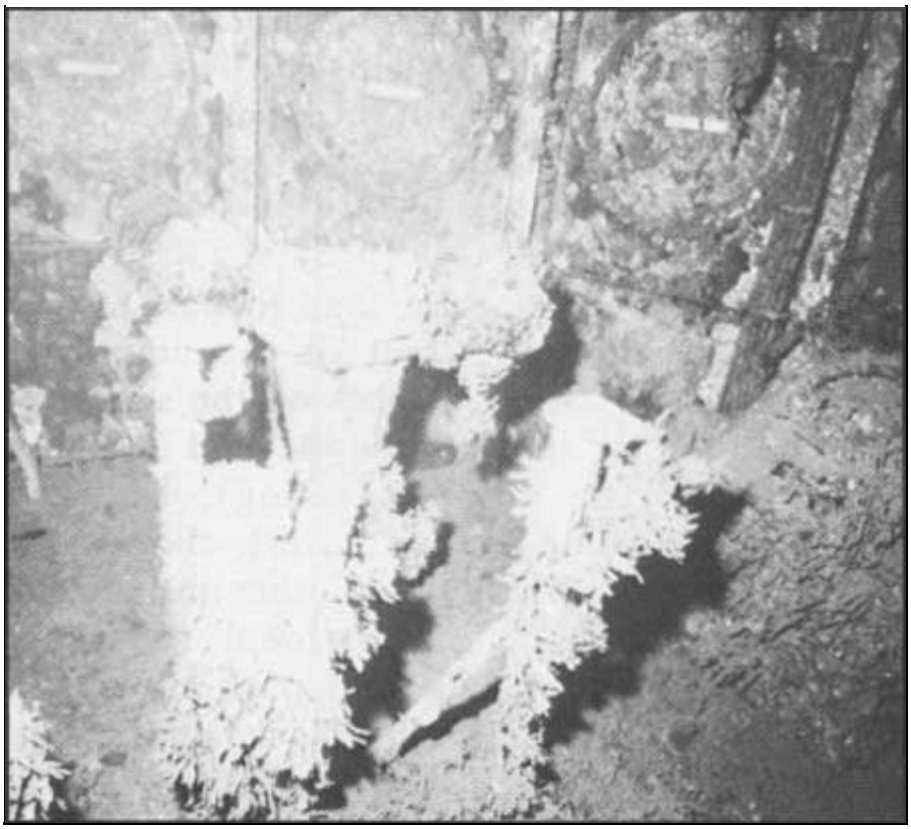


Lead indentation pressure gauges on *Saratoga*'s flight deck, port side, amidships. *(NPS, Daniel Lenihan)*



Catherine Courtney inspects the blast covers on *Saratoga*'s bridge. *(NPS, Larry Murphy)*

An open door to the right (and forward) opens into the pilothouse. Most of the equipment remains inside. A chart table on the starboard bulkhead is first encountered; beyond it sits the helm (with the wheel missing), binnacle (missing the compass and cover), the mounts for the signal telegraph and other instruments now missing, and a navigational radar set. Moving to port, a panel with push switches is labelled with an engraved black plastic sign that provides "emergency signals." On the bulkhead above it is an annunciator. Moving aft on the port side, an indicator is next encountered. This instrument, with a digital display, is marked "ENGINE TELEGRAPH," and "REVOLUTIONS AHEAD." On the aft bulkhead is an open door, with the door partially collapsed into the companionway. Moving to starboard is a chart table and the electrical panel for the ship's lights. Several black plastic engraved labels are fixed to the bulkhead next to switches; among them are "MAN OVERBOARD," and "MAST HEAD."



Helm position on *Saratoga*'s bridge, showing the binnacle, helm, and radar. The compass, wheel, and other equipment has been removed, presumably for Crossroads. *(NPS, Larry Murphy)*

To starboard of this panel is the doorway through which entry into the pilothouse was made. The overhead is covered with a thin film of oil.

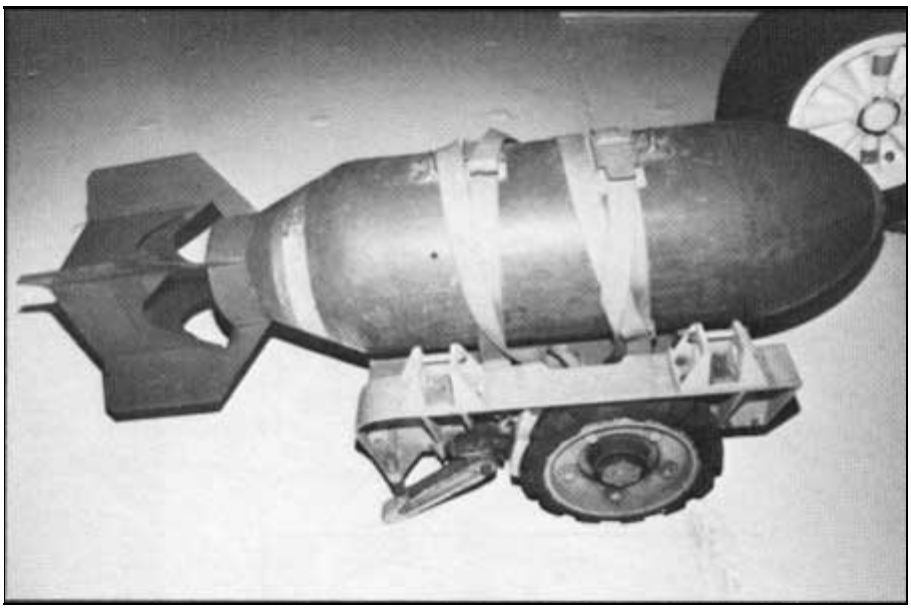
The chartroom is aft the bridge. The only access is by a starboard bulkhead hatch; it is blocked by a partially fallen piece of electrical equipment, possibly a SC-3 radar set. A nitrogen bottle for an SC-3 radar is mounted on the after starboard external corner of the chartroom. The chartroom was ventilated on the port side by a circular vent--once protected by a hinged cover; the remains of the cover hang down by the hinge.

The aerological office is the aftermost compartment in the aerological platform, which is one level above the flight deck on the island. The starboard bulkhead has fallen away, providing access into the office. The original access, a door on the port bulkhead, stands open, with the hatch off its hinges. The interior of the office is largely open; against the port bulkhead is a steel desk bolted to the deck; forward is an unidentified piece of electronic equipment and a steel file cabinet. Beyond this is a companionway that leads to a ladder that provides access to the decks above and below.

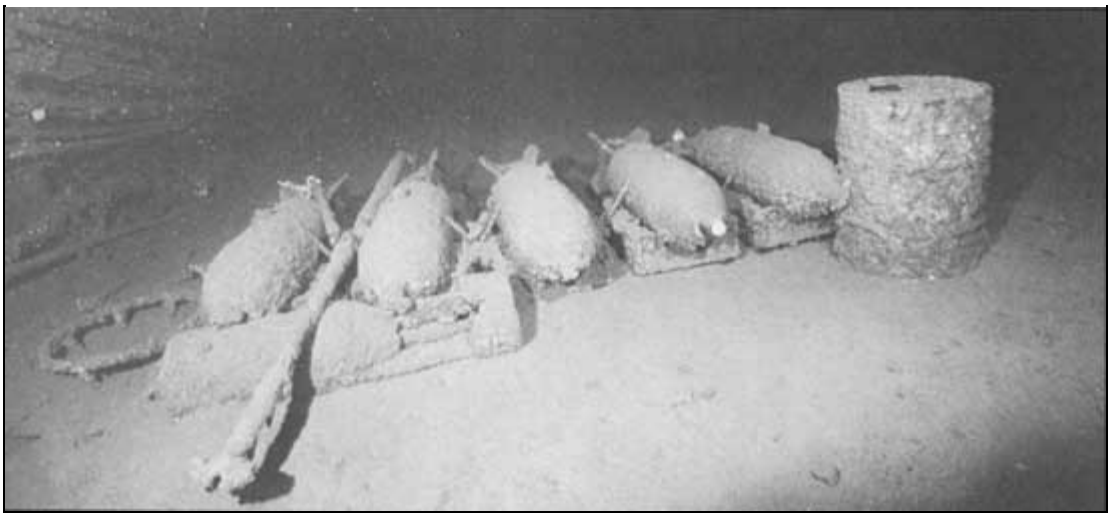
Hangar Deck. Navy divers did not enter the hangar in either 1946 or 1947. The first recorded entry into this space was during the 1973 filming of the documentary, "Deadly Fathoms," for which no detailed observations were made, save the presence of one or more aircraft. The 44-by-44-foot shaft drops one deck into the hangar deck, which is approximately 20 feet high and 70 feet wide. The elevator platform lies on the bottom of the shaft. Navy divers correctly noted in 1946 that the platform "was dished diagonally from the forward port to after starboard corner." [71] The elevator shaft opens aft into the hangar deck. Just inside the deck, near the after starboard corner, lies a rack of what the Bureau of Ordnance's records show are five 500-lb. general purpose aerial bombs, model AN Mk 64, Mod 1, equipped with AN Mk

243 nose fuzes and AN Mk 230 tail fuzes--the primary armament of the SBF-4E Helldiver aircraft in the hangar. These weapons remain in their test location at frame 82 on the starboard side of the hangar deck. Inside the deck, at the after port corner of the elevator, are four 350-lb. aerial depth bombs, model AN Mk 64, Mod 1, "plaster loaded and fuzed" [72] equipped with AN Mk 219-3 nose fuzes and AN Mk 230-6 hydrostatic tail fuzes. Navy EOD divers working with the NPS team confirmed these identifications. One of these fuzes was armed and was defuzed by a Navy EOD technician who "safed" it with epoxy. These bombs are in their original test location at frames 80-81 on the port side of the hangar deck. [73]

Inside the hangar deck, moving aft, are two loose fueling drums and loose bomb and torpedo racks once secured to the bulkheads and overhead. Pipes for fire sprinklers hang from the overhead, some loose. Electric lightbulbs are intact and line the overhead, which is covered with a thin film of fuel oil released from the ship's bunkers. Three U.S. Navy dive-bombers, Curtiss SBF-4E "Helldiver" single engine aircraft, were observed during the dive, stowed with their wings folded. It was found that the forward airplane's engine, cowling, and propeller have detached from the plane and lie on the deck. This aircraft, which should be BuAer serial number 31894 according to the Bureau of Aeronation Report, was according to the report, stowed on the hangar deck at frame 90, starboard, for the Baker test. The plane, armed with twin 20mm fixed M-2 cannon, with twin .30 caliber free guns aft, was noted as being "intact and operable, wings folded" and combat-ready except for "bombs, ammunition, fuel, safety equipment, pyrotechnics." The bolts were removed from the guns, which were loaded with ten rounds. The clock was removed from the instrument panel for the tests. Aft of plane 31894, a second SBF-4E, BuAer serial number 31850, was observed, noted in the Bureau Report as stowed on the hangar deck, frame 100, starboard, in the same condition and configuration as 31894. [74] Aft of plane 31850, a third, partially crushed SBF-4E, BuAer serial number 31840 was found. The Bureau Report noted this plane as stowed on the hangar deck, frame 110, starboard in the same condition and configuration as planes 31894 and 31850.

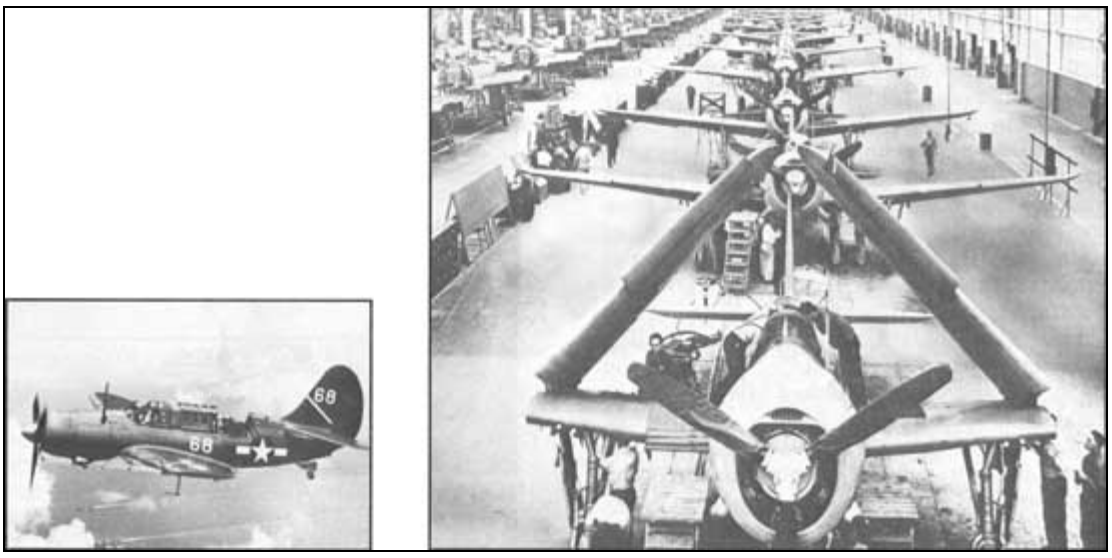


A 500-lb. bomb on USS *Yorktown. (NPS, James P. Delgado)*

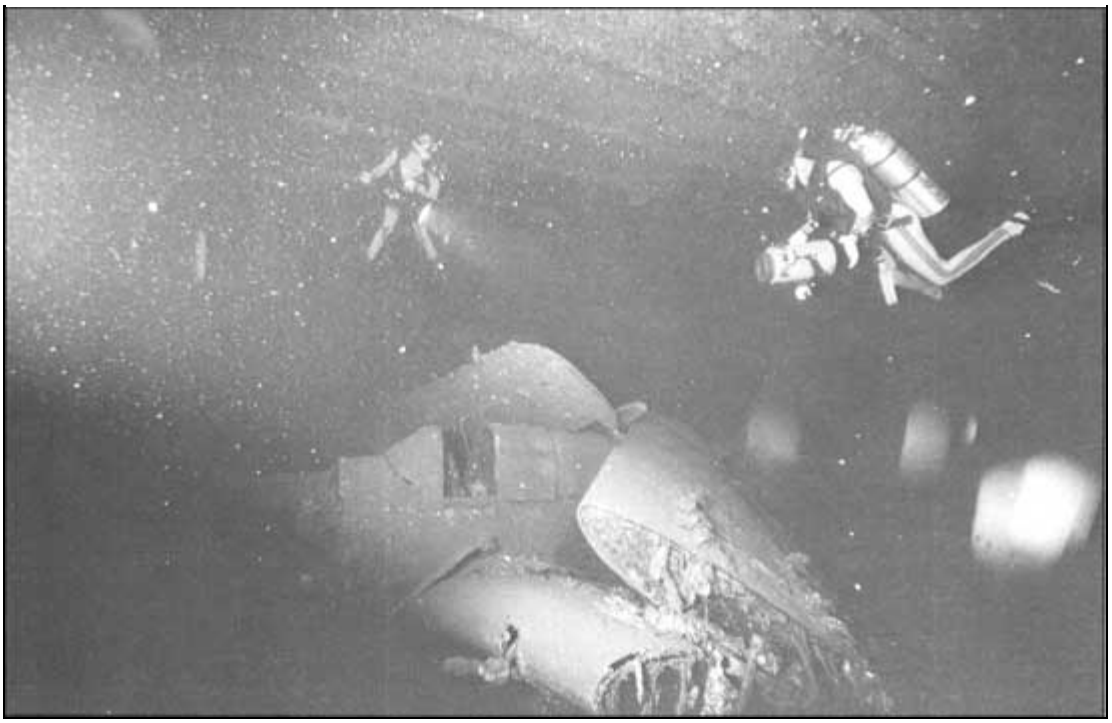


Five general purpose 500-lb. bombs, AN-Mk 64, on their bomb carts, on the starboard side of *Saratoga*'s hangar deck at frame 82. Lying forward of the bombs is a single 350-lb. depth bomb, AN-Mk 64, originally stowed with four others on the port side, which rolled free and lodged against the 500-lb. bombs. *(National Geographic Society, Bill Curtsinger)*

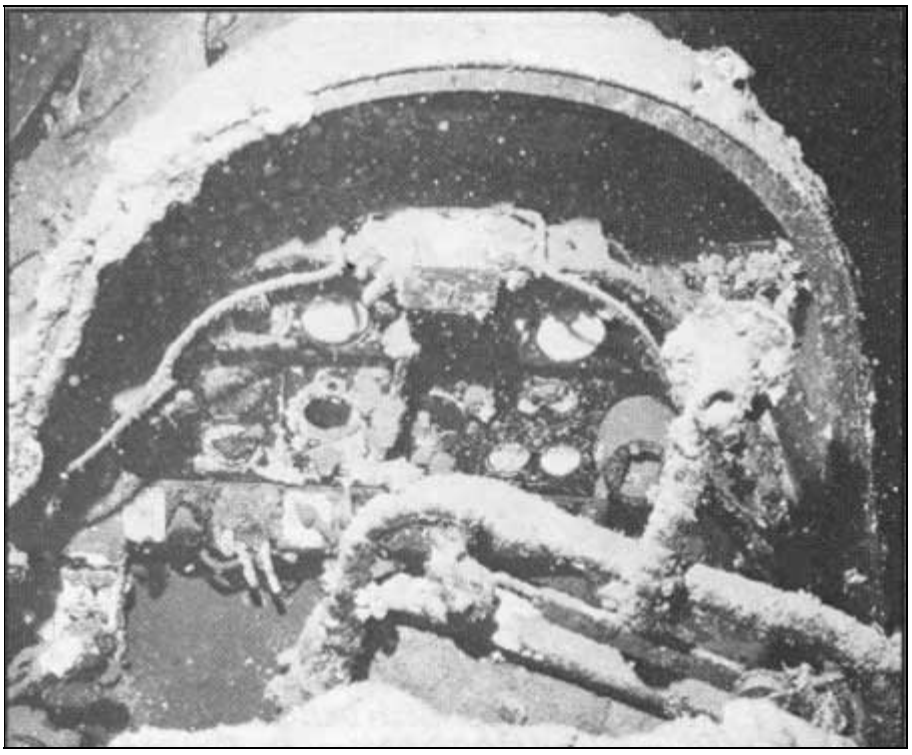
All three aircraft were aboard *Saratoga* for the Able test; 31894 was on the hangar deck, frame 110, port side; 31850 was on the hangar deck, frame 100, starboard; and 31840 was on the hangar deck, frame 110, starboard. All three aircraft, as well as SBF-4E, BuAer serial number 31889 (also on the hangar deck, frame 100, port) were undamaged. Plane 31889 was removed from *Saratoga* and placed aboard USS *Independence,* and 31894 was shifted to starboard forward of 31850 and 31840, which remained in their Able test locations, for the Baker test. All aircraft were noted as "missing--Sank with *Saratoga,"* after the test. A fourth aircraft, a TBM-3E "Avenger" torpedo-bomber, BuAer serial number 69095, noted as stowed on the hangar deck, frame 120, starboard, was the only other aircraft aboard *Saratoga* and in the hangar. This aircraft, also "missing--sank with *Saratoga,"* is presumably the airplane spotted by divers in the hangar area at the deck collapse, aft of plane 31840. [75]



Two views of the Helldiver. Wings folded, an SB2C-4 is readied at the factory. In flight over the Pacific, a carrier task force below, an SB2C-4 shows the trim and features of the aircraft. *(U.S. Naval Institute)*



ABC-Television divers illuminate an SBF-4E "Helldiver" on *Saratoga*'s hangar deck. This is aircraft BuAer #31894. *(National Geographic Society, Bill Curtsinger)*



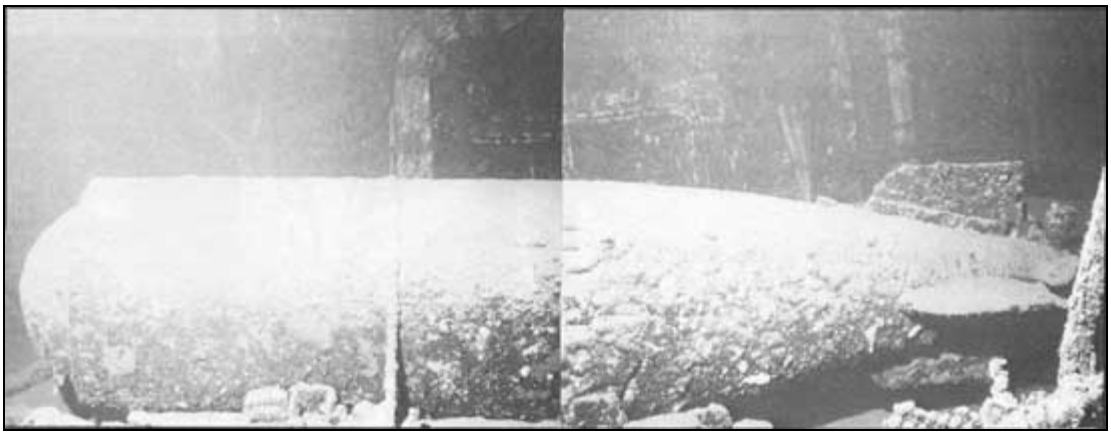
Pilot's cockpit instrument panel, SBF-4E, BuAer #31850. Note that only the clock has been removed. *(NPS, Larry Murphy)*

The Helldiver was a wartime-production model designed to replace the prewar Douglass SBD Dauntless dive-bomber. The Helldiver had a combat range of 1,165 miles and was capable of 295 mph at 16,700 feet. The service ceiling was 29,100 feet. The SB2C-4/5 (same

as the SBF-4E) Helldiver's wing span was 49 feet, 9 inches; the plane's length was 36 feet, 8 inches and its height was 13 feet, 2 inches. The empty weight of the Helldiver was 10,547 lbs.; the loaded weight was 16,616 lbs. The plane was powered by a Wright R-2600-20, 1,900-hp radial engine and was armed with two fixed forward firing 20mm cannon in the wings and two 0.30-inch machine guns in the rear cockpit. The plane carried up to 2,000 lbs. of bombs (1,000 internal/1,000 external) or eight 5-inch rockets. The Helldivers were used in mounting the air offensive against Japan; capable, they were difficult to handle, and earned the nickname "beast." One hundred SBF-4E (BuAer serial numbers 31836 to 31935), a Fairchild-Canada version of the Curtiss SB2C "Helldiver," were built in 1944-1945. [76]

Aft the aircraft the hangar is open; to starboard lie a number of Mk 13 torpedoes, some missing their warheads. Dating to the 1930s, the Mk 13 torpedo was the only aerial torpedo in use during World War II; it was not replaced until the 1950s. The Mk 13 was 161 inches long, 22.5 inches in diameter, and weighed 2,216 lbs. Propelled by a steam turbine, it developed 33.5 knots with a range of 6,300 yards. The control system was air/gyro.

The Mk 13 was replaced after 1950 by the Mk 14, an 84-inch long, 680-lb. weapon. [77] The torpedoes, like the bombs, were placed on the ship by the Bureau of Aeronautics for testing; the depth charges and torpedoes were prepared by BuAer in two ways; (1) in normal condition but without the booster and detonator but with the main charge, or; (2) with booster and detonator installed but with the main charge replaced by inert material. "Thus a sensitive explosive would not necessarily detonate a less sensitive charge." [78] Bureau of Ordnance photographs of the ordnance placed on *Saratoga*'s hangar deck shows the inert material labelled "plaster." The torpedoes specifically are noted as having inert warheads, "but the flask is fully charged." Weapons noted in the BuOrd photographic documentation, but not yet observed during dives, include a rack of 5-inch High Velocity Aerial Rockets with Mk 6-1 heads and 149 nose fuzes and 164 base fuzes at frame 160, hangar deck, starboard; 11.75 "Tiny Tim" rocket, 2-100-1 Base Fuzes, marked "Inert" in photographs, at frame 162, hangar deck, port; and a mine, Mark 24 (secret), at frame 163, hangar deck, port. [79] Aft the torpedoes is a catwalk that has partially collapsed.



A single Mk 13 aerial torpedo, on a cradle, inside the hangar. *(NPS composite photo, Larry Murphy)*



An Mk 13 torpedo suspended beneath a TBM-3E on USS *Yorktown. (NPS, James P. Delgado)*



Daniel Lenihan illuminates an unbroken light on the overhead inside *Saratoga*'s hangar deck. The dark splotches on the overhead are patches of oil. *(NPS, Larry Murphy)*



Radio equipment in the emergency radio equipment compartment at *Saratoga*'s bow. *(NPS, Larry Murphy)*

Aft of the planes, the hangar deck is empty except for ordnance mentioned above. At the bulkhead that ends the hangar, there is a large pile of piping and debris that could be remains of bunks from "Magic Carpet." NPS divers penetrated to this point and then into one compartment beyond. The compartment, listed as the aviation metal shop, was mostly empty. Expected lathes and other machinery were apparently removed. Vessel plans indicate further compartments aft. These compartments were not entered and their condition and contents are unknown.

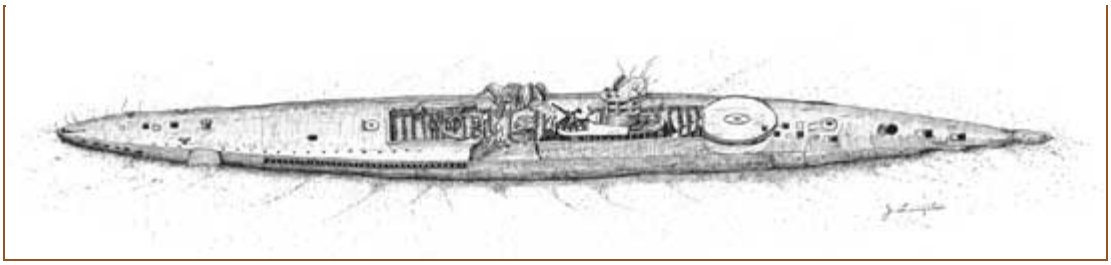
The intakes for the boilers in the funnel area are clogged with debris, prohibiting visual access to the engineering spaces. Numerous open hatches on the starboard side were visually inspected; in all cases they opened into companionways that quickly terminated with gun hatches leading below or into the ship. These were not entered. The hatch of the handling room below the No. 3, 5-inch/38 caliber gunhouse stands open; limited visual inspection from outside indicated that the hoisting machinery is in place, as well as a number of cartridges in their aluminum containers.

USS *PILOTFISH*

The five-man team did one dive on the wreck of USS *Pilotfish* in 1989. A narrated video, site map, and still photographs were obtained.

Pre-Test Alterations

Known *Pilotfish* alterations include the installation of weights and wire rope moorings, as well as salvage fitting connections, that allowed the unmanned submarine to submerge and surface for the tests. The two periscopes were removed and the shears scope tubes were blanked out.



Perspective sketch of *Pilotfish. (NPS, Jerry Livingston) (click on image for a PDF version)*

Able Post-Blast Observations

Like the other submarines, *Pilotfish* was on the surface during the Able Test. The bomb detonated 2,506 yards off the vessel's starboard side, scorching and charring superstructure paint. The sub's ability to submerge and conduct normal combat operations was determined unimpaired: "There is no reduction in fighting efficiency from a material standpoint. Exposed personnel topside would have been at least temporarily out of action." [80]



Jerry Livingston hovers over the sail of *Pilotfish.* Note the periscopes have been removed, a twin 20mm is mounted on the aft cigarette deck *(NPS, Larry Murphy)*

Baker Post-Blast Observations

Pilotfish was submerged for the Baker test. The eight boats were moored at various depths throughout the lagoon target array. *Pilotfish* was submerged at a keel depth of 56 feet in 28 fathoms (168 feet) of water at a range of 363 yards from the blast. [81] *Pilotfish* was the only submarine moored adjacent to USS *Arkansas* and of three submarines sunk, was closest to the blast. Post-test diver evaluations in 1946 reported *Pilotfish* on the bottom

> with a starboard list.... The deck is covered with silt to a depth of 3-18 inches. A few pieces of loose coral are resting on the deck...it is considered likely that all compartments are flooded and that the tips of the ballast tanks are no longer tight. It is believed that a comparatively lengthy operation would be required to salvage this ship. [82]

Navy divers' post-Baker test reports of 1946 noted the vessel was on the bottom at a depth of 170 feet, with a 30- to 40-degree starboard list, apparently completely flooded and covered "to about three-quarters height with silt and coral." Aft, by the torpedo room, the plating was dished inward about six inches between the frames *(Pilotfish*'s stern faced the blast). Navy reports indicated the tank tops and superstructure plating were dished in several places and the superstructure plating "has numerous tears and holes...superstructure has shifted to starboard about six inches amidships and one inch at the stern. This shift makes salvage connections inaccessible unless part of the deck is cut away." [83]

Site Description

The 1989 dive survey found that USS *Pilotfish* lies in 175 feet of water. The deck is reached at about 150 feet, and the top of the conning tower shears lie at 130 feet. The submarine is readily identifiable as USS *Pilotfish* and conforms to late war and Bikini test photographs. The boat is upright, listing about 15 degrees to starboard. The pressure hull is intact, but the aft portions are dished as much as six inches between frames; this confirms 1946 Navy diver reports and is indicative of the boat's stern facing the blast. The pressure gives the impression of having been "shrink-wrapped" around the circular frames.

The diving planes are present and stowed, folded up against the hull. The bow torpedo shutters and stern tube shutters are closed. The anchors were not observed and probably removed prior to the test; *Pilotfish* was moored by means of weights and cables to enable the boat to submerge without a crew aboard.

The superstructure is intact, but dented in all areas except the sail front. Here the superstructure is broken, deck beams have collapsed, and debris litters the pressure hull and the lagoon bottom on the starboard side. This damage may be the result of aborted Navy salvage attempts because salvage fitting access required cutting away the shifted superstructure. The teak decking of the superstructure is largely missing, apparently consumed by marine organisms. Only stubs of the decking around fastenings have survived.

Numerous fittings were noted on the deck. The superstructure and deck are missing in the area of the forward torpedo loading hatch, which is closed. There is no trace of the hatch deck skid. The forward escape and rescue hatch are closed, as is the aperture for the marker buoy. The forward tank valves cover is open, probably from 1946 salvage attempts. The aft escape hatch, leading into the after battery, is open. This hatch was closed for the tests; 1946 photographs of the sunken submarine also show it closed. The hatch was either opened by

Navy divers attempting to salvage the boat or was opened after the Navy salvage effort. The portable capstan, usually stowed when underway, is mounted on the deck near the bow.

No antennas were noted on the deck, but a topside JP sonar hydrophone is mounted on the deck to starboard just forward of the torpedo loading hatch. The hydrophone is missing its black rubber cover. Powered by the submarine's batteries, the JP hydrophone was a passive listening sonar often called "iron-board sonar" because it is an oblong metal tube atop a shaft mount.

Pilotfish's original armament was a single 5-inch/25 caliber gun and a single 40mm gun. The 5-inch gun mount is located aft on the deck. Another gun mount is forward. The aft 5-inch deck gun, mounted near the war's end, was apparently removed for Crossroads. A single 40mm gun is mounted on the forward fairwater; the barrel is slightly elevated and cants to starboard. This is a typical mounting for a late war boat engaged in lifeguard duty off the Japanese home islands. Navy manuals for the time indicate the 40mm, while "principally an anti-aircraft weapon, may be used against surface craft. It is a rapid fire, recoil-type weapon." [84] Aft, on the after "cigarette" deck of the sail, a twin 20mm Orelikon gun is mounted. This gun is elevated and points aft and slightly to port.

The sail is intact and slightly dented. The navigating bridge on the sail forward the shears is open; the mount for a target bearing transmitter (TBT) is located at the bridge starboard side, but the instrument is missing, probably reflecting selective stripping of specific types of reusable equipment for Crossroads. The shears are intact, but the two periscopes have been removed. Forward the No. 2 periscope shear is an SJ (surface-search) radar antenna of a late-war model. This radar gave the boat range and bearing of a target. Aft the No. 2 shear is the antenna mount for an SS (air-search) radar. The antenna, a larger version of the SJ, is missing.

The interior of the submarine was not entered. The only open hatch is the after escape trunk. It is believed that the boat is flooded, based on Navy reports from the 1946 dives.

USS *APOGON*

Pre-Test Alterations

Apogon's periscopes were removed, as were its anchors, for the tests. The vessel retained its two single 40mm guns on the sail.





ROV view of *Apogon*, looking forward from aft of the sail, starboard side. *(U.S. Navy, ROV)*

Able Post-Blast Observations

Apogon, like all the other submarines, was surfaced during the Able test. The bomb detonated 975 yards off the boat's port side, "moderately" scorching and charring paint on that side. The boat was left partially open; pressure distorted three internal bulkheads, but *Apogon* was operational. [85]

Baker Post-Blast Observations

The boat was then submerged for the Baker test; "the submarines proved to be useful 'instruments' for subjection to the enormous pressures created by the atomic bombs, since their hulls are expressly designed to withstand high pressures...." [86] The submarines were moored at different depths throughout the lagoon. *Apogon* was submerged at a keel depth of 100 feet at a range of 850 yards from the bomb. The boat was one of three submarines that sank as a result of the blast. "Air bubbles and fuel oil escaped from the *Apogon* as she went down." [87]

The 1946 Navy divers located the submarine in 180 feet of water, entered the boat, and began salvage operations, which included blowing air into the flooded hulk. The salvage efforts were abandoned, however, before the boat was brought to the surface.

A Navy report states, "All compartments were flooded or partially flooded with the exception of the conning tower." [88] The boat was flooded through a 30- by 15-inch hole in the hull forward and through a rupture either in the trunk or hatch cover for the after torpedo room. Additionally, a tank top cover on a ballast tank was reportedly ruptured. The water pressure from the blast was recorded at 1,200 lbs. per square inch. [89] The Navy, probably while attempting to salvage the vessel, found that the interior bulkheads were no longer air or watertight. This was presumably the deciding factor in the abandonment of salvage operations on *Apogon.*

Site Description

The investigation, consisting only of ROV surveys, found that the intact hulk of USS *Apogon* lies on a more or less even keel, slightly listed to port. The submarine is in better condition than *Pilotfish.* None of the dishing between frames that deforms *Pilotfish*'s pressure hull aft is discernable on *Apogon.* Damage seems confined to the superstructure, which is lightly dished and broken, forward of the sail, as well as aft on the port side. A major section of the superstructure is missing in the area of the forward torpedo loading hatch. This appears to have been cut away. There are jagged edges of metal visible, indicating a post-Baker intrusion, perhaps from a 1946 salvage attempt or the 1947 resurvey. The hole in the pressure hull in the area of the forward torpedo compartment at the bow reported in 1946 was not observed in the ROV video dive tape, and is presumed to rest beneath the superstructure debris in this area.

The wooden decking of the superstructure is missing, like that of *Pilotfish.* No hatches or other apertures in the hull were observed open. The sail is intact, and the shears mount an SJ radar, as does *Pilotfish.* It also mounts an SV radar. The cigarette, fore and aft, mounts a single 40mm gun at each end of the sail. Unlike *Pilotfish, Apogon* retains its target bearing transmitter on the sail. The vessel appears, with the exception of minor fouling and the observed damage, much as it does in Crossroads photographs of its test submergences.



Apogon's stern has the wire cables that moored the submerged target and rubber air hose connected to salvage fittings. *(U.S. Navy, ROV)*

The submarine's screws were observed, partially buried in the silt. The dive planes are stowed against the hull, and the torpedo door shutters are closed. Wire cable, part of the system to moor the submarine and submerge it without a crew on board, remains attached to the fairleads on the hull aft. No sign of the 10-ton anchor to which the stern was moored was observed. A rubber air hose is attached to the salvage connection to the aft torpedo room, left, most probably, from the 1946 salvage attempt.

YO-160

Pre-Test Alterations

There were no known alterations to YO-160. Blast gauge towers may have been fitted.

Able Post-Blast Observations

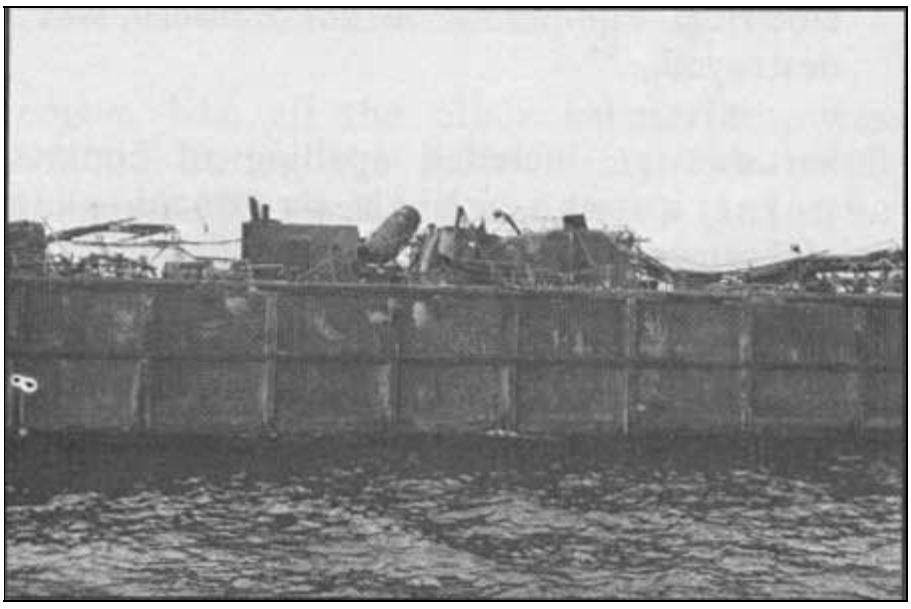
YO-160 was heavily damaged by the Able test detonation. One 1946 Navy report notes, "The wooden bridge house and all equipment inside burned. Concrete deckhouses had their bulkheads and overheads blown in. The wooden catwalk was demolished." [90] Major damage was done by radiant heat from the bomb, which started fires that raged throughout the vessel, burning

> practically all inflammable material and equipment aft on the main deck and above. The areas burned included the vessel's living and berthing spaces, steering engine room, engine room, wooden bridge, and part of the catwalk. It is estimated that approximately 90 percent of the electrical equipment in these areas was destroyed.... [91]

Other damage included spalling of concrete superstructure which exposed steel reinforcement and partly collapsed decks and overheads, sending large chunks of concrete into the spaces below, smashing equipment. The Navy concluded that the "air blast from above and aft is considered to be the primary cause of damage...." [92]

Baker Post-Blast Observations

Though seaworthy, YO-160 was useless. Its ability to serve was seriously impaired by the destruction of pumping equipment, electrical systems, and engines. YO-160 was swamped and sunk by the Baker blast, which lifted the bow before deluging the vessel. [93]



YO-160's appearance has not changed since photographed on the surface after Able and sunk during test Baker. *(National Archives)*

Site Description

In 1989, a NPS dive was made on the midships deck area and no observations of bow, stern, or hull area were made. The vessel was found upright on an even keel with the deck at 140 feet below the surface. Intact pipes ran fore and aft along the deck. A hose, about a foot in diameter, likely a fuel hose, ran across the deck. The deck was littered with pipes, broken

equipment and steel plates, which were likely from deckhouse structures. The concrete deck was broken and separated in some areas.

The main feature in the midships deck area was the standing portion of a large deckhouse, which was missing its roof. Bulkheads, some with hatches remained. One deckhouse doorway had the door still attached and hanging by the middle hinge. In the deck were two manway hatches with both covers off. The deckhouse floor seemed clear and sound. Vertical pipes about six inches in diameter were observed in the floor of the deckhouse, which may have been sounding pipes for the midships tanks.

Other prominent deck features were the remaining stubs of a centerline catwalk support. The vessel was of a well-deck design and catwalks led to the raised decks fore and aft. There were three pairs of large globe valves--one pair on the centerline and the other two pairs halfway to the gunwale on each side. No ventilators, which would be expected on a fuel ship were observed--likely blown off the deck by the blast.

HIJMS *NAGATO*

Pre-Test Alterations

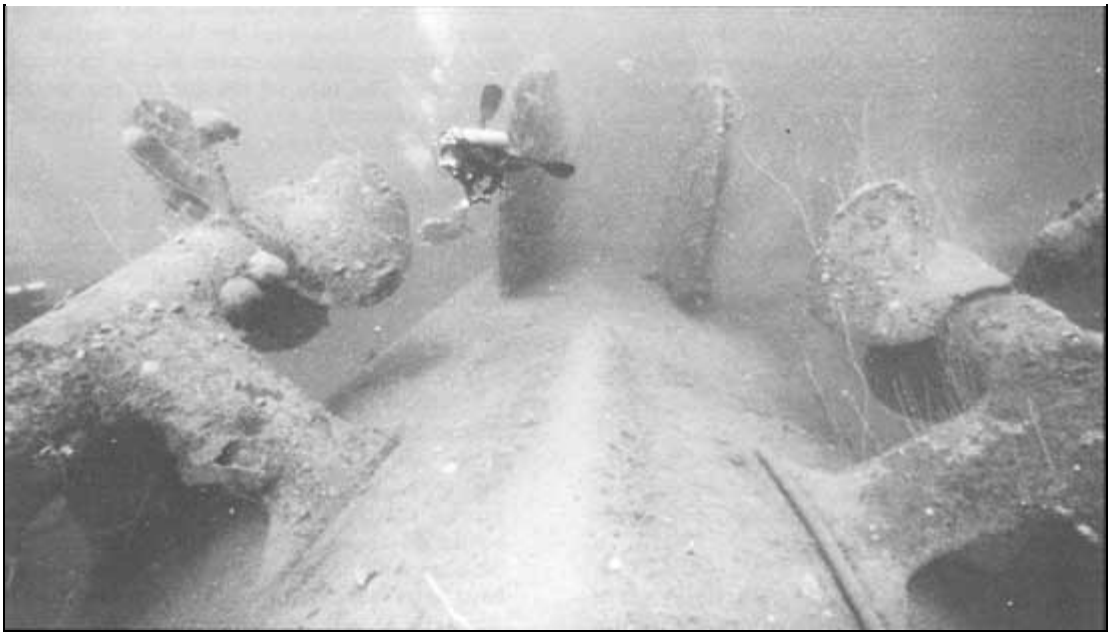
The main mast and stack were removed by Japanese prior to U.S. capture to confound identification. At Crossroads, *Nagato* showed signs of recent combat. The superstructure was holed and blasted. The antiaircraft batteries were put out of commission, the deck was splintered, but not penetrated, and there were hull dents near the bilges. Test instruments were installed belowdecks and a "Christmas Tree" blast gauge tower was installed atop the "C" turret.

Nagato's sinking was unobserved. Little is known about the specific pretest preparations. Most likely there were two "Christmas trees"; reportedly all ships were so fitted. Apparently no Army Ground Group material was placed aboard for either test.

Able Post-Blast Observations

Nagato was moored 400 yards to the starboard of USS *Nevada*, target ship and ground zero for the Able test and was moderately damaged by the blast. Light superstructure plating was wrinkled, non-watertight doors were blown off their hinges, and paint was scorched during Able's detonation. A ship's report after the blast concluded *"Nagato* is structurally sound.... The poor condition of the ship and her equipment is due to lack of preventive maintenance and overhaul, and to the fact that her engineering plant sat idle for over a year." [94] This is counter to later reports after the Baker test that reported holes in the hull shell plating.





Daniel Lenihan swims past the rudders and toward two of *Nagato*'s four screws. *(National Geographic Society, Bill Curtsinger)*

Baker Post-Blast Observations

The Baker test displaced the battleship sideways some 400 yards. [95] *Nagato* was observed with a 5-degree list 4-1/2 hours after the blast. The list increased continually over the next four days. At one point the ship was observed to have increased its listing to an angle of 120 degrees, with the starboard side down. *Nagato* apparently was never reboarded after the test, despite the slow progressive flooding. The Director of Ship Material for Operation Crossroads advised the Task Force Commander on July 29 that "radiological hazards prevented salvage operations on *Nagato*...and that he intended to concentrate decontamination efforts...on other damaged ships which would in time require salvage measures." [96]

On the evening of July 29, *Nagato* sank unobserved. According to the final report, the sinking was caused by

> capsizing as a result of progressive flooding. The watertight integrity of the *Nagato* was found by test to be poor prior to the test...holes discovered by divers after B test plus known leakage sources were the causes of flooding. The absence of internal watertight integrity permitted progressive flooding. The probable area of main flooding was around frame 190 starboard. [97]

Post-Baker test diver inspection reports noted a number of underwater dents:

> these include dents between frames, as well as those where both longitudinal and transverse framing had given way. A hole about two feet in diameter about seven feet above the port bilge keel at frame 140 where plating had ruptured out, was emitting streams of air bubbles and fuel oil 29 days after the burst. There were seven other major leakage points, but it was not determined whether they were caused by loose rivets or holes in the shell. [98]



Daniel Lenihan inspects the muzzle of one of *Nagato*'s 16.1-inch guns beneath the capsized battleship. *(NPS, Larry Murphy)*

Site Description

Nagato received the second greatest amount of attention from the NPS dive team; the greatest was given to *Saratoga.* The ship is laying inverted in 165-170 feet of water. The ship's four turrets, lettered A, B, C, and D bow to stern, are intact and in their normal position, though inverted. The turrets have not separated from the barbette, as in *Prinz Eugen.* Post-blast diver reports had indicated that the A turret had separated. This mistake might be the result of low visibility resulting from suspended sediment.

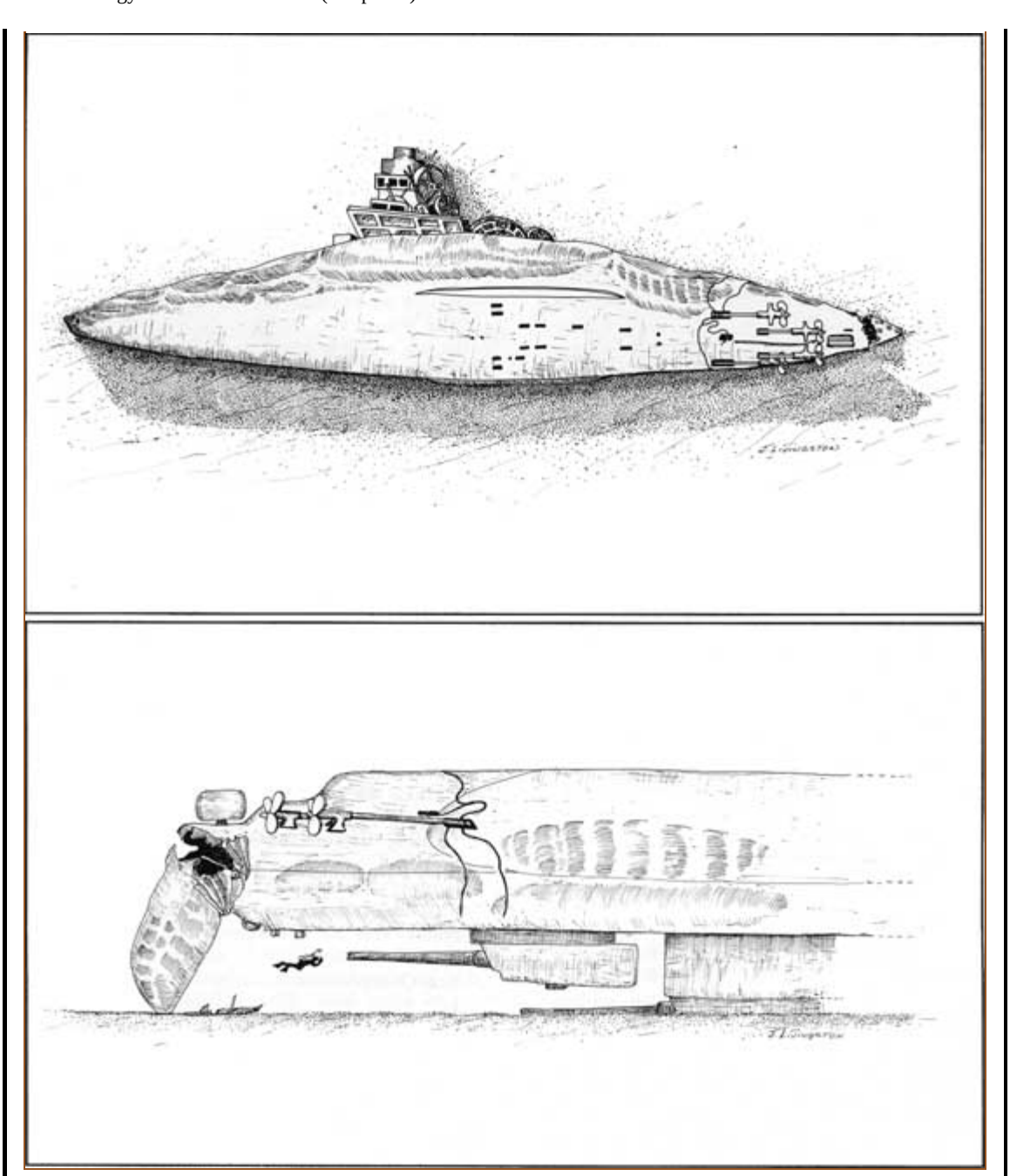
The 16-inch gun barrels of both stern turrets are pointing directly aft; the forward turrets are pointing to the bow and secured at the muzzle. The tampions are in the muzzles of the A turret, which is secure and in its proper position. The tops of the turrets rest on the bottom, obscuring any trace of the Christmas tree blast gauge tower atop turret "C."



Catherine Courtney hovers over the superstructure of *Nagato* at the air defense level, now lying folded over and protruding beyond the port beam of the hull. *(National Geographic Society, Bill Curtsinger)*

There is a major break aft the rudders and screws. The vessel stern rests on the bottom at a steep angle; the hull bottom is tilted to starboard. The hull shell plating is ripped and separated athwartship. Through the torn plates floor frames can be seen. These frames are twisted and splayed about, reflecting the forces that tore the hull plates.

Apparently *Nagato* capsized and sank by the stern, with the transom hitting the sea bottom first. The hull folded across the deck aft, the screws tearing the shell plates as the bow continued to sink. Distortion and tearing of transom hull plates indicates the vessel may have been moving toward the stern through the water column as it sank. The port side is tilted upward from 180 degrees.



Perspective sketches of *Nagato. (NPS, Jerry Livingston) (click on image for a PDF version)*

Nagato bow observations confirm the suggested sinking sequence. Both anchor chains are extended beyond the limits of visibility straight out their hawses. A large mooring weight is directly below the bow. The bridge is pushed straight off to starboard, indicating the ship rolled to starboard as it sank. The ship settled and pushed the bridge superstructure to starboard rather than crushing it directly beneath the ship, as was the case with *Arkansas* and to some extent with *Prinz Eugen.*



Bow of capsized *Nagato. (NPS, Larry Murphy)*

The forward turrets are intact and pointing toward the bow. The range finders are visible. There is a center line capstan forward of the A turret. There is a hatch in the deck below the barrels of this turret. A brief search of the bow above the waterline was conducted. The chrysanthemum crest was not located. The bridge is open and accessible. The starboard gun director is located on the bridge. There is an approximately 10-foot-square hole below and slightly aft of the port hawsepipe.

LCT-1175

During the 1989 survey, the outline of a barge-like hull and protruding structure located between the high and low tide mark in Bikini Lagoon along with mooring cables on the beach were observed near the present garbage dump. This wreck was briefly snorkeled by James Delgado, who identified it as an LCT. By examining aerial photographs of beached target vessels, and then plotting their position and orientation, the wreck was identified as LCT-1175, which was scuttled after the Baker test. [99] Further work is needed to locate other, perhaps less visible, beached craft nearby, such as LCTs 1187 and 1237, which are noted as lost in the vicinity.

Pre-Test Alterations

This vessel was noted in the Bureau of Ships report on beached landing craft, test Baker, as "the non-target, derelict" LCT-1175. It is not known why this vessel was considered "derelict." The LCT's 20mm gun armament was removed, as is shown in pretest photographs of the vessel. [100] There was no other pre-test documentation located.

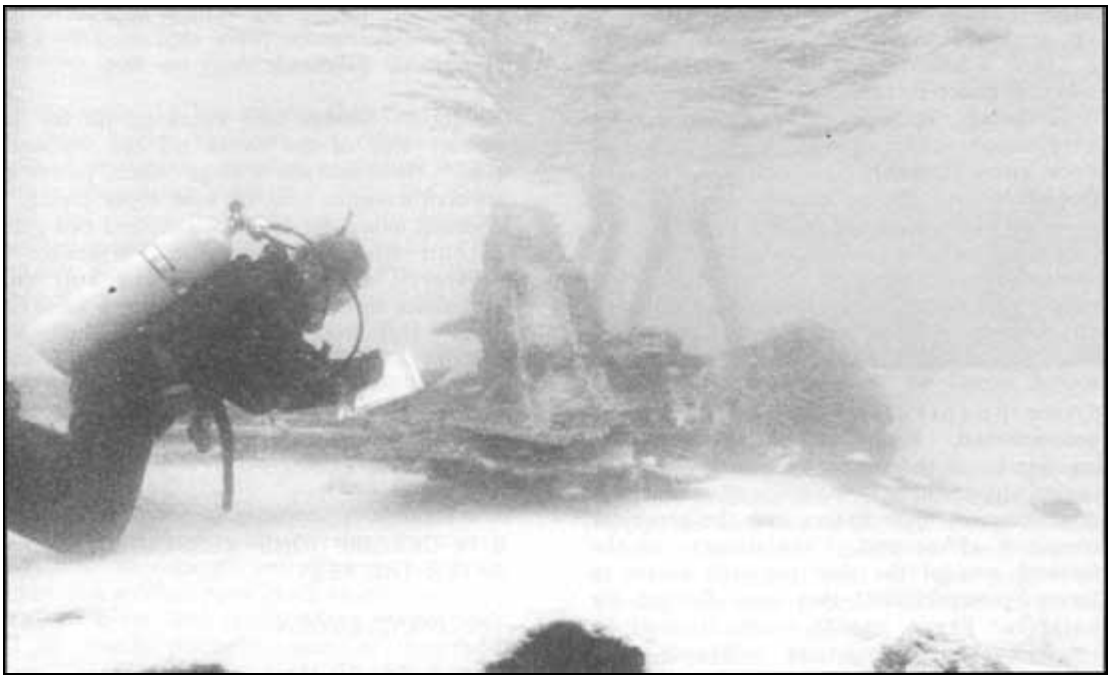
Baker Post-Blast Observations

Before the Baker test, the vessel was moored close to the beach, cabled to the stern of the beached LCM-4, outside the target array on the lagoon shore. Wave action caused by Baker displaced several moored landing craft, including LCT-1175, which was pounded on coral ledges and sank, decks awash. Eight days after Baker, the LCT was located and examined, with later documentation by BuShips personnel.

The vessel reportedly pounded on coral ledges in the surf line and may have been swamped. It sank on the sloping beach, starboard side inshore, with the bow angled toward the beach, pointing west-northwest. The bow ramp was reported missing. The BuShips observers thought the ramp had been torn off by the blast-induced waves, or by pounding on the coral.

Site Observations

The 1989 survey found that the LCT lies in a position that approximates its location and position shown in August 1946 photographs of the beached landing craft. The port side faces offshore, and is buried to within a foot of the gunwale with the exception of scoured areas near the bow and port side. The bow is free of the sand, while the stern is partially buried to midships. The decks are free of sand, and are variously covered by a foot or more of water. The deck plates are uniformly corroded and covered by biofouling, and do not exhibit differential states of corrosion that wet-dry cycling would produce. The level of corrosion and fouling is not heavy; weld seams are visible on the deck plates, as are rivets, bolt heads, and the round seams of deck scuttles inside the deckhouse areas.



Larry Nordby maps the aft deck of LCT-1175. *(NPS, Larry Murphy)*

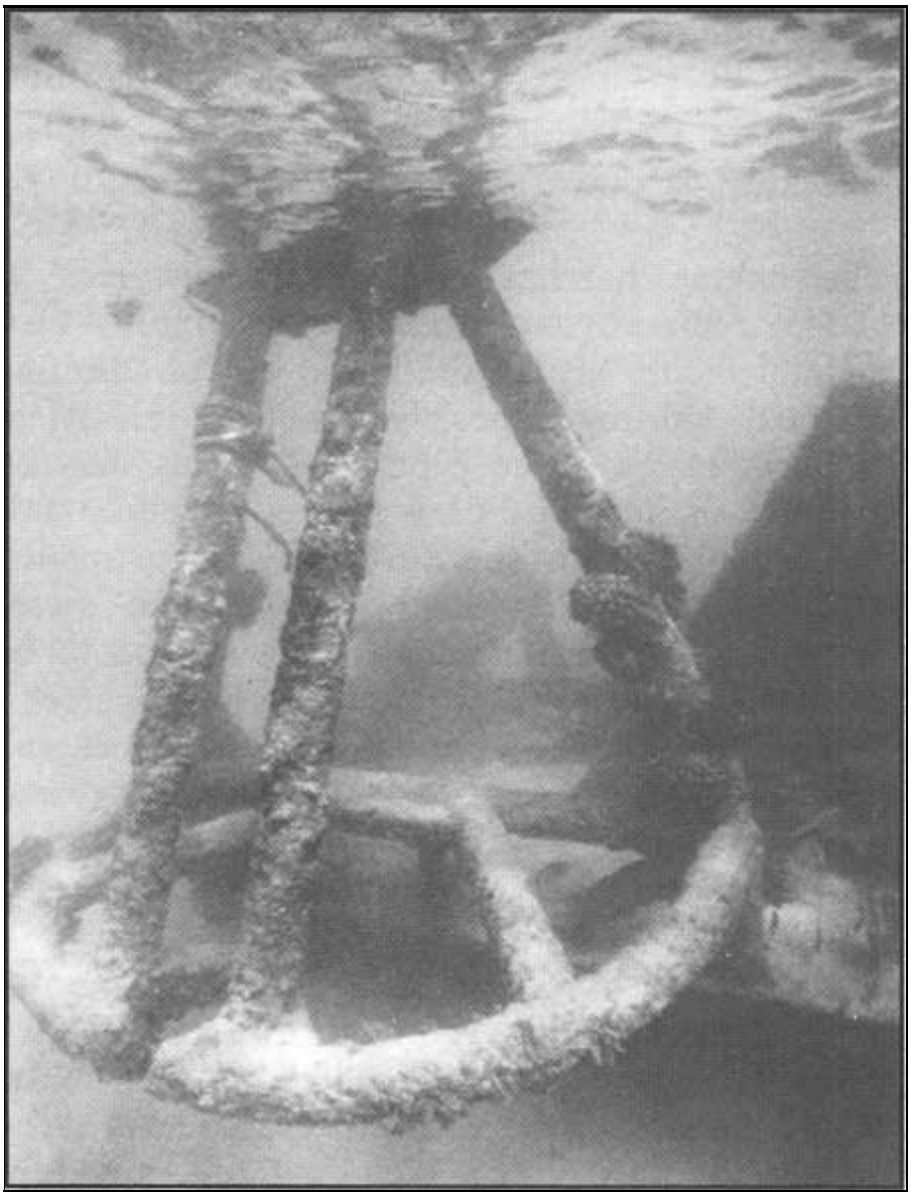
The deck is holed in several locations, most notably near the bow, where an approximately 10-foot-wide section of the athwartship deck is missing. The longitudinal bulkheads in this area are also missing, with worn stubs in the sand indicating their position. This matches up with the scoured area along the port hull and a hole worn into the portside. The hull plating is missing on the starboard side in this area, indicating current, surf, or other action that has worn a channel through the wreck.

The bow is intact and slopes down to the ramp, which is either missing, or, if a line of plating in the sand in front of the bow is an indicator, is down and buried in the sand.

The engine hatches lie atop the engines in their respective compartments. The compartments are divided into two areas, one forward holding pipes, valves, and electrical junction boxes. The pipes and valves may be for fuel or are part of a system to pump salt water ballast into the forward compartments. Three hatches each lead to a marine diesel engine. All three

engines were observed to be in place. The midships and starboard screws and rudders were observed aft of each engine beneath the transom. The port screw and rudder, not observed because of deeper sand in this area, are also presumed present.

The deckhouses are missing, although outlines of the port and starboard houses aft are marked by remnant bulkheads on the decks. Miscellaneous fittings are present inside the deckhouse perimeters, including one apparent electrical through-deck fitting. Hatches at the port and starboard beam on a line with the engine hatches lead to generator compartments. The area around the starboard hatch coaming is holed; a hole in the hull on the starboard side also penetrates this space. Bitts and other deck fittings, including centerline tie-downs were noted. The rudder quadrants are on deck connected by a tie-rod. A tapered three-pole cage anchor mount is portside aft. A small winch mounted on the portside deck forward was also noted. A cleat on the starboard deck, aft quarter, has a wire line passed through it that runs down the hull and aft, past the transom and disappears into the sand--presumably a mooring line.



Anchor mount at stem and port quarter of LCT-1175. *(NPS, Larry Murphy)*

Some penetration of the LCT was accomplished. Piping and wiring, as well as junction boxes

and valves, were observed in the engine compartments. A series of athwartship doors connect these spaces with the generator rooms at either end. The damage to the forward area of the ship provided access to forward compartments that were flooded for ballast. These spaces were divided by longitudinal and athwartship bulkheads, with open doors linking the various compartments. These compartments were separated by solid athwartship bulkheads every ten feet.

Numerous fittings and wreckage lie on the inshore side of the wreck off the starboard side. These include a large winch, pieces of superstructure, a reel of wire rope, piping, a pedestal mount for a 20mm gun, and two pairs of bitts attached to decking. Wreckage is clustered along the starboard hull and diminishes as the bottom slopes up to meet the coral ledge near the surf line. The scant remains of LCM-4, to which the LCT was moored, lie in the surf nearly a hundred feet forward of the LCT. The outline of the hull, the engines, and some loose plating are all that is left of the LCM.

SITE DESCRIPTIONS: VESSELS LOST AFTER THE TEST

USS *PRINZ EUGEN*

Prinz Eugen was dived twice by the team. The German cruiser survived both Bikini test blasts. The ship was towed to Kwajalein Atoll and was lost during a storm that drove it ashore where it capsized and sank.

Site Description

The vessel was dived by the SCRU team during a layover at Kwajalein Atoll. The Kwajalein Dive Club provided boat air tanks and other support. During the two dives on this target ship, no damage clearly attributable to the atomic blasts was observed.

The sunken hulk of *Prinz Eugen* inverted at a 40 degree angle toward the bow, stern toward shore, was on a steeply-dipping bank, in 26 to 110 feet of water, 200 yards off the north end of Carlson (Enubuj) Island in Kwajalein Atoll Lagoon. The vessel lies on an approximate N-S axis and cants about 30 degrees to starboard, resting on its starboard gunwale and superstructure. The rudder, port shaft, and center screw are above the water. The starboard screw is attached to the shaft; the port screw was cut off in 1978 and presented to the Government of West Germany. Shell plating has failed on the hull bottom in the stern area between frames and longitudinals, and may be the result of wet-dry cycling between tides.

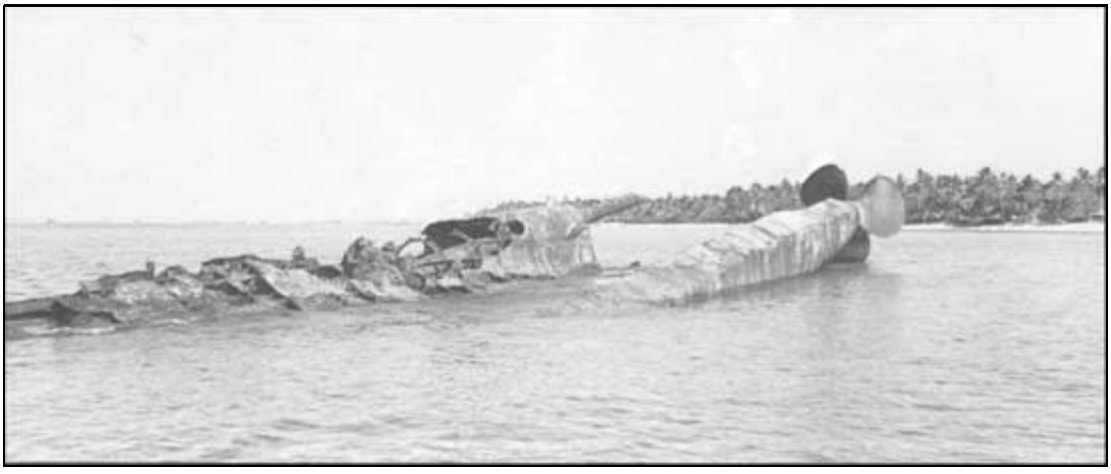




Prinz Eugen's stern rises to the lagoon surface. *(NPS, Larry Murphy)*

Dropping to the bottom aft, the cruiser stern of *Prinz Eugen* is intact; the rubrail curves around the fantail. Another prominent feature is the degaussing cable that rings the ship's hull just below the waterline. No lettering indicating the ship's name was noted. The vessel's fine lines are apparent; *Prinz Eugen* ably represents the salient characteristics of a cruiser, with a length-beam ratio of 9 or 10.5 to 1, indicating a combination of speed and cruising range with limited armor protection.

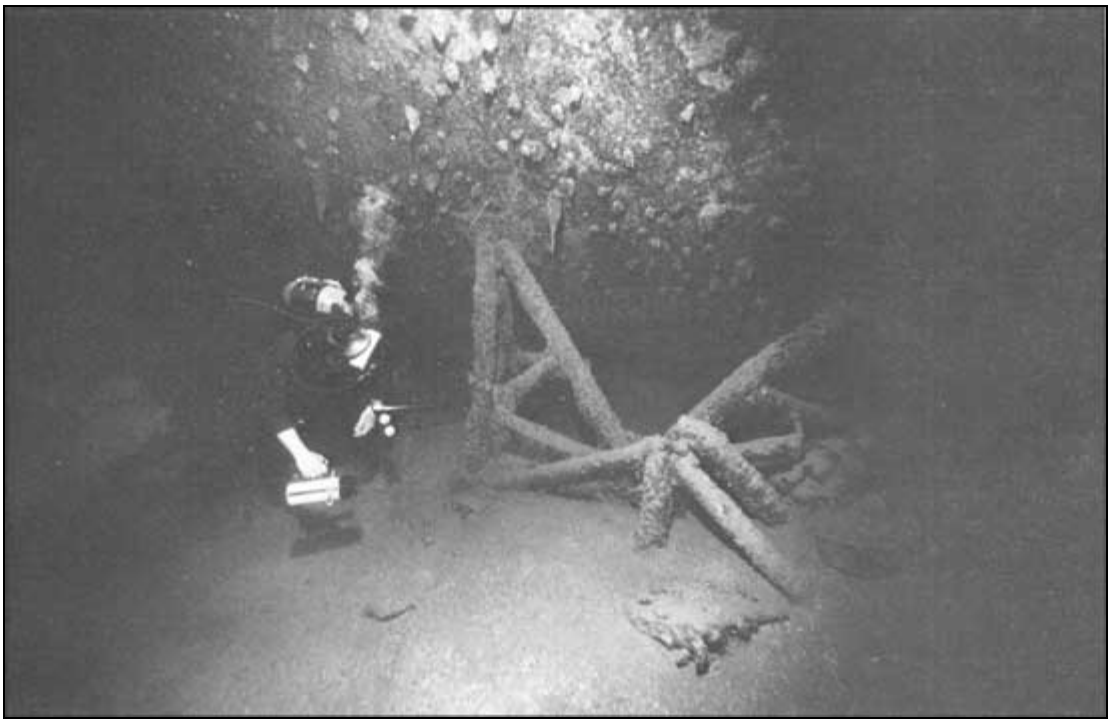
The two aft turrets ("C" and "D") lie partially unseated with gun barrels pointed sternward as they would be if the ship was underway. Nearby is a twin-gun house, probably for a 4.1-inch antiaircraft gun. A stern capstan is seated to the deck aft, and nearby a hatch lies open with another open hatch visible leading to the next lower deck level. Along the port side of the wreck, portholes, many of them with deadlights in place, line the freeboard. Considerable damage to the hull side amidships was noted, apparently the result of capsizing and rolling over onto the reef.



In this view, *Prinz Eugen*'s rudder, a shaft, and a screw rise above the surface of Kwajalein Lagoon. *(NPS, James Delgado)*

The center island superstructure is intact; to port the 21-inch torpedo tube loading rails are visible. Areas above the upper deck, including the stack, fire control radar towers, bridge, and mast are crushed; the top of the mast lies bent to port, as does one of the fire control director towers. The unique "mushroom" head director top lies detached and off the port side. Forward the superstructure lies the "B" turret, which has also dislodged. The "A" turret remains seated. This turret is missing its gun tubes, which were removed in 1946 prior to the Crossroads tests.

In the port midships area near the torpedo tubes there is a cabin containing rack-mounted torpedoes. Some of these torpedoes are missing their bronze propellers, likely removed by visiting divers. It is likely that the torpedoes are live.



Daniel Lenihan inspects a partially buried "Christmas Tree" blast gauge tower on the port quarter of the capsized *Prinz Eugen. (National Geographic Society, Bill Curtsinger)*

A detailed inspection of the forward areas was not made, nor was the wreck penetrated. The starboard side of the hull was not observed forward of the struts. The hull bottom was inspected from stem to stern. The hull is flat-bottomed, with two V-shaped bilge keels. The port bilge keel is broken in several areas aft; a piece of it was found lying detached against the starboard bilge keel. Severe hull damage is noticeable along the port side amidships; a large hole has opened and plates and decking have fallen away.

Hull bottom features observed included the intakes for the boilers and several other through-hull fittings. Forward on the bottom is a small housing, probably for sonar. A circular rose was observed on the port side; the hull is broken near the rose, exposing the pipes that connect it to the engineering spaces.

The hull bottom is not fouled; weld seams were readily evident throughout. Damage to the bottom is confined to the after areas, where rust holes have eaten through the shell plating, exposing the frames and intercoastals. In the port stern area the shafting, thrust bearings, and the shafts are exposed. The center propeller, which protrudes above the water, bears the

marks of repeated attempts to hack pieces of it away; the edges of the blades are nicked and cut.

We were surprised to find that the vessel carried three screws. *Jane*'s (1945) was consulted during research prior to the first field session. This normally reliable resource indicated *Prinz Eugen* carried four screws.

FINAL OBSERVATIONS

All of the major vessels lost during or immediately after the Able and Baker tests at Bikini were dived with the exception of *Sakawa, Anderson, Lamson,* and ARDC-13. Of these four vessels, only ARDC-13's wreck has been located. Marked with a buoy placed by Navy and Holmes and Narver personnel who report that the wreck lies upside down on the bottom, with one wing wall cracked at its junction with the hull bottom and tilted over to rest against the lagoon bottom. Of the various small craft, the largest of which were the LCTs that were lost and then scuttled inside the lagoon, most on the beach of Bikini, only one was dived, although the visible remains of another LCT rises above the water surface near the garbage dump area. The remains of an LCM on the beach of Bikini, heading toward Enyu, was also investigated and was determined to be of more modern origin. Discussions with Holmes and Narver personnel indicate it was lost around the time of the aborted resettlement of Bikini.

The failure to locate *Sakawa* may be explained by the fact that after the Able blast, *Sakawa* probably sank very close to the location at which Baker detonated and lays within a few hundred yards of the suspended Baker test bomb, submerged 90 feet off the lagoon bottom. While it is unlikely that the bomb's detonation would have completely destroyed the vessel, it is possible that it was crushed, possibly broken, and perhaps even partially buried by the 500,000 tons of excavated material from the bomb crater that fell back into the lagoon in the area in which it should lie. We postulate, based on the comparison of the arrays for each test, that remains of *Sakawa* should lie between *Arkansas* and *Saratoga.*

Although dived in 1946, but not located in 1988, 1989, or 1990, the wrecks of *Anderson* and *Lamson* presumably lie in their original sinking locations in the prohibited zone quadrangle shown on the Bikini Atoll navigation charts. The failure to locate the wrecks may be due to incorrect positions provided by Holmes and Narver during the 1988 survey and the high rate of occurrence of tall coral heads encountered during the survey in 1988 which made detection by sonar difficult. Additional systematic survey efforts in this section of the quadrant should disclose these two wrecks.

The graduated levels of damage sought by the planners of Operation Crossroads in their placement of ships of the same type at staged locations is demonstrated by the different site descriptions of *Apogon, Pilotfish, Gilliam, Carlisle, Arkansas,* and *Nagato.* The ships more distant from each zeropoint showed lesser damage than those closer, as would be expected. At the same time, the ships showed different damage. An example is the variation in pressure hull failure in the two submarines. *Apogon* suffered a ruptured hatch and thus a less catastrophic hull failure. While less dished than *Pilotfish,* however, the boat has a large hole blown through the hull forward. The designed maximum operating depth of these boats was 412 feet, the crush depth was 600 feet, which would be equal to 300 psi. [101] Given the 1,200-4,000 psi peak overpressures that hit the two submarines, their hull failures become understandable.

For many of the ships observed at Bikini, it appears that the worst damage resulted from the peak overpressures of the shock wave, particularly to *Gilliam* and *Carlisle* on the surface, and the submarines while submerged. The same pressures also did considerable damage to the

underwater hulls of *Nagato, Arkansas,* and *Saratoga.* The major contributor toward the sinking of the vessels, however, was the overwashing of them by the blast-generated waves, particularly in the case of *Saratoga,* and the collapse of the blast column, which materially contributed to the sinking of *Arkansas* by hammering it more or less straight down into the lagoon bottom. The effects of thermal radiation, which were visible on the ships after Able, is now no longer readily observable. Scorched paint and burned materials have now disintegrated in the sea water or are masked by coral and fouling, even on ships known to have burned fiercely, such as *Carlisle.* Other evidence of thermal radiation, such as warped metal, is indistinguishable, if it exists, from pressure or wave damage. Beta and gamma radiation, measured at various levels in 1946 and 1947 and noted as "high," are no longer significantly above background (see the appendix authored by Dr. W. Robison). While these two particular effects of the bomb are no longer apparent, the basic fact remains that they were contributing factors in the sinking of *Carlisle,* and the as-yet-undiscovered *Anderson,* and *Sakawa.* More importantly, radionuclide contamination and its resulting radiation was a major contributing factor in the abandonment of salvage efforts on some ships, and in the limited nature of assessments made in 1946 in radioactive water and silt. The most visible victim of radiation is *Prinz Eugen,* now resting as the major monument to the Able and Baker "spared" target ships that like *Prinz Eugen* were taken to Kwajalein or other ports. Ultimately most of the other target ships were scuttled because of their radioactive hazard. *Prinz Eugen,* lost by accident before the decision to scuttle other surviving target ships, is now the most accessible of these surplus ships of Crossroads. It was not salvaged, even when a recent (1989) request for scrapping the ship was considered by Naval Sea Systems Command, but rejected because of concerns of contaminating the world steel supply.

The outfitting of the ships at Bikini shows some variation in the historical accounts of stripping of target ships. Items of potential value for military purposes, such as some weapons and electronic equipment, were left aboard many of the ships. As indicated by the large number of militarily valuable weapons and equipment left on the ships and now on the bottom, the value of military reuse of the stripped items balanced against the need to test the effect of the atomic bomb reinforces in part the concept of Crossroads as a potlatch, while also offering another insight into the relative wealth of the U.S. at this time. As other evidence of this attitude, veterans of World War II service have reported the disposal of complete silverware sets and dishes that were in excess of a ship's allotment at war's end, rather than returning them to the quartermaster and filling out paperwork. A German veteran of *Prinz Eugen*'s crew has noted his amazement at American wastefulness on his ship when it was in the U.S. after the war: leftover and "extra" food, some of it uncooked sausages, were fed to the sea gulls, while a box of bolts, opened to get the few bolts needed, was thrown overboard to avoid the paperwork of returning it. This is just one human behavior that may be reflected by the material record of Operation Crossroads.

The sunken fleet of Operation Crossroads is, as the significance chapter will discuss, a unique underwater material record of the dawn of the atomic age. It also demonstrates that a force as powerful as nuclear weapons is nonetheless measurable, quantifiable, and understandable. Much more work remains to fully quantify and understand the effects of the bombs on the ships at Bikini. At the same time, analysis and consideration must also be given to understanding the cultural forces that assembled the fleet and sank it, and the behaviors that influenced the artifactual record on the bottom, as indicated in the outfitting discussion above, as well as the ramifications of these events in the world after mankind passed over the Crossroads.

NOTES

[1]Samuel Glassione, ed., *Radiological Defense: The Principles of Military Defense Against*

Atomic Weapons (Washington, D.C.: Armed-Forces Special Weapons Project, 1951), Vol. 2, p. 5.

[2]*Ibid.*

[3]Shurcliff, "Technical History," p. 12.4.

[4]*Ibid.*, p. 21.1.

[5]*Ibid.*, p. 30.3.

[6]*Ibid.*, p. 13.20.

[7]Samuel Glassione, ed., *The Effects of Nuclear Weapons* (Washington, D.C.: Government Printing Office, 1957), p. 29. Also see Shurcliff, "Technical Report," p. 28.9.

[8]Glasstone, *Radiological Defense.*, p. 36.

[9]*Ibid.*, p. 39.

[10]Shurcliff, "Technical History," pp. 13.3-13.4.

[11]*Ibid.*, p. 13.6.

[12]*Ibid.*

[13]*Ibid.*, p. 13.5.

[14]*Ibid.*

[15]*Ibid.*, p. 13.6

[16]*Ibid.*, p. 20.3.

[17]Glasstone, *The Effects of Nuclear Weapons*, p. 52.

[18]*Ibid.*

[19]*Ibid.*, p. 45.

[20]*Ibid.*, pp. 45-46; also see Shurcliff, "Technical History," p. 28.3.

[21]Shurcliff, "Technical History," p. 28.3

[22]*Ibid.*, p. 28.7.

[23]*Ibid.*, p. 26.3.

[24]*Ibid.*, p. 26.4.

[25]*Ibid.*

[26]*Ibid.*, pp. 28.5-28.6.

[27]Glasstone, *The Effects of Nuclear Weapons,* p. 46.

[28]Shurcliff, *"Technical History,"* p. 28.4.

[29]*Ibid.*, p. 27.3.

[30]*Ibid.*, pp. 27.4-27.7.

[31]*Ibid.*, p. 27.7.

[32]*Ibid.*, pp. 23.2-23.4 and 23.8.

[33]*Ibid.*, p. 23.5.

[34]*Ibid.*, p. 23.6.

[35]*Ibid.*, pp. 23.6-23.7.

[36]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS *Gilliam* (APA-57), Test Able," National Archives Record Group 374, p. 5.

[37]*Ibid.*

[38]*Ibid.*

[39]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS *Carlisle* (APA-69), Test Able, Operation Crossroads," National Archives Record Group 374, p. 9.

[40]*Ibid.*

[41]*Ibid.*

[42]Shurcliff, *Bombs at Bikini,* p. 161.

[43]*Ibid.*, p. 134.

[44]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS *Arkansas* (BB-33), Test Baker, Operation Crossroads," National Archives Record Group 374, p. 5.

[45]*Ibid.*, p. 7.

[46]*Ibid.*, pp. 6-8.

[47]*Ibid.*, p. 5.

Director of Ship Material, Joint Task Force One, "Bureau of Ships Group Technical Inspection Report, USS *Saratoga* (CV3), Test Able, Operation Crossroads," National Archives Record Group 374, p. 14. Hereafter cited as "Technical Inspection Report, *Saratoga*, Test Able"; the identical report, from Test Baker, will be similarly cited.

[49]Glasstone, *The Effects of Nuclear Weapons,* p. 208.

[50]Director of Ship Material, "Technical Inspection Report, *Saratoga*, Test Baker,." pp. 6-7, *passim.*

[51]*Ibid.*, p. 6.

[52]*Ibid.*, p. 7.

[53]*Ibid.*, p. 7.

[54]Director of Ship Material, Joint Task Force One, "Final Report of Tests Able and Baker, Bureau of Aeronautics, " (October 11, 1946), copy on file at National Technical Information Service, p. 204. Hereafter cited as Director of Ship Material, BuAer final report.

[55]*Ibid.*, p. 73.

[56]Director of Ship Material, BuAer final report, p. 74.

[57]*Ibid.*, p. 73.

[58]Director of Ship Material, "Technical Inspection Report, *Saratoga*, Test Baker," p. 8.

[59]*Ibid.*, p. 8.

[60]Director of Ship Material, BuAer final report, p. 74.

[61]Col. J. P. Frederick, "Final Report of Army Ground Group (Task Group 1.4), Operation Crossroads Atomic Bomb Tests," (1946), copy on file, National Technical Information Service. Volume III, p. 117. Hereafter cited as Frederick, "Final Report of Army Ground Group."

[62]*Ibid.*, p. 146.

[63]Frederick, "Final Report of Army Ground Group," Vol. I, pp. 5, 7.

[64]*Ibid.*, pp. 5, 8.

[65]Shurcliff, *Bombs at Bikini,* p. 69.

[66]Shurcliff, "Technical History," Vol. III, p. 9.5.

[67]Shurcliff, *Bombs at Bikini,* p. 65.

[68]Shurcliff, "Technical History," p. 9.5.

Shurcliff, *Bombs at Bikini,* p. 69.

[70]*Ibid.,* Plate 12 caption, between pp. 70-71. Also see W. A. Shurcliff, *Operation Crossroads: The Official Pictorial Record* (New York: Wm. H. Wise Co., 1947), p. 150.

[71]Director of Ship Material, "Technical Inspection Report, *Saratoga*, Test Baker," p. 7.

[72]The ordnance was carefully labelled in BuOrd photographs, Record Group 74, Records of the Bureau of Ordnance, photographs labelled 74-BO-B4, USS *Saratoga* (CV-3), Still Pictures Branch, National Archives, Washington, D.C. Hereafter cited as 74-B0-B4. Originally labelled BACR-63-1563, these photographs are contact prints of 4x5 negatives; picture boards in each view indicate they were taken either on June 17 or June 19, 1946. The BACR stands for "Before Able, Crossroads." The bombs remained in their original positions for Baker.

[73]Photographs, Bureau of Ordnance, BACR Series, National Archives.

[74]Director of Ship Material, BuAer final report, pp. 129, 139, 141-143, 197, 205-207.

[75]*Ibid.*

[76]Gordon Swanborough and Peter M. Bowers, *United States Navy Aircraft Since 1911* (Annapolis: Institute Press, 1969), pp. 150-152; also see Andrade, *U.S. Military Aircraft Designations and Serials Since 1909,* p. 222.

[77]E. W. Jolie, *A Brief History of US. Navy Torpedo Development,* (Newport, R.I.: Naval Underwater Systems Center, 1978), pp. 33-34, 43, 45, and 80. The Mk 13 torpedo was produced by Pontiac Motors Division, International Harvester Co., the Naval Torpedo Stations at Newport, Keyport, and Alexandria, and the American Can Co., of Forest Park, Illinois. In all, 16,600 Mk 13 torpedoes were produced during the war, undergoing refinement through the war's end. The Mk 25 torpedo was developed to replace the Mk 13 but was not produced. The most notable Mk 13 success was the sinking of the Japanese battleship *Yamato* in 1945.

[78]Shurcliff, "Technical History," Vol. II, pp. 7.11-7.12.

[79]See footnote 73.

[80]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS *Pilotfish* (SS-386), Test Baker, Operation Crossroads, National Archives Record Group 374, p. 7.

[81]*Ibid.,* p. 6.

[82]*Ibid.*

[83]*Ibid.,* p. 5.

[84]*The Fleet Type Submarine, Nav Pers 16169* (Washington, D.C.: Standards and Circulation Division, Training, Bureau of Naval Personnel, June 1946) p. 16.

[85]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical

Inspection Report, USS *Apogon* (SS-308), Test Able," National Archives Record Group 374, p. 7.

[86]Shurcliff, *Operation Crossroads: The Official Pictorial Record*, p. 106.

[87]Shurcliff, *Bombs at Bikini*, p. 166.

[88]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS *Apogon* (SS308), Test Baker," p. 5, National Archives Record Group 374.

[89]*Ibid.*, p. 6.

[90]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS YO-160, Test Able, Operation Crossroads," National Archives Record Group 374, p. 3.

[91]*Ibid.*, p. 5.

[92]*Ibid.*, p. 6.

[93]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, USS YO-160, Test Baker, Operation Crossroads," National Archives Record Group 374, p. 5.

[94]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, Nagato (Ex-Jap BB), Test Able, Operation Crossroads," National Archives Record Group 374, pp. 105-106.

[95]*Ibid.*, p. 6.

[96]*Ibid.*

[97]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, *Nagato*, Test Baker," p. 5.

[98]*Ibid.*, p. 6.

[99]Director of Ship Material, Joint Task Force One, Bureau of Ships Group, "Technical Inspection Report, Beached Landing Craft, Test Baker, Operation Crossroads," National Archives Record Group 374, pp. 16, 18, 19, 21.

[100]*Ibid.*

[101]Norman Polmar, Naval Historian, Alexandria, Virginia, Personal Communication, November 6, 1990.

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Last Updated: 22-Sep-2008

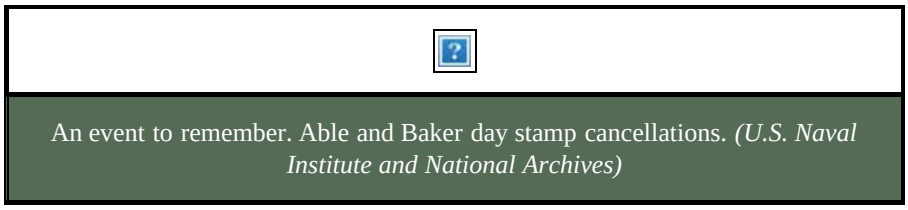
National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER FIVE: THE SIGNIFICANCE OF THE SUNKEN VESSELS OF OPERATION CROSSROADS

James P. Delgado

Ruminating on the nature of nuclear wars after Operation Crossroads, the Joint Chiefs of Staff concluded that with atomic weapons "it is quite possible to depopulate vast areas of the earth's surface, leaving only vestigial remnants of man's material works." [1] Forty-four years after Crossroads, Bikini Atoll stands depopulated. Its people, relocated for the tests, have not permanently resettled Bikini. Efforts to "clean up" Bikini island after a 1968 declaration that it was once again safe for human habitation erased all traces of Operation Crossroads from the surface of the island. Geometrically planted palms and rows of uniform concrete houses for a reestablished Bikinian community brought a new look to the island. Found unsafe for continual habitation in 1978, Bikini was again abandoned, and today hosts a small, transient population of field station support personnel, scientists, and occasional visitors.



An event to remember. Able and Baker day stamp cancellations. *(U.S. Naval Institute and National Archives)*

Visitors to Bikini seeking to confront the tangible evidence of the world's first nuclear weapons effects tests are therefore disappointed. While the island itself, with all its "reconstruction," is a reflection of nuclear-induced change brought about by the tests, the tall observation towers and concrete foundations erected in 1946 for Operation Crossroads are gone. The only evidence lies beneath the surface of the lagoon, scattered about the rim and inside the now-nearly completely silt-buried crater formed by the Baker test bomb's detonation. The ships of Operation Crossroads, lying where they were sunk by two nuclear blasts, are the last "vestigial" remnants of that time and place. Substantially unchanged, they are the only essentially unmodified museum of the dawn of the era of the atomic bomb--unlike the picked-over, filled-in, and fenced ground zero of the Trinity Site, or the rebuilt Hiroshima and Nagasaki.

The ships assembled at Bikini for Operation Crossroads and sunk in the tests represent 34 years of naval design and development, from the oldest ship, *Arkansas*, built in 1912, to the newest, ARDC-13, which was rushed to completion in March 1946. These vessels, as the tests' planners intended, reflect a range of ship types, construction methods, and hull forms, and in total represent in microcosm many of the elements of a typical naval force, with an aircraft carrier, battleships, cruisers, destroyers, submarines, attack transports, and landing craft. Some of these vessels, such as USS *Anderson*, are the sole surviving intact representatives of specific classes of ships. Many of the ships had long and significant careers, beginning with the Veracruz landings of 1914 and the First World War. Most ships now sunk at Bikini also had significant World War II careers including roles in major

engagements and battles--the Bismarck breakout, Pearl Harbor, the Battle of the Coral Sea, Midway, the Aleutians campaign, the Battle of the Solomons, the Battle of the Philippine Sea, and the Battle of Leyte Gulf--and represent some of the better known and significant aspects of the war at sea, such as wolf pack attacks in the submarine war of attrition against Japan, the seaborne line of supply and replenishment, shore bombardment, kamikaze attacks, and the development of the fast carrier task force.

The place of these ships in the history of naval development, their roles in naval history, and their World War II combat records establish their significance only up to the moment they were selected for Operation Crossroads. From that point on, their previous histories become secondary, for the pre-Crossroads significance of the ships is overshadowed by the social, political, and military decisions that brought them to Bikini, and the forces unleashed by the detonation of two atomic bombs that sent them to the bottom of the atoll's lagoon. Each of these vessels passed over a threshold at the "crossroads" between conventional and nuclear warfare, as did the world that had built and manned them. Regardless of type, age, or career, each vessel that now lies where it was sunk by the Able and Baker test blasts is of equal significance as the only uncompromised material record of the early, formative stages of nuclear weapons design and the development of a nuclear military policy. While the wreck of *Prinz Eugen*, secondarily deposited at Kwajalein as a direct result of the tests is also significant, its value as an artifact of the beginning of the atomic age is less so than the ships in their primary deposition at Bikini; this also follows for the highly contaminated 53 target vessels later scuttled or sunk by conventional weapons in the deep ocean because they were radioactively "too hot to handle."

MONUMENTS AND MEMORIALS TO THE DAWN OF THE ATOMIC AGE

The sunken fleet of Operation Crossroads, through its assessment and documentation, now joins other monuments and memorials to the atomic age. There are many such places in the United States and Japan, ranging from the display of mock-up full-scale versions of the "Little Boy" and "Fat Man" atomic bombs to the proud display by the Department of Energy of the Project Sedan crater excavated by nuclear detonation in the Nevada desert. The effort to memorialize and celebrate the impact of the bomb began at the same time the new age dawned. Social historian Paul Boyer has noted, when asked how a people reacts when the entire basis of its existence is fundamentally altered, that usually these changes are more discernable to historians than to those who live through them; however, "the nuclear era was different. It burst upon the world with terrifying suddenness. From the earliest moments, the American people recognized that things would never be the same again." [2]

As early as 1946 two actions were taken to preserve both a site and an artifact of the new age. On March 5, 1946, Senator Carl Hatch of New Mexico, a staunch supporter of the bomb, introduced a proposal to create an Atomic Bomb National Monument, to be administered by the National Park Service. The memorial, at the Trinity Site in the New Mexico desert near San Antonio, was to include a nearby museum where artifacts of the bomb's development and first test, including the B-29 *Enola Gay*, "from which the first atomic bomb used in warfare was dropped...," [3] would be displayed. The planned National Monument and museum were never realized; *Enola Gay* was held in reserve for possible use in Operation Crossroads, and the Trinity Site remained in military hands. (It is now included within the White Sands Missile Range.) A stone and bronze monument was erected by the missile range command in 1965 to mark "where the world's first nuclear device was exploded on July 16, 1945." Designated a National Historic Landmark in 1975, the site is open to the public twice each year. In 1990, nearly 6,000 persons visited the site.

Pieces of "Trinitite," the ceramic-like pale green fused sand from ground zero, have been

carried off as souvenirs by visitors to the Trinity Site since 1945. Trinitite was fashioned into costume jewelry by "enterprising entrepreneurs" in 1945, and by 1952 concern over the future of the vanishing Trinitite temporarily resurrected National Monument plans, with the National Park Service requesting a 100-lb. box of the fused nuclear slag for retention in its Santa Fe, New Mexico, regional office for a future museum at the Trinity Site. [4] While most of the Trinitite is now gone from Trinity Site, other atomic artifacts were saved. *Enola Gay* was not used for Crossroads because of engine problems and remained in storage until 1949, when it was donated to the Smithsonian Institution. Restoration of the plane began in 1984 and is expected to end in 1994, when *Enola Gay* will be placed on display by the Smithsonian in a facility outside Washington, D.C. [5] *Bock's Car*, the B-29 used to drop an atomic bomb on Nagasaki was preserved after Crossroads and is now on display at the U.S. Air Force Museum at Wright Patterson Air Force Base in Dayton, Ohio.

Other monuments to the beginning of the atomic age do not reflect historical significance or national pride in a technological achievement. The blasted remains of the Industrial Exhibition Hall in Hiroshima, whose twisted metal dome has become a symbol of the destructive power of the atomic bomb, and is now known as the "A-Bomb Dome," is one such site. Termed both a monument "left behind by the bomb," and a memorial to the city demolished by "Little Boy," the dome is the only tangible remnant of August 6, 1945, apart from the physical and emotional scars of the survivors. The preservation of the dome was controversial as Hiroshima was rebuilt. According to journalist Peter Wyden, many survivors and "peace groups wanted it preserved as a reminder of human vulnerability, especially for American visitors to see." Others found it painful, a constant reminder for those who wanted no reminding. It was left to slowly disintegrate without demolition until 1965, when the Hiroshima City Council voted to preserve the ruin. Money was raised over the next two years throughout Japan as a "national act for peace," and in 1967 work to stabilize the dome began. [6] Today the ruins, part of an atomic peace park, are the backdrop of a museum that offers souvenirs of another sort--the charred, twisted relics of life disrupted or ended by the Bomb---watches, shoes, books, a human hand's bones fused to a melted pane of glass, and other personal items interspersed with photographs of its effects on August 6, 1945, and the days, weeks, and years that followed.

Unlike the Trinity Site, *Enola Gay*, *Bock's Car*, or the A-Bomb Dome, the ships at Bikini are neither monuments to technology's impact nor memorials. They are now, in their isolation from the rest of the world, in a depopulated land, simply evocative artifacts, the material record not only of Operation Crossroads, but of the fundamental human behaviors that inspired and brought Crossroads to fruition.

The Able and Baker blasts were more than the world's first nuclear weapons effects tests. They were a statement by the United States on many fronts, a demonstration of U.S. pride in its great and terrible achievement as well as a striking material example of U.S. power and wealth. Operation Crossroads was the beginning of an American determination to test and refine the bomb, and at the same time make it more commonplace in order to alleviate American fears that the bomb made them more like "potential victims" rather than being "a potential threat to other peoples...." [7] Crossroads partially succeeded at first by falsely alleviating some fears, not only at home but abroad, yet for the first time it demonstrated that the bomb's greater threat lay in radioactive contamination. More importantly, Bikini was part of a swift and complete absorption of the atomic bomb into the new and vastly altered landscape of American defense, in which vigilance, suspicion, and the concept of the best defense being a strong offense, born of Pearl Harbor and confirmed with the development of the bomb, changed not only America's military but foreign and domestic policy--in large measure moves made in response to the perceived threat of global communism.

INSURING THE NAVY'S SURVIVAL IN THE AGE OF THE BOMB

The primary purpose of Operation Crossroads was focused more acutely on its value as a demonstration than as a test. At its simplest level, Operation Crossroads, although billed as a joint exercise, was a key aspect of the postwar struggle between advocates of naval and air power--the latter represented by the Army Air Corps--over control of the United States' military power and national defense. Advocates of air power, using the argument that saturation bombing, particularly the fire-bombing raids in Europe and Japan, was capable of winning a war without pitched sea battles or invasions, felt that the atomic bomb had made the concept of naval power--even naval aviation--obsolete. The Navy, meanwhile, was acutely sensitive to such suggestions, remembering, as historian Lloyd Graybar notes, "how the Army Air Service had usurped the headlines for the 1921 bombing test against the ex-German battleship *Ostfriesland* off the Virginia Capes...." [8] The Navy had previously responded to the threat of air power by incorporating it--as is demonstrated by the development of the aircraft carrier, the Navy's earliest surviving example of which, *Saratoga*, was sent to Bikini in an ironic role. The Navy moved toward Operation Crossroads in an effort to incorporate the atomic bomb into naval warfare by demonstrating "that ships were not excessively vulnerable to atomic attack...." and "Navy carrier aircraft could be just as useful and valuable as Air Force bombers for the delivery of atomic weapons." [9]



USS *Skate* in the aftermath of Able, its superstructure crushed, conning tower bent, and "very radio-active." *(National Archives)*

As discussed in Chapter One, the initial plans for Operation Crossroads were laid by the Navy, but were preempted by Brig. Gen. B. M. Giles' provocative suggestion on September 14, 1945, to atomic bomb captured Japanese ships. The Navy, already planning a naval test of the bomb, was quick to assent, in hope of taking the lead, but subsequent demands by the Army Air Force that they be included ultimately led to Presidential intervention and the creation of Joint Task Force One, in large measure because of Air Force fears that the Navy would skew the results of the tests to prove that ships could and would survive the bomb. While efforts were made to promote a public image of mutual cooperation and interservice amity, a major motivating factor behind Operation Crossroads and the actual conduct of the tests, was interservice rivalry and the strong determination of each service that they be preeminent. Ironically, for each branch Crossroads' results were "inconclusive." The Air Force, citing the fact that only nine of the target vessels escaped sinking, damage, or "unacceptable radioactive contamination," found proof of "what it had argued all along; ships were intolerably vulnerable in the atomic age." [10] More significant, however, was the Navy's response to the inconclusive results. The Navy responded, in large part through the press, that the seeming knockout of its ships stressed by the Army Air Force was the result of unmanned and undefended ships anchored in tight formation. The Navy argued that "modern" ships, "properly dispersed, executing evasive maneuvers and utilizing their own defenses, would be far less vulnerable...than, for instance, fixed air bases." [11] Obliquely noted was the fact that the Army Air Force had missed the target ship by "two miles"; the implication was that dispersed, mobile ships could outmatch a plane-dropped bomb.



USS *Skate* makes its triumphant, yet radioactive return to the fleet after Able, as seen from USS *Fulton* (AS-11). *(U.S. Naval Institute)*

The Navy found an ideal proponent of its survival in *New York Times* reporter Hanson W. Baldwin, who, in the aftermath of Able, noted that as terrible as the damage seemed, "the results at Bikini must...be qualified." Baldwin also noted the tight spacing of the ships, their crewless state, and claimed that much of the damage "could have been avoided had there been fire-fighting crews and damage control parties aboard." [12] This argument repeatedly resurfaced, even after Baker, despite the prevailing high levels of radiation on the ships; hence, even when the excessively "hot" *Saratoga* sank, the loss of the ship was attributed less to the bomb by Baldwin, who opined "perhaps she might have been saved, had there been a

crew aboard. But she died a lonely death...pumps idle and boilers dead...." [13]

Baldwin felt that to meet the bomb and survive, "ships must seek safety in dispersion," with redesigned superstructures to better protect radar and radio antennae--the greatest operational casualties of Able--and that concrete skins be added to armor hulls against radiation because of the "relative success of concrete structures (buildings in Japan, a floating drydock and a small auxiliary craft at Bikini) in withstanding blast, heat and radiation." [14] After Baker, these recommendations, probably more reflective of the Navy's than Hanson Baldwin's opinions, were modified to include protection from radioactive fallout through wash-down systems and greater underwater protection. Baldwin proposed "a reversion to the turtle-back Monitor-type ship, with thick underwater plates and little exposed superstructures.... Shallow draft vessels were less exposed to shock damage.... Naval designers, therefore, may sacrifice draft for security." [15] The Navy emphasized many of the same points, and in the immediate aftermath of Crossroads spoke repeatedly and yet vaguely of redesigning ships to meet the atomic threat. A proposal for redesigned warships surfaced as early as September 1946, when Vice Adm. E. L. Cochrane, chief of the Bureau of Ships, announced that as a result of Crossroads, superstructures would be redesigned; "the results may be emphatically streamlined topside structures designed to reduce the effect of the enormous wide-area pressures produced by atomic bomb blast." [16] As late as 1958, the Navy, in describing USS *Norfolk* (DL-1) claimed that the ship was "designed as a special category of anti-submarine vessel...and incorporates lessons learned at Bikini in her construction." [17] The Navy won its case "to the extent that public and political pressure" to merge as a secondary partner with the Air Force and Army, or even to cease to exist "somewhat eased," giving the Navy time to develop a nuclear capability at sea. [18]

The harsh lessons of the efforts to decontaminate the target ships at Bikini, Kwajalein, and on the mainland, though not stressed at the time, were in fact proof that the Navy, on the surface, was excessively vulnerable to atomic attack. Even with moderate damage and a crew aboard, the radioactivity could not be washed away, despite design changes such as rounded surfaces, steel decks, and wash-down systems. The only means of dealing with this threat was either avoidance or the harsh reality that "crews doomed to slow death from exposure to lethal radioactivity are nevertheless able the first few days after exposure to continue normal duties. The seamen of tomorrow must be prepared to accept radioactivity as part of the hazards of their living and be ready to work and fight and save their ship even though they know they are doomed to slow death." [19] With no adequate defense against the bomb at sea (as well as on land), the Navy moved firmly into line with the prevalent theory of defense brought about by the atomic age. When defense was impossible, the best means of defending one's territory was through demonstrating a superior ability to inflict damage, namely through a greater nuclear capability.

A DEMONSTRATION OF WEALTH AND POWER

At a similar, but higher level, Crossroads was a demonstration to the world, particularly the Soviet Union, of the United States' wealth and power at a time when the nation, in the aftermath of the war, was assuming the role of the global leader. The Los Alamos National Laboratory's archivist and historian notes that the prevalent attitude of the lab's weapons scientists then, as well as now, was that Crossroads was not a true scientific test. Rather, it was "purely a show." [20] Such a demonstration is critical when a new leader assumes the stage. The demonstration of this fact, given the nuclear apprehension of its own citizens, was of paramount importance to the U.S. government, and as early as April 1946, Admiral Blandy, speaking in a live radio broadcast, stated that Crossroads would "help us to be what the world expects our great, non-aggressive and peace-loving country to be--the leader of those nations which seek nothing but a just and lasting peace." [21] More bluntly, commentator Raymond Gram Swing noted that Crossroads, "the first of the atomic era war

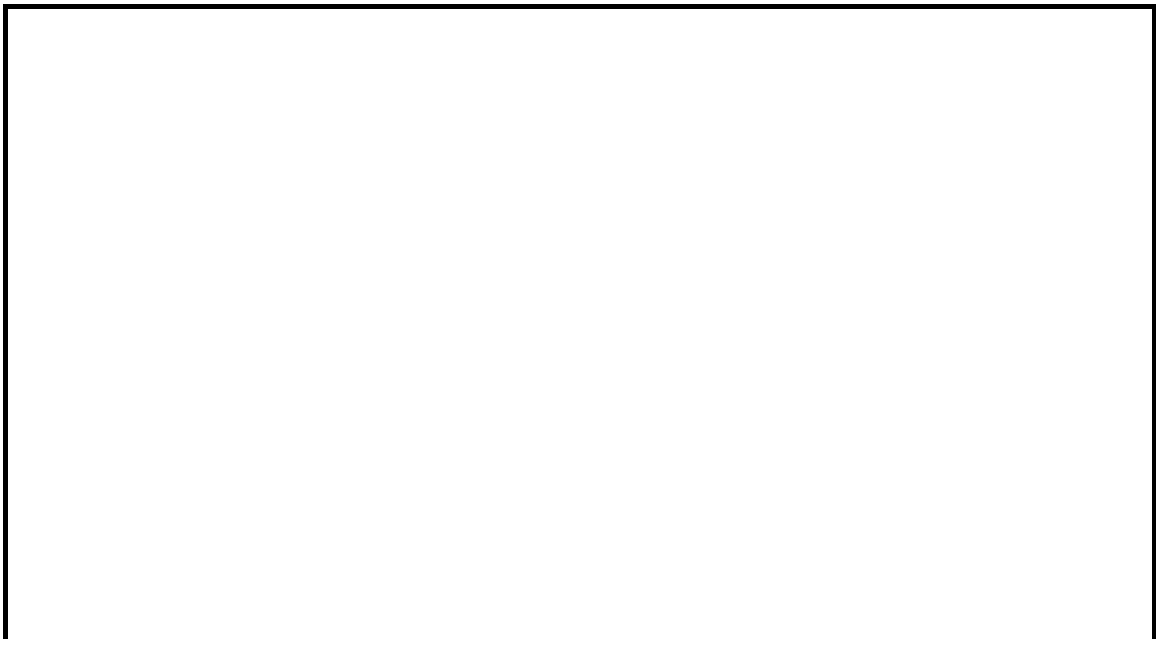
games....is a notice served on the world that we have the power and intend to be heeded." [22] Several factors support this view. The concept of the United States as the richest nation on earth was implicit at Bikini.

Vannevar Bush, writing in 1949, noted that the production of atomic weapons "requires such major expenditures and such major effort that they cannot be afforded at all except by countries that are very strong economically and industrially." [23] Such a nation was the United States, "for we paid the bill" for developing such weapons. By expending two of these extremely expensive and rare weapons at Bikini, the United States was demonstrating its wealth, a fact underscored by the sacrifice of a tremendous fleet of target ships, all in a destructive display that echoed the potlatch ceremonies of Northwest Native Americans who proved their wealth by purposeful destruction of valued and valuable items. [24]

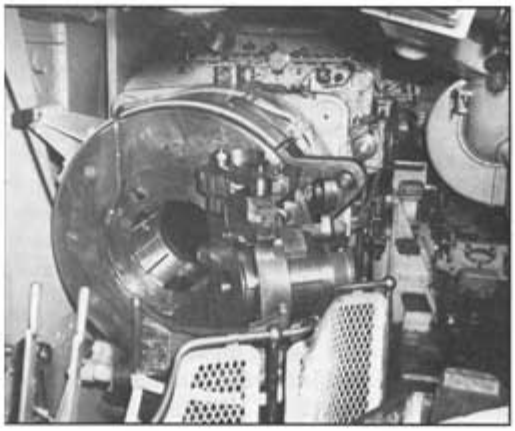
The size of the target fleet at Bikini also underscored the image of a powerful nation, for, as the Crossroads press releases emphasized, this cast-off fleet of target ships represented the world's fourth or fifth largest Navy. The United States, at that time, even if faced with the loss of all its target ships (as indeed was the case) was still the world's greatest naval power, a fact obliquely, and, according to Lloyd Graybar, "disingenuously" mentioned by Admiral Blandy when asked if the tests were "provocative:"

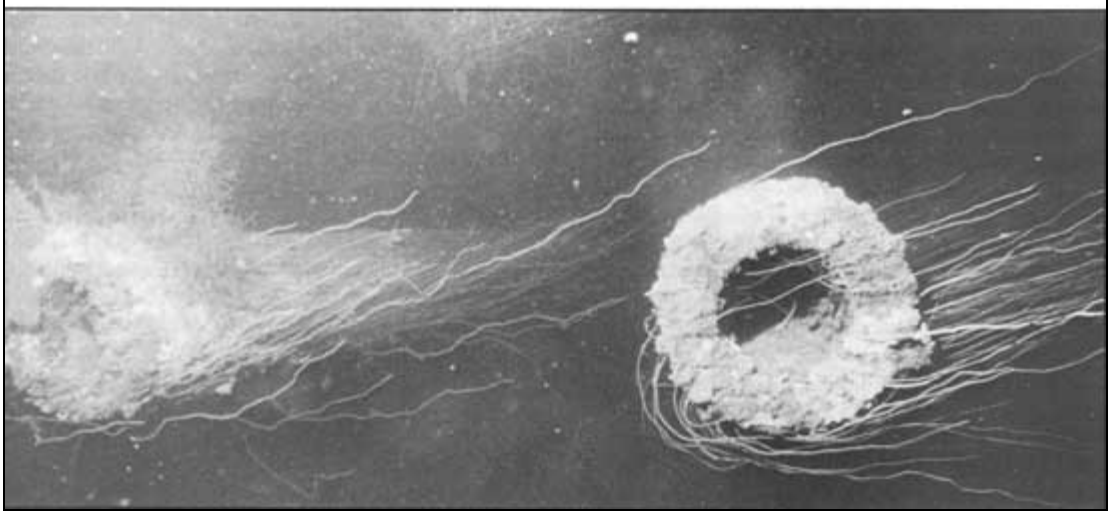
> Some people fear that these tests may be construed by other nations as a "martial gesture." But the principal targets are naval ships. Great Britain, the only other country possessing a strong Navy, certainly does not believe that we are planning to use the bomb against her fleet. [25]

The United States also backed up its image as a powerful nation by symbolically emphasizing America as the principal victor in the war. The inclusion of *Prinz Eugen*, *Nagato,* and *Sakawa* as target ships was an echo of the earlier triumphant victory parades of conquering heroes in Republican and Imperial Rome. Particularly indicative of Crossroads as a spectacle were *Nagato* and *Sakawa*, both of which were moored within the so-called "fatal" zone of proximity to the planned detonations. Neither vessel was extensively dived after sinking at Bikini; *Sakawa,* although briefly boarded after Able, was not dived at all and *Nagato* only briefly to assess the causes of its sinking. *Prinz Eugen*, however, was moored well outside the fatal zone, since it was intended that the German warship would survive. Efforts to save the foundering *Sakawa* after Able, balanced against this view, may only be indicative of keeping the ship afloat for its final destruction in the Baker test.









Breech and the muzzles of *Nagato*'s 16.1-inch guns, 1946 and muzzles in 1990. The shells from these guns were modified for use in the Pearl Harbor attack. *(National Archives and NPS, Larry Murphy)*

The two Japanese warships reflect not only the United States' particular enmity towards Japan with underlying racial overtones and bitterness over Pearl Harbor and the brutal war that followed, but a symbolic killing of the enemy's ships with the same weapon that had forced his capitulation. *Nagato* especially fulfilled that role as the onetime flagship of the Imperial Japanese Navy and the scene of operational planning for Pearl Harbor. *Nagato*'s "capture" as a derelict on Tokyo Bay after the Japanese surrender had symbolized the surrender of the Imperial Japanese Navy. Sinking the Japanese battleship at Bikini ritually "destroyed" that

Navy far better than scrapping or bombarding the already bombed and badly damaged battleship with big guns, torpedoes, or 500-lb. bombs--so-called "conventional weapons." Reminiscent of the Aztec practice of caring for and feeding a captured enemy for inevitable sacrifice was the attention given the Japanese ships. The Navy took quick action against five sailors accused of trying to scuttle *Sakawa* while en route to the Marshalls, and at Bikini, the ships were carefully tended with support vessels alongside since "there was some danger that the captured Japanese ships...might actually sink...if they were left unattended..." [26] The impact of the two ships' loss would be less, if not non-existent, if allowed to simply founder--it was essential that they be "killed." *Nagato,* badly damaged during Baker, was only then left to slowly die, with no attempt made to save the ship over a four-and-a-half day period while the equally radioactive *Hughes* and *Fallon* were beached. There was no moving eulogy for the once mighty warship, simply a notation that the "Jap" BB had disappeared during the night after listing and settling in the water throughout the day. *Nagato*'s fate in particular reinforced the concept of America's superiority through atomic power.

CROSSROADS AS SPECTACLE AND DEMONSTRATION

Crossroads as a spectacle and demonstration is also underscored by the massive publicity and the presence of foreign observers at the tests. Operation Crossroads was heavily publicized, with Joint Task Force One providing special facilities aboard USS *Appalachian* (AGC-1), which became the "press headquarters ship," and the preparation of more than a hundred detailed and lengthy press releases, as well as "open" press conferences during the planning, execution, and aftermath of the tests. Additionally,

> to help those correspondents who were starting off "cold," Captain Lee (Crossroads public information officer) arranged, besides press conferences, various orienting schemes. Lectures were arranged; motion picture films were prepared and shown; press packets of pamphlets...were prepared and distributed. No effort was spared in making this the *best*-reported as well as being the *most*-reported technical experiment of all time [original emphasis]. [27]

In all, 114 U.S. radio, newspaper, magazine, and news service reporters attended the Able test at Bikini, with 75 attending Baker, while 10 foreign reporters attended Able and eight attended Baker. Able's detonation was even broadcast "live" around the world. Hundreds of articles and features dominated the nation's newspapers, newsmagazines, and newsreels, while two books were published highlighting the non-classified story and images of the "bombs at Bikini." As seen earlier, this not only paid off for the Navy but also provided the U.S. with a world stage for its demonstration of the bomb's effects. Bikini as a world stage for the United States is also reflected by the invitation to foreign observers. Each country having membership in the United Nations Atomic Energy Commission was allowed to send two representatives to Bikini; ten nations accepted, sending 21 observers. Particular attention was paid in the press to the Soviet observers, as was doubtless the case by the Crossroads staff. While the reason for the invitation to the observers was the stated intent of allaying foreign "suspicion and disapproval of the planned experimental use of the world's most terrible war weapon" because "the atomic bomb is an international concern," another, underlying motivating factor was the demonstration of power the tests represented. [28] The "target" of this demonstration was the Soviet Union, then the U.S.'s primary opponent for global domination.

The tremendous investment the United States had in Operation Crossroads is also reflected by the American attitude that the tests were indicative of a national achievement of tremendous significance and reflective of a uniquely democratic society. As Vannevar Bush noted three years after Crossroads, the U.S. at that time, while expecting that a potential enemy could in time develop the bomb, felt that the time when "two prospective belligerents [would be]

frowning at each other over two great piles of atomic bombs" was far off. Reflecting on an unnamed but nonetheless explicit enemy, Bush stated:

> The time estimate depends, of course, on how fully we think our adversaries may put their backs into the effort, how much they are willing, or able, to reduce their standard of living in order to accomplish it. They lack men of special skills, plants adapted to making special products, and possibly materials....they lack the resourcefulness of free men, and regimentation is ill-adapted to unconventional efforts. On the other hand, their tight dictatorship can order effort, no matter how much it hurts. [29]

Thus the atomic bomb was perceived more as a product of American democracy than as a product of American intellect, particularly given the large contribution of European scientists to the birth of the concept and the production of results. Colleagues of these great minds who had remained in occupied Europe had failed to succeed where their relocated, newly American compatriots had triumphed. American pride eventually conspired to recast history it seemed, so that, in the opinion of some foreign observers

> even official American publications dealing with the history of the production of the atomic bomb, the British considered, minimized the contributions of British, French, and Canadian scientists. It seems typical of this attitude that in the official American film of the Bikini test the voice of the British scientist Ernest Titterton on the loud-speaker system, counting the seconds that elapsed before the explosion, was cut out and replaced by a voice with an American accent. [30]

The McMahon Act of 1946 excluded foreign participation in further U.S. A-Bomb work. However, Crossroads required the use of many of the British and Canadian scientists from Los Alamos who had worked to develop the bomb. At Bikini, more or less "under the table," their vital participation had to be discounted. Hence the "voice over" Titterton's count down was actually a product of this new law.

The production of the bomb had been accomplished with cooperation and mutual sharing between the United States, Britain, Canada, and to some extent other European countries, during the Manhattan Project. Now, with Operation Crossroads, the stakes of the game were different, and the tests underscored the fact that the United States, which alone had the bomb and the facilities to make it, was the absolute power, even to the point of emphasizing in as many ways as possible that nuclear weapons and tests of them were American. American pride in the bomb, and the tests, was also indicated by the preparation of special certificates for Crossroads participants, similar to those issued for graduations, promotions, awards, and rites of initiation and passage, such as those given to people who "crossed the line" at the equator for the first time.

Finally, the emphasis of the tests as a key demonstration of U.S. power and global leadership was even evinced from those critical of Operation Crossroads. Senator Scott Lucas of Illinois, one of a handful of Congressional opponents of Crossroads, pointedly asked, "If we are making plans to outlaw the use of the atomic bomb for military purposes, why should we be making plans to display atomic power as an instrument of destruction?" [31] Harsher words were spoken by the Rev. A. Powell Davies of Washington, D.C., a Unitarian pastor, who "thundered" from his pulpit that the widely-reprinted picture of Admirals Blandy and Lowry, cutting a mushroom-cloud-shaped cake with Mrs. Blandy to celebrate the successful dissolution of Joint Task Force One was "utterly loathsome":

> Try to imagine yourself for a moment a continental European, wondering,

brooding, asking yourself a hundred times a day, will America lead us? Then imagine yourself being shown this picture. If I had the authority of a priest of the Middle Ages, I would call down the wrath of God upon such an obscenity. I would damn to hell...these traitors to humanity who could participate in such a monstrous betrayal of everything for which the brokenhearted of the world are waiting. [32]



Admiral and Mrs. W H. P. Blandy and Rear Admiral F. J. Lowry celebrate the end of Operation Crossroads and the dissolution of Joint task Force One at Washington, D.C., in November 1946. The angel food cake drew criticism. *(Pictorial Histories)*

LEARNING TO LIVE WITH THE BOMB

Operation Crossroads also was intended to demonstrate U.S. power and the ability to come to terms with the bomb for the citizens of the United States. The basic domestic message of Operation Crossroads was planning for and supporting national defense. The fear, immediately voiced by many Americans, that the bomb would in time be used against the United States, most probably in an unannounced, "sneak attack," required an answer from the military and political leaders of America. Crossroads was the first vehicle for that answer. Admiral Blandy, speaking on the larger issue of why Crossroads would proceed, stated that "the tests stand out clearly as a defensive measure," stressing the operation would determine the how and why of naval survival in the atomic age. "By no stretch of the imagination can such steps of caution and economy be taken as a threat of aggression. If, because of such a false assumption, we failed to carry out these experiments, to learn the lessons which they can teach us," said Blandy, military planners and weapons designers "would be groping their way along a dark road which might well lead to another and worse Pearl Harbor." [33] The

fear of a worse Pearl Harbor was, however, not alleviated by Crossroads, but magnified.

In the aftermath of Able and Baker, the government was placed in the difficult position of stressing the potent power of its new weapon to strengthen its global leadership role while at the same time attempting to soothe popular fears. Thus public statements from Joint Task Force One emphasized the terrible effect of the bombs while knocking down the straw man of imagined wide-scale death and destruction as a result of the tests. Admiral Blandy on numerous occasions repeated the fact that some "wags" had stated after Able that Bikini should be renamed "Nothing Atoll," or "No Atoll Atoll." An attitude of business as usual was stressed at Bikini, too. On at least one target vessel, USS *Pensacola*, the ship's painted battle record was augmented with a mushroom cloud and the word "Able," in a place on the record previously reserved for narrow escapes with death, such as kamikaze attacks. Yet the classified, more sophisticated analysis of Able and Baker, never released to the public, showed far worse results. Assessing "combat readiness," the Bureau of Ships group found many of the "surviving" vessels would be virtually dead in the water, their boilers, radar, radio, and equipment out of commission, and their crews dead or dying from radiation.

The fears of atomic scientists that the bomb's deservedly terrible image would be lessened was also widely reported. William L. Laurence, the "dean of atomic reporters" who had covered the Manhattan Project, Trinity, and the atomic bombing of Japan before going on to report Operation Crossroads, was highly sympathetic to the government's view of the new atomic age since he was the only media representative privileged with an inside view of the top-secret Manhattan Project prior to Hiroshima. A confidante of many of the "fathers" of the bomb and responsible for molding many of the initial public statements about the atomic bomb, Laurence viewed it as the beginning of a new age of hope, perhaps more so than fear. Critical of what he termed an "unreasoning fear" of radiation, Laurence also either overtly participated in knocking down the straw man or firmly believed Navy assertions, noting in a famous dispatch that

> Before Bikini the world stood in awe of this new cosmic force.... Since Bikini this feeling of awe has largely evaporated and has been supplanted by a sense of relief unrelated to the grim reality of the situation. Having lived with the nightmare for nearly a year, the average citizen is now only too glad to grasp at the flimsiest means that would enable him to regain his peace of mind. He had expected one bomb to sink the entire Bikini fleet.... He had even been told that everyone participating in the test would die. When none of these things happened, he is only too eager to conclude that the atomic bomb is, after all, just another weapon. [34]

The emphasis to alleviate fear did produce some results. A few foreign observers ridiculed the bomb; Soviet press accounts "minimized the results," while "an Argentine radio announcer said he would broadcast the sound of the explosion" of Able, and "then gave a ludicrous peep." [35] Public fears, bolstered by the clever manipulation of the straw man by Joint Task Force One, declined, though the major reason for less American concern, at least for a while, was because of what Norman Cousins termed the "standardization of catastrophe" since "after four bombs, the mystery dissolves into a pattern." Paul Boyer notes this was because "there are distinct limits on people's capacity to sustain interest in any issue--even atomic war." [36] Thus, Boyer notes, the "short-term effect" of the tests "was to dampen fears of the atomic bomb....For government spokesmen and others seeking to mute 'excessive' and 'hysterical' atomic bomb fears...the apparent 'failure' of the Bikini test was a godsend." [37]

THE REALITY OF THE BOMB: RADIOACTIVE FEARS

Yet Operation Crossroads did inspire fear, for "relief was not the only reaction...for Bikini became a sort of ideological battleground, as its symbolism was appropriated for different polemical purposes." [38] The issue that ultimately induced fear, even among the military, and which in time reached the public, was not the destructive power of atomic blasts, but of the radiation that followed. The day after Baker, *The New York Times* editorial noted that the test had introduced a new factor in nuclear war--"the huge mass of radioactive water which may fall on a ship." [39] Efforts to keep the true lesson of Crossroads--the virtual destruction of the target fleet by radioactive contamination--failed as the news slowly leaked out, for the Navy could not keep the fate of so many capitol ships and lesser vessels out of the public eye, even at far off Kwajalein. As David Bradley noted upon his departure from the ghost fleet of contaminated ships at Kwajalein, leaving the ships behind provided only the "illusion of escape." [40] The accounting of ships "lost" to contamination, first alluded to in Crossroads releases in September 1946, fed a growing fear of radioactivity that was confirmed by color photographs of atom-blasted internal organs and blood-swollen brains of irradiated test animals published in *Life* magazine in August 1947. The selection of goats and pigs for test exposure because of their internal similarities to humans reinforced the grim, if not devastating impact of the photos--these could be the radiation-destroyed remains of *people.* Boyer has stated, "it was Bikini, rather than Hiroshima and Nagasaki, that first brought the issue of radioactivity compellingly to the nation's consciousness." [41] The 1948 publication of David Bradley's *No Place to Hide* and its grim message that the real story "was not the spectacle but the aftermath," and the 1949 publication of an article by Drew Pearson that added up the various press releases about the sinking of contaminated ships and reported that the sinking of 61 radioactive vessels constituted a "major naval disaster" focused more public attention on the Crossroads radiation problem. [42] One government response to the news was an attempt to focus radiation fears only on bombs detonated in or on the water--1950 Civil Defense handbooks discussed at length the effects of an atomic attack on a harbor, which presumably only then would release a "radioactive mist." Left unemphasized were the ionizing effects of neutron radiation from an air burst, or the possibility of lingering radiation in such a circumstance.

Surviving the Bomb. A sailor paints a mushroom cloud for Able on *Pensacola*'s battle record. *(National Archives)*

P. M. S. Blackett, writing in 1948 in an attempt to alleviate the "nuclear neurosis," drove home the point that the government was stressing, namely that

> at Hiroshima and Nagasaki, where the bombs were exploded well up in the air, it has been stated that very little radioactivity remained.... On the other hand, after the underwater test explosion at Bikini, intense radioactivity remained for several months in the water and on the ships which had been deluged with active water, and would have killed all living things remaining there for any length of time. [43]

This message muted the fact that the deadly radioactivity remained for more than several months, leading to the sinking of nearly every target ship within a four-year period after the tests, and no mention was made, nor was the danger fully apprehended of the initial burst of radioactivity during a detonation and its effects.



Independence at San Francisco in January 1951, ready for sinking as a target off the Farallones after three years of radiological testing and use as a training ship for radiation monitoring and decontamination. The hulk was recently discovered in 3,000 feet of water. *(San Francisco Maritime National Historical Park)*

In the end, Crossroads had a tremendous impact, in its time, in refocusing nuclear apprehension from the blast effect to the real, more potent danger of the radioactive "toxins" left by the bomb. The significance of this lesson has been forgotten, however, in the era of the subsequent development of the hydrogen bomb, which introduced not only the capacity to vaporize fleets and devastate vast regions, but destroy nations and dust the globe with highly radioactive fallout. In an age of megatonnage, the pre-1954 "simpler" age of kilotonnage has faded from memory with the exception of "key" dates, such as the Trinity explosion, or the wartime use of the bomb. As Lloyd Graybar notes, Operation Crossroads is now obscure, its role in the nuclear arms race for the most part forgotten, scarcely cited in standard histories of the bomb or of the Cold War, and its role in accelerating the Cold War still the topic of debate.

Bikini Atoll is better remembered for the Bravo test shot of 1954 that ushered in the new, more terrible era of the H-Bomb, and for the French-named bathing suit that characterized both the sexual imagery of the bomb and an attempt to find some element of humanity in a weapon that aroused another primal instinct--the fear of racial annihilation. The linkage is more than symbolic, for the response to the threat of extinction is increased efforts to reproduce.

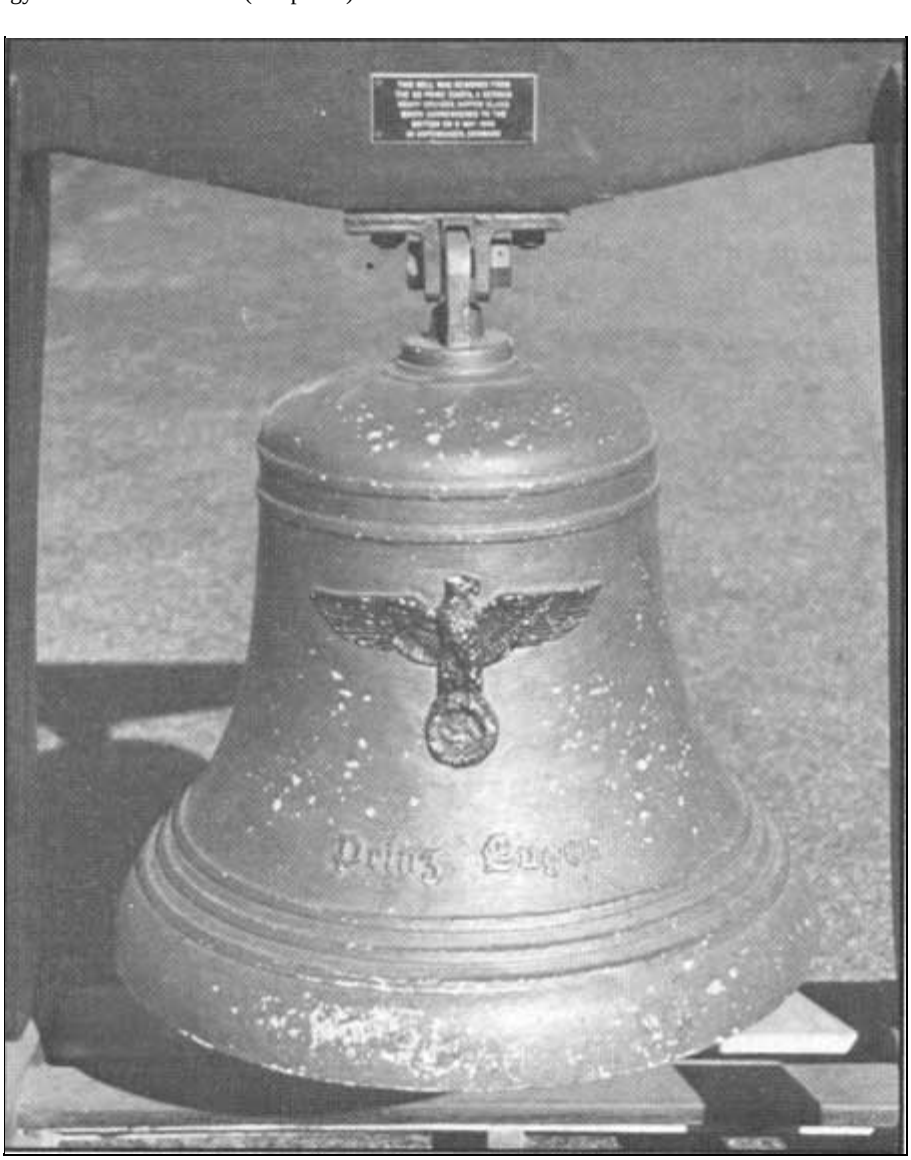
For a few, Bikini and Operation Crossroads represented a crossroads in their own lives--particularly for the now exiled Bikinians, the "nuclear nomads" of the Pacific, and surviving Crossroads veterans, some of whom are battling crippling and fatal diseases traced to their exposure to the contaminated ships and the fallout of Able and Baker.



Certificate issued to the 42,000 participants in Operation Crossroads. *(National Archives)*

CROSSROADS AT THE BOTTOM OF THE SEA

The sunken ships of Operation Crossroads, now brought out of obscurity by their archeological assessment, not only join the sites, memorials, monuments, and places that commemorate the dawn of the atomic age, but also provide the material means to explore the motivating factors and results of the Able and Baker tests. What do the ships represent? At one level, they embody the first human attempts to grapple with the bomb, at first by confronting it, as represented at one stage by the "can-do" attitude of the crew of the battered, radioactive USS *Skate,* who boarded their beached sub, pumped it out, ran up the flag on a bent periscope, fired up the diesels, backed off the reef, and anchored with the fleet as a "live ship." [44] At a later stage, the ships represent in a very real sense, in their most compelling role, the ultimate dilemma, when the problem of contamination and hence "living with the bomb" was found insurmountable and the option taken was the "illusion of escape"--leaving them at Bikini as wrecks, or taking them to Kwajalein to rust and eventually be sunk out of sight and out of mind.



Prinz Eugen's bell, removed prior to Crossroads, like those of the other targets. For most of these vessels, the bells are the major tangible reminder of the ships. *(NPS, Candace Clifford)*

The ships are also artifacts of the key factors motivating Crossroads, represented in part by the selective stripping of the vessels. The spectacle of destruction, a demonstration of wealth and power, had to be reconciled with thrifty American public opinion despite the intention of the message to foreign audiences. Thus an emphasis was placed upon "obsolete" ships, scrap costs vs. replacement costs, and the removal of certain "valuable" objects and equipment from the target ships. Archeological examination of the target ships at Bikini shows selective stripping of some weapons, but not all, such as two of *Saratoga*'s 5-inch gun houses, and the retention of many of the 40mm, 20mm, and single 5-inch guns and gun directors, as well as the removal of Pelorus from their stands on the exposed areas of the bridge and the removal of only the clocks from target aircraft.

The periscopes of *Apogon* and *Pilotfish* were removed along with *Pilotfish*'s target-bearing transmitters. Yet *Apogon*'s TBT was left behind. Clearly the stripping was insufficient, if not token, as demonstrated by the retention of many valuable items, and the subsequent problems with the pilfering of medical supplies, linen, and food from the target ships during Operation Crossroads by the crews of lesser-supplied support ships. The argument that the ships were not intended to be lost must be balanced with the fact that a special emphasis was placed on

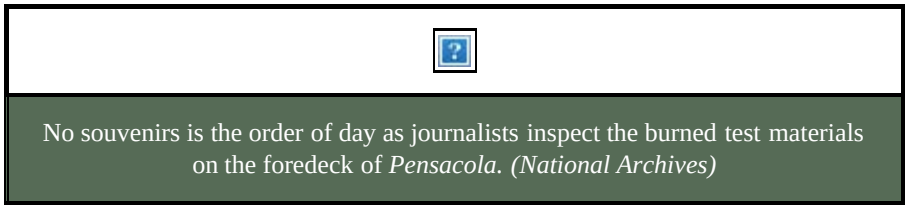
the removal of all ceremonial, ornamental, and "historically significant" artifacts from the ships, such as commemorative plaques and bells.

The presence of the Japanese ships is material proof--along with the ships' mooring in the fatal zone, and the undocumented sinking of the scarcely assessed *Nagato*--of the significant symbolic role of the battleship. *Nagato* alone stands apart from the other ships as being a vessel whose pre-Crossroads history establishes its Crossroads significance. *Nagato,* like *Sakawa,* was brought to Bikini to die under the fatal blow of the atomic bomb.

The large number of test gauges and other instruments observed on *Saratoga* are indicative of two human phenomena. The first is the adaptation of technology to comprehend the incomprehensible--namely measuring the force and actions of an atomic blast. The instruments, as sophisticated as the inclinometer gauges that still rest on *Saratoga*'s bridge, and as simple as tin cans and the ruptured foil peak pressure gauges on the ubiquitous "Christmas trees" and the indentation pressure gauges that litter the flight deck and aftermost 5-inch gun mount on the carrier, are compelling micro-artifacts of humanity's attempts to grapple with the bomb, just as the ships themselves are the larger, macro-artifacts. The second phenomenon is the abandonment of the gauges, reflective of the radionuclide contamination of the ships and the water which brought about the decision to abandon the project, leave the wrecks, and sink the contaminated ships left afloat.

CONFRONTING THE ATOMIC AGE

In viewing and visiting the wrecks of Operation Crossroads, and trying to prognosticate a probable future for them, a few thoughts come to mind. People have an attraction to horror, and a human need, at least for some, to confront their fears. Bikini offers the opportunity to face the ultimate horror of our society--nuclear destruction--at a time when the unleashed atom was sufficiently powerful to rend steel, vaporize water, and sink capital ships. At the same time, the power was not so great as to leave no trace at all but a dark blue, deep crater in the atoll, as was the case with Bravo's hydrogen burst in 1954. The ships provide a human scale of reference, a checkpoint from which to begin to comprehend, at its now minor scale, what Able and Baker's progeny can reap. The power of these "small" bombs to sink and maim a ship are represented in the mangled, "stomped flat" *Gilliam*, the twisted, half-smashed *Arkansas,* the split bottom, toppled stack, and dented flight deck of *Saratoga,* and the abandoned, irradiated, capsized hulk of *Prinz Eugen.*



No souvenirs is the order of day as journalists inspect the burned test materials on the foredeck of *Pensacola. (National Archives)*

The significance of the bomb and what it had done was not lost on contemporary observers and participants, and is materially represented by the taking of souvenirs from the ships after each test. Thus painted signs that command visitors to take "No Souvenirs" occasionally appear in the photographs of scorched and mangled ships. Reflective of the pilfering of the radioactive Trinitite, the collection of souvenirs from Bikini was done without apparent concern over the possible risk. David Bradley reports that one man "collected a chunk of metal from the ship considered to have been nearest to the blast" after Able. "He had it stowed away in a locker beside the bed. Then one day somebody was checking a geiger counter in the vicinity and began to pick up a strong emission. At once he tracked down and located the loot and showed its anxious owner that he'd been sleeping in a shower of gamma rays." [45] Reports of looting artifacts from the ships, notably running lights from *Saratoga* in recent years reflect the compulsion for souvenirs from this atomic graveyard, as does the

removal of shells and wave-washed dead coral by visitors to the Bikini field station, including the archeological assessment team and the media representatives there at the same time.

Yet the implications and reality of the bombs at Bikini is too much for some people. While some confront their fears, others deny them. This is found in the need by some to focus on the non-nuclear history of the ships, a phenomena that began before and during the tests as war records and the symbolic value of "great" and famous ships were touted. *Saratoga* is perhaps most reflective of this, for it was the most eulogized of Crossroads' victims. It can be argued that *Saratoga* at Bikini was to a great extent not the same ship commissioned in 1927, nor the ship that had fought pitched battles at sea during the war. To be those things, the ship would have to have sunk during those times and in those roles. Changed and modified for Crossroads, the carrier was reflective of a new reality and a new role.

Oceanographer Willard Bascom, working at Bikini during the various nuclear tests of the early 1950s, wrote in his memoirs of how he and others sought to dive *Saratoga,* "famous for its exploits in World War II." This telling comment demonstrates the human preoccupation with the "great," or as Bascom termed the carrier, the "wonderful." The need to dive the ship was to see *Saratoga*, not to assess what the bomb had done, and in this Bascom was and is no different from anyone else who has ever dived at Bikini, including the National Park Service team, as well as those who have focused submerged archeological efforts on famous ships like *Monitor* or *Titanic*. We too at times succumb to the historical aura of a famous ship. The need to confront and touch the ship was powerful for Bascom and his colleagues; "Most important, we walked, or at least touched down, on the flight deck, stirring up wisps of dust." The images that the ship evoked were not of Crossroads or of the bomb. Rather,

> Back aboard our LCM the four divers were unusually pensive, our minds still communicating with the spirits of the *Saratoga*'s long-gone pilots and crew. Having visited their old haunts, our minds reconstructed the ship as it had been in its glory days. We could see the uniformed figures on the rail of the bridge and A-5s on the deck, as the ghost ship streamed through the fourth dimension, running into the wind like the Flying Dutchman to launch phantom aircraft. [46]

The need to deny the bomb's impact on the ships, and by extension into our lives, is also reflected by the reaction of some of USS *Arkansas'* crew. The 26,100-ton battleship, popularly but incorrectly thought to have been lifted up, end on end, in the Baker blast column, was nonetheless battered, smashed half flat, and capsized to lie bottom-up in 180 feet of water. Viewing color slides and video of the wreck, some of *Arkansas'* crew at the 4th annual reunion in 1990 questioned the ship's identity, one man mistakenly stating that he had seen previous footage of the battleship upright, its guns pointing forward in their turrets. Another wrote that he was "amazed and spellbound," because "somehow, I had always imagined that our Grand Old Lady...was sitting upright on the bottom of the ocean floor still looking as gallant as she did the day I last went ashore in 1946." [47]

Battle record painted on *Saratoga*'s island, 1945. *(Joe Fetherston)*

The future of the ships at Operation Crossroads might be more secure if advertised as a collection of great and famous ships of World War II and a museum of wartime ship types. Yet tourism of the site may hinge more in the long run on its role as monument to the dawn of the atomic age and as a museum of material remains of the attitudes, thoughts, and actions of that time. The human need to confront the past, even its unpleasant aspects, is ingrained in

our culture, as shown by tourism of battlegrounds and other "sacred" sites sanctified by great loss of life in war or visiting scenes of disaster, such as the Johnstown, Pennsylvania, flood, now a unit in the National Park System. The tourists at Pearl Harbor, Custer Battlefield, Johnstown, Dachau, and Hiroshima confront their human mortality and perhaps reaffirm their joy in personal survival. Bikini, without loss of life, faces a difficult challenge in that people might have difficulty in making that same association. Yet the spectre of the extinction of all life clings only to nuclear weapons sites. As a member of the first generation to live completely under the nuclear sword of Damocles that was slung at Trinity, Hiroshima, Nagasaki, and Bikini, the ships at Crossroads, more so than any other site or battlefield, gave me the first true opportunity to assess my mortality, as well as the world's.

NOTES

[1]"The Evaluation of the Atomic Bomb as a Military Weapon: The Final Report of the Joint Chiefs of Staff Evaluation Board for Operation Crossroads," (June 30, 1947), CCS 471.6, 10-15-46, Section 9, Part 1, p. 60. National Archives Record Group 218.

[2]Boyer, *By the Bomb's Early Light*, p. 4.

[3]"Atomic Bomb National Monument, Proposed," S.2054, 79th Cong., 2d Sess., March 5, 1946.

[4]"First A-Bomb Blast Site to be National Monument," Washington *Daily News*, April 3, 1952. The National Park Service's Chief of its Museum Division urged collection of Trinity Site artifacts and "material evidence of the bomb explosion" on March 15, 1946. On October 7, 1947, the Service's Chief Historian urged the same after a tour of the site, including saving the rapidly dispersing "atomsite" in the blast crater. The Director of the NPS wrote to the Atomic Energy Commission on January 7, 1952, requesting the 100-lbs. of Trinitite. This correspondence is on file in the Trinity Site National Historic Landmark (NHL) file, Division of History, National Park Service, Washington, D.C.

[5]"Enola Gay Resurrected: Craftsmen Restore First Atom Bomber," Washington *Times*, April 28, 1989, p. B6. Also see the *Bock's Car* National Historic Landmark (NHL) file, Division of History, National Park Service, Washington, D.C.

[6]Peter Wyden, *Day One: Before Hiroshima and After* (New York: Simon and Schuster, 1984), pp. 342-343.

[7]Boyer, *By the Bomb's Early Light*, p. 14.

[8]Lloyd J. Graybar, "Bikini Revisited," *Military Affairs* (October 1980), p. 118. Ironically, the wreck of *Ostfriesland*, recently located by sport divers, is now also the subject of investigation.

[9]Vincent Davis, *Postwar Defense Policy and the U.S. Navy, 1943-1946.* (Chapel Hill: The University of North Carolina Press, 1966), p. 243.

[10]*Ibid.*, p. 246.

[11]*Ibid.*

[12]Hanson W. Baldwin, "Atom Bomb is Proved Most Terrible Weapon: Surveys in Japan and

Bikini Test Are Enough to Change Concepts of War," *The New York Times,* July 7, 1946.

[13]Hanson W. Baldwin, dispatch of 22:02 to *The New York Times,* July 25, 1946, on board USS *Appalachian.* Press dispatches, July 25, 1946, from nos. 2543 to 2644, National Archives Record Group 374, Records of the Defense Atomic Support Agency, National Archives.

[14]Baldwin, "Atom Bomb is Proved Most Terrible Weapon," *The New York Times,* July 7, 1946.

[15]Hanson W. Baldwin, "Lessons Learned in Bikini Tests," *The New York Times,* August 1, 1946.

[16]"Guided Missile Warships on Way for Redesigned Atomic-Age Navy," *The New York Times,* September 8, 1946.

[17]*Jane's Fighting Ships, 1958-1959,* (1958), p. 366. USS *Norfolk* was the first of the Destroyer Leaders, later reclassified as frigates. The ship featured rounded gun mounts and steel decks for passive defense against fallout. "Far too expensive to duplicate," *Norfolk* "spent most her career as an experimental prototype." See *Destroyers,* pp. 258-259. Friedman, interestingly, does not mention Bikini-induced changes to warships in his book *The Postwar Naval Revolution* (Annapolis: Naval Institute Press, 1986), citing only tactical and strategic changes as the result of the development of the atomic bomb--for example the dispersion at sea of carrier task groups (see p. 51).

[18]Davis, *Postwar Defense Policy,* p. 246. Also see Graybar, "Bikini Revisited," p. 121.

[19]Baldwin, "Lessons Learned in Bikini Tests," *The New York Times,* August 1, 1946.

[20]Interview with Roger Meade, LANL, Los Alamos, New Mexico, December 19, 1990.

[21]Address by Vice Admiral W. H. P. Blandy, U.S.N., Commander Joint Task Force One, on New York Herald-Tribune Youth Forum, over Columbia Broadcasting System, Waldorf-Astoria Hotel, New York City, April 13, 1946: "Why Test the Atom Bomb?" Joint Army-Navy Task Force One, Crossroads Release No. 36, Department of Energy Archives, Las Vegas, document #101008. Hereafter cited as Blandy, "Why Test the Atom Bomb?"

[22]As cited in Boyer, *By the Bomb's Early Light,* p. 83.

[23]Vannevar Bush, *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy* (New York: Simon and Schuster), p. 92.

[24]All of this had to be rectified with postwar budget cuts, swords-to-plowshares ideology, and a thrifty American taxpayer. See the discussion of this concept at the end of the chapter.

[25]"Statement of Vice Admiral Blandy, U.S.N., Commander Joint Army-Navy Task Force Number One on Purposes of Atomic Bomb Tests," Joint Army-Navy Task Force Number One, Crossroads Release No. 37, Department of Energy Archives, Las Vegas, Document No. 101007.

[26]"Cruiser Sabotage Alleged," *The New York Times,* May 8, 1946, and Shurcliff, *Bombs at Bikini,* p. 52.

[27]*Ibid.*, pp. 36-38, *passim.*

[28]"Bikini Observers," *The New York Times*, May 9, 1946.

[29]Bush, *Modern Arms and Free Men*, pp. 93-94.

[30]Robert Jungk, *Brighter Than a Thousand Suns: A Personal History of the Atomic Scientists* (New York: Harcourt, Brace and Co., 1956), p. 251.

[31]Graybar, "Bikini Revisited," p. 120.

[32]"Atomic Age Angel Food," *Time* Magazine, November 18, 1946, p. 31.

[33]Blandy, "Why Test the Atom Bomb?"

[34]William L. Laurence, "Bikini 'Dud' Decried for Lifting Fears," *The New York Times*, August 4, 1946. Laurence's seminal and sympathetic role in introducing the bomb is discussed in Spencer R. Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988), pp. 98-102, *passim.*

[35]Weart, *Nuclear Fear*, p. 109.

[36]Norman Cousins, "The Standardization of Catastrophe," *Saturday Review of Literature*, August 10, 1946, p. 10, as cited in Boyer, *By the Bomb's Early Light*, p. 293.

[37]Boyer, *By the Bomb's Early Light*, p. 84.

[38]*Ibid.*

[39]"The Underwater Test," *The New York Times*, July 26, 1946.

[40]Bradley, *No Place To Hide*, p. 166.

[41]Boyer, *By the Bomb's Early Light*, p. 90.

[42]Drew Pearson, "Bikini Losses Naval Disaster," *Washington Post*, February 18, 1949.

[43]P. M. S. Blackett, *Fear, War, and the Bomb: Military and Political Consequences of Atomic Energy* (New York: McGraw-Hill Book Co., Inc., 1949), p. 71.

[44]Bradley, *No Place to Hide*, pp. 66-69, *passim.*

[45]*Ibid.*, p. 70.

[46]Willard Bascom, *The Crest of the Wave: Adventures in Oceanography* (New York: Harper & Row, 1988), p. 169.

[47]Roy L. Alton, President, USS *Arkansas* (BB-33) Association, to James P. Delgado, June 4, 1990. Letter in the author's files.

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swcr/37/chap5.htm
Last Updated: 22-Sep-2008

National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

CHAPTER SIX: NUCLEAR PARK POTENTIAL

Daniel J. Lenihan

Making the sunken fleet at Bikini into a marine park carries with it two inherent concepts that are common to all park lands. One is to preserve something of value for future generations and the other is to create "pleasuring grounds" for the present.

The values worth preserving in Bikini are tied to history and archeology and the natural diversity of life forms on the ships which now comprise artificial reefs in the lagoon. The ships' more immediate role as pleasuring grounds for recreation are due to their dramatic appeal as diving attractions for use by a large and growing international population of scuba divers. Additionally, they have educational value as the focus for an interpretive program aimed at the full spectrum of potential park visitors--divers and nondivers.

The socioeconomic implications of a marine park of this magnitude are considerable. The fact that a displaced society might use the atomic pollution of its environment virtually as the focus for its reestablishment and revitalization is also significant as a model beyond the immediate case of Bikini.

PRECEDENT

There is precedent in Micronesia for World War II period shipwrecks serving as stimuli for economic growth. Truk Lagoon is by far the most dramatic example, although significant visitation also occurs for purposes of wreck diving at Guam and Palau. In the latter cases, however, the shipwrecks in Apra Harbor and the lagoon at Palau are secondary to the excellent reef diving which is the primary attraction for sport divers.

Other parts of the world have capitalized on shipwrecks for diving/recreation attractions, including the Great Lakes region of North America. Fathom Five Provincial Park in Tobermory, Ontario (now a federal park), was one of the first to focus specifically on ship remains as a diving attraction. Others in the Great Lakes include Isle Royale National Park, a natural area (a unit of the U.S. National Park System) in which shipwreck sites were inadvertently included when the offshore boundaries were established. These sites have became the focus of much attention from divers, and a sophisticated program of custodianship for the shipwrecks as resources was put into effect by park managers. Other shipwrecks have become important to the local economy of certain Great Lakes communities. The State of Michigan in particular has been very active in establishing state bottomlands preserves to ensure that a degree of protection and control be accorded shipwrecks.

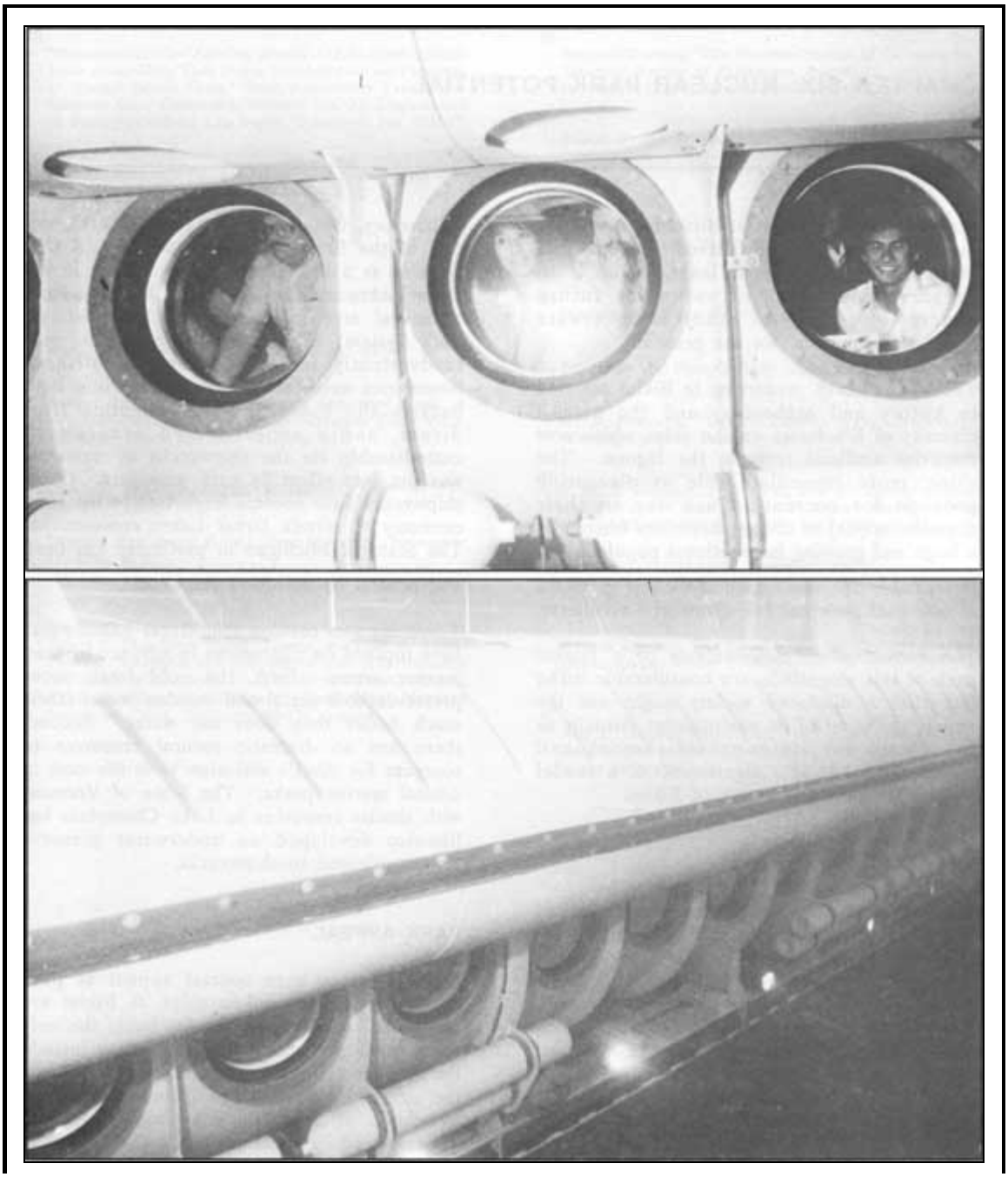
There are two reasons that Great Lakes parks have focused on shipwrecks in advance of most marine areas. First, the cold fresh water preserves both metal and wooden vessel fabric much better than does salt water. Second, there are no dramatic natural resources to compete for diver's attention as is the case in coastal marine parks. The State of Vermont with similar resources in Lake Champlain has likewise developed an underwater preserve system oriented

to shipwrecks.

PARK APPEAL

Unique things have special appeal as park attractions. The sunken ships at Bikini are unique in several ways besides being the only ships sunk by nuclear weapons. They include the only aircraft carrier in divable waters. Just the size of *Saratoga* makes it an awesome site to behold. It is virtually intact with planes and armament easily accessible at depths within the community standard for sport diving.

Additionally, the selection of vessels which lay on the lagoon floor have unusual historical significance. It is rare to have several warships within range of divers, let alone ships as historically significant as *Saratoga* and *Nagato.* The U.S. battleship *Arkansas,* two submarines, the badly damaged remains of two U.S. destroyers, *Anderson* (recipient of 10 battle stars) and *Lamson,* two transports, and a floating drydock, a yard oiler, and several landing craft round out an unparalleled underwater museum of WW II relics.



Underwater visitation by nondivers is one of the greatest areas of potential growth in marine parks. Forty passenger submarines have been found commercially viable in several parts of the world; this particular one is in Guam. *(NPS, Joe Strykowski)*

Most of these sites are at depths that are at the outer limits for safe sport diving. They are not, however, undivable and are certainly within ranges that the advanced diving community of ardent wreck divers would find extremely attractive. Although *Saratoga* sits on the lagoon bottom at 180 feet, it is important to note that the flight deck is at only 100 feet and many fascinating dives can be made to its island, reached at depths as shallow as 70 feet. *Pilotfish* and *Apogon, Baldo*-class submarines, may be the focus of a thrilling overflight dive which does not exceed 150 feet. In many other locations each would be considered a main attraction in its own right. The beached LCT-1175 would make a good snorkel or shallow-water dive for novices.

Besides the unique shipwreck population, Bikini has an appealing coral reef environment which has had little disturbance since the testing, making it unusually intact compared to many places in Micronesia. Even the large numbers of sharks outside the reef may be a draw to certain advanced divers and underwater photographers.

Other aspects of Bikini which make it appealing as a dive site are the proximity of all the ships to each other and the fact that they are all within a 15-minute boat ride from Bikini island in a relatively protected lagoon.

If there were a commercial diving facility on the island, it is hard to imagine a more logistically feasible diving resort. There is not a great deal at this point to hold the attention of the nondiving public, but that might be remedied by orienting the interpretive efforts on the whole island to a nuclear theme. Many pioneer studies have been conducted on Bikini regarding radioactivity, and there are few other places in which as much has been learned about living with the nuclear age, as opposed to dying with it. An interpretive center or museum which included artifacts from the ships and others brought from abroad could capitalize on that theme. If the physical remnants of the blockhouses and experimental agricultural stations are preserved, they could be a focus of interpretation efforts by Bikinian Park Rangers or commercial tour guides.

It would be important also to maintain the written legacy of what happened at Bikini in the form of an archive located on the island. This should become part of the patrimony of the Bikinian people rather than being accessible only in far-flung libraries around the globe, including material that has become declassified at Los Alamos and other centers.





Underwater monuments are appropriate in some cases. *(NPS)*

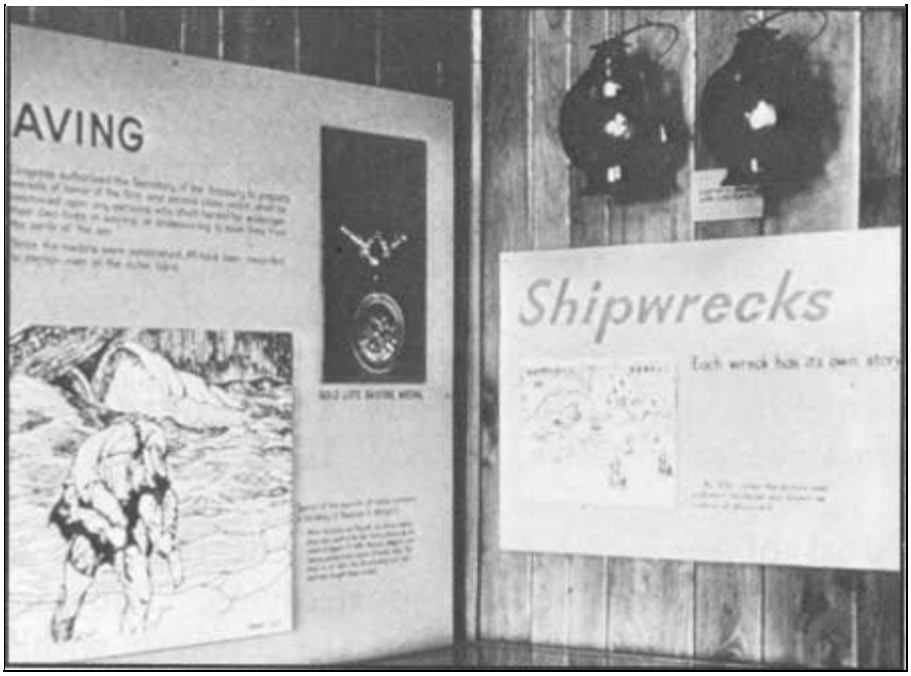
PARK PROTECTION

One of the most critical aspects of park management is protection of the resources which form the basis of the park. For our purposes, these can be divided into the natural, cultural, and scenic values associated with the shipwrecks of Bikini. These include systemic factors such as the ecological health of the lagoon, which should be the focus of ongoing environmental monitoring. They also include the specifics of visitor use of the dive sites, which is the focus of our present discussion.

The most effective tools for site protection are the right balance of education and enforcement. Most attrition to the underwater environment of Bikini can be mitigated simply by ensuring that visitors are aware they are in a marine-protected area. Because a large percentage of the potential visiting public comes from nations that have been exposed to marine park concepts, education will be an especially important part of the resource protection process. Sport divers visiting Bikini should know that they are in a park, that there exist clear enforceable regulations, and that they are expected to live by them.

The other necessary part of the equation is enforcement of these regulations when any flagrant violations occur. It is important that an enforcement officer is available to the guides and that infractions are reported and impartially dealt with.

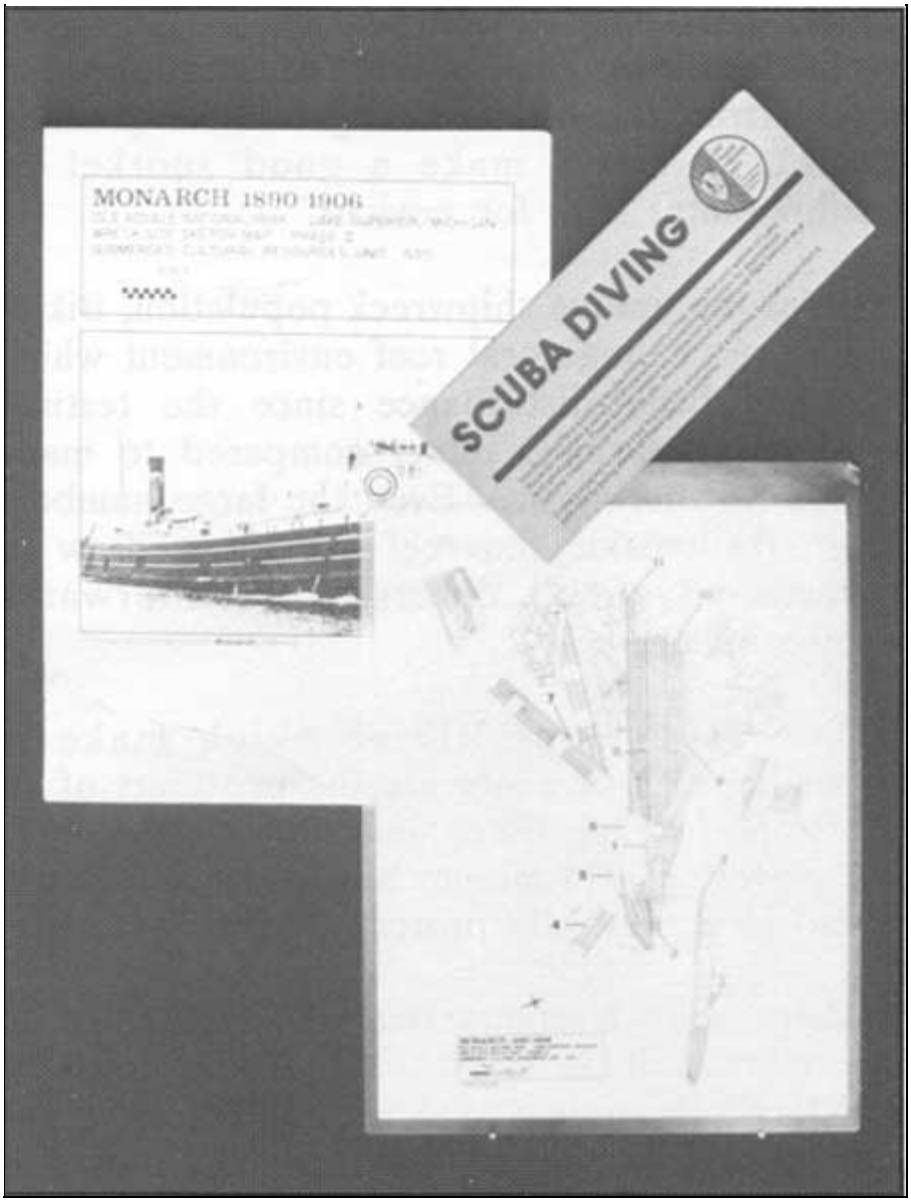
Whatever rules are decided on, it is critical that removal or disturbance of artifacts on the ships is prohibited. It seems strange to think of "disturbing" ships that have been the target for atomic bombs, but what is really being preserved is not the ship but rather a historic scene, i.e., the shipwreck. It is possible in very short time to remove much of the magic and ambience of a shipwreck with crowbars and hammers.



Exhibits in a visitor center can be useful for interpreting shipwrecks to nondivers or prepping divers for visits to sites. *(NPS)*

INTERPRETIVE/EDUCATIONAL DEVICES

A basic tenet of park management is that the visitor experience can be significantly enhanced with an imaginative interpretive program. Educational devices also help protect the resources because informed visitors tend to be more respectful of resources they understand.



Package of materials experimented at Isle Royale National Park includes generic brochure on all the wrecks, topside foldout on a particular wreck site, and plasticized underwater trail guide. *(NPS)*

Among the devices that have been most successful in underwater parks are brochures that explain the nature of the resource and messages that help alert the diving public to what they are seeing and why it is significant. This may include large-format line drawings of shipwreck sites and plasticized schematics for use underwater. These orient divers (thereby also increasing the safety factor) and help them comprehend what can be an overwhelming number of visual stimuli on a complex underwater wreck site.

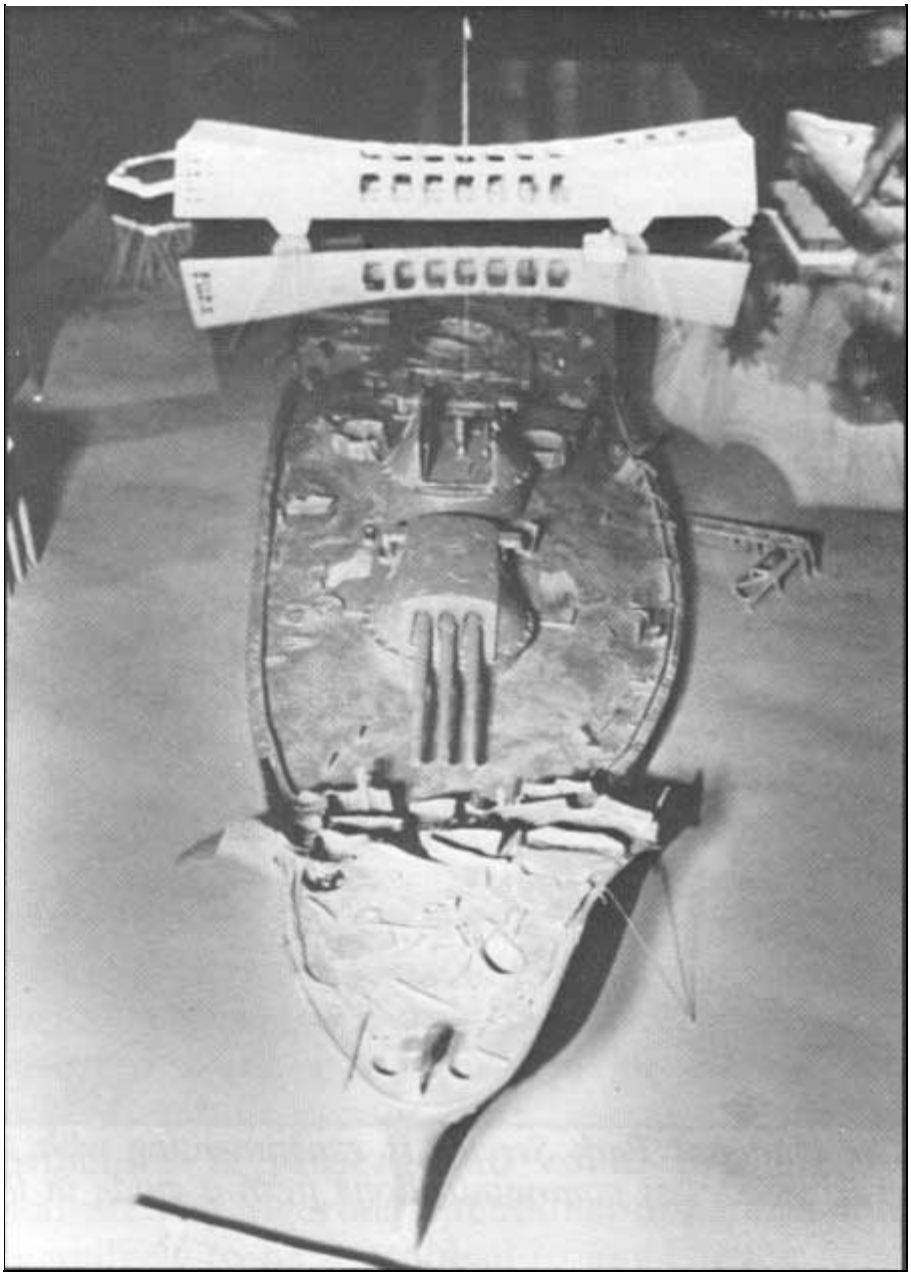
Short, edited video tapes of each site with a narrative lasting 5-10 minutes can also prepare visitors and raise expectations of what may be seen on the dive. It also permits the narrator the opportunity to identify hazards or point out fragile features which should not be disturbed.



Foldout brochure that includes line drawing of a particular wreck, historic photo, and other pertinent data to be consulted by the visitor before diving. *(NPS)*

A visitor center which housed both a museum of nuclear testing and various exhibits should not be prohibitively expensive and would enable tourists to understand the full significance of what transpired at Bikini. Part of it should be devoted to the portrayal of the traditional pre-test Bikinian lifestyle and the subsequent plight of the displaced population. This may also be attractive as a mechanism for preserving local knowledge of traditions which may be easily lost. Although the personal recollections of older generations of Bikinians are the greatest repository of these folkways, there exist a number of anthropological studies that may also provide some help in this regard.

It would be an intriguing challenge for an interpretive program to convey to the visitor a multifaceted experience--one in which they had some feeling for what traditional Bikinian lifestyle was like in contrast to what happened during the period Bikini played a part in an international postwar political theater.



Three-dimensional models of shipwrecks on the bottom can be used effectively in a visitor center. This example is of the USS *Arizona* at the USS Arizona Memorial at Pearl Harbor. *(NPS, Larry Murphy)*

Though billed as an "experiment," it is clear that Crossroads was also a "statement." How the tests were viewed variously by Americans, Japanese, Europeans, and the developing Soviet block nations provides fascinating subject matter for an interpretive program.

It is important too that the full significance of the testing is apparent to both diving and nondiving visitors. Part of this can be accomplished by a diorama of the lagoon showing the ships in place on the bottom and "play-on-demand" historical footage that shows how they got there.

Lastly, firsthand visits by nondiving visitors should be carefully considered. The use of submersibles for transport of visitors in a tour bus arrangement has been commercially successful in recent years in Guam, Cayman Islands, Hawaii, and Saipan, among other places. The protected nature of the lagoon and the presence of such dramatic historical

remains would make this a potentially lucrative enterprise in Bikini. It has the important aspect of being attractive to the large populations of visitors who do not dive or in which only one member of the family dives.



National Service is experimenting with special earphones that visitors could use which allow them to hear wireless communications from a guide in the water or in a boat on the surface. *(NPS, Larry Murphy)*

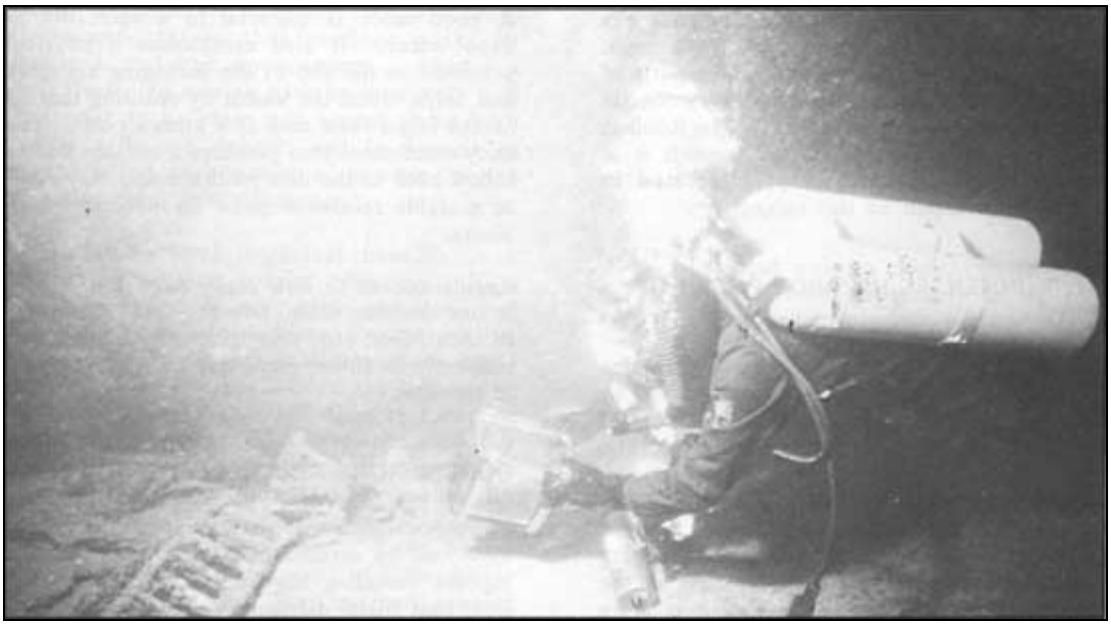
LIVING SAFETY/LIABILITY

It should be understood at the outset that diving is not a risk-free activity. Diving on deep shipwrecks is especially risky and penetrating them at depth offers another magnitude of hazard. This report is not designed to begin to address the legal complexities of liability, claims, etc., that might devolve from visitor injury on a shipwreck at Bikini. We can only offer some observations on how to make this as safe an experience as possible, and leave legal advice to legal experts. Assuming that a decision had been made to offer the ships as a diving attraction, it is then the responsibility of the Bikini Council to inform the visitor of hazards, provide reasonable and prudent recourse to a person who has been injured, and to recover the remains of a victim of a fatal diving accident.

Anyone diving in the park should sign a registration and release form which ensures that they have been warned of the risks and understand what rules they must abide by to afford the greatest degree of protection to others. This includes conduct on the surface in boats as well as on the dive.

Perhaps the most problematic area comes in trying to evaluate the competence of visiting divers, and it is strongly recommended that no attempt be made to do this by the management agency beyond the most standard practices. The latter would include asking to see a valid diver certification card and having the card number recorded on the registration form. Attempts at trying to evaluate visitors' equipment, decompression protocols, etc., are not recommended. Divers adhere to widely differing philosophies and approaches, which are difficult to evaluate. Assuming direct oversight of their activities could only increase whatever degree of liability that may exist while doing little to increase visitor safety, possibly even hampering it.

The most critical area of interaction for the site managers would be in the area of accident management. It should be mandated that all boats have radio contact with a shore facility which is constantly monitored and that first aid and oxygen administration equipment are available on all craft. The maintenance of a recompression facility on the island would be ideal; however, it may also be unrealistic because such facilities take considerable maintenance and are useless without trained operators in continual radio contact with medical professionals. It may be more realistic to develop a reliable air evacuation program with the military at Kwajalein and negotiate a protocol for access to their recompression facilities.



Daniel Lenihan takes radiation readings on the lagoon bottom next to *Saratoga. (NPS, Larry Murphy)*

SPECIAL DIVING HAZARDS: EXPLOSIVES AND RADIATION

The special risk areas for diving that need to be addressed at Bikini are those related to live ordnance and radiation. There is no question that various types of bombs and projectiles are still intact on the vessels, and that radiation was a serious problem on the ships shortly after the tests. The issue at hand is how much of a hazard these factors now present a visiting sport diver.

The U.S. Navy Explosive Ordnance Disposal (EOD) experts who have examined some of the most accessible and obvious bombs and projectiles felt there was indeed some risk, but that it was not excessive. It was their opinion that if someone tried hard enough at Bikini, he or she could hurt themselves, for example, by intentionally disturbing some of the items that they personally observed in the hanger deck of *Saratoga.*

There is some question after consulting the archives that entire explosive trains were left intact, i.e., that either the initiating charge or major working charge was left inert in many cases. Whether or not this is true, the potential for injury of an individual is still present because even an armed initiating charge can be lethal if discharged in the vicinity of the diver.

It was the opinion of the National Park Service diving team after consulting with the Navy experts that there is an acceptable level of risk involved in the ordnance at Bikini from a park management perspective. Although live ordnance is present and could possibly be activated by vigorous intentional disturbance, it is unlikely to be a problem to any but the most

reckless of park visitors. Any situation in which inadvertent disturbance might cause a detonation would be considered an unacceptable risk, but that prospect appears very unlikely. The EOD experts did safe one bomb which they felt presented an unreasonable hazard. EOD operations at Bikini are discussed further in a 1990 internal U.S. Navy report by Lt. David Rattay.

The question of radiation on the ships is going to be a major concern in the mind of any rational sport diver who first considers the possibility of diving Bikini. This is an area in which myth can be as powerful an inducement to behavior as reality, since most societies are far from having come to any sense of resolution over this issue. Suffice it to say that it was not the least area of concern for the NPS team when it conducted its own risk assessment before going to Bikini.

Again, from the perspective of nonexperts who are called upon to interpret the findings of specialists, it is our opinion that external radiation is not a significant hazard on the ships at Bikini. The NPS team carefully scrutinized tests conducted by Holmes and Narver, read the assessment by Lawrence Livermore Labs, and personally took beta and gamma detection instruments on several dives through the ships and to the sediments in the bottom of the lagoon. There were never any signs of radiation danger past what one might expect from living day-to-day in most parts of the continental United States. (A very concise and authoritative document by W. L. Robison comprises Appendix III of this report; it is recommended to any reader interested in further information on this subject.)

ENVIRONMENTAL HAZARDS POSED BY SHIPS

The threat of pollution from a massive release of fuel oil is an area of concern expressed by the Bikini Council, particularly in the event of structural collapse of the ship's bunkers. The problem should probably be seen as follows: We can assume in the worst case that there are significant quantities of oil present in some of the ships--indeed some is visibly seeping slowly from *Saratoga* and other vessels in the lagoon. The question of how much is more problematic. Although we may know original fuel loads, we do not know how much was lost is the wreck event. One must therefore assume the worst case until proven wrong.

This leaves the option of recovering the ships, recovering the oil, stabilizing the oil so it cannot come to the surface, or no action. Probably the worst option would be the attempt to salvage the ships. Besides being enormously expensive, the attempt would almost certainly cause a massive release of any fuel present because of the deteriorated condition of the vessels. It would also result in destruction of a major historical (and economic) resource for the Bikinians. Recovering the oil through "hot-tapping" may be possible but carries some risk of incurring a major spill and would be moderately expensive at the least.

MOORING SYSTEMS

One important element in any diving park is a mooring system for dive boats. This enables the managing agency to increase safety by controlling points of access to the wreck sites and natural attractions while diminishing impacts from anchor dragging.

A good moor is essential to a safe dive in deep water. It also establishes a physical presence on the site by the managing authority and helps orient the visitor by ensuring that he or she begin their dive at a known point. The buoy attachment also provides a reliable line to follow back to the dive platform and may serve as a stable reference point for decompressing divers.

Regulations as to how many boats may attach to one mooring cable, how they are "rafted off" to each other, etc., also allows the Bikinians to indirectly establish preferred carrying

capacity of the sites.

CONCLUSIONS AND RECOMMENDATIONS

To responsibly assess park values at Bikini, we have had to scrutinize carefully the negative aspects, including any hazards to users. It is clear that Bikini offers far greater rewards and somewhat greater risks to the diving public than most diving attractions. They are by no means unreasonable risks, however, and there is no expectation that outdoor parks be sanitized, risk-free environments. Should a diving oriented marine park be instituted, it is important to be clear and honest about both the rewards and dangers and to provide as controlled an environment as possible for the divers to enjoy this experience.



Management control of underwater sites can be enhanced by installing mooring buoys with appropriate visitor use guidelines. *(NPS)*

There are several important benefits to a marine-park-based tourist economy. It is nonconsumptive of resources, but does not necessarily preclude multiuse concepts where, for instance, traditional fishing practices could still occur in most portions of the lagoon. It is environmentally sound if support bases on land are engineered correctly and the development of park cultural interpretive programs would provide another motive for reestablishing

traditional lifeways. Besides being informative to visitors, a living history approach might help the youth of Bikini better understand their own heritage and present them with additional options for personal lifestyles.

If such a focus is adopted in a resettlement program, it should be done with great forethought and planning. Assistance should be requested from agencies and institutions that specialize in marine park planning from the nations most likely to form the reservoir of potential visitors. The following procedures are recommended:

1. Establish a park concept development committee which includes park professionals from other nations and concession managers. Include American, Japanese, and Australian tourism specialists.

2. Follow this with a park planning group to operationalize whatever concepts are decided upon.

3. Develop a dependable corps of Bikinian rangers or wardens.

4. Send Bikinian ranger trainees to American and Canadian marine parks which manage shipwrecks for periods of intensive training so they can learn techniques and options for protection, interpretation, and diving accident management. Possible candidates are Fort Jefferson National Monument in Florida, Tobermory in Canada, Isle Royale National Park in Michigan, and Channel Islands National Park in California.

5. Establish a visitor center/contact station which orients newcomers to the park theme and regulations.

6. Explore the range of options for interpretation, including a model of the lagoon bottom with ships, graphic displays of the wrecks using line drawings, photos, and videotape programs in the visitor center.

7. Ensure that Bikinian culture is given a prominent role in the interpretive prospectus and that the history and significance of the Bikinian nuclear experience is not memorialized from only an American perspective. Living history programs should be considered.

8. Contact commercial tourist submarine specialists and discuss what would be involved in establishing a submarine concession at Bikini. Consult with U.S. National Park Service concessionaire specialists for advice on setting up contracts for such services.

9. Consider a 3D video viewing center for nondivers. Request assistance from National Geographic Society and others in the technical aspects of obtaining footage and setting up a viewing center.

10. Explosive Ordnance Disposal teams should be requested to continue examining the sites for any ordnance that presents exceptional hazards to visiting divers.

11. Contact experts in industry and government who have knowledge of petroleum products' potential for pollution after longterm immersion in order to explore possible means of stabilization or control.

12. Develop dialogue between Bikinians and parks and recreation programs

affiliated with universities.

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Last Updated: 22-Sep-2008

National Park Service

The Archeology of the Atomic Bomb
A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons

APPENDIX I: TARGET VESSELS AT BIKINI AND THEIR DISPOSITION

Carriers

Independence (CVL-22	Sunk as target off San Francisco, California, January 27, 1951.
Saratoga (CV-3)	Sunk by BAKER at Bikini, July 25, 1946.
	Total: 2

Battleships

Arkansas (BB-33)	Sunk by BAKER at Bikini, July 25, 1946.
Nagato (Japanese)	Sunk by BAKER at Bikini, July 29, 1946.
Nevada (BB-36)	Sunk as target off Pearl Harbor, July 31, 1948.
New York (BB-34)	Sunk as target off Pearl Harbor, July 8, 1948.
Pennsylvania (BB-38)	Scuttled off Kwajalein, February 10, 1948.
	Total: 5

Cruisers

Pensacola (CA-23)	Scuttled off the Washington Coast, November 10, 1948.
Prinz Eugen (IX-300)	Stranded and sank at Kwajalein, December 22, 1946. *(New York Times* article indicates December 16).
Sakawa (Japanese)	Sunk by ABLE at Bikini, July 2, 1946.
Salt Lake City (CA-25)	Sunk as target off San Clemente, California, May 25, 1948.
	Total: 4

Destroyers

Anderson (DD-411)	Sunk by ABLE at Bikini, July 1, 1946.
Conyngham	

(DD-371)	Scuttled off California, July 1948.
Hughes (DD-410)	Sunk as target off Washington, October 16, 1948.
Lamson (DD-367)	Sunk by ABLE at Bikini, July 1, 1946.
Mayrant (DD-402)	Sunk off Kwajalein, April 4, 1948.
Mustin (DD-413)	Sunk off Kwajalein, March 18, 1948. *(New York Times* article indicates April 17).
Ralph Talbot (DD-390)	Scuttled off Kwajalein, March 1948. *(New York Times* article indicates March 8).
Rhind (DD-404)	Scuttled off Kwajalein, March 22, 1948. *(New York Times* article indicates March 23).
Stack (DD-406)	Sunk as target off Kwajalein, April 24, 1948.
Trippe (DD-403)	Sunk as target off Kwajalein, February 3, 1948.
Wainwright (DD-419)	Sunk as target off Kwajalein, July 5, 1948.
Wilson (DD-408)	Scuttled off Kwajalein, March 8, 1948.
	Total: 12

Submarines

Apogon (SS-308)	Sunk by BAKER at Bikini, July 25, 1946.
Dentuda (SS-335)	Sent to West Coast, sold for scrap, January 20, 1969.
Parche (SS-384)	Sent to West Coast, sold for scrap, July 1970.
Pilotfish (SS-386)	Sunk by BAKER at Bikini, July 25, 1946.
Searaven (SS-196)	Sunk as target off California, September 11, 1948.
Skate (SS-305)	Scuttled off California, October 5, 1948.
Skipjack (SS-184)	Sunk as target off California, August 11, 1948.
Tuna (SS-203)	Scuttled off California, September 24, 1948.
	Total: 8

Attack Transports

Banner (APA-60)	Scuttled off Kwajalein, February 16, 1948.
Barrow (APA-61)	Scuttled off Kwajalein, May 11, 1948.
Bladen (APA-63)	Sent to East Coast, transferred to U.S. Maritime Commission, August 3, 1953.

Bracken (APA-64)	Scuttled off Kwajalein, March 10, 1948.
Briscoe (APA-65)	Scuttled off Marshall Islands, May 6, 1948.
Brule (APA-66)	Scuttled off Kwajalein, May 11, 1948.
Butte (APA-68)	Scuttled off Kwajalein, May 12, 1948.
Carlisle (APA-69)	Sunk by ABLE at Bikini, July 1, 1946.
Carteret (APA-70)	Sunk by gunfire in the Pacific, March 19, 1948.
Catron (APA-71)	Sunk by gunfire in the Pacific, May 6, 1948.
Cortland (APA-75)	Sent to East Coast, transferred to U.S. Maritime Commission, March 31, 1948.
Crittenden (APA-77)	Scuttled off California, October 5, 1948.
Dawson (APA-79)	Scuttled off Kwajalein, March 19, 1948.
Fallon (APA-81)	Scuttled off Kwajalein, March 10, 1948.
Fillmore (APA-83)	Sent to East Coast, transferred to U.S. Maritime Commission, April 1, 1948.
Gasconade (APA-85)	Sunk by torpedoes off California, July 21, 1948.
Geneva (APA-86)	Sent to East Coast, sold for scrap, November 2, 1966.
Gilliam (APA-57)	Sunk by ABLE at Bikini, July 1, 1946.
Niagara (APA-87)	Sent to East Coast, sold for scrap, February 5, 1950.
	Total: 19

LSTs (Landing Ship, Tank)

LST-52	Sunk in Pacific, April 1948.
LST-125	Sunk off Bikini, August 14, 1946.
LST-133	Scuttled off Kwajalein, May 11, 1948.
LST-220	Scuttled off Kwajalein, May 12, 1948.
LST-545	Scuttled off Kwajalein, May 12, 1948.
LST-661	Scuttled off Kwajalein, July 25, 1948.
	Total: 6

LSMs (Landing Ship, Medium)

LSM-60	Completely destroyed by BAKER at Bikini, July 25, 1946.
	Total: 1

LCTs (Landing Craft, Tank)

LCT-412	Scuttled off Kwajalein, September 1947.
LCT-414	Scuttled by BAKER at Bikini, July 1946.
LCT-705	Scuttled off Kwajalein, September 1947.
LCT-746	Scuttled off Kwajalein, March 1947.
LCT-812	Scuttled by BAKER at Bikini, July 1946.
LCT-816	Scuttled off Kwajalein, June 1947.
LCT-818	Scuttled off Kwajalein, September 1947.
LCT-874	Scuttled off Kwajalein, September 1947.
LCT-1013	Scuttled off Kwajalein, September 1947.
LCT-1078	Scuttled off Kwajalein, September 1947.
LCT-1112	Scuttled off Kwajalein, September 1947.
LCT-1113	Scuttled off Kwajalein, June 1947.
LCT-1114	Sunk by BAKER at Bikini, July 30, 1946.
LCT-1175	Sunk by BAKER at Bikini, July 25, 1946.
LCT-1187	Scuttled by BAKER at Bikini, July 1946.
LCT-1237	Scuttled by BAKER at Bikini, July 1946.
	Total: 16

Auxillaries

YO-160	Sunk by BAKER at Bikini, July 25, 1946.
YOG-83	Scuttled off Kwajalein, September 16, 1948.
ARDC-13	Sunk by BAKER at Bikini, August 6, 1946.
	Total: 3

LCIs (Landing Craft, Infantry)

LCI-327	Destroyed on Bascombe (Mek) Island, Kwajalein, October 30, 1947.
LCI-329	Scuttled off Kwajalein, March 16, 1948.
LCI-332	Scuttled off Kwajalein, September 1947.
LCI-549	Sold to private party in California, August 19, 1949.
LCI-615	Sold to private party in California, August 19, 1949.
LCI-620	Scuttled off Bikini Lagoon entrance, August 10, 1946.
	Total: 6

LCMs (Landing Craft, Mechanized)

[Note these craft, like the LCVP, did not ordinarily receive hull numbers. The numbers were provided by Joint Task Force One to facilitate damage reports.]

LCM-1	Fate unknown.
LCM-2	Fate unknown.
LCM-3	Fate unknown.
LCM-4	Sunk by BAKER at Bikini, July 25, 1946.

LCM-5	Fate unknown.
LCM-6	Sold for scrap in Guam, n.d.
	Total: 6

LCVPs (Landing Craft Vehicles, Personnel)

LCVP-7	Fate unknown.
LCVP-8	Fate unknown.
LCVP-9	Fate unknown.
LCVP-10	Sunk by BAKER at Bikini, July 25, 1946.
LCVP-11	Fate unknown.
LCVP-12	Fate unknown.
	Total: 6

Sources: A. G. Nelson, Capt. USN, "Crossroads Target Ships," Memorandum, NNTPR #24-78, May 25, 1978, Department of the Navy, Office of the Chief of Naval Operations; NAVSEA Shipbuilding Support Office, "U.S. Vessels Involved in Operation Crossroads," NAVSEASHPSO, Philadelphia, n.d.; Commander, Joint Task Force One, "Report on Atomic Bomb Tests Able and Baker (Operation Crossroads) Conducted at Bikini Atoll, Marshall Islands, on 1 July 1946 and 25 July 1946," (1946) Vol. 1, Part VII, pp. 6-15; and James L. Mooney, ed. *Dictionary of American Naval Fighting Ships*, 8 volumes. (Washington, D.C.: Government Printing Office, 1959-1981). Jonathan Weisgall provided the *New York Times* articles which indicate different sinking dates for several of the vessels.

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APPENDIX II: RELICS OF OPERATION CROSSROADS

The target ships of Operation Crossroads, even those that survived sinking at Bikini and those that also outlasted subsequent sinking, are now scrapped. The same holds true in large measure for the support fleet of ships. Nonetheless, four Crossroads veterans remain in active naval service as of 1990, and another one is preserved as a museum ship. In 1990, surviving vessels of Operation Crossroads are:

USS *Conserver* (ARS-39). Attached to the repair and service group for Operation Crossroads, the *Bolster*-class salvage vessel *Conserver* is assigned to the Pacific Fleet and based at Pearl Harbor.

USS *Fulton* (AS-11). Also assigned to the repair and service group for Operation Crossroads, the submarine tender *Fulton* is now attached to the Atlantic Fleet and based at Norfolk, Virginia.

USS *Laffey* (DD-724). Attached to the support fleet for Crossroads, *Laffey* patrolled the seas outside the atoll. Preserved and open as a museum display vessel at Patriot's Point, Mount Pleasant, South Carolina, *Laffey* is one of five historic vessels there, including USS *Yorktown* (CV-10).

USS *Preserver* (ARS-8). Attached to the repair and service group, this salvage ship is now assigned to the Naval Reserve Training Facility at Little Creek outside Norfolk, Virginia.

USS *Reclaimer* (ARS-42). Attached to the repair and service group as its first assignment, this then-new *Diver*-class salvage ship later returned to Bikini in 1954 for the Castle-Bravo test. This vessel remains in active service at Pearl Harbor.

Additionally, preserved portions of one target and one support ship survive as historic exhibits. The bridge of the target submarine *Parche* (SS-384), one of the nine vessels to survive the spate of post-Crossroads scuttlings, served as a Naval Reserve training boat at Mare Island, California, until November 1969. Sold for scrap in July 1970, portions of the submarine were saved and retained by the Navy. The bridge is on display at the Subase, Pearl Harbor, while the conning tower once inside the sail and bridge is displayed outdoors at the USS *Bowfin* Submarine Museum and Park at Pearl Harbor. The above-the-waterline portion of the bow of USS *Fall River* (CA-131), the target ship group flagship for Crossroads, was saved after the cruiser was stricken and scrapped in 1971. It is now on display at Battleship Cove, Fall River, Massachusetts, where the battleship *Massachusetts*, the destroyer *Joseph P. Kennedy Jr.*, and the submarine *Lionfish* are preserved.

At least one Crossroads aircraft survives as a museum exhibit. An F6F Hellcat used as a

drone to sample the air after each burst is now at the National Air and Space Museum in Washington, D.C. The ARADO 196 spotting plane from *Prinz Eugen* that did not accompany the cruiser to Bikini is also owned by U.S. Navy, and is in storage.

Some of the items of "historical interest" removed from the Crossroads target ships are displayed at various memorials, sites, and museums. The ship's bell of USS *Arkansas* is the centerpiece of the Arkansas War Memorial in Little Rock, while the Governor's office retains the ship's silver service for use on ceremonial occasions. *Saratoga*'s bell is displayed at the Naval Aviation Museum at Pensacola, Florida. The bell of USS *Anderson* is displayed at the Anderson, South Carolina, post of the Veterans of Foreign Wars (VFW). *Lamson*'s bell is displayed at the 9th Naval District Headquarters in Des Moines, Iowa. The U.S. Navy retains *Prinz Eugen*'s bell, now in storage, as well as *Lamson*'s commissioning plaque in Washington, D.C. Ordnance items stripped from *Prinz Eugen* prior to Crossroads are now in the Navy's museum collections, and include a 20mm and 37mm antiaircraft gun. Flags flown from the ships at Bikini, including a Japanese Naval Ensign from *Nagato* are in the Navy's collections.

Other artifacts from the target ships rest throughout the country in various museums and in private hands, and many are proudly displayed by the veterans of these vessels at their reunions--the last remnants in hand of the sunken fleet of Operation Crossroads.

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APPENDIX III: ESTIMATES OF THE RADIOLOGICAL DOSE TO PEOPLE LIVING ON BIKINI ISLAND FOR TWO WEEKS WHILE DIVING IN AND AROUND THE SUNKEN SHIPS IN BIKINI LAGOON

Introduction

Bikini Island and Bikini Lagoon were contaminated by fallout from nuclear weapons tests conducted at the atoll by the United States from 1946 to 1958. The second test, Baker, of the Crossroads series was an underwater detonation in 1946 that sank several ships in the lagoon, including the USS *Saratoga* and the Japanese battleship *Nagato.*

The ships received high-intensity gamma-ray and neutron bombardment from the Baker test, which induced radioactivity in the metal structures. Some of the tests conducted after the Baker shot (there were 21 tests in all) injected contaminated carbonate particles into the air, some of which were deposited across the lagoon surface. Most of this contaminated soil then settled onto the ships' decks and other structures and on the lagoon bottom.

These sunken ships provide an interesting location for divers. Recreational diving and swimming in and around the ships raises the question of the potential radiological dose from the radionuclides present in or on the ships and in the lagoon sediments.

In addition, radionuclides were deposited on the islands. We have spent several years evaluating the radiological conditions on Bikini and Eneu Islands at Bikini Atoll and Enjebi Island at Enewetak Atoll, and estimating the radiological dose people might receive living on these islands (1-8). As a result, we have the data to also evaluate the radiological dose people would receive if they were to live on Bikini Island for a two-week period while diving near the sunken ships in the lagoon.

The purpose of this paper, therefore, is to present an analysis of the potential radiological dose to persons who would dive near the sunken ships and live on Bikini Island for a short period of time.

The Radiological Dose while in the Lagoon and around the Ships

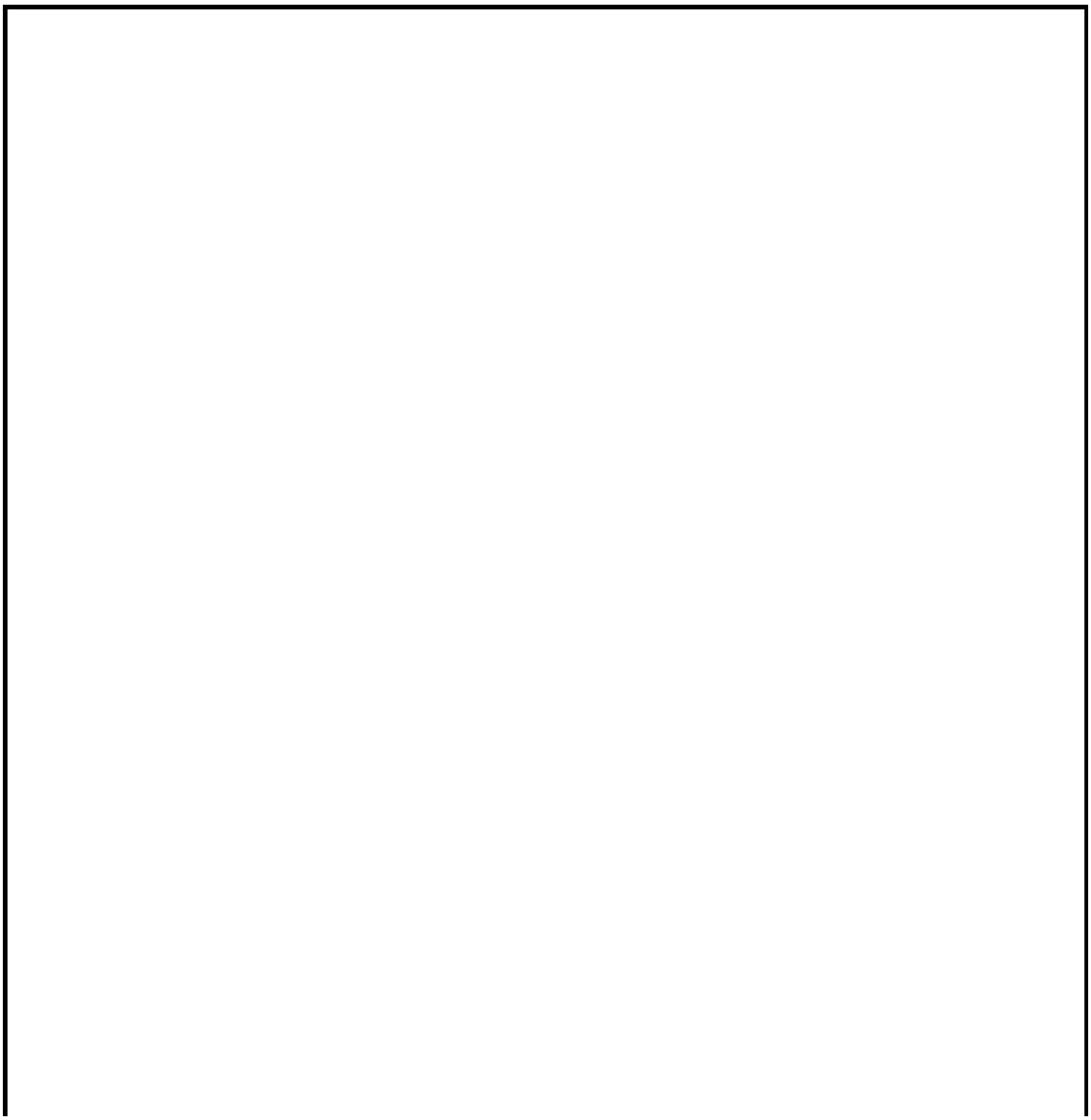
Radionuclides in the Sediment

Many of the radionuclides produced at detonation and induced in the ships' structure (by the resulting neutron flux) have very short half-lives, ($T_{1/2}$), ranging from seconds to a few weeks. Consequently, most of the radioactivity decayed away very early. Those radionuclides with half-lives in the range of several years or more are the only ones still present and that have the potential of causing exposure.

The estimates of the radiological dose will be calculated for 1990 which is 44 years after the Baker test and 32 years after the last test at Bikini Atoll. (Any dose received after 1990 would be lower.) The radionuclides currently present in the lagoon sediments and on the islands are Cesium—137 (^{137}Cs; $T_{1/2}$ = 30 years), Strontium—90 (^{90}Sr; $T_{1/2}$ = 28 years), Cobalt—60 (^{60}Co; $T_{1/2}$ = 5.3 years), Plutonium209 (^{239}Pu; $T_{1/2}$ = 24065 years), Plutonium —240 (^{240}Pu; $T_{1/2}$ = 6537 years), and Americium—240 (^{241}Am; $T_{1/2}$ = 432 years). We rarely can detect other radionuclides in island soil; however, in lagoon sediments, we often detect one of the Europium nuclides or ^{207}Bi. Moreover, even ^{60}Co is found in very low concentrations because it has been through at least 6 half-lives from 1958 to 1990 and even more from 1946.

Gamma-Emitting Radionuclides (^{137}Cs and ^{60}Co)

The average ^{137}Cs, ^{60}Co, and ^{207}Bi concentrations in the lagoon sediment around the sunken-ship area are between 0.1 and 1.0 pCi/g (for sampling locations see Figures 1 — 3). These unpublished data are from an extensive survey of the radionuclide concentrations in the sediments across Bikini lagoon conducted by Dr. Victor Noshkin of the Lawrence Livermore National Laboratory (LLNL) in 1979 and 1983.



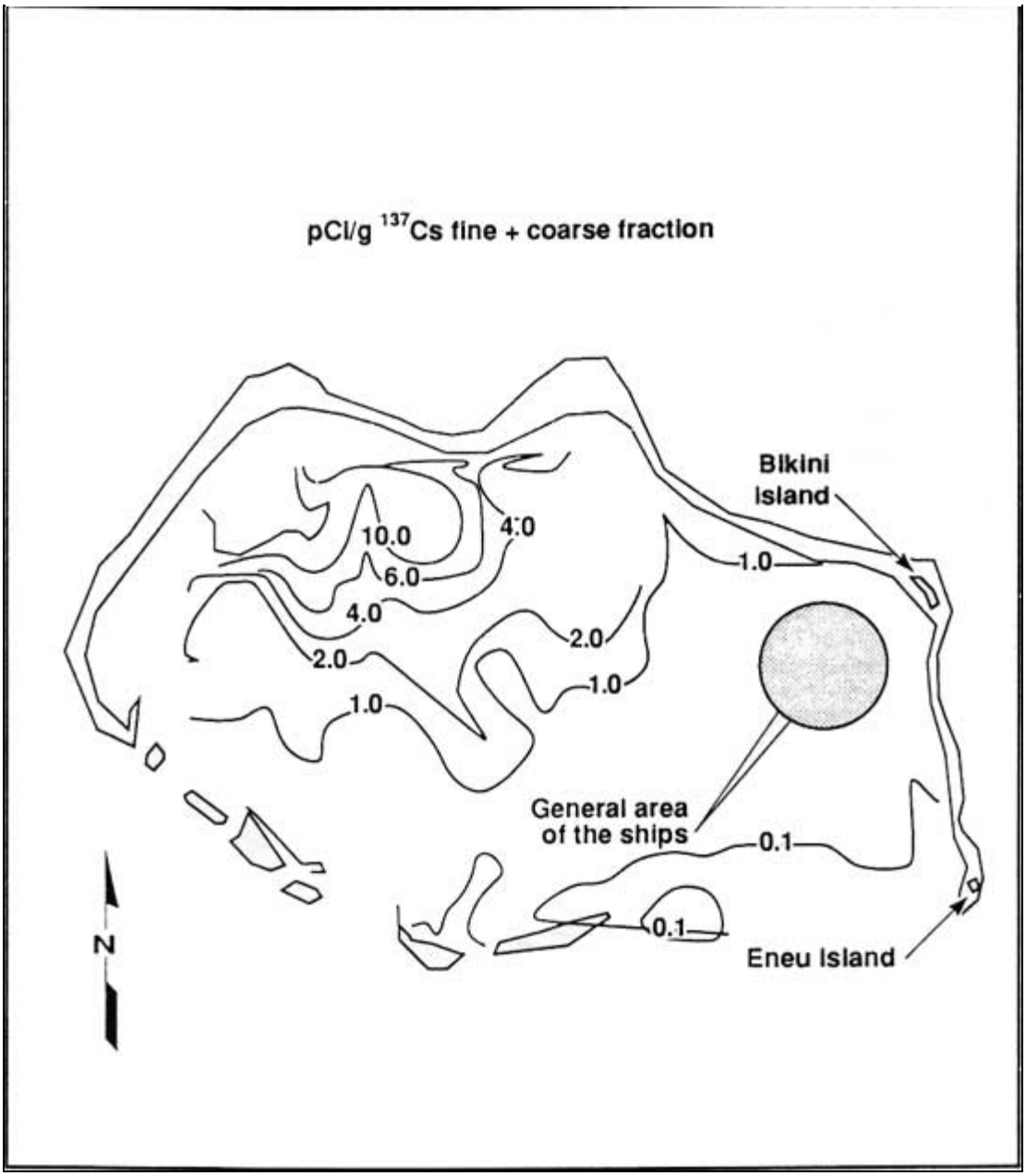


Figure 1. Cesium-137 concentration contours in the lagoon surface sediments at Bikini Atoll in 1979.

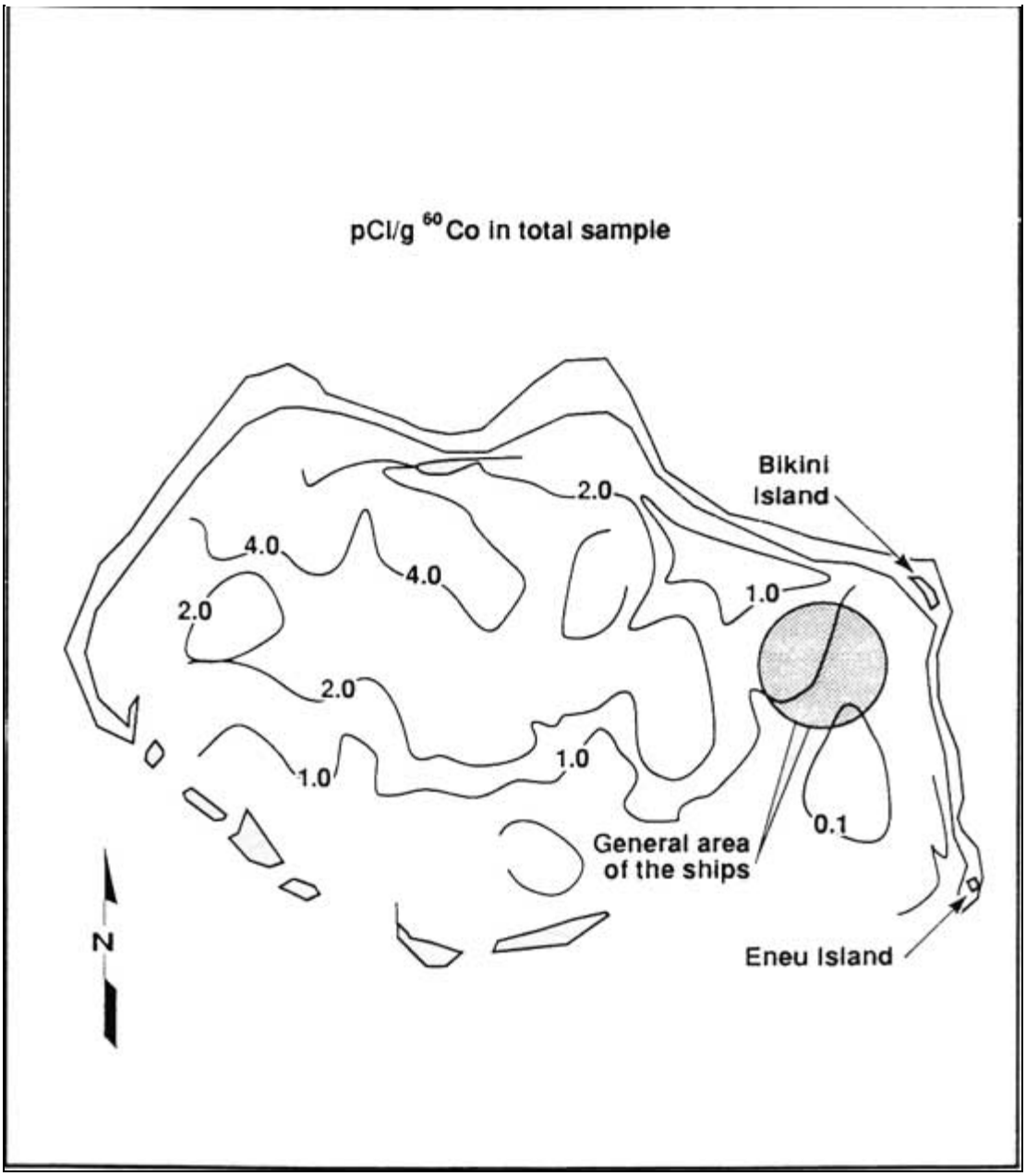


Figure 2. Cobalt-60 concentration contours in the lagoon surface sediments at Bikini Atoll in 1979.

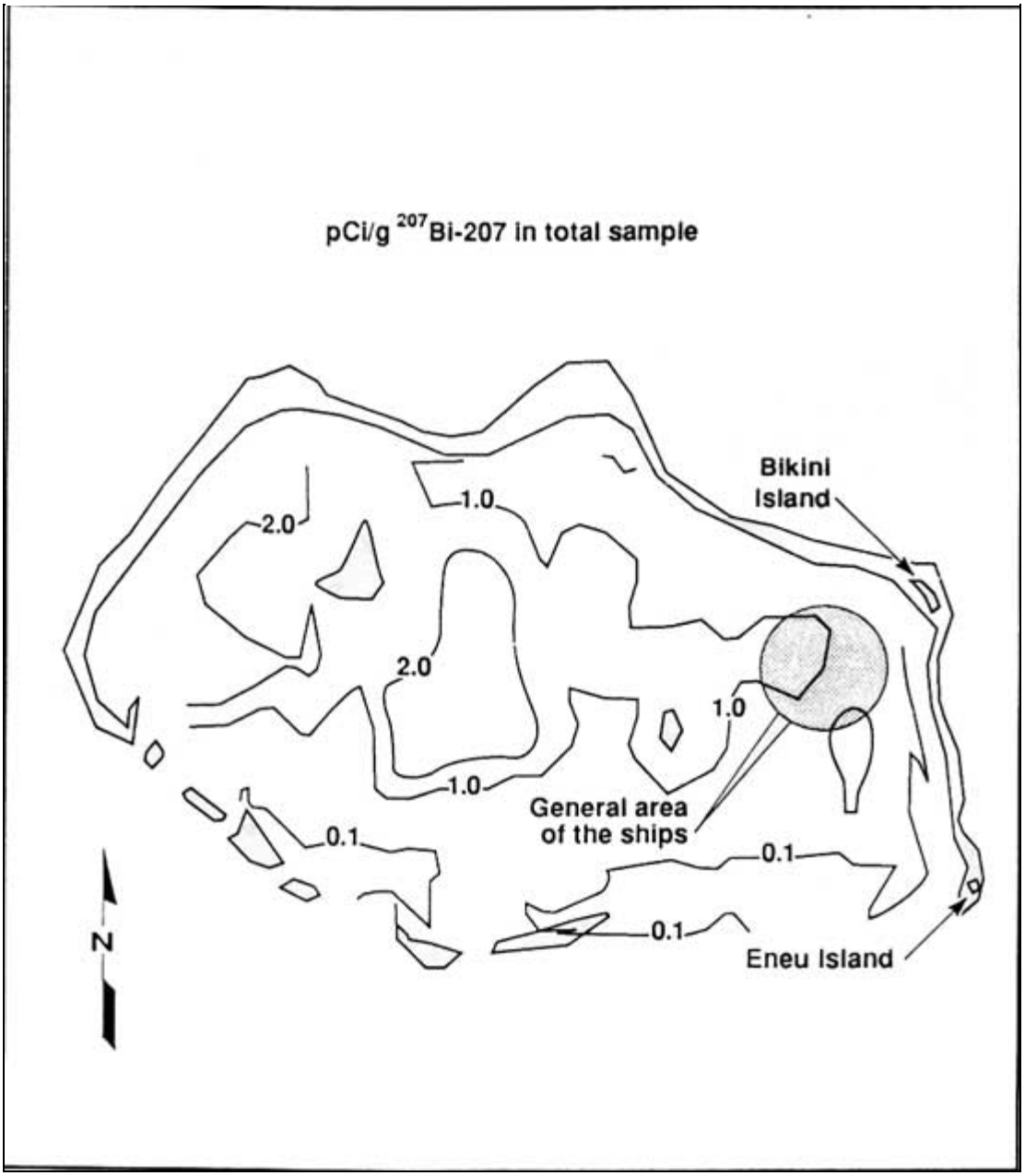


Figure 3. Bismuth-207 Concentration contours in the lagoon surface sediments at Bikini Atoll in 1979.

Additional sediment samples were collected between Bikini Island and the sunken ships in December 1983. The locations of the samples are shown in Figure 4. The results from the analysis of these samples are listed in Table 1. The concentration of ^{137}Cs is below 0.2 pCi/g for all samples and below 0.1 pCi/g for most samples.

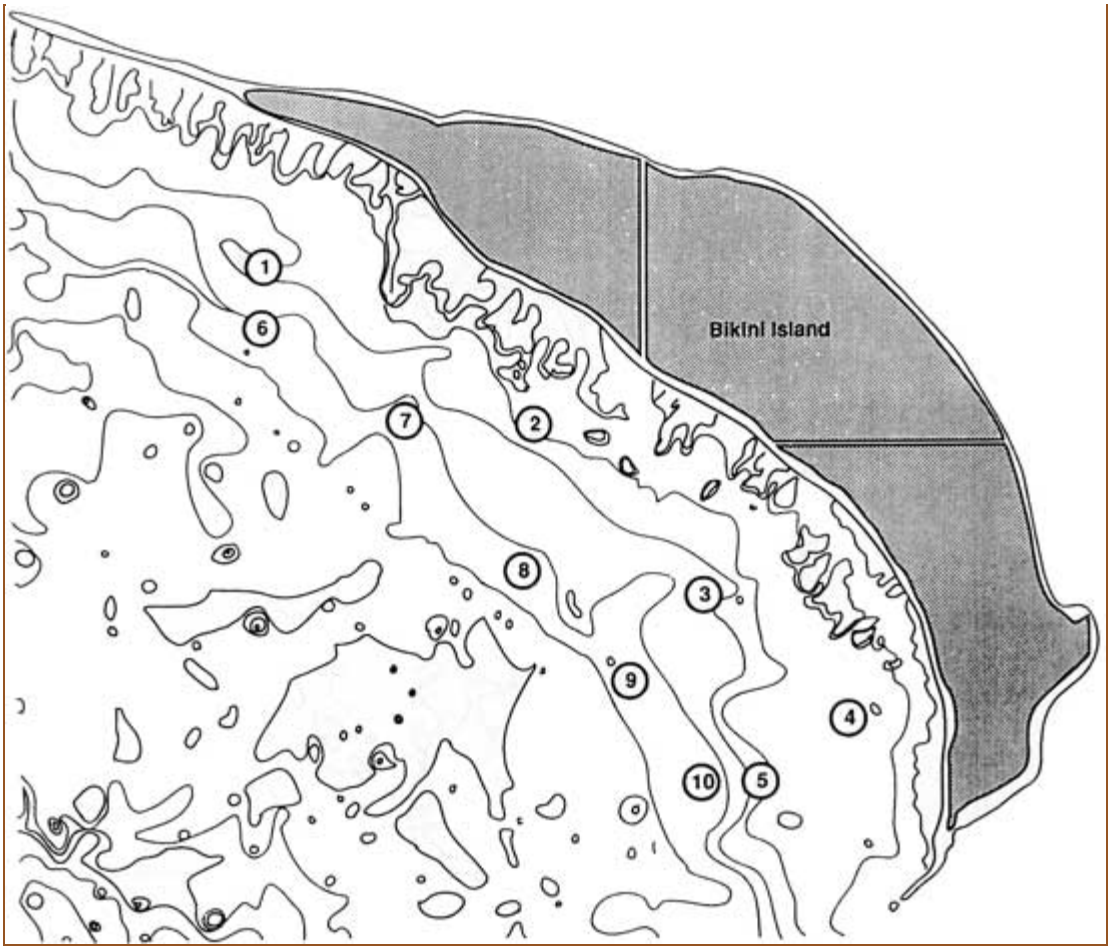


Figure 4. The locations of sediment areas collected in 1983 near Bikini and Eneu Islands at Bikini Atoll. *(click on image for a PDF version)*

Table 1. Concentrations of ^{137}Cs (in pCi/g dry weight) for sediments collected near Bikini Island.

Site No.	Core Depth cm	^{137}Cs	Site No.	Core Depth cm	^{137}Cs
1	0-25	0.03	8	0-10	0.13
	25-50	0.04		10-20	<0.08
2	0-25	0.10		20-30	<0.07
	25-50	0.03		30-37	<0.07
3	0-25	0.03	9	0-10	<0.07
	25-50	0.03		10-20	<0.08
6	0-25	0.08		20-30	<0.06
7	0-25	0.09		30-40	<0.08
	25-50	0.06		40-50	0.13
4A	0-10	<0.06		50-60	<0.07
	10-20	<0.07		60-70	<0.09
	20-30	0.16		70-75	<0.07

	30-40	<0.05	10	0-10	<0.06
	40-47	<0.08		10-20	<0.08
4B	0-10	0.16		20-30	<0.07
	10-20	<0.08		30-40	<0.07
	20-30	<0.08		40-50	<0.06
	30-37	<0.09		50-60	<0.08
5	0-10	<0.07		60-70	<0.08
	10-20	<0.07		70-80	<0.09
	20-30	<0.08		80-90	<0.06
	30-40	<0.07		90-100	<0.08
	40-50	0.14			
	50-60	<0.06			
	60-65	<0.06			

Samples of sediment and algae plus fine, rusty metal were collected from several of the sunken ships in 1989 by a Navy dive team. The samples were analyzed at LLNL and the results are listed in Table 2. The ^{137}Cs, ^{60}Co, ^{155}Eu, and ^{207}Bi concentrations are generally about a few tenths of a pCi/g only two samples from the hanger deck of the Saratoga showed higher concentrations of ^{60}Co and ^{207}Bi.

Table 2 Analytical results for samples taken from the sunken ships in Bikini Lagoon

Type of Sample	Location of Sample	Radionuclide Concentration, pCi/g				
Co-60	Cs-l37		Eu-155	Bi-207	Am-241	
Algae + Rust	from Gilliam	<0.01	<0.01	<0.19	<0.01	<3.45
Sediment	Gilliam Stern	0.78	0.17	0.66	0.96	10.9
Sediment	Gilliam Starboard Beam	0.09	0.17	0.38	0.25	6.7
Sediment	Gilliam Starboard Inboard Beam	0.17	0.13	0.34	0.32	4.6
Sediment	Gilliam Bow	0.67	0.13	0.63	0.67	13.0
Sediment	Gilliam Stern Outboard	0.06	0.13	0.42	0.29	4.2
Sediment	Gilliam Port Beam	0.84	0.16	0.64	0.94	11.8
Algae + Rust	from Pilot Fish	0.36	0.11	0.09	0.42	0.9
Algae + Rust	EOD Collection Pilot Fish	0.27	0.14	0.15	0.50	2.3
Wood	from Pilot Fish	0.11	0.18	<0.05	0.17	1.1
Elec. Wire	Electrical Wire from Pilot Fish	<0.12	<0.11	<0.28	<0.09	<0.4
Algae + Rust	from Carlisle	0.49	0.08	<0.04	0.47	1.4
Sediment	Carlisle	1.16	0.21	0.44	1.24	6.1
Sediment	Saratoga Hanger	10.82	0.88	2.75	14.22	56.5
Sediment	Saratoga Fight Deck	2.18	0.26	1.07	3.79	14.4
Algae + Rust	Saratoga Hanger	0.20	0.47	<0.29	0.18	<0.4

Sediment	Arkansas Port Side	0.06	0.08	0.43	0.17	8.7
Sediment	Arkansas Bow	0.10	0.16	0.38	0.24	7.1
Algae + Rust	Arkansas	0.38	0.14	0.17	0.49	1.7
Sediment	Arkansas Starboard Midship	<0.02	<0.03	0.16	0.18	3.5
Sediment	Arkansas Port Bow	0.09	0.14	0.32	0.15	4.9
Sediment	Arkansas Stern Outboard	0.12	0.07	0.32	0.28	5.1
Sediment	Arkansas Stern Inboard	0.11	0.08	0.38	0.30	5.0
Algae + Rust	Nagato	0.41	0.26	0.17	0.29	3.3

The gamma-emitting radionuclide concentrations observed in the sediment samples from all of these sources are very low ranging between 0.03 and 1 pCi/g for ^{137}Cs. For perspective, the average concentration of ^{137}Cs in the surface soil across the United States due to world-wide fallout ranges from about 0.4 to 1.2 pCi/g. For additional perspective, the ^{137}Cs concentration in lagoon sediment is much less than the ^{137}Cs concentration in surface soil in the United Kingdom and Northern Europe from the Chernobyl accident (9).

In addition, the gamma rays associated with ^{137}Cs, ^{60}Co, and ^{207}Bi are attenuated exponentially as they traverse through water. The half-thickness, i.e., the thickness of water that will attenuate half of the radiation, is about 10 cm (4 inches) of water (10). Consequently, the dose from ^{137}Cs, ^{60}Co and ^{207}Bi in the sediments on the ships and in the lagoon bottom while swimming near the ships is so low that it is, for all practical purposes, zero. The dose to a person on land anywhere in the world for a specific period of time would be higher than the dose from swimming in the lagoon and diving near the ships for the same period of time.

Alpha, Beta, and Very Low Energy Gamma Emitting Radionuclides

The concentration of ^{241}Am in the sediments from the ships is higher than for the other radionuclides and ranges from 1 to 50 pCi/g. We have sufficient data on the ratios of $^{239+240}$Pu to ^{241}Am at the atoll to know that the $^{239+240}$Pu concentration would be about 20% higher than the ^{241}Am. The concentration of ^{90}Sr in the lagoon sediment would be expected to be somewhat higher than the ^{137}Cs concentration.

The other radionuclides found in the sediments are ^{240}Am, $^{239+241}$Pu, ^{90}Sr and europium—155 (^{155}Eu). The primary radiation from ^{90}Sr and ^{155}Eu is beta particles, which can only penetrate a few millimeters of water. Plutonium and ^{241}Am are primarily alpha particle emitters and can only penetrate a few microns (1 micron = 0.0001 cm) of water. The x radiation or gamma radiation associated with these nuclides are so low energy that they too do not penetrate any significant distance in water. Consequently. radionuclides such as $^{239+240}$Pu, ^{241}Am, ^{90}Sr, and ^{155}Eu do not contribute to underwater external exposure because the emanating radiations are totally absorbed in a few millimeters or less of water and thus cannot expose people swimming nearby.

The primary potential route of exposure of people from alpha- and beta-emitting radionuclides is by inhalation. There is no chance of inhalation of these radionuclides while diving on the ships or swimming in the lagoon near the ships. The other potential route of exposure is ingestion and it is not as significant a pathway as inhalation; it is unlikely that a

diver would ingest sediment. Even if small amounts of sediment could be ingested through the mask and regulator, the intake would not be significant and the very low transfer of plutonium and americium across the gut wall to the blood (fraction ingested transferred to blood = 0.001) would produce an insignificant dose.

Activation Products in the Ships

The activation products produced by the neutron flux from the Baker test interacting with the steel, iron, and other metals of the ships all have a short half-life. Most of the activation products have long since decayed and are no longer present. The major activation product that is still present is ^{60}Co, with a half-life of 5.27 years. Consequently, the ^{60}Co produced at the time of detonation in 1946 has decayed to 0.35% of its original value; in other words, it is also essentially gone or will be in very few more years. If diving does not begin at Bikini until 1995 or 1996, then ^{60}Co will have decayed one whole half-life, or by 50%, from the values listed in Table 2. In the same time period, ^{137}Cs will have decayed by another 13%. The ^{60}Co observed in the samples listed in Table 2 are primarily the result of ^{60}Co induced in the metal components of the ship and the subsequent deterioration and oxidation producing a fine, rusty material that spalls from the metal surfaces and becomes mixed with the sediment and algae on the ships and lagoon bottom.

The very short half-life associated with activation products has essentially eliminated them as an exposure source over the last 43 years. The small gamma flux still present is absorbed by the water as described in the previous section.

Summary of the Potential Radiological Dose while Swimming in Bikini Lagoon

The potential dose to a person swimming in the Bikini Lagoon around or through the sunken ships is so low from both the activation products originally induced in the ships and from radionuclides in the lagoon sediment that it can be considered essentially zero.

The Radiological Dose while Living on Bikini Island for Two Weeks

Inhalation Dose

The only radionuclides on the island that are of any significance via the inhalation pathway are $^{239+240}$Pu and ^{241}Am. The dose from ^{137}Cs and ^{90}Sr are of no consequence, being 4 or more orders of magnitude less than plutonium and americium via inhalation (11).

The estimated effective committed dose equivalent for $^{239+240}$Pu and ^{241}Am at Bikini Atoll is based on resuspension studies conducted at Bikini Atoll (12). The estimate is based on a scenario of 9 hours on the island in a resting state in which 4.8 m^3 of air are breathed, 5 hours active time in which 6.0 m^3 of air are breathed, and 10 hours on or near the lagoon and beaches, which are not relevant to inhalation of resuspended Pu or Am.

The calculated committed effective dose equivalent for a two-week stay on Bikini Island is 0.02 mrem for $^{239+240}$Pu. The contribution from ^{241}Am would be about 70% of the plutonium dose, or about 0.014 mrem. The total effective committed dose equivalent is, therefore, 0.03 mrem. For perspective, the annual committed dose equivalent in the United States is 300 mrem/y. For additional perspective, the increased dose equivalent received flying at altitude in a jet aircraft for about 8000 miles is 4 mrem (9).

External Gamma Dose

The external gamma dose equivalent rate from ^{137}Cs on Bikini Island is estimated to be about 11.8 mrem/year. This estimate is based on a scenario of 12 hours every day inside the schoolhouse (bunk and mess hall building), 4 hours/day around the schoolhouse, 1 hour/day in the interior of the island, and 7 hours/day in or on the lagoon. Consequently, for a person visiting for only two weeks, the dose equivalent would be about 0.45 mrem. For perspective, this can be compared to the U.S. background committed dose equivalent rate of 300 mrem/year or about 12 mrem/2 weeks.

Summary of the Total on Island Radiological Dose

The estimated effective committed dose equivalent for two weeks residence on Bikini Island or the United States are listed in Table 3. The net result is that the estimated dose for Bikini Island, for the scenario outlined above including natural background, is about 1/10 that for a similar period of residence in the United States.

Table 3. The estimated dose equivalent for two weeks at Bikini Island and the average United States.

	Committed Effective Dose Equivalent, mrem/2 weeks residence	
Source	Marshall Islands	United States
Natural Background	0.85	12
^{137}Cs External	0.45	--
$^{239+240}Pu + {}^{241}Am$ Inhalation	0.03	--
Total	~1.3	12

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12. J. H. Shinn, D. N. Homan, and W. L. Robison, *Resuspension Studies at Bikini Atoll,* Lawrence Livermore National Laboratory, Livermore, CA, UCID-18538 (1980).

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APPENDIX IV: ARCHEOLOGICAL SITE RECORD FORMS FOR THE DOCUMENTED SHIPWRECKS

National Maritime Initiative Shipwreck/Hulk Database

INIT #10596

Popular Name: APOGON
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 180
Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? NO
Auxiliary Machinery? YES
Anchors? UNKNOWN
Decks? YES
Rigging? NO
Ballast? NO
Cargo? NO
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1990
Surveyor: DANIEL J. LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS APOGON (SS-308)
Vessel Type: SUBMARINE, BALAO CLASS

of Masts: 0; Rigging: UNRIGGED
Length: 311.90; Beam: 27.30; Draft: 15.30
Displacement: 1526.00

Hull Materials: STEEL
Engine: DIESEL
Propulsion: SCREW
Armament: 10X21-INCH TT; 2X40MM

Year Built: 1943; Place of Construction: PORTSMOUTH, NEW HAMPSHIRE Builder: PORTSMOUTH NAVY YARD

Wreck Year: 1946
Use at Loss: TARGET SHIP, OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10570

Popular Name: ARKANSAS
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 180
Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES
Anchors? YES
Decks? YES
Rigging? YES
Ballast? NO
Cargo? NO
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1990
Surveyor: DANIEL J. LENIHAN
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS ARKANSAS (BB-33)
Vessel Type: BATTLESHIP; ARKANSAS CLASS

of Masts: 2; Rigging: UNRIGGED
Length: 562.00; Beam: 106.00; Draft: 32.00
Displacement: 31900.00

Hull Materials: STEEL
Engine: STEAM TURBINE
Propulsion: SCREW
Armament: 12X12'", 6X5", 10X3", 9X40MM QUADS, 36X20MM

Year Built: 1912; Place of Construction: CAMDEN, NEW JERSEY
Builder: NEW YORK SHIPBUILDING CO.

Wreck Year: 1946
Use at Loss: TARGET SHIP, OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10595

Popular Name: CARLISLE
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 180
Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? YES; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES

Anchors? YES
Decks? YES
Rigging? YES
Ballast? NO
Cargo? YES
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1990
Surveyor: DANIEL J. LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS CARLISLE (APA-69)
Vessel Type: ATTACK TRANSPORT/GILLIAM CLASS

of Masts: 2; Rigging: UNRIGGED
Length: 426.00; Beam: 58.00; Depth: 37.00; Draft: 15.60
Displacement: 6800.00

Hull Materials: STEEL
Engine: STEAM TURBINES
Propulsion: SCREWS
Armament: 1X5-INCH/38; 4X40MM; 10X20MM

Year Built: 1944; Place of Construction: WILMINGTON, CALIFORNIA Builder: CONSOLIDATED STEEL CORPORATION

Wreck Year: 1946
Use at Loss: TARGET VESSEL/OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10572

Popular Name: GILLIAM
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 180 Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? YES; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES
Anchors? UNKNOWN
Decks? YES
Rigging? UNKNOWN
Ballast? NO
Cargo? YES
Superstructure? YES
Engines/Boilers? YES
Armament? UNKNOWN
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1989
Surveyor: DANIEL LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS GILLIAM (APA-57)
Vessel Type: ATTACK TRANSPORT/GILLIAM CLASS

of Masts: 0; Rigging: UNRIGGED
Length: 426.00; Beam: 58.00; Depth: 37.00; Draft: 15.60
Displacement: 6800.00

Hull Materials: STEEL
Engine: STEAM TURBINE
Propulsion: SCREW
Armament: 1X5-INCH/38 4X4OMM 10X20MM

Year Built: 1946; Place of Construction: WILMINGTON, CALIFORNIA Builder: CONSOLIDATED STEEL CORPORATION

Wreck Year: 1946
Use at Loss: TARGET SHIP/OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10568

Popular Name: NAGATO
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 180 feet Percent Present: 76-100%

Present Remains are: Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES
Anchors? YES
Decks? YES
Rigging? NO
Ballast? NO
Cargo? NO
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1990
Surveyor: DANIEL J. LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: HIJMS NAGATO (BB-9)
Vessel Type: BATTLESHIP/NAGATO CLASS

of Masts: 2; Rigging: UNRIGGED
Length: 708.00; Beam: 95.00; Draft: 30.00
Displacement: 38500.00

Hull Materials: STEEL
Engine: STEAM TURBINE
Propulsion: SCREW
Armament: 8X16", 20X5.5'", 4X3.1"AA, 3MGS, 8X21"TT(4 AW/4 VW)

Year Built: 1912; Place of Construction: KURE, JAPAN
Builder: KURE DY

Wreck Year: 1946
Use at Loss: TARGET SHIP, OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10571

Popular Name: PILOTFISH
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND
Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? NO; Underwater? YES; Depth: 170 Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? NO
Auxiliary Machinery? YES
Anchors? UNKNOWN
Decks? YES
Rigging? NO
Ballast? NO
Cargo? NO
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1989
Surveyor: DANIEL J. LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS PILOTFISH (SS-386)
Vessel Type: SUBMARINE, BALAO CLASS

of Masts: 0; Rigging: UNRIGGED
Length: 311.80; Beam: 27.30; Draft: 15.30
Displacement: 1525.00

Hull Materials: STEEL
Engine: GE/GM DIESEL-ELECTRIC
Propulsion: SCREW

Armament: 10X21-INCH TT; 1X20MM; 1X40MM

Year Built: 1943; Place of Construction: PORTSMOUTH, NEW HAMPSHIRE Builder: PORTSMOUTH NAVY YARD

Wreck Year: 1946
Use at Loss: TARGET VESSEL/OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10569

Popular Name: PRINZ EUGEN
Location: KWAJALEIN ATOLL LAGOON
Nearest City: CARLSON ISLAND

Owner/Manager: U.S. NAVY
Address: C/O NAVAL HISTORICAL CENTER WASHINGTON NAVY YARD
WASHINGTON, DC 20374
Phone: 202-433-6437

Is Site on the Shoreline? YES; Underwater? YES; Depth: 120 Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES
Anchors? YES
Decks? YES
Rigging? YES
Ballast? NO
Cargo? NO
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1989
Surveyor: DANIEL J. LENIHAN
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? YES; Archival? YES

Vessel Name: USS PRINZ EUGEN (IX-300)

Vessel Type: CRUISER, HIPPER CLASS

of Masts: 2; Rigging: UNRIGGED
Length: 654.50; Beam: 71.00; Draft: 15.00
Displacement: 10000.00

Hull Materials: STEEL
Engine: GEARED TURBINES
Propulsion: SCREW
Armament: 8X8", 12X4.1", AA, 12X37MM AA, 12X21"TT, 4AC/6X8" SUNK

Year Built: 1936; Place of Construction: KIEL, GERMANY
Builder: KRUPP AT GERMANIA WERFT SHIPYARD

Wreck Year: 194.6
Use at Loss: LAID UP AFTER OPERATION CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

National Maritime Initiative Shipwreck/Hulk Database

INIT #10576

Popular Name: SARATOGA
Location: BIKINI ATOLL LAGOON
Nearest City: BIKINI ISLAND

Owner/Manager: REPUBLIC OF THE MARSHALL ISLANDS
Address: C/O HISTORIC PRESERVATION OFFICE
ALELE MUSEUM/BOX #629
MAJURO, MH 96960 Phone: 3264

Is Site on the Shoreline? No; Underwater? YES; Depth: 180
Percent Present: 76-100%

Present Remains are Intact? YES; Scattered? NO; Buried? NO; Excavated? NO

Present Remains consist of:
Hull? YES
Masts? YES
Auxiliary Machinery? YES
Anchors? YES
Decks? YES
Rigging? YES
Ballast? NO
Cargo? YES
Superstructure? YES
Engines/Boilers? YES
Armament? YES
Associated Material? YES

Wreck Date: 20TH CENTURY

Archeological Survey? YES; Date: 1990
Surveyor: DANIEL J. LENIHAN, NPS
Publication Resulting? YES
Publication Name: NPS CULTURAL RESOURCES ASSESSMENT NO. 37

Vessel Identity Firmly Established? YES
Source: Archeological? YES; Oral History/Tradition? NO; Archival? YES

Vessel Name: USS SARATOGA (CV-3)
Vessel Type: AIRCRAFT CARRIER/LEXINGTON CLASS

of Masts: 1; Rigging: UNRIGGED
Length: 880.00; Beam: 106.00; Draft: 24.10
Displacement: 33000.00

Hull Materials: STEEL
Engine: STEAM TURBINES
Propulsion: SCREW
Armament: 8X8", 12X5", 4-6 PDRS. 81 AC

Year Built: 1922; Place of Construction: CAMDEN, NEW JERSEY Builder: NEW YORK SHIPBUILDING CO.

Wreck Year: 1946
Use at Loss: TARGET SHIP, OPERATIONS CROSSROADS
Cargo at Loss: TEST EQUIPMENT

Contact: DANIEL LENIHAN/SUBMERGED CULTURAL RESOURCES UNIT
Phone: 505-988-6750 or FTS-476-1750

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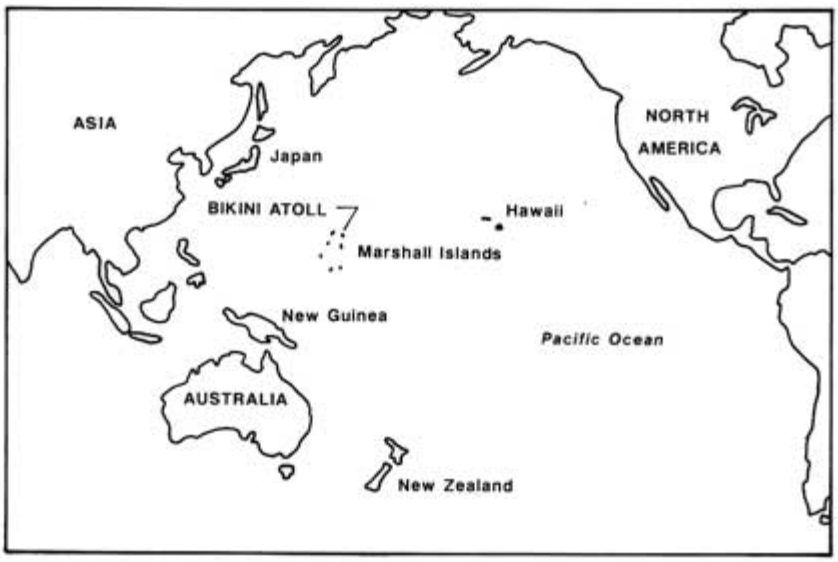
INTERVIEWS

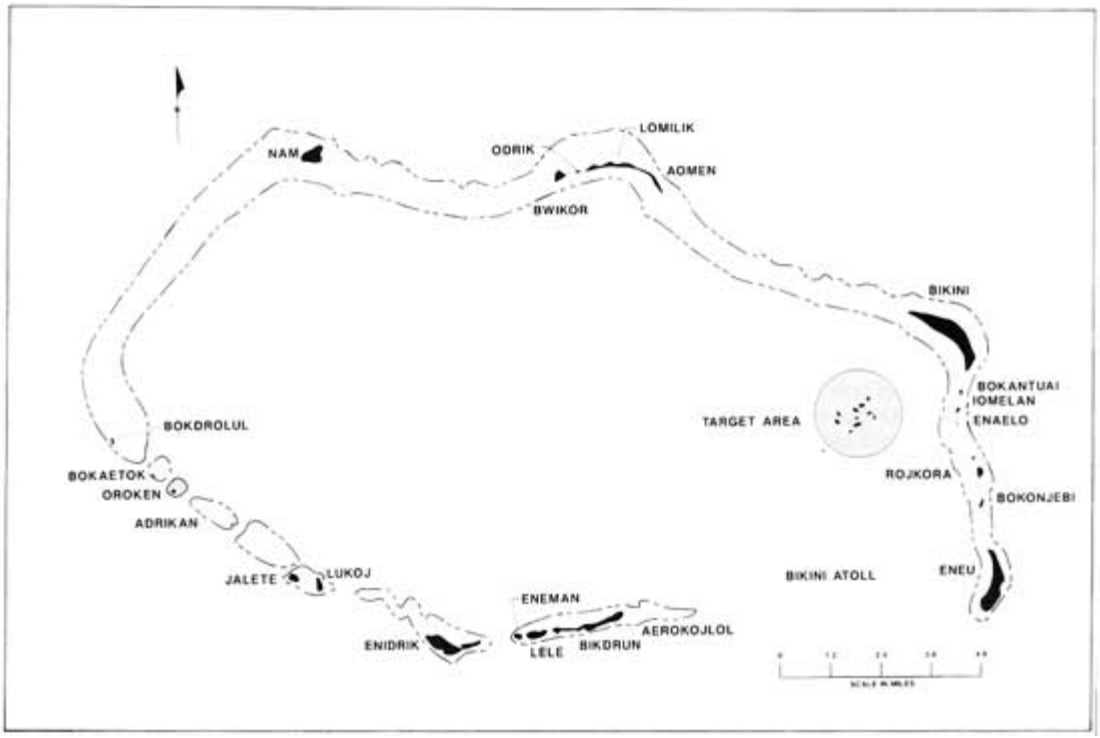
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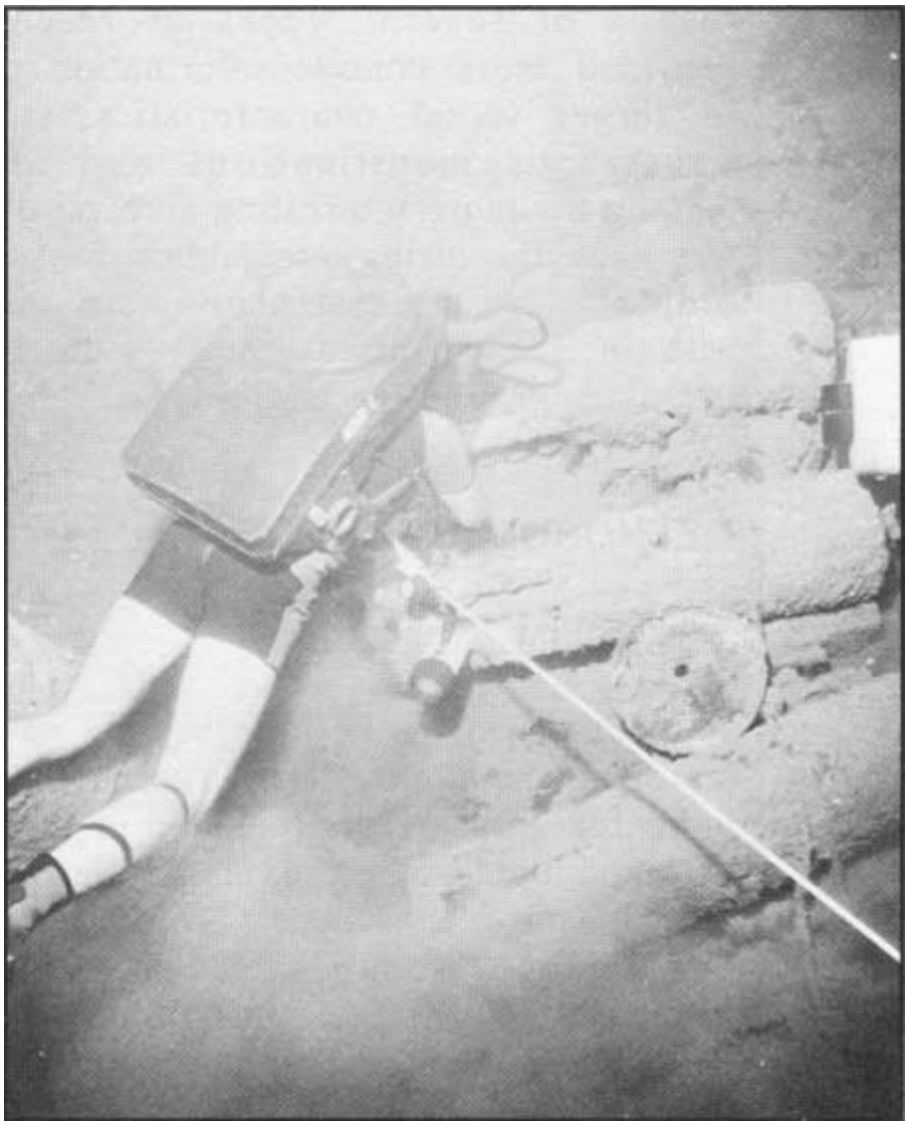
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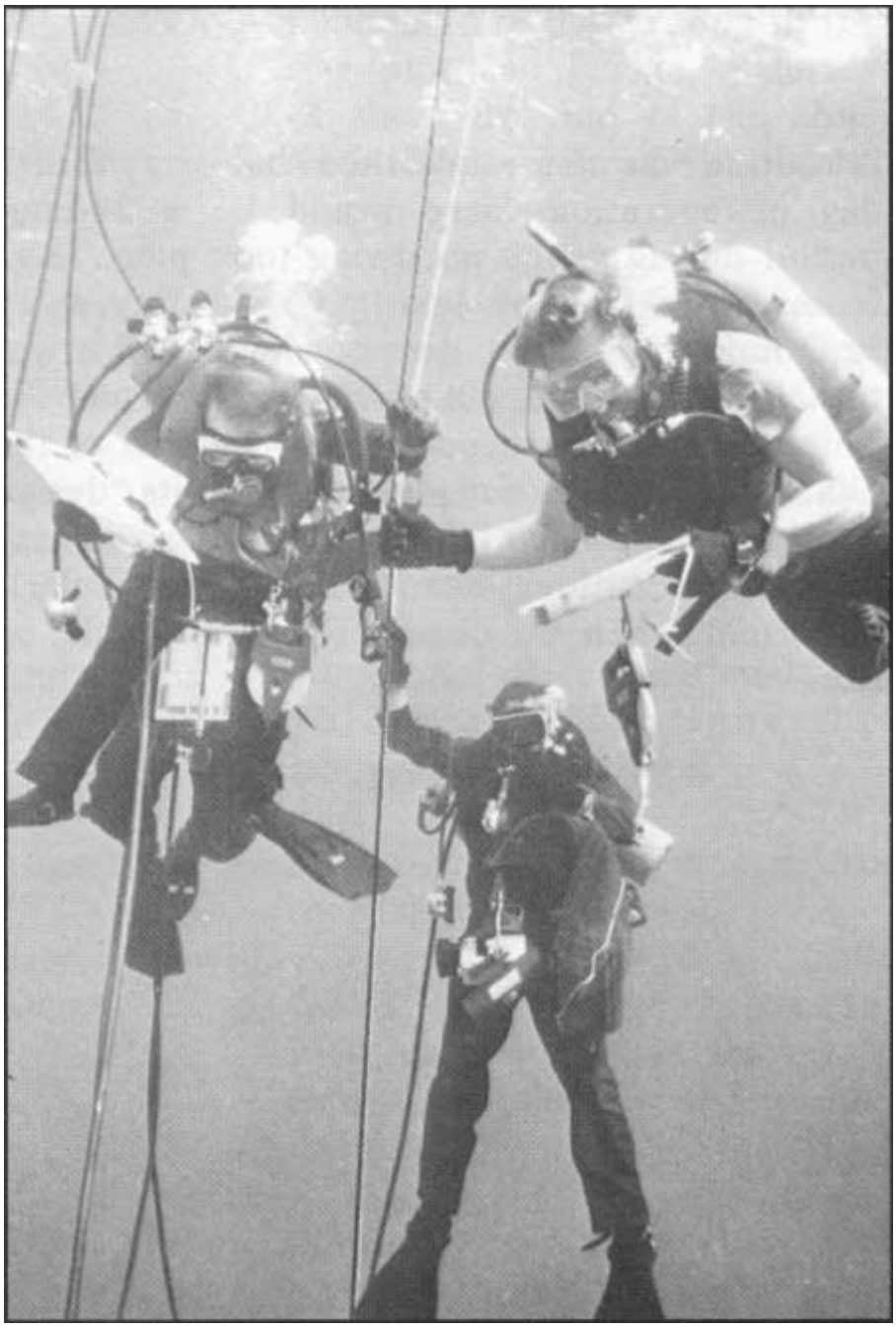
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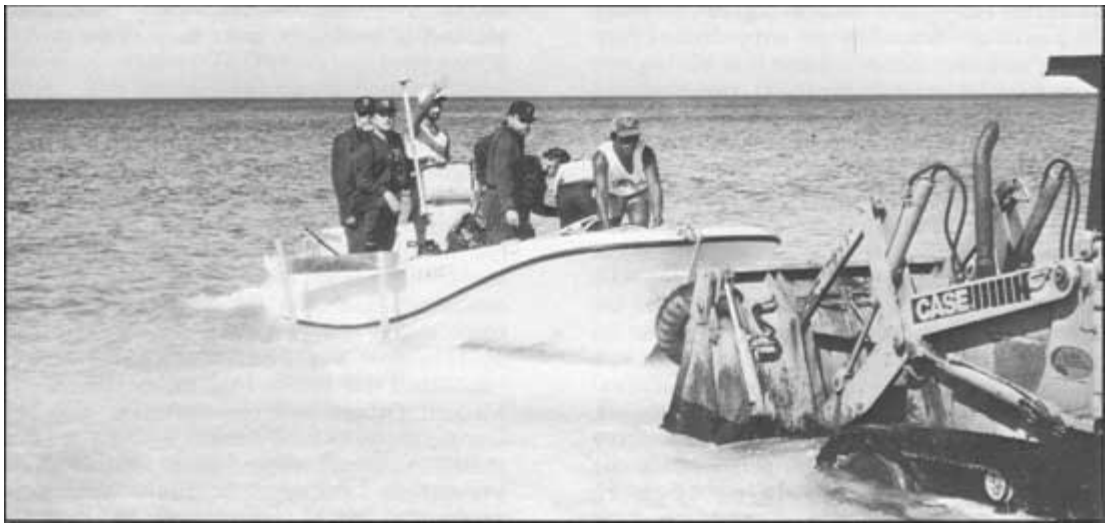

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Japan
BIKINI ATOLL
Hawaii
Marshall Islands
NORTH
AMERICA
New Guinea
Pacific Ocean
AUSTRALIA
New Zealand

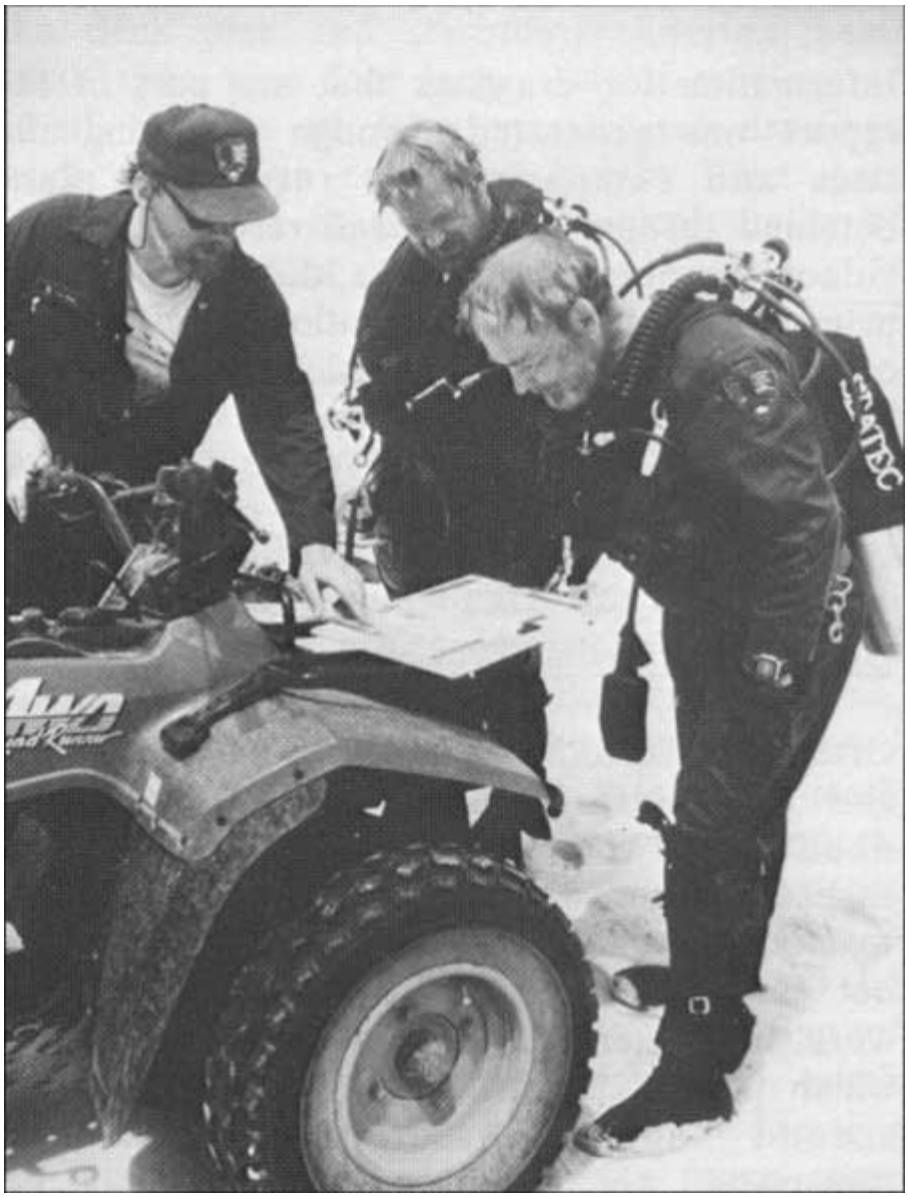

NAM
ODRIK
LOMILIK
AOMEN
BWIKOR
BIKINI
BOKANTUAI
IOMELAN
ENAELO
TARGET AREA
BOKDROLUL
BOKAETOK
OROKEN
ADRIKAN
ROJKORA
BOKONJEBI
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BIKDRUN








CASE

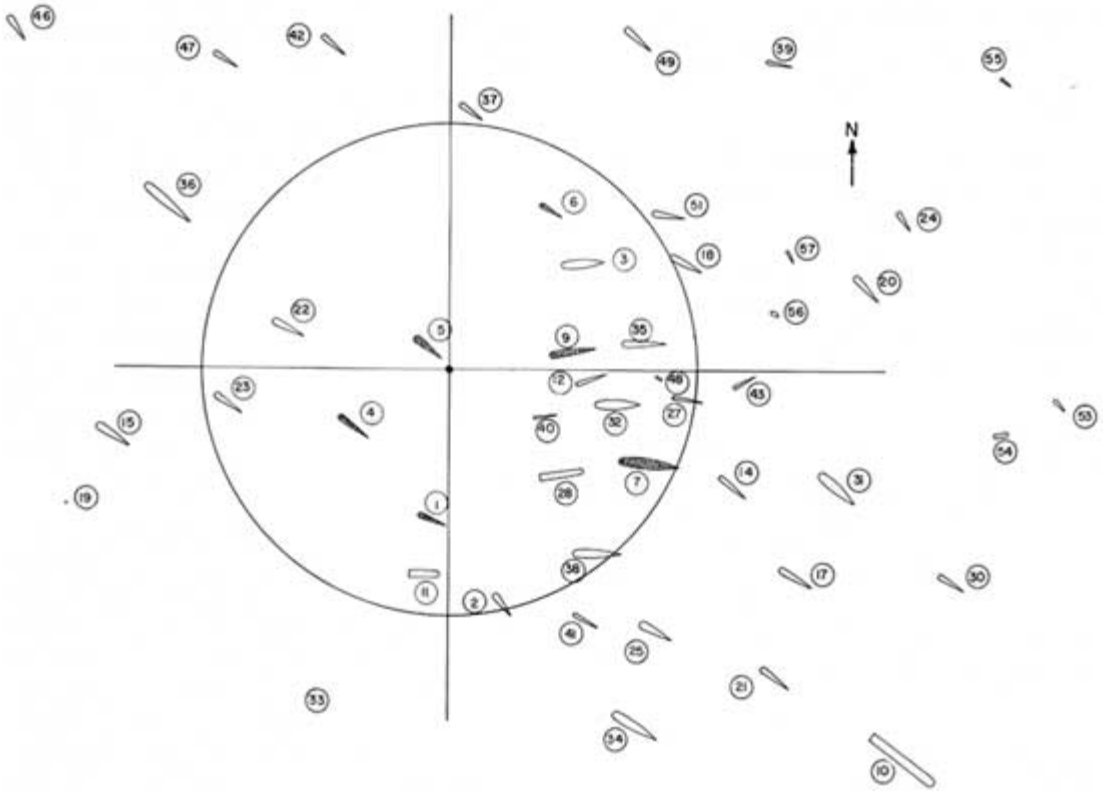


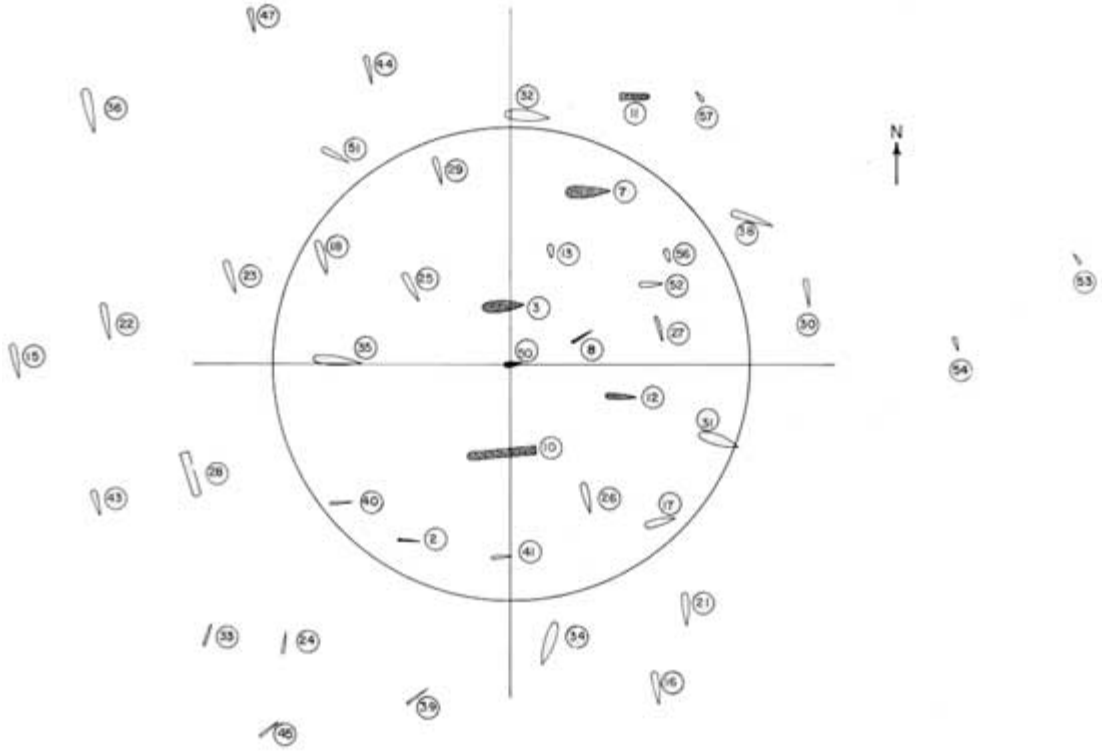


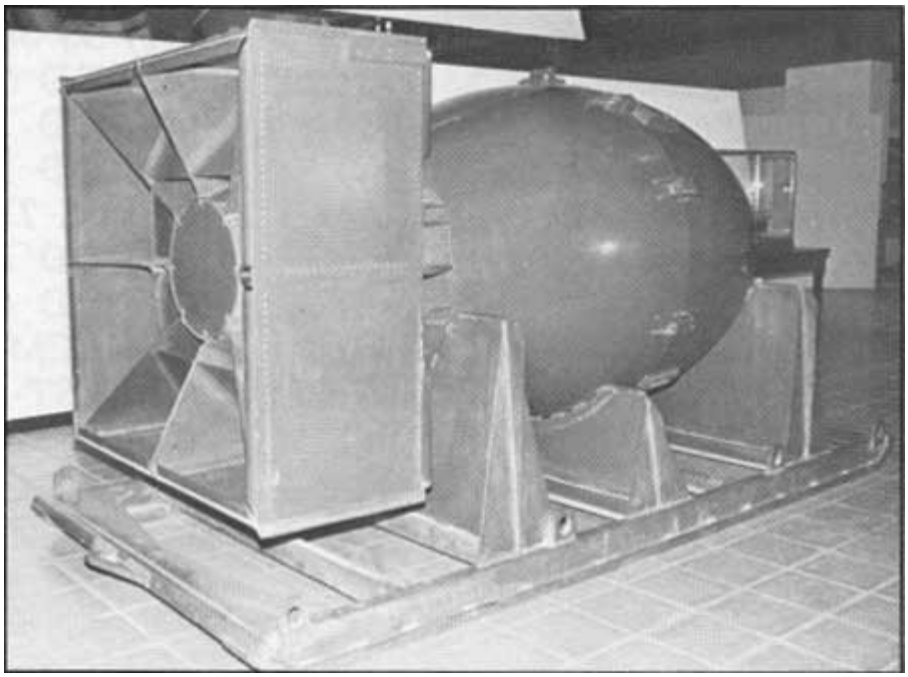

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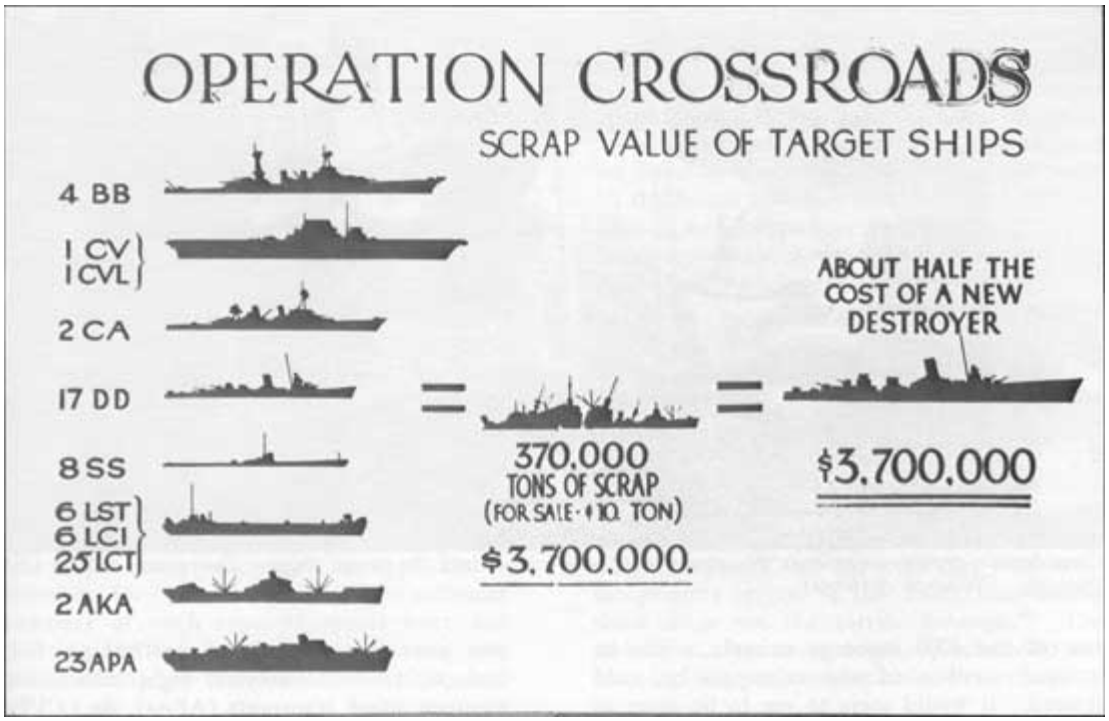

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BIKINI
AIRU KIIJI
ENYU

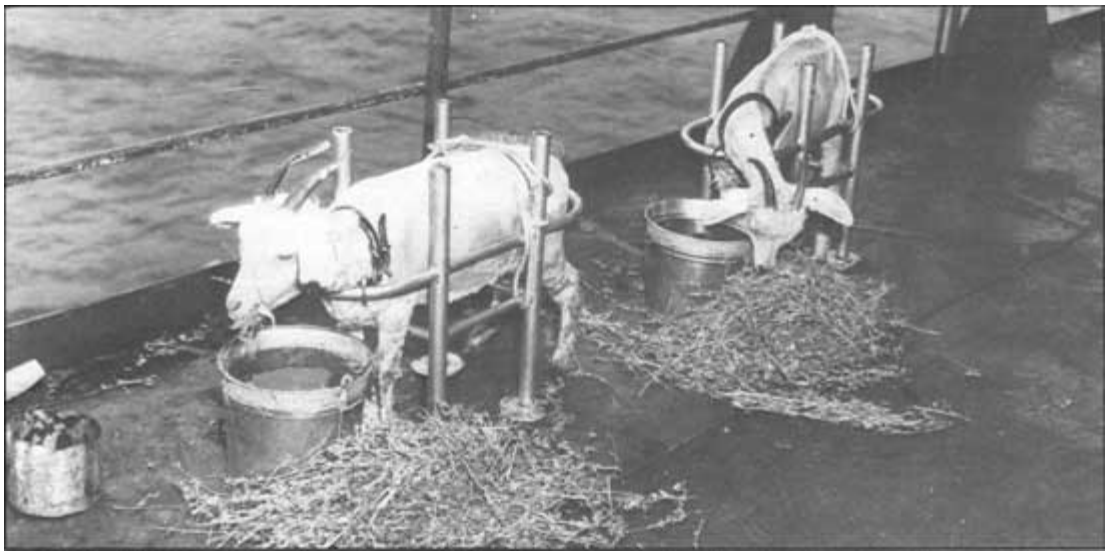

PERIODIC
Atoms Grouped According to the Number of Outer (Valence)
II
III
IV
V
VI
VII
Be
9.02
B
10.82
F
19.00
Mg
24.32
Ca
40.08
Zn
65.38
Ga
69.72
Sr
87.63
Y

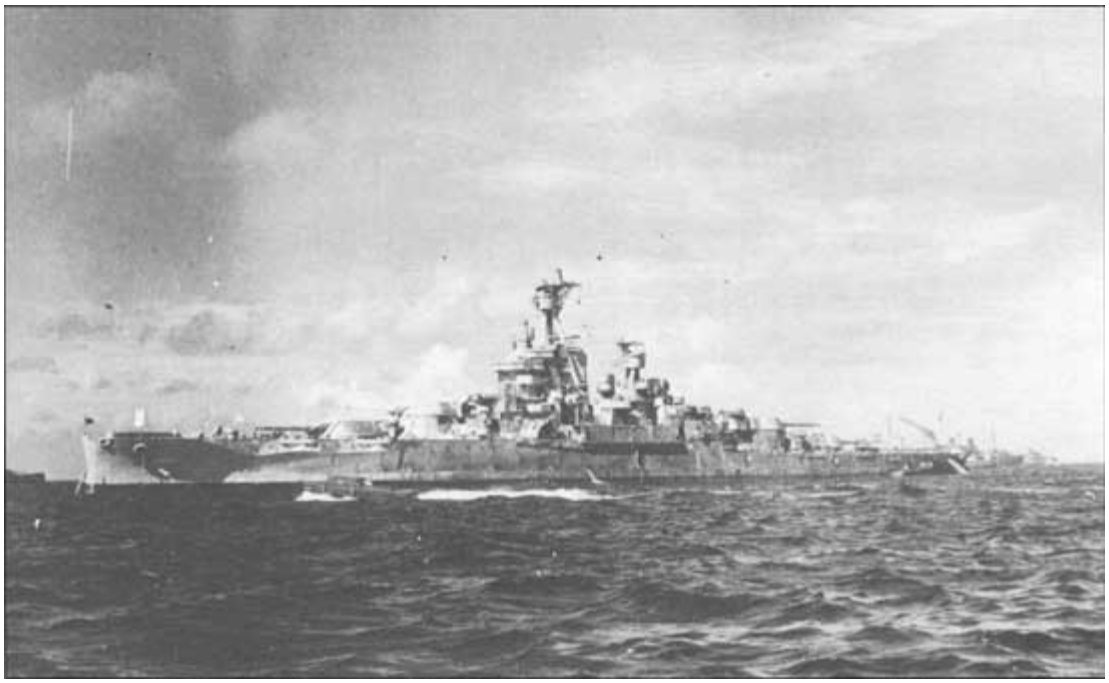

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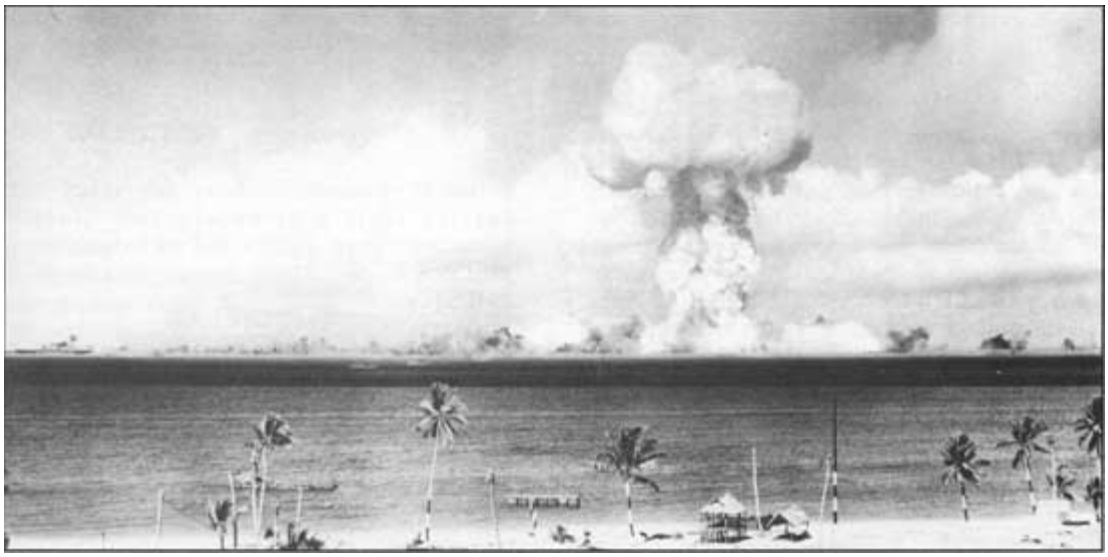

OPERATION CROSSROADS
SCRAP VALUE OF TARGET SHIPS
4 BB
1 CV
1 CVL
2 CA
17 DD
8 SS
6 LST
6 LCI
25 LCT
2 AKA
23 APA
=
370,000
TONS OF SCRAP
(FOR SALE @ $10. TON)
$3,700,000.
=
ABOUT HALF THE
COST OF A NEW
DESTROYER
$3,700,000












60

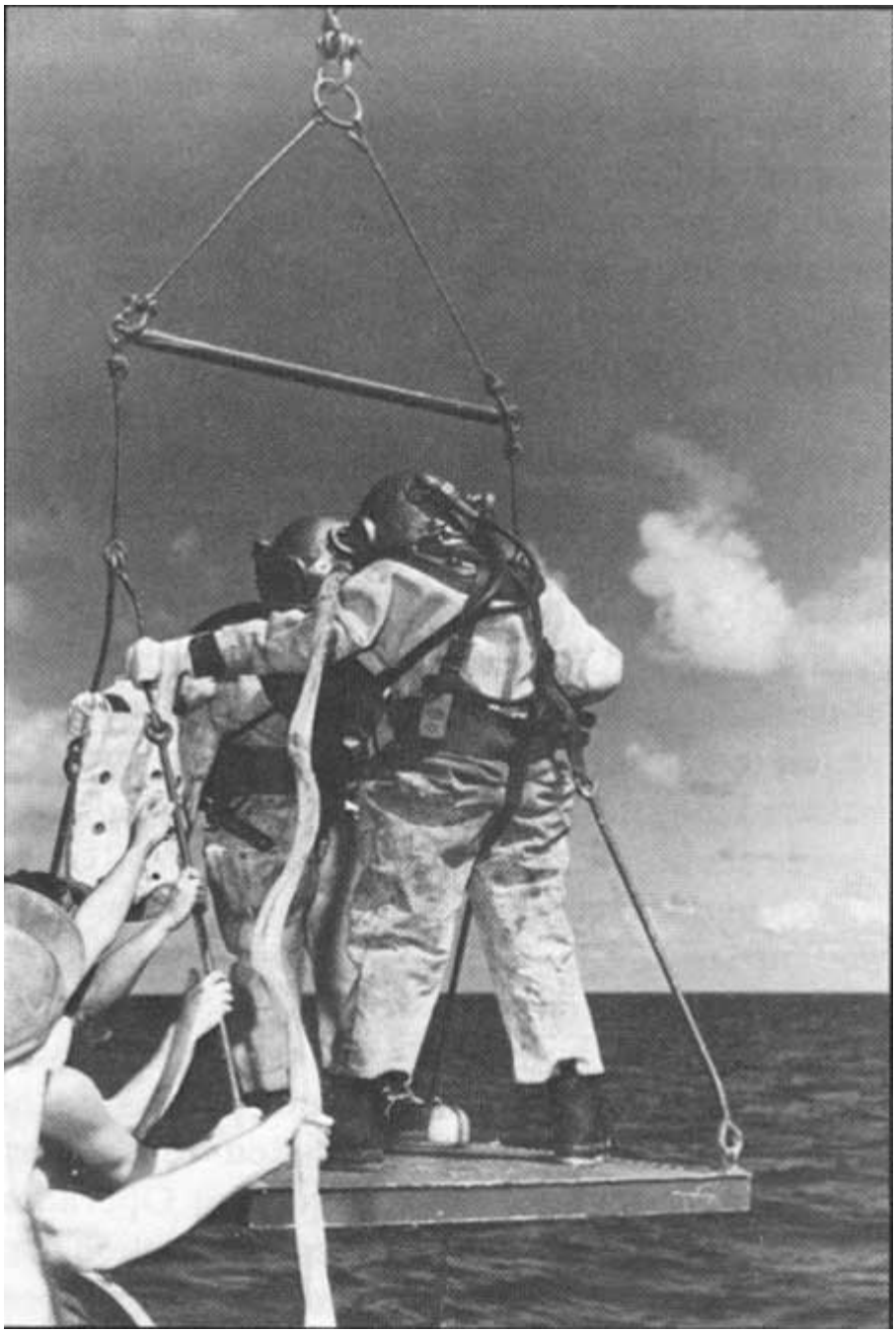


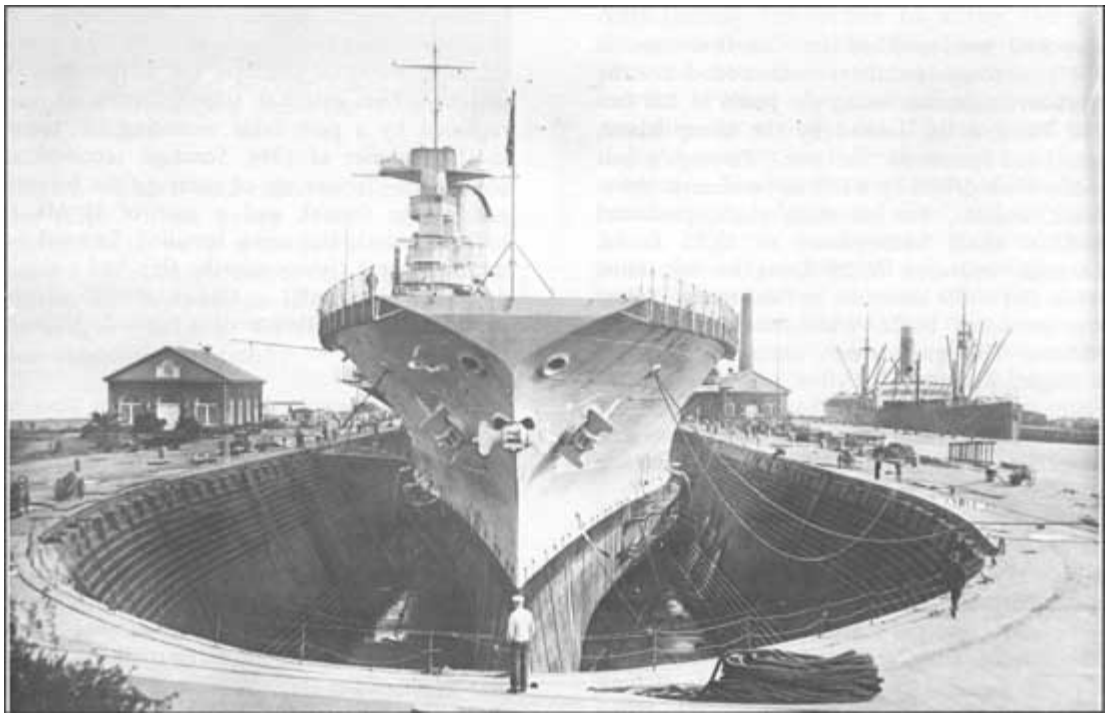






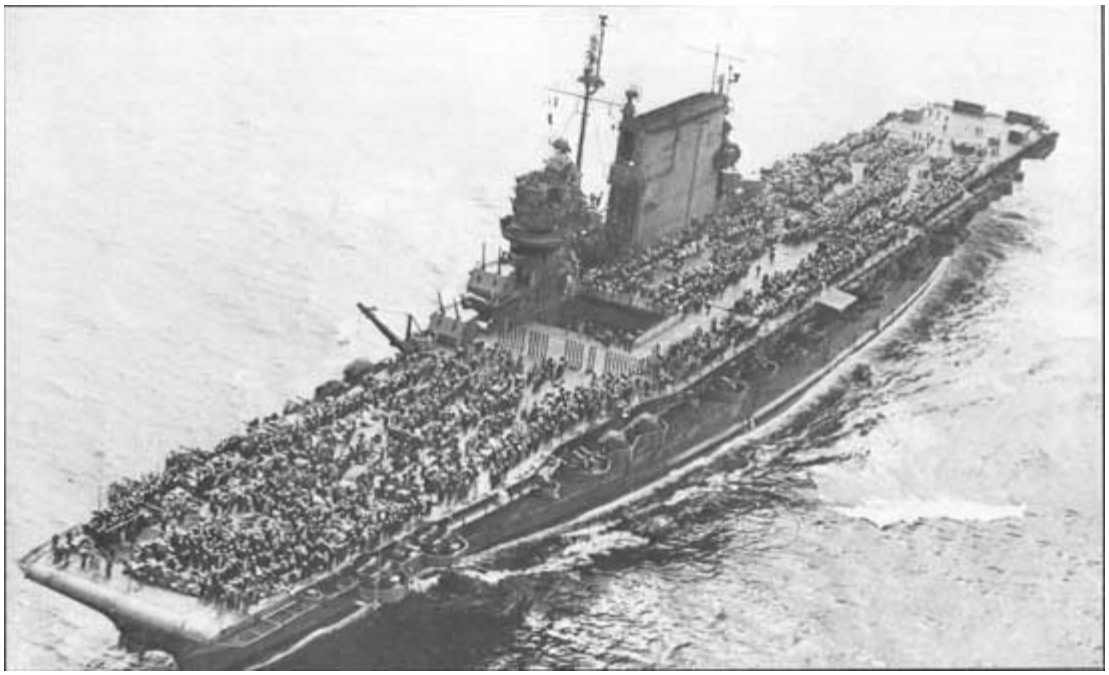






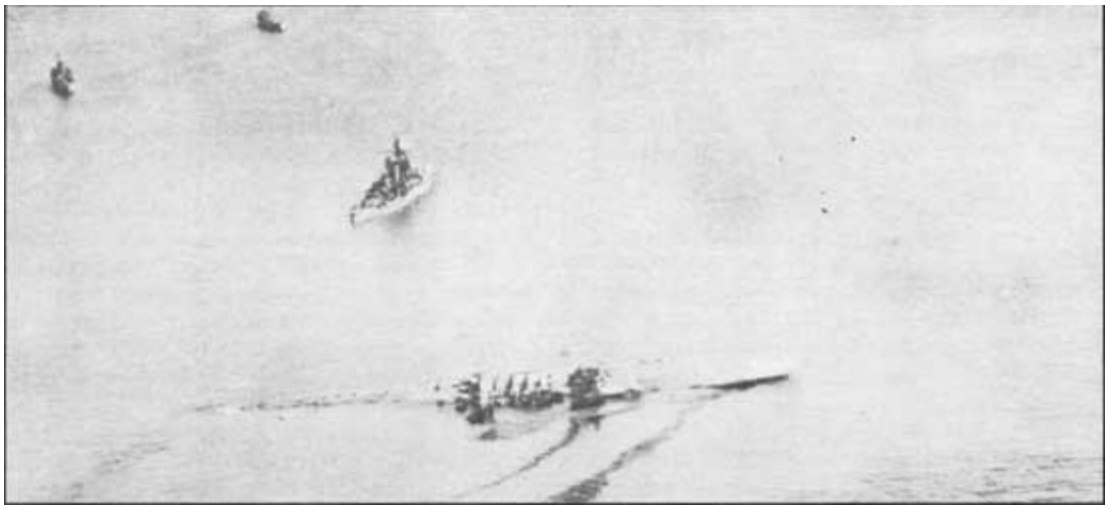


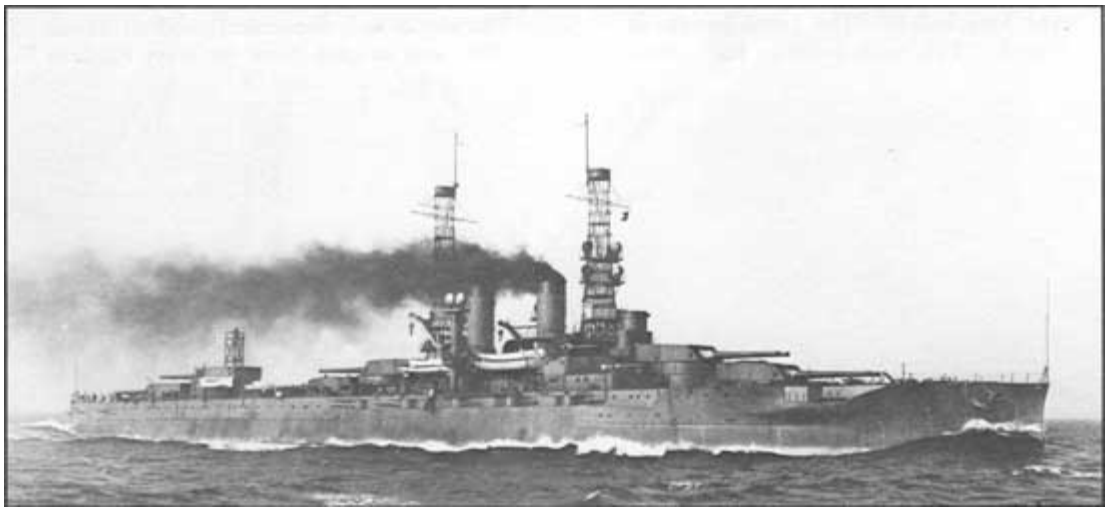




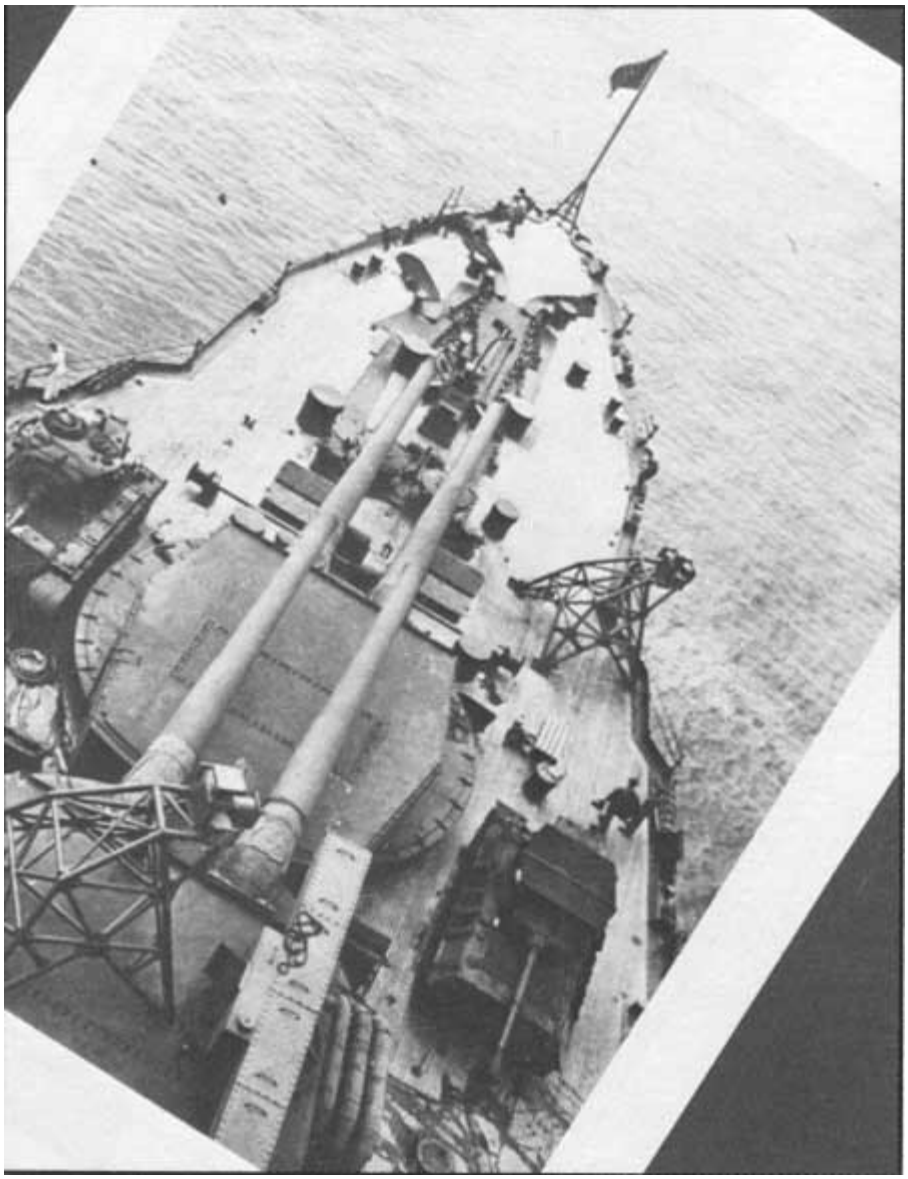




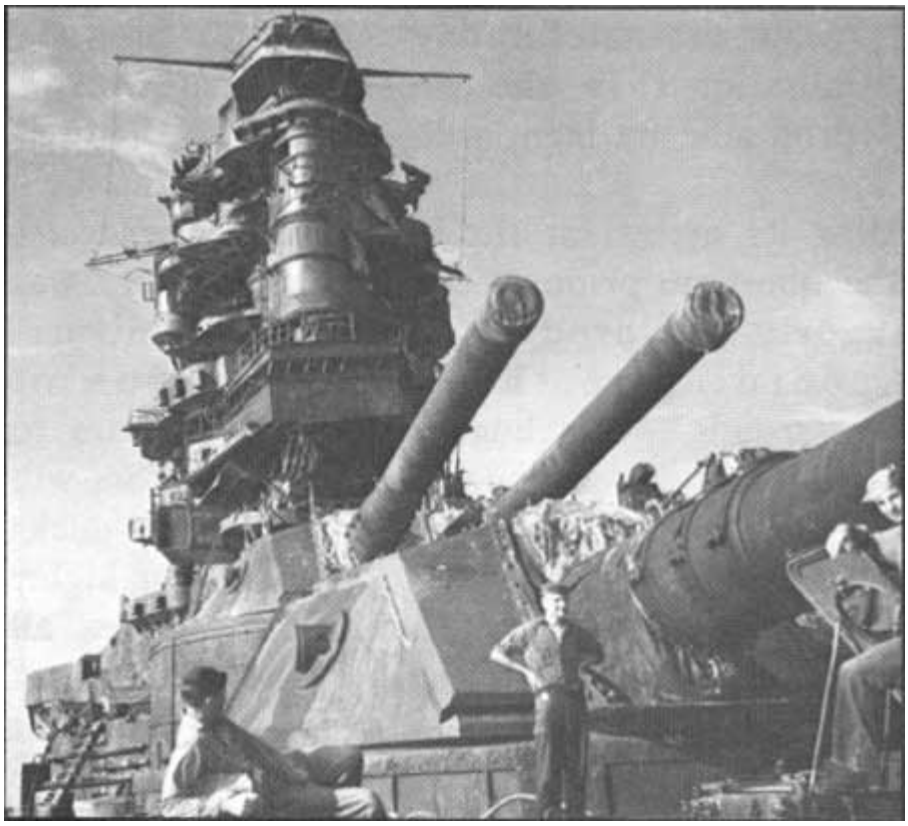


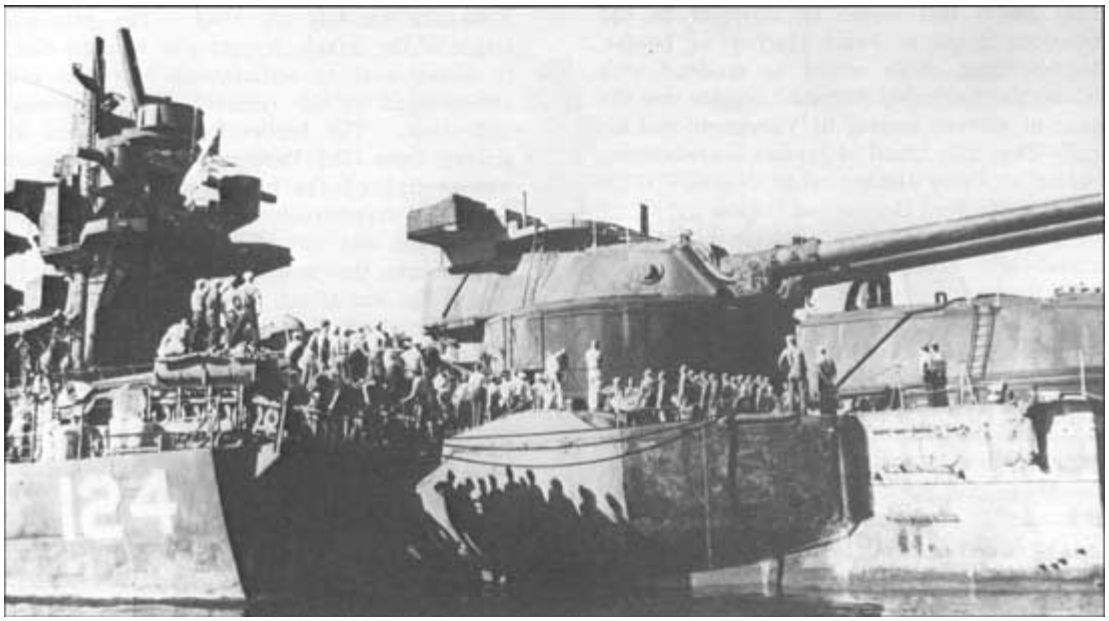


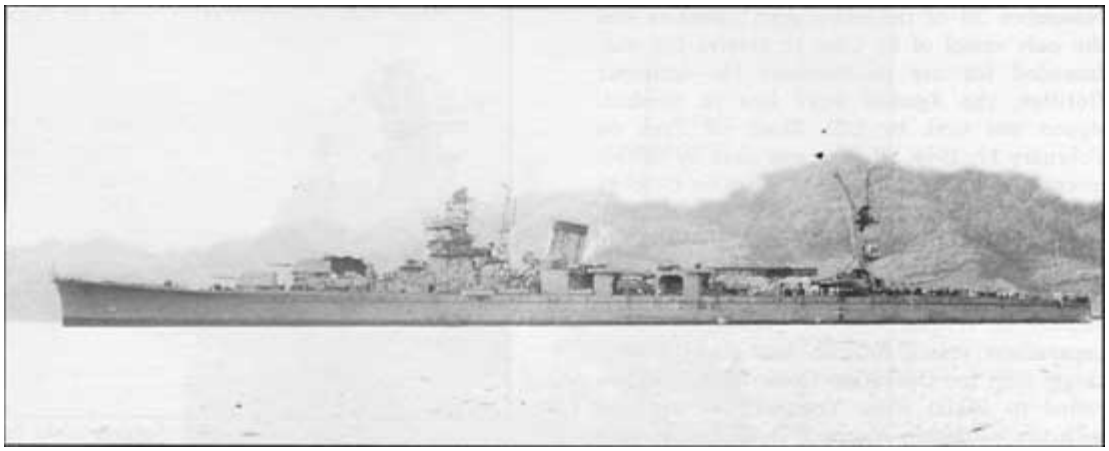

-33, USS ARKANSAS



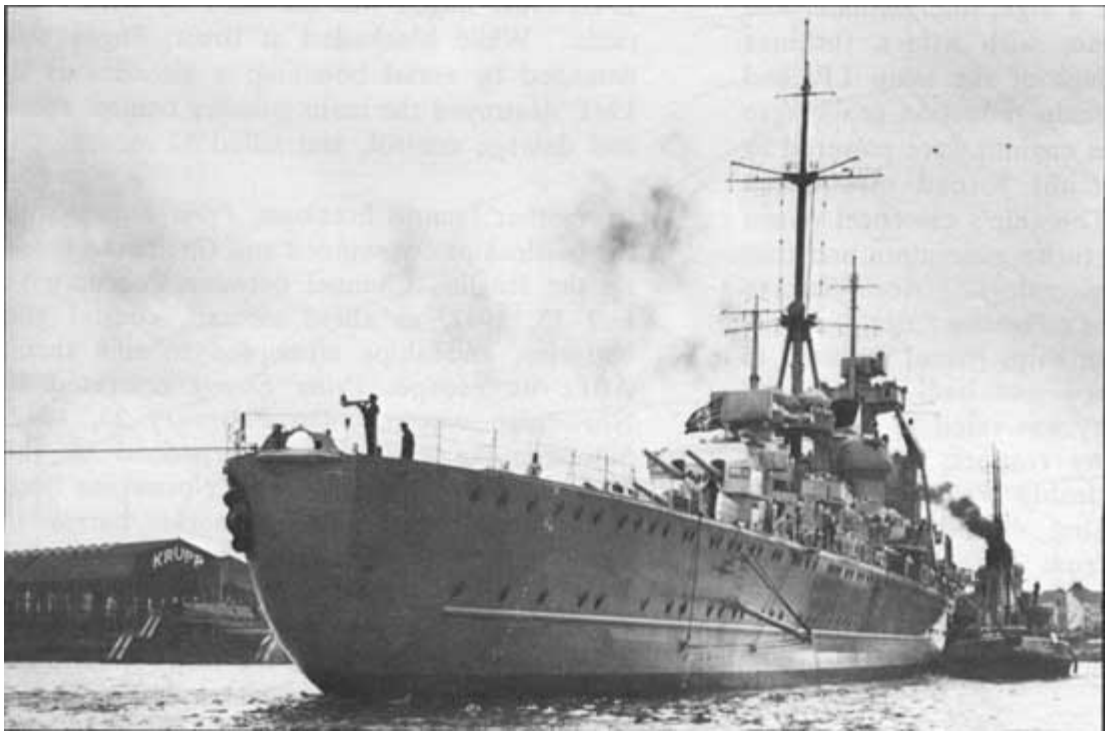




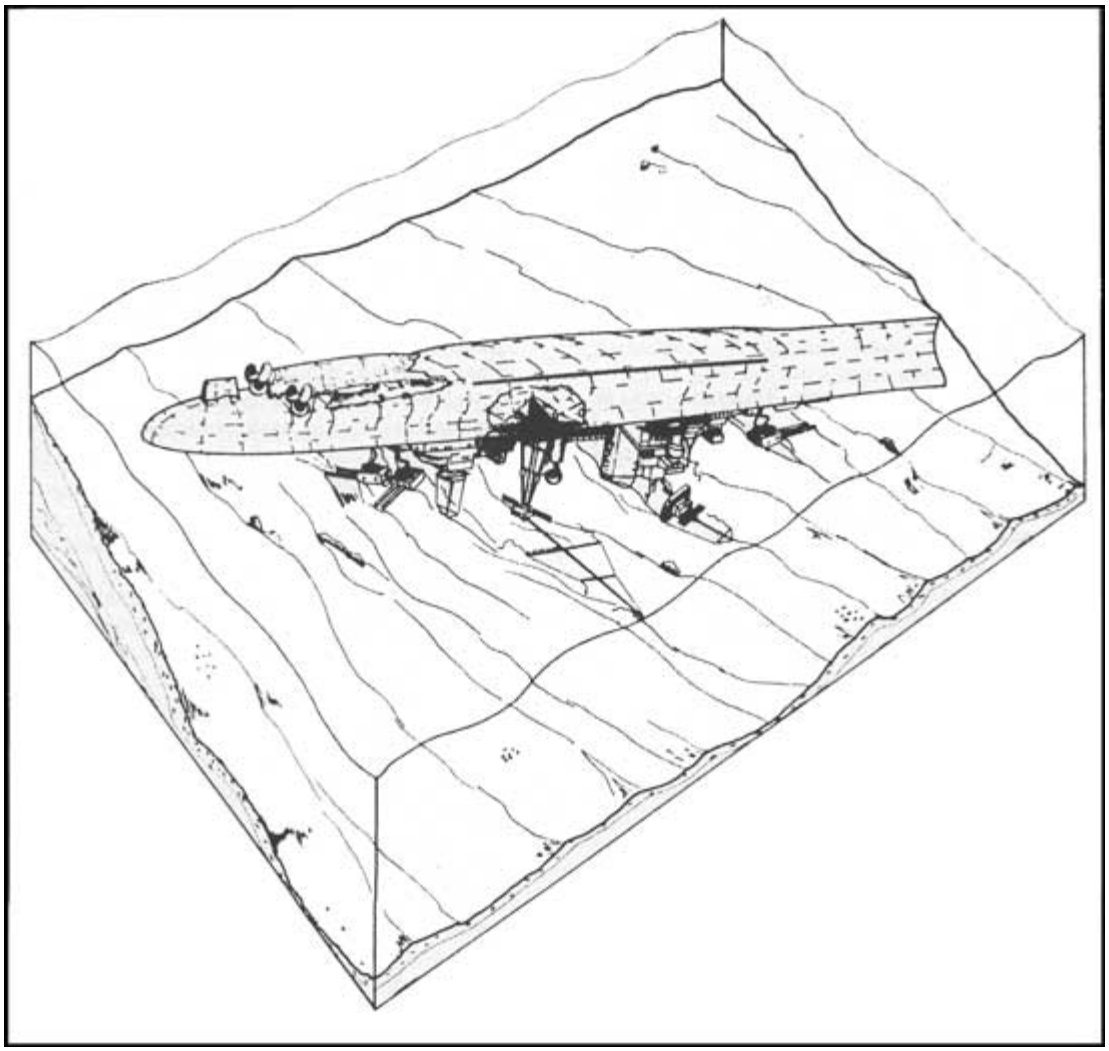

124






KRUPP



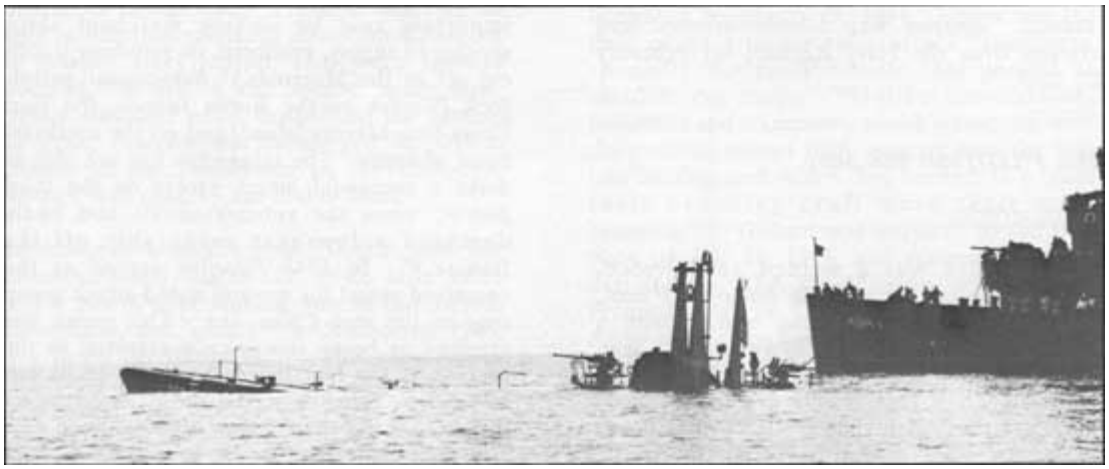


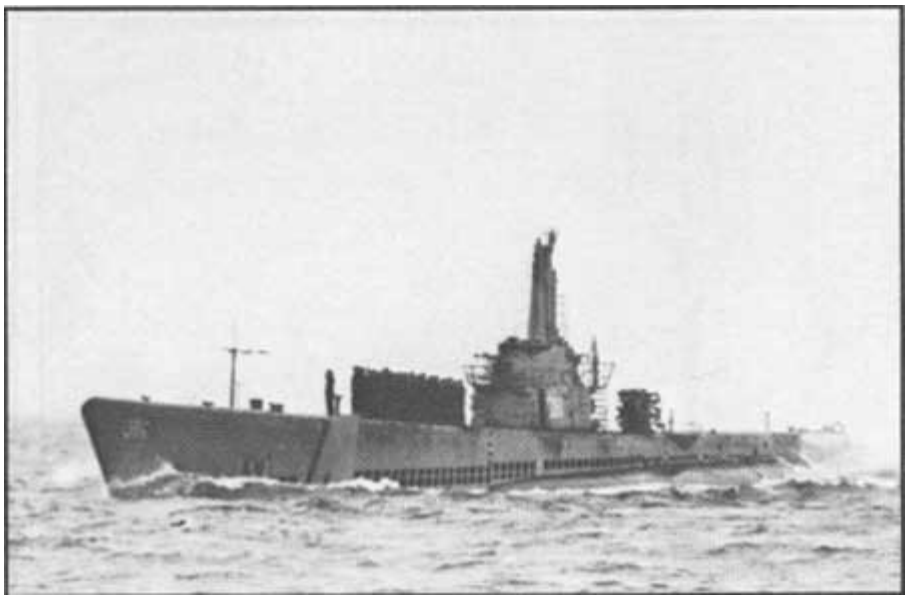

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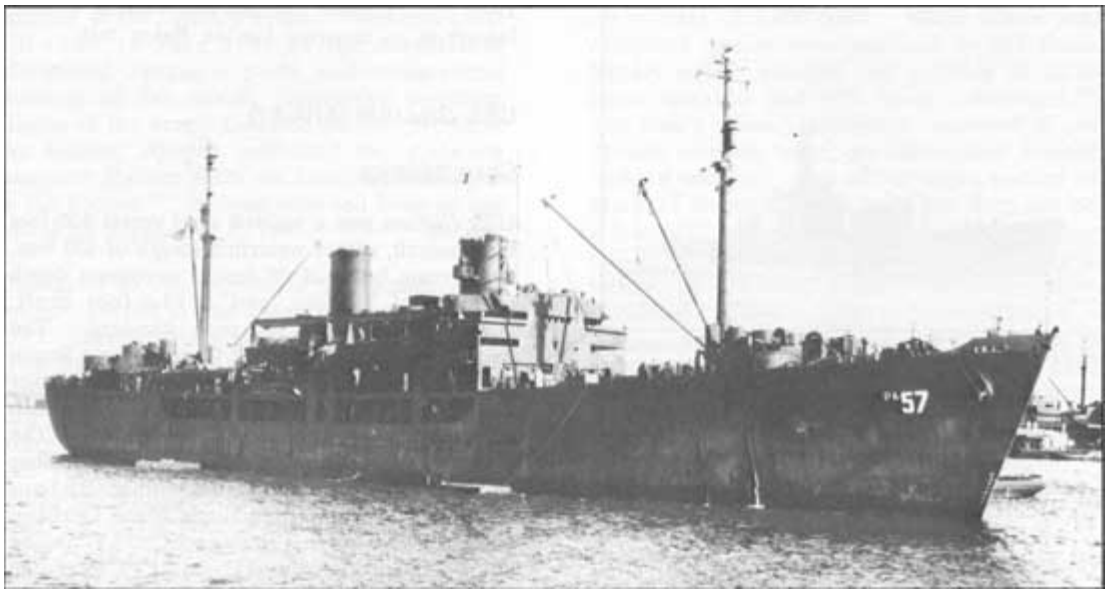

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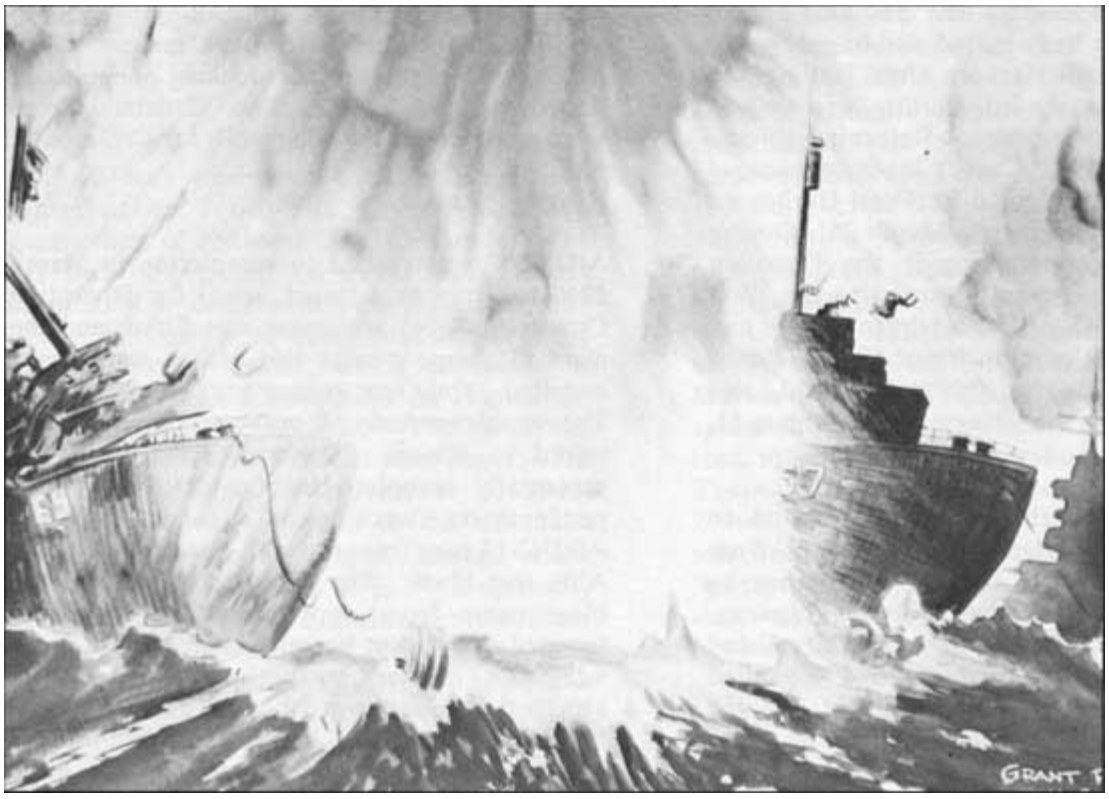

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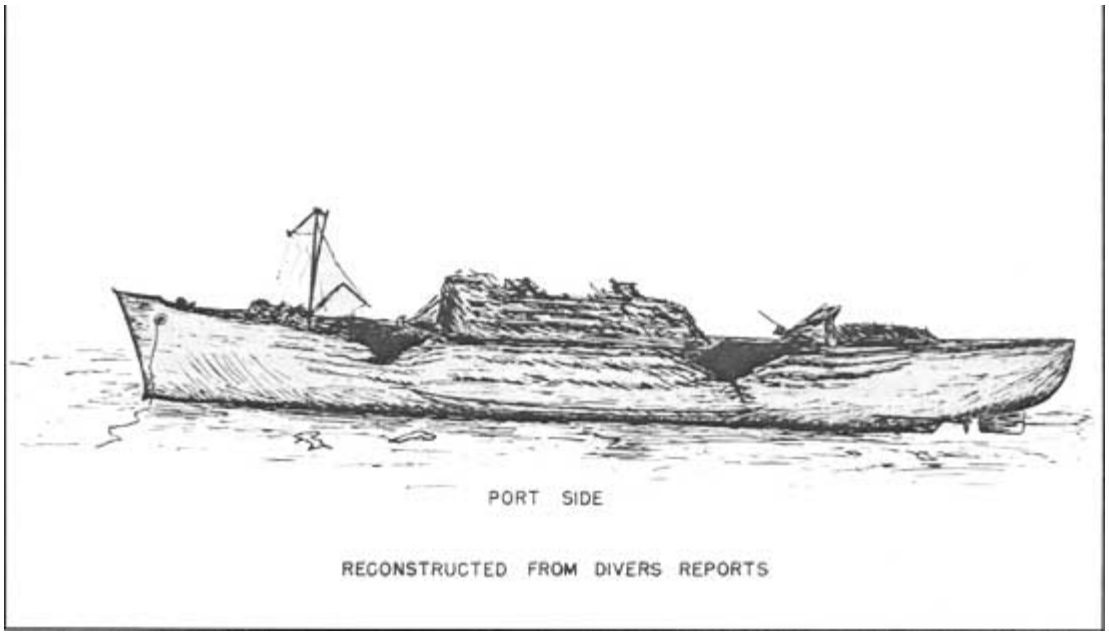

LAMSON





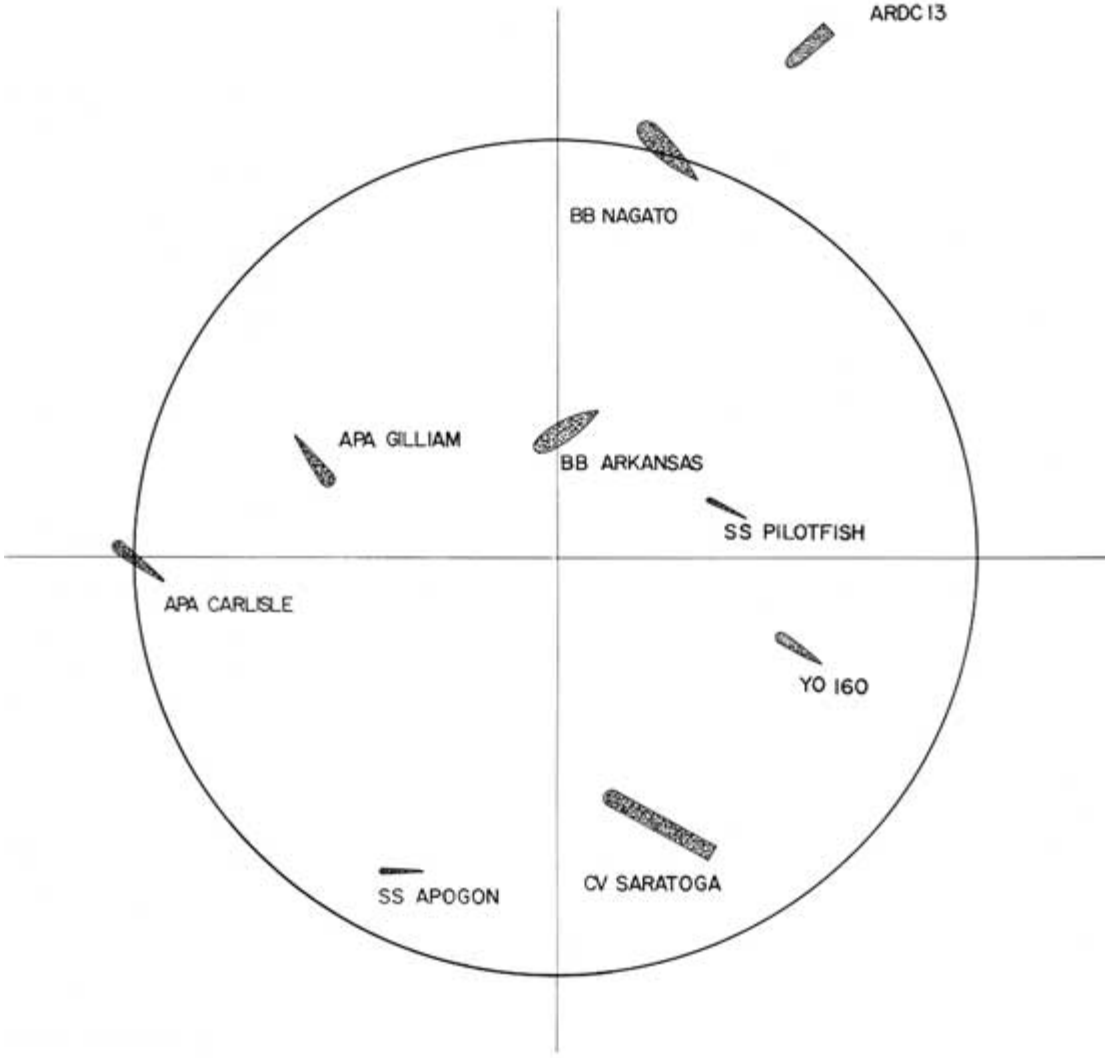

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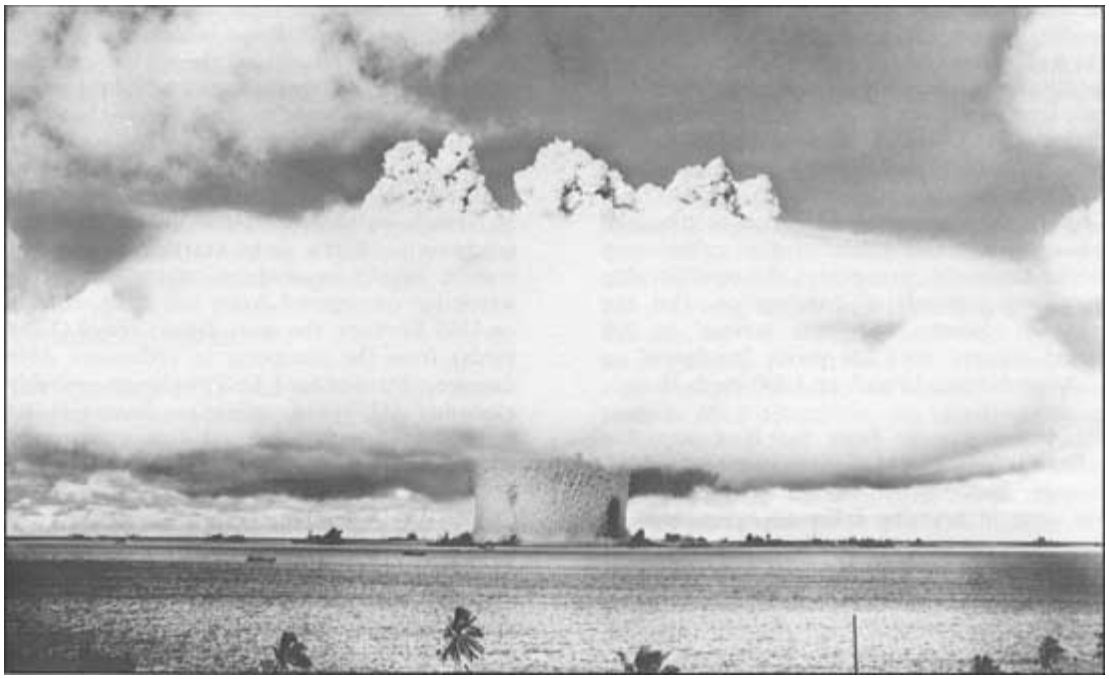

GRANT



PORT SIDE

RECONSTRUCTED FROM DIVERS REPORTS


ARDC 13
BB NAGATO
APA GILLIAM
BB ARKANSAS
SS PILOTFISH
APA CARLISLE
YO 160
SS APOGON
CV SARATOGA

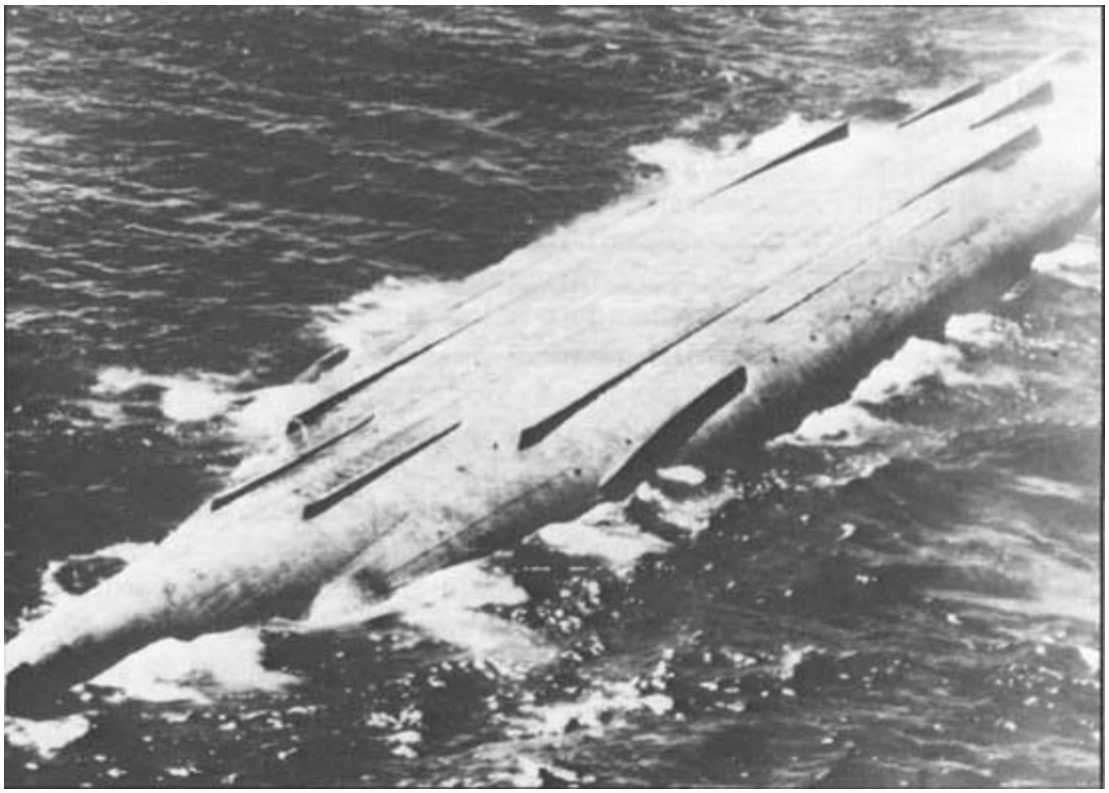


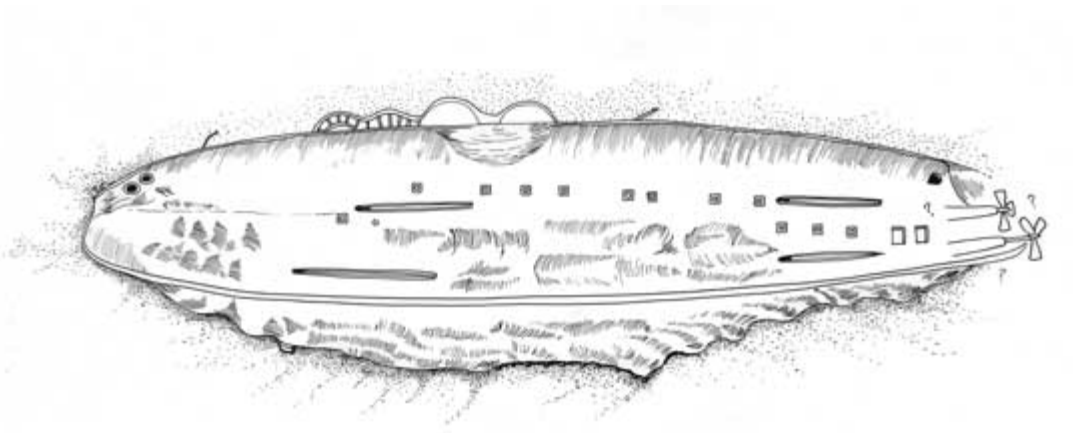




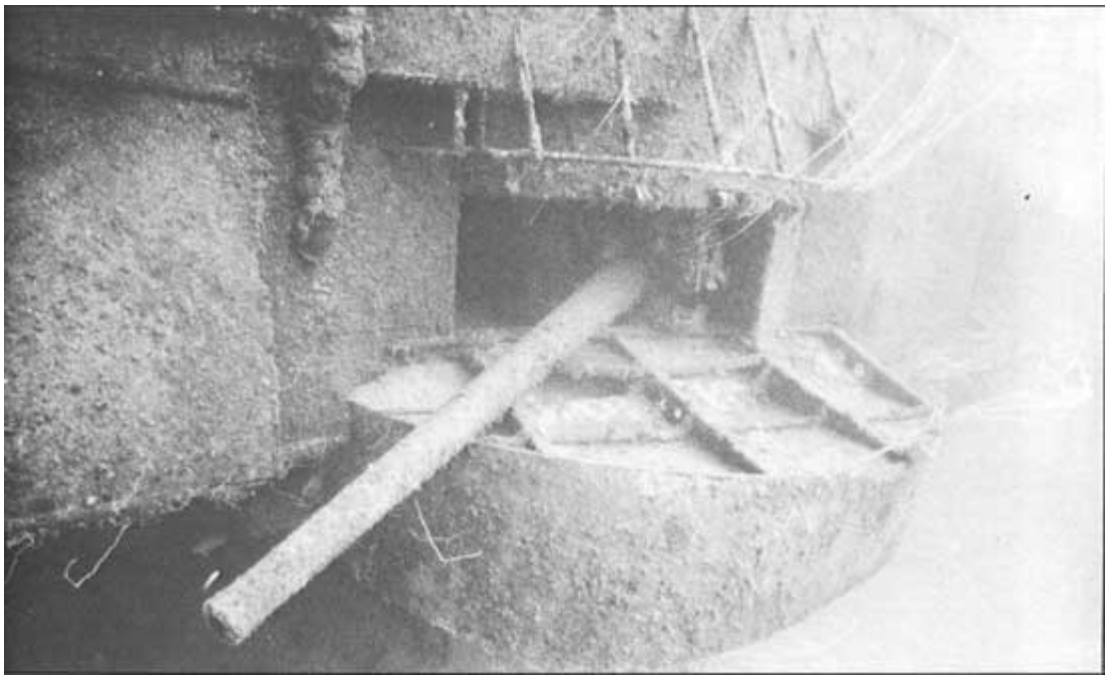

124 D
123 Rd

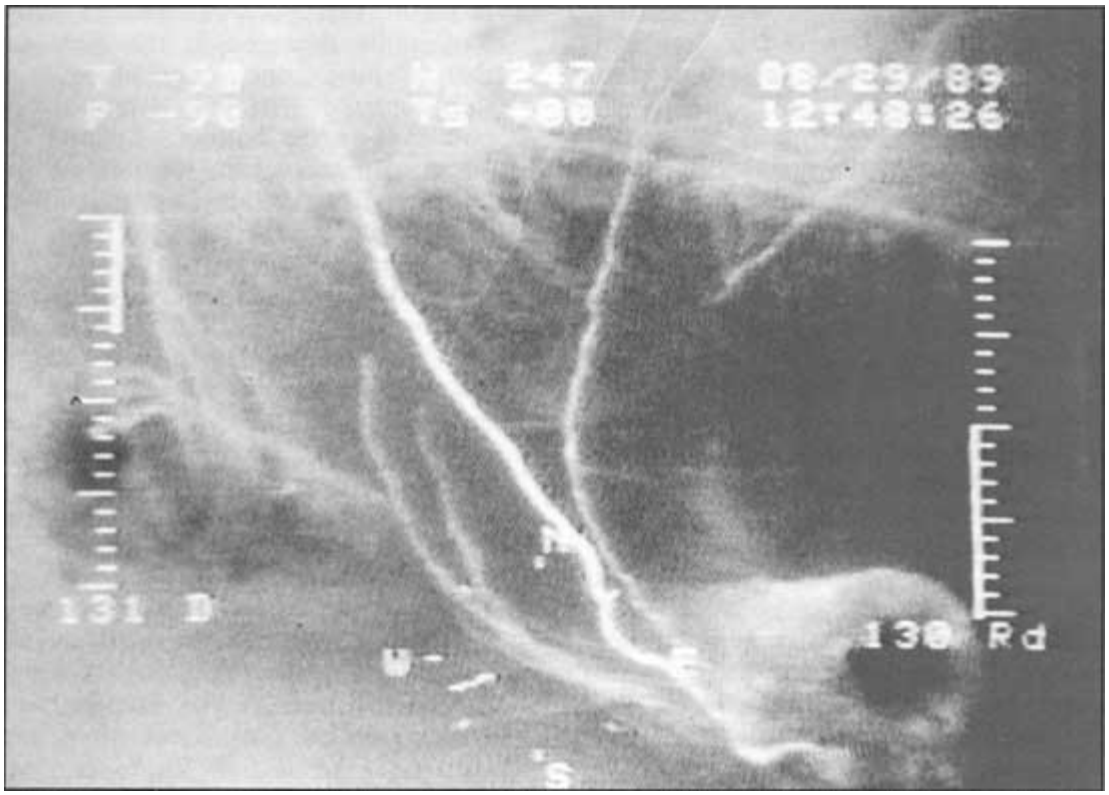


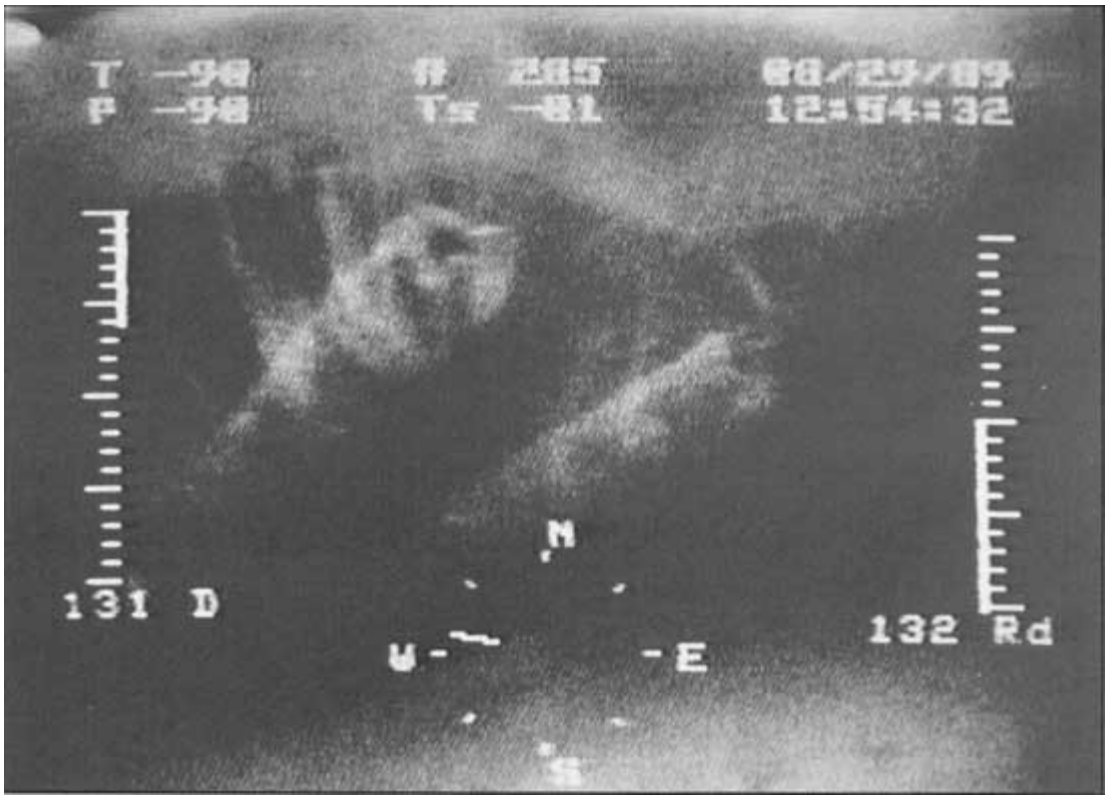


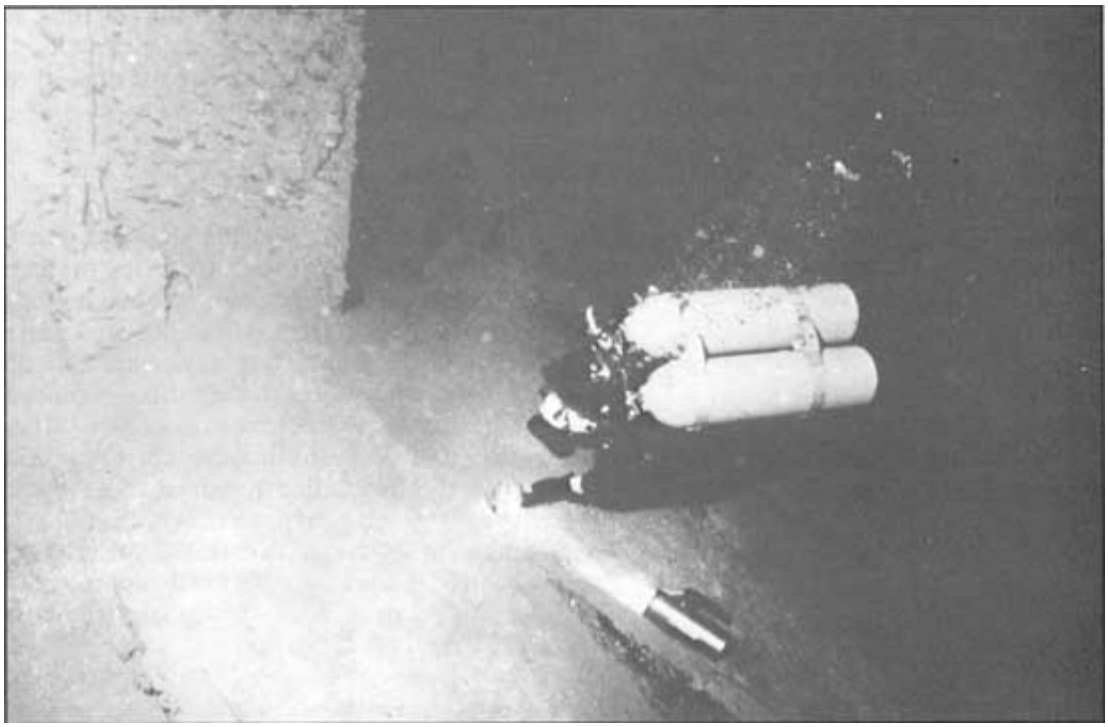


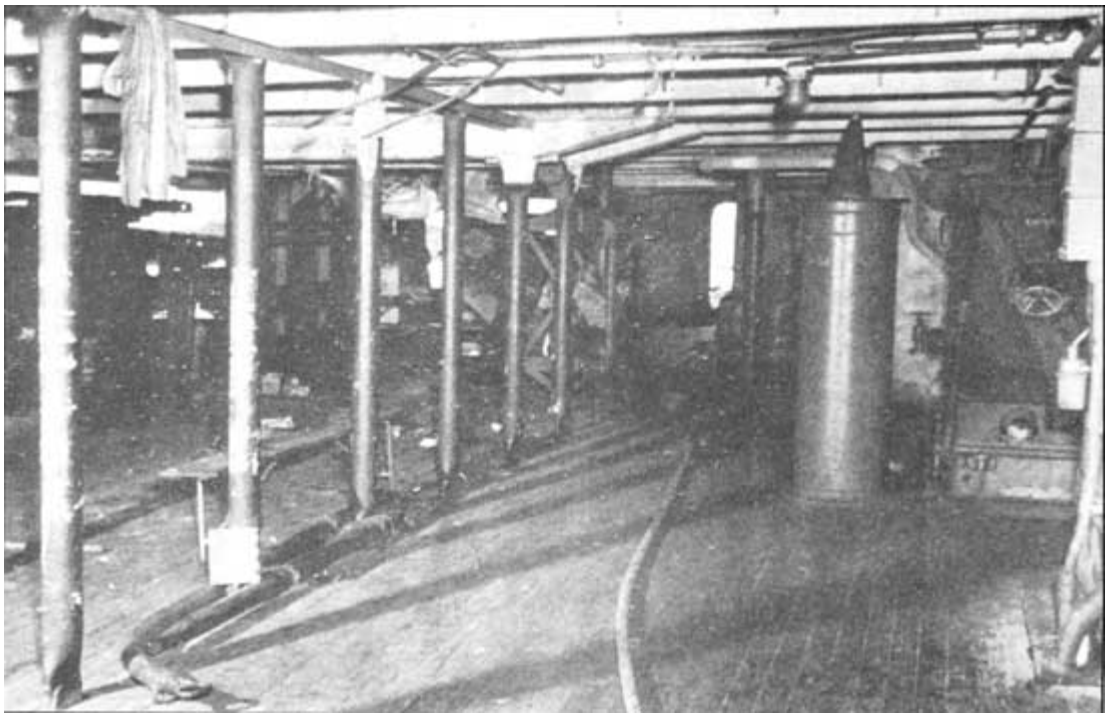


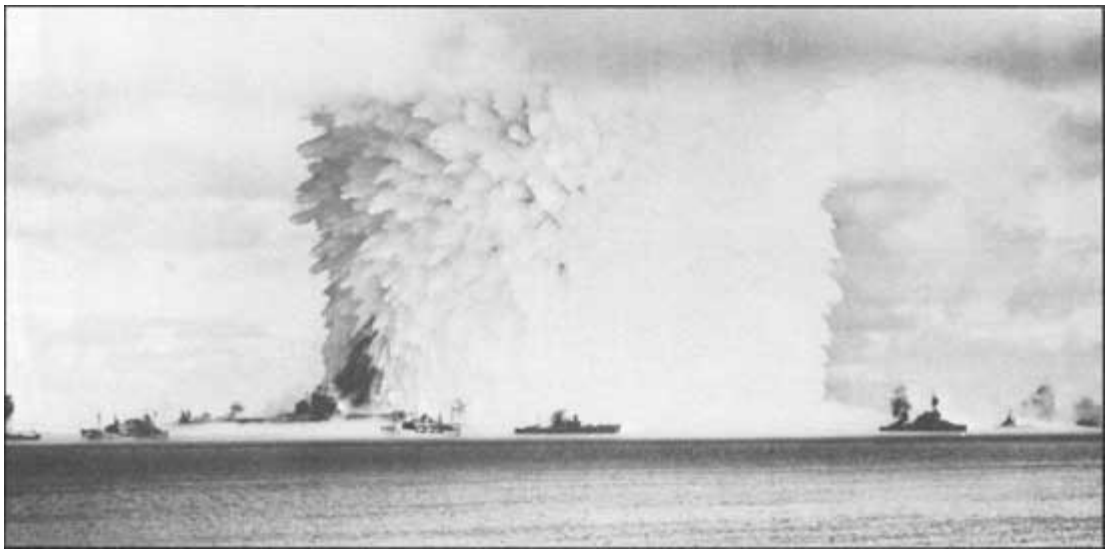


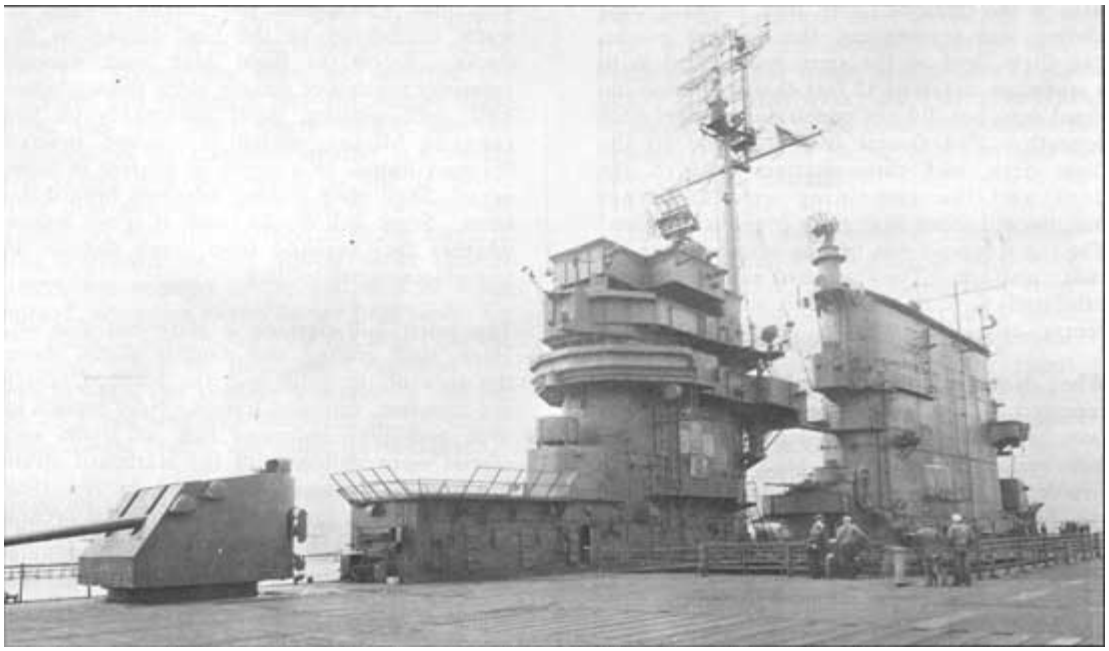

08/29/89
12:48:26
131 D
130 Rd


T -94
P -94
Tsr -81
08/29/89
12:54:32
131 D
N
W
E
S
132 Rd

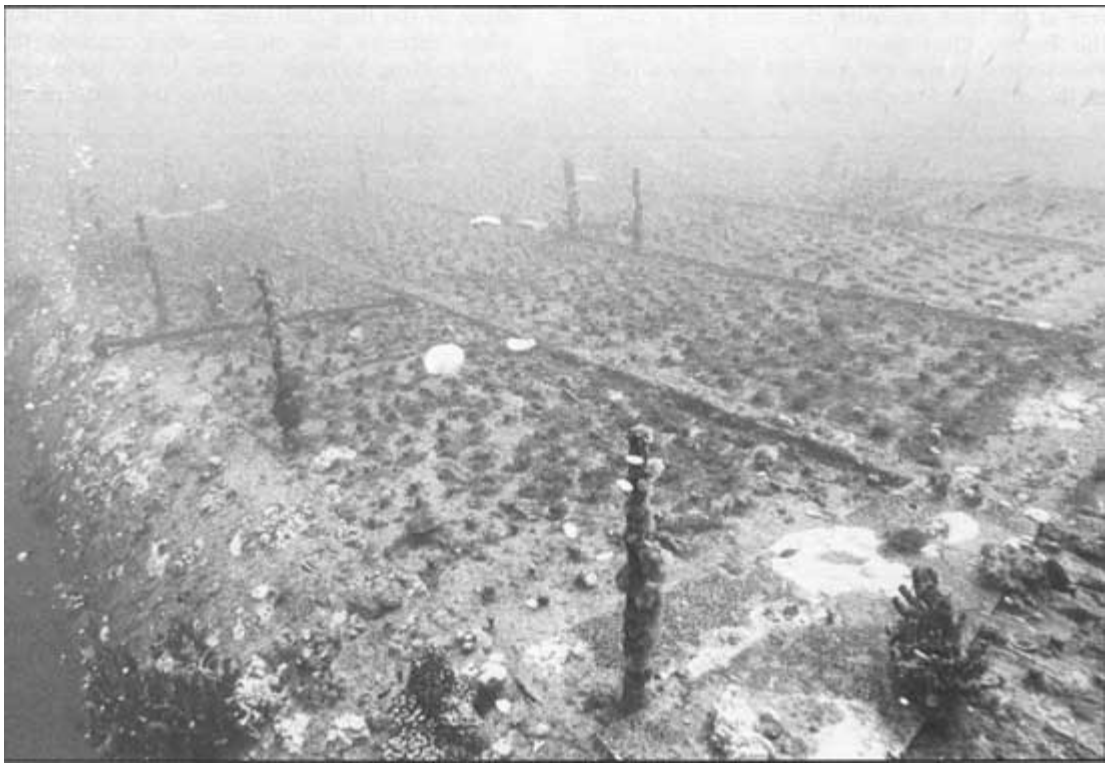


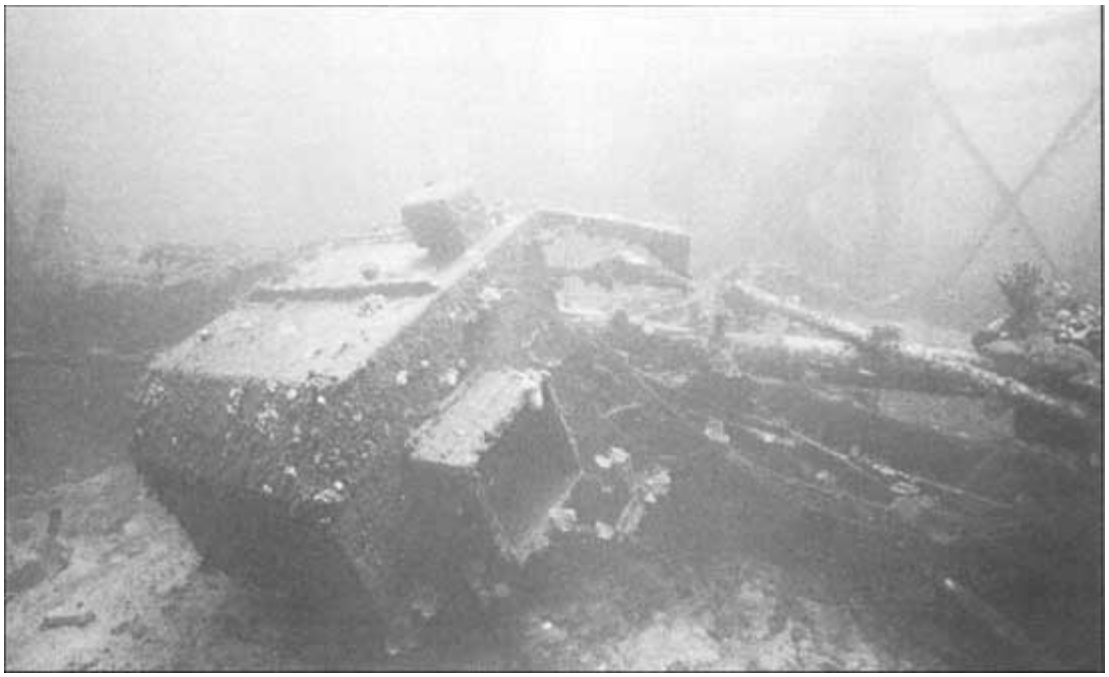




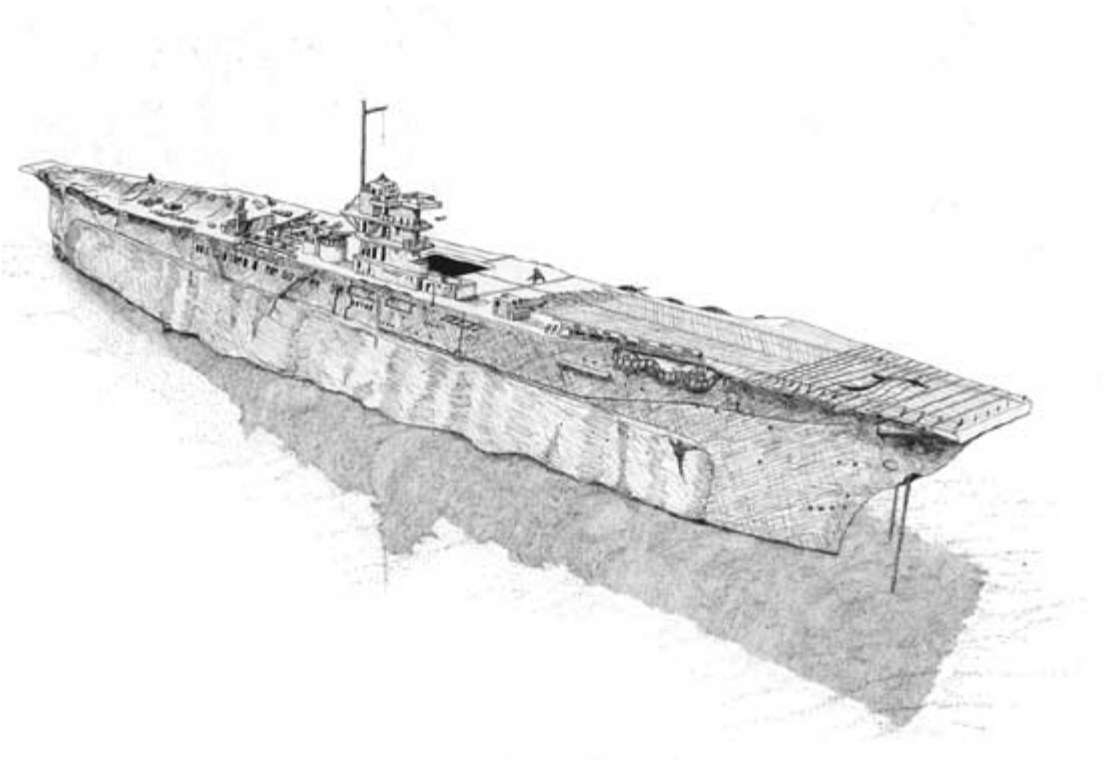


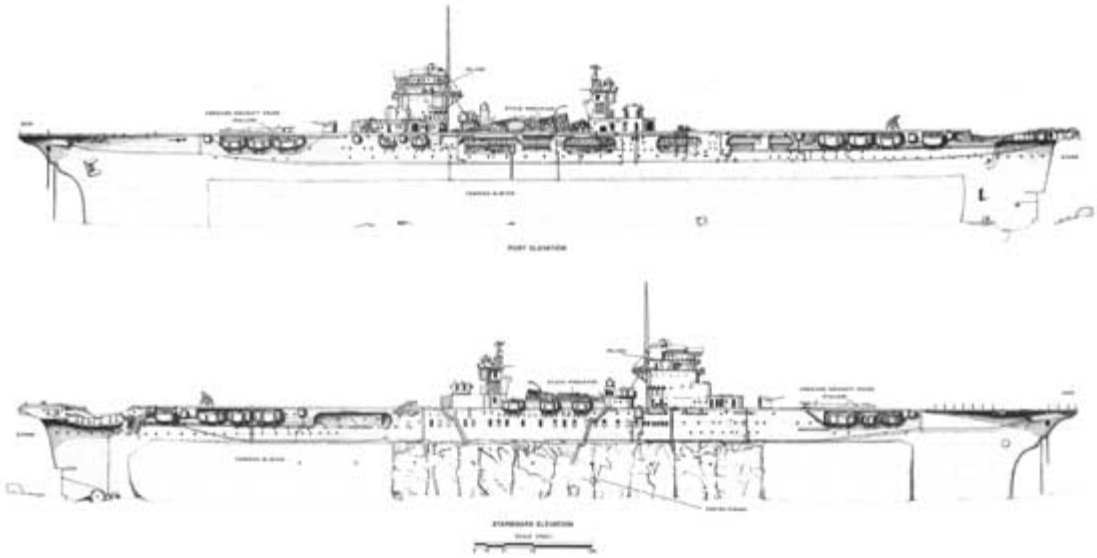


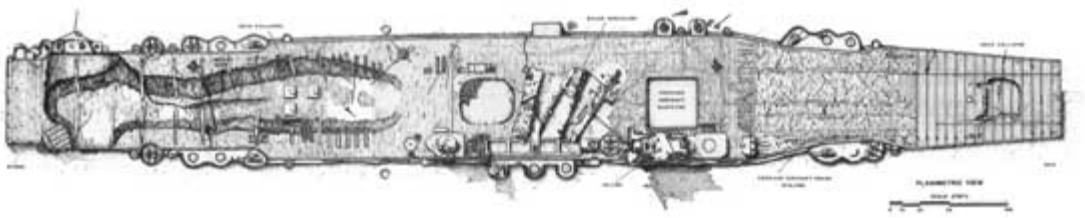


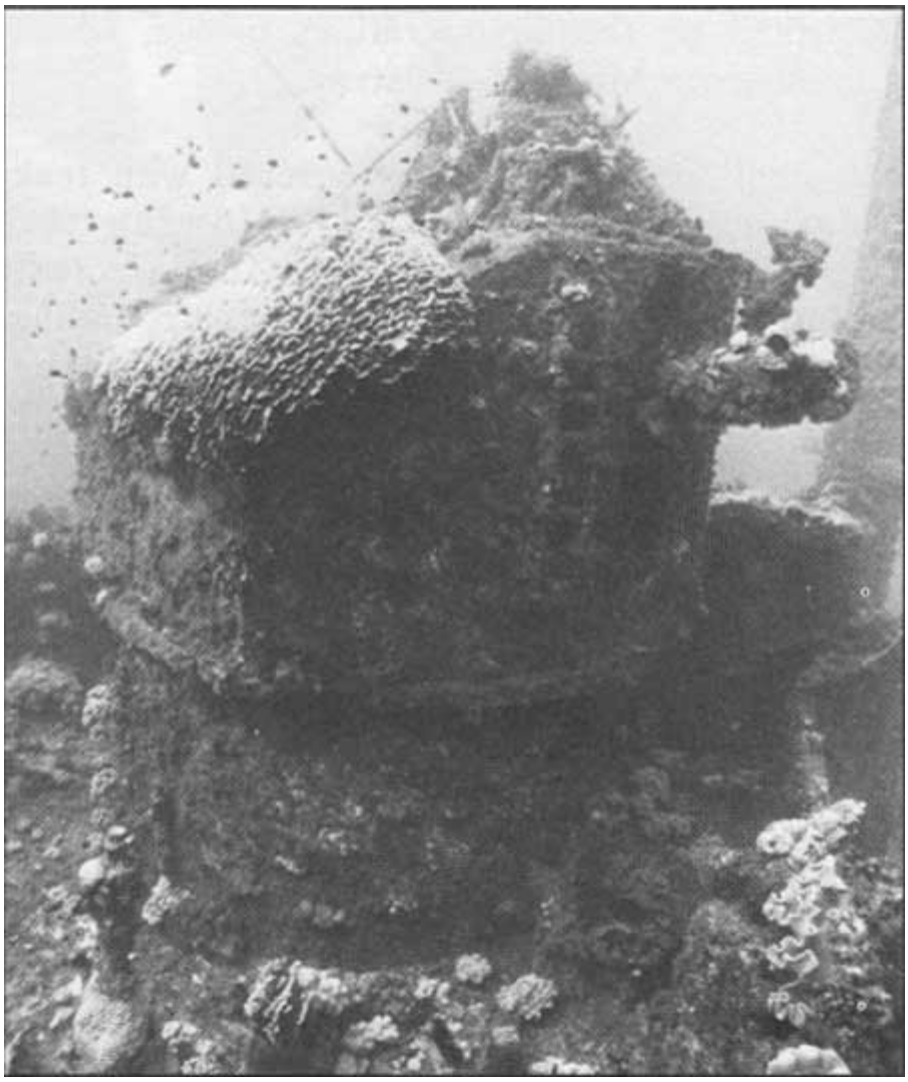


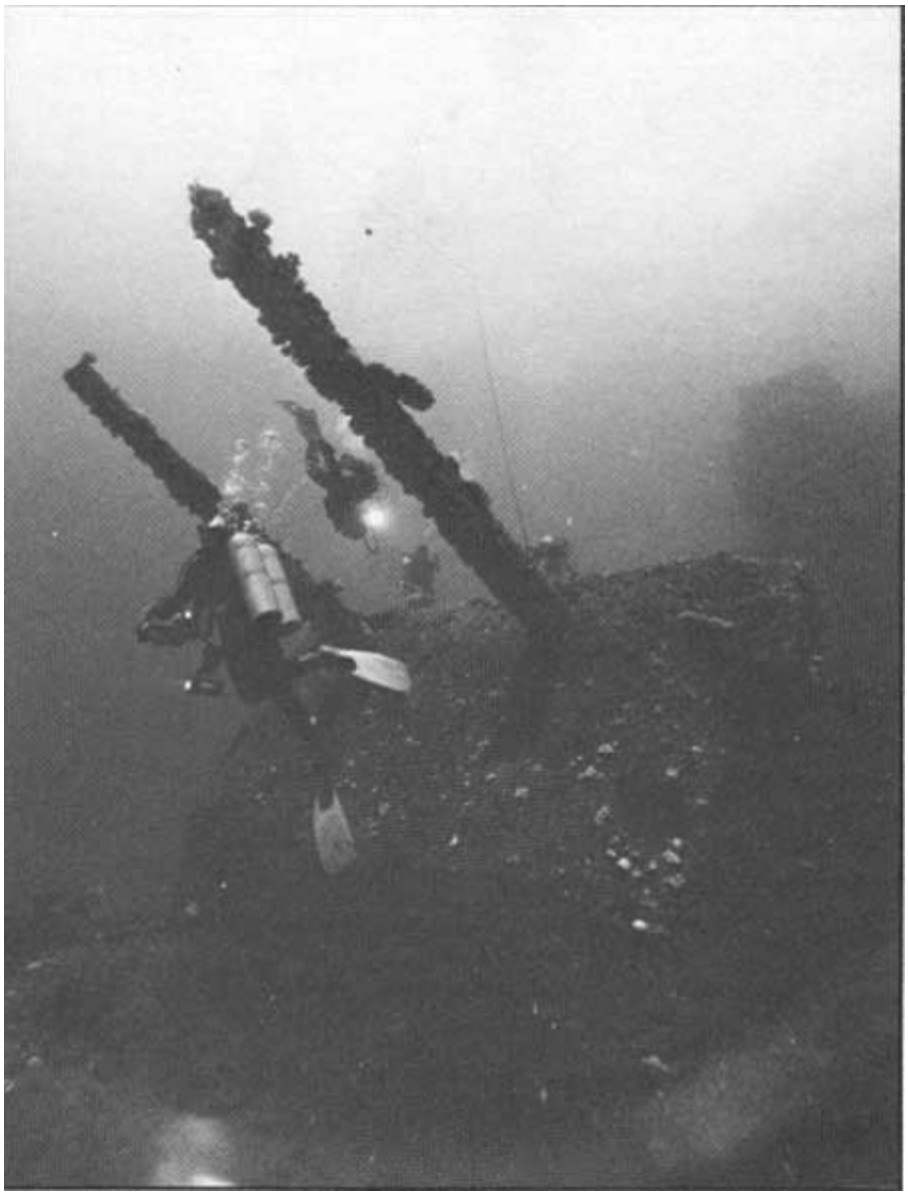




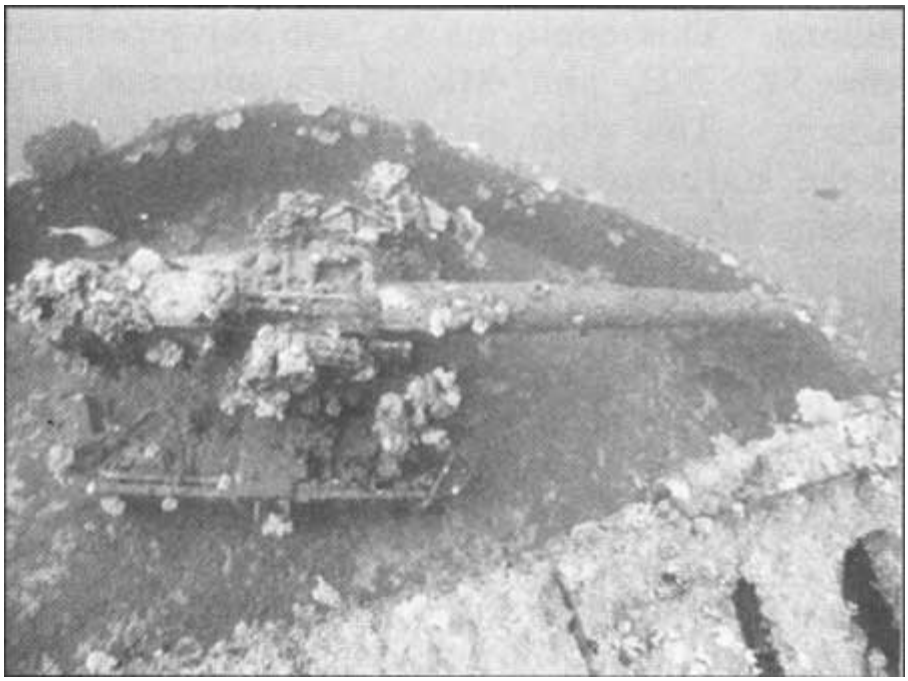


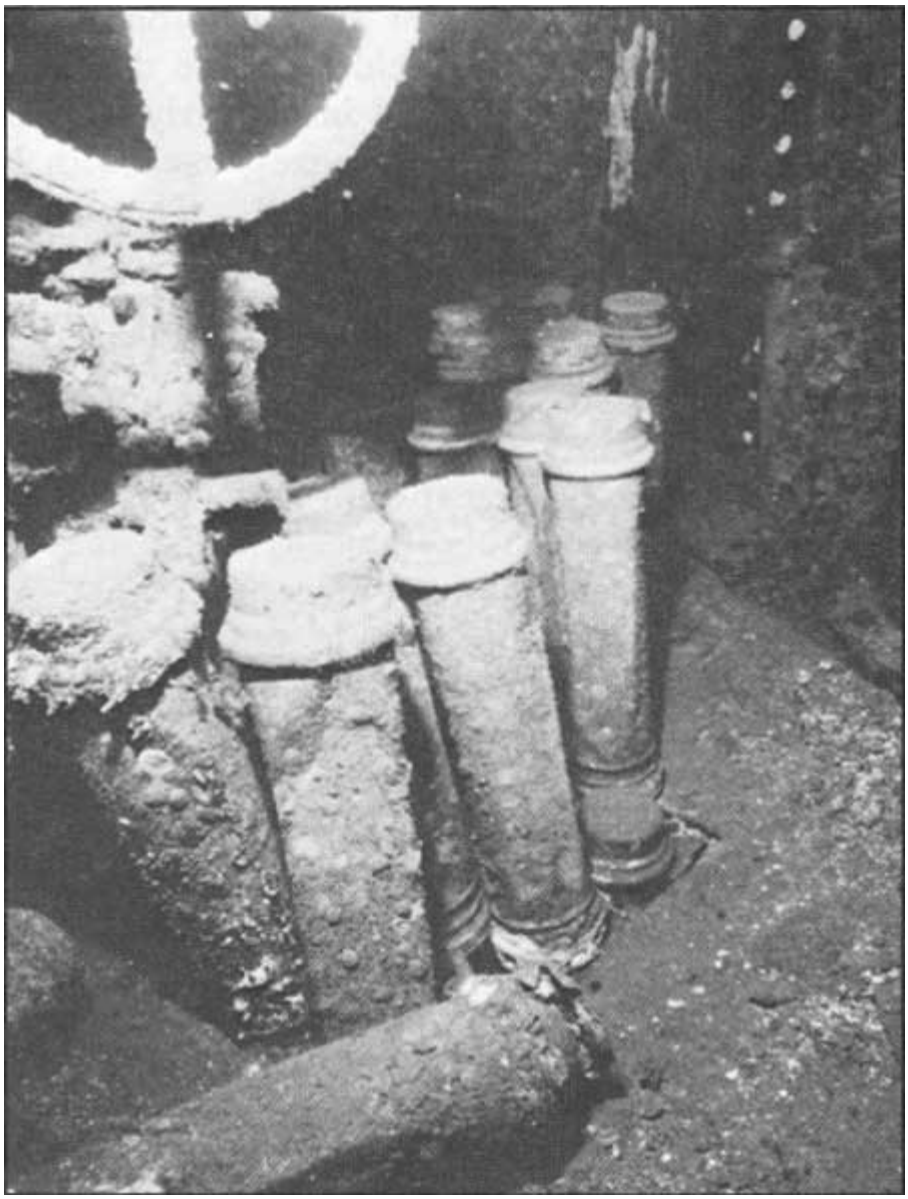


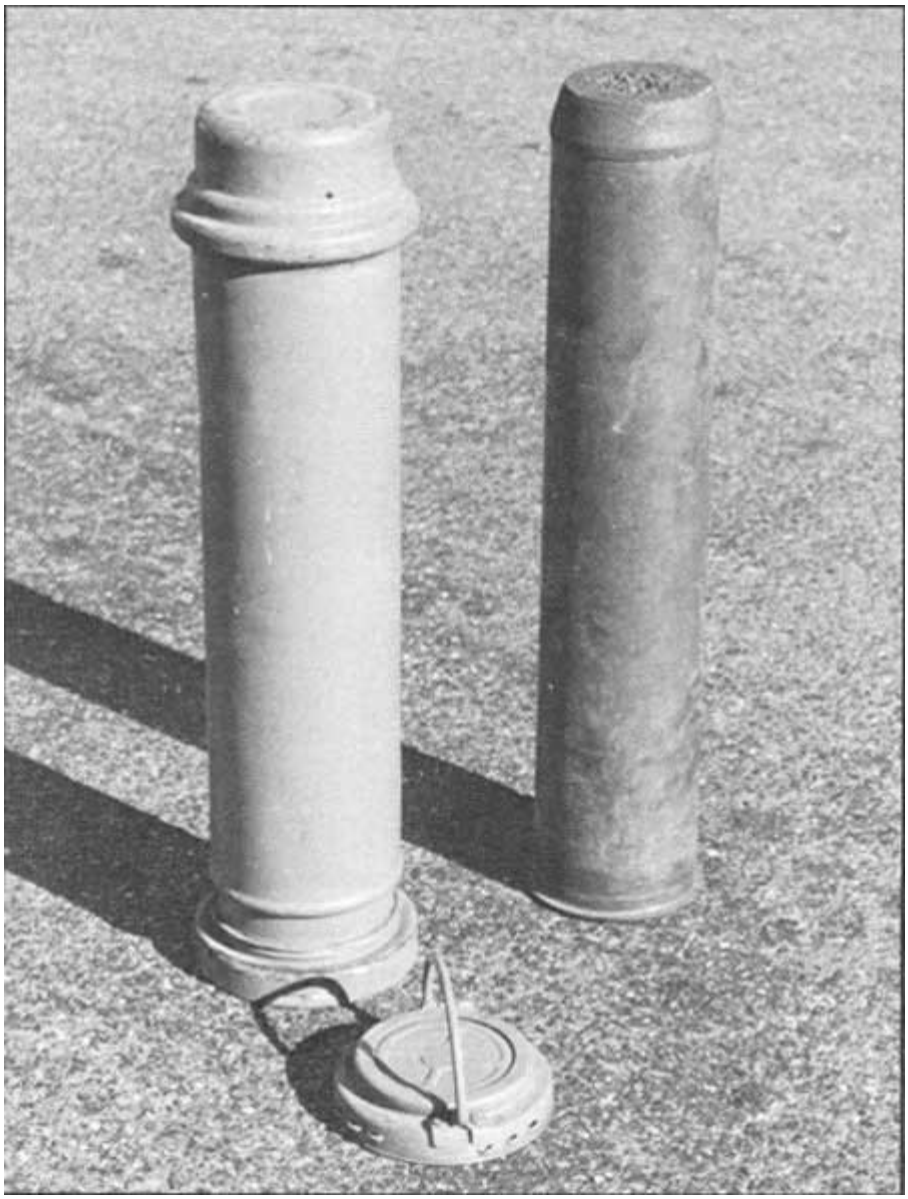


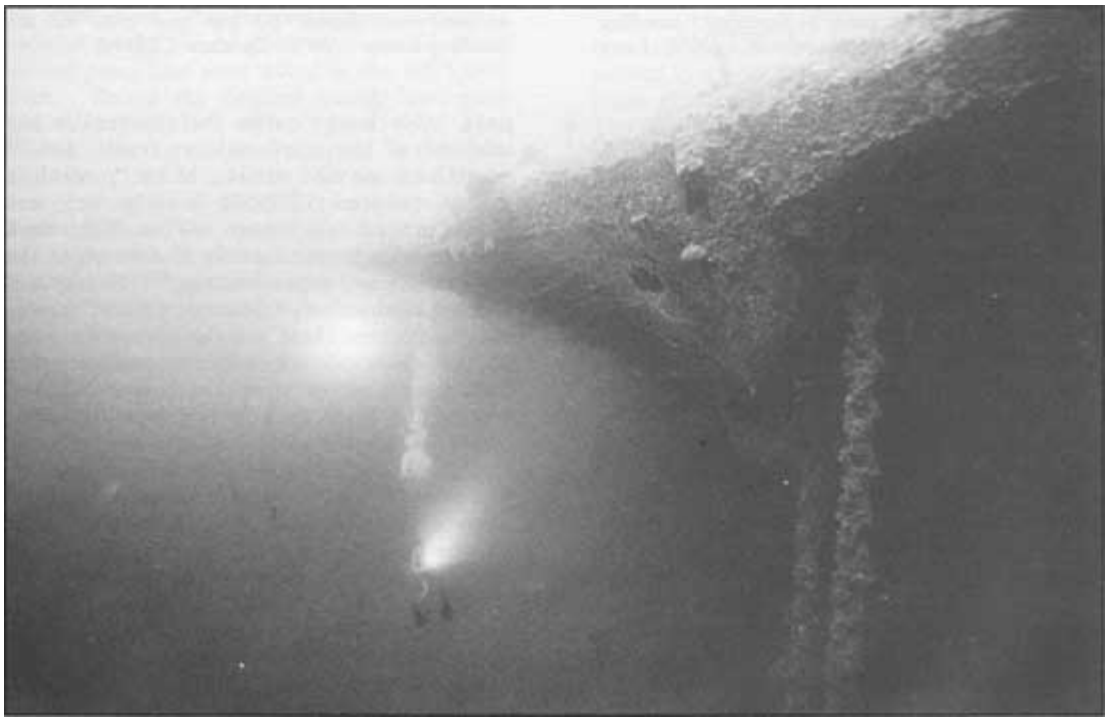




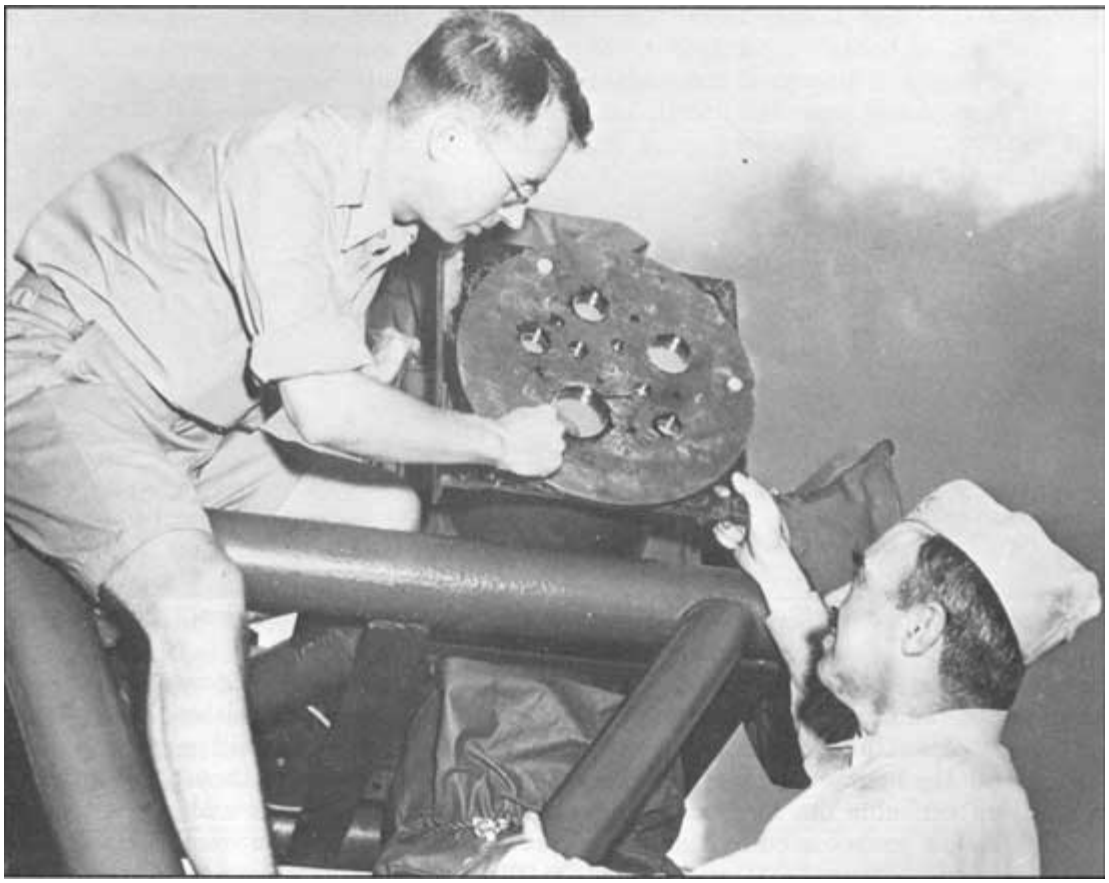


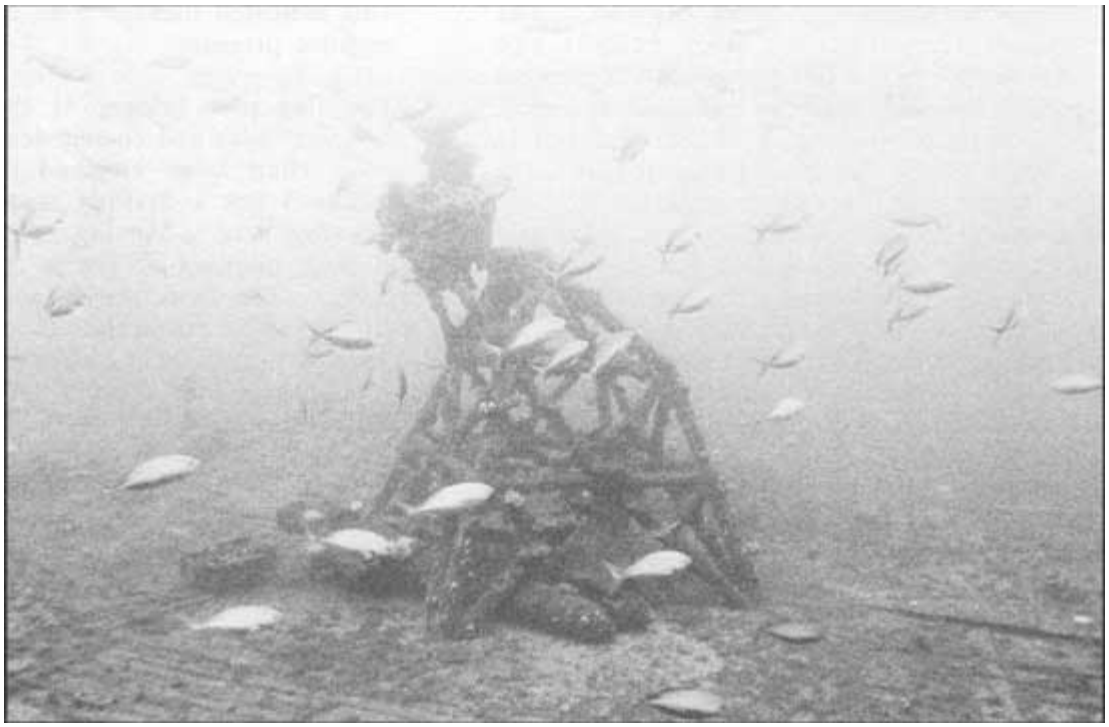


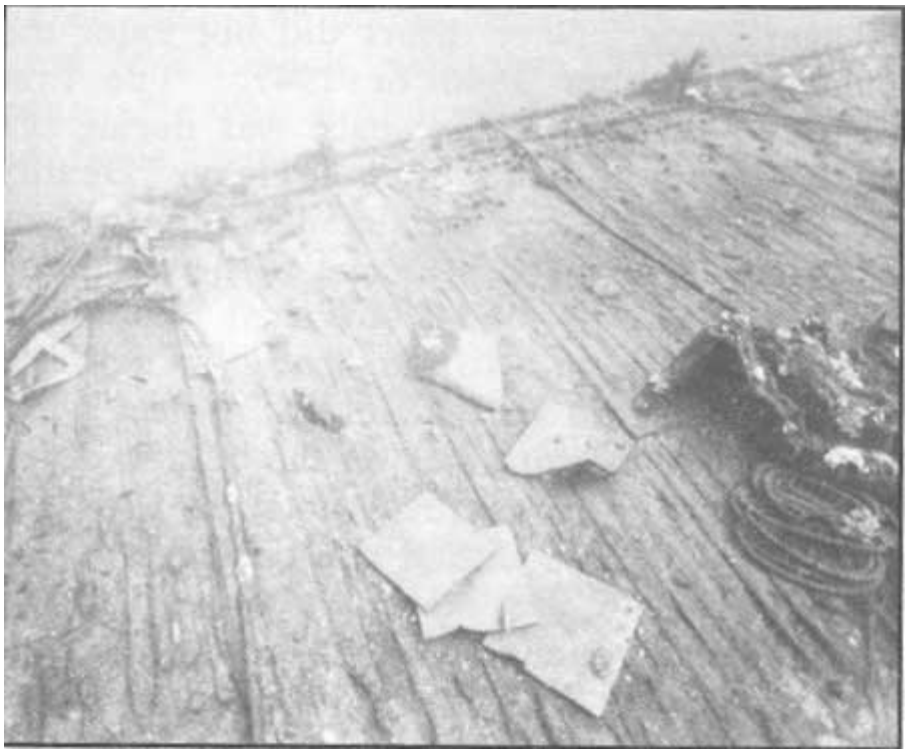




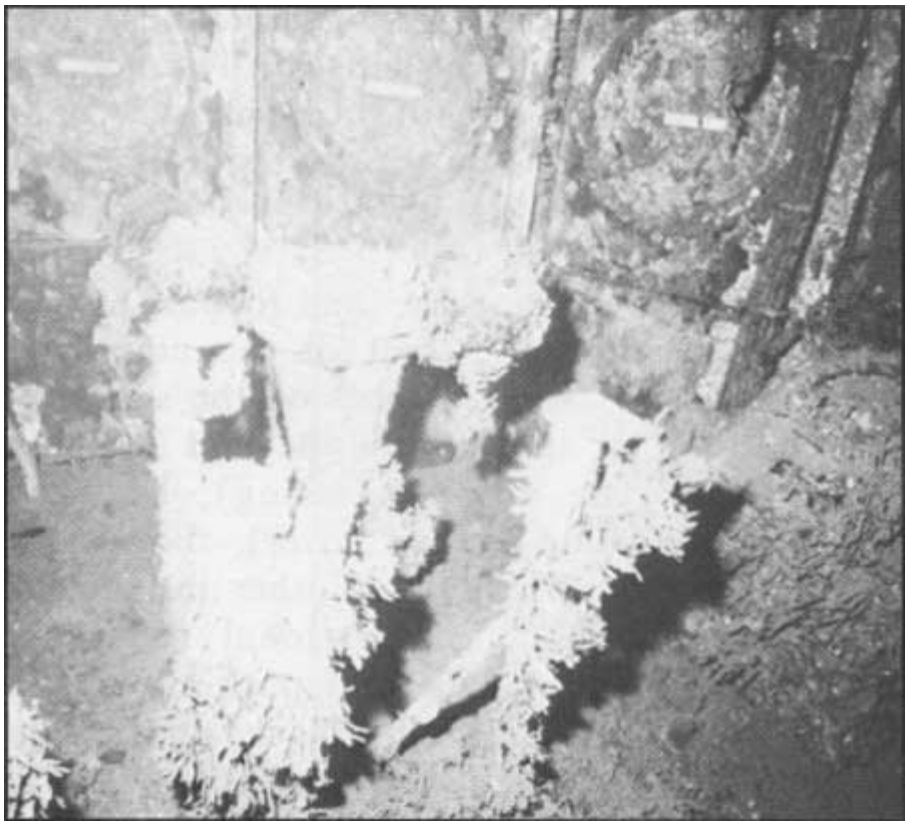


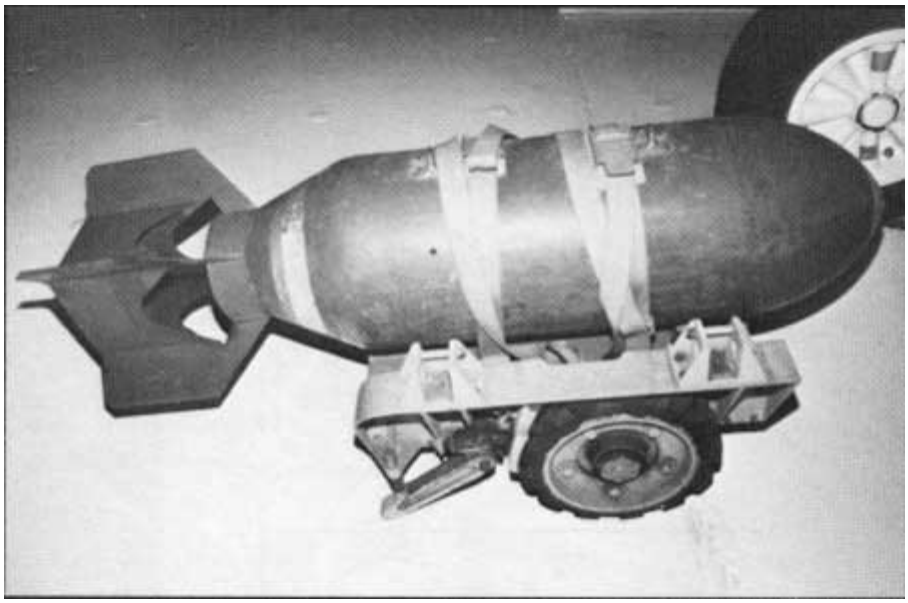


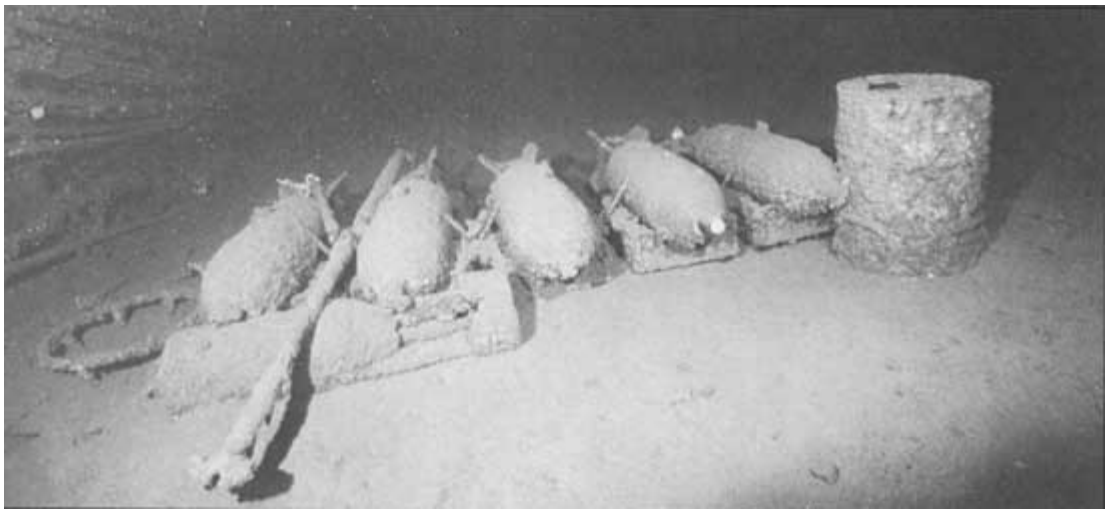




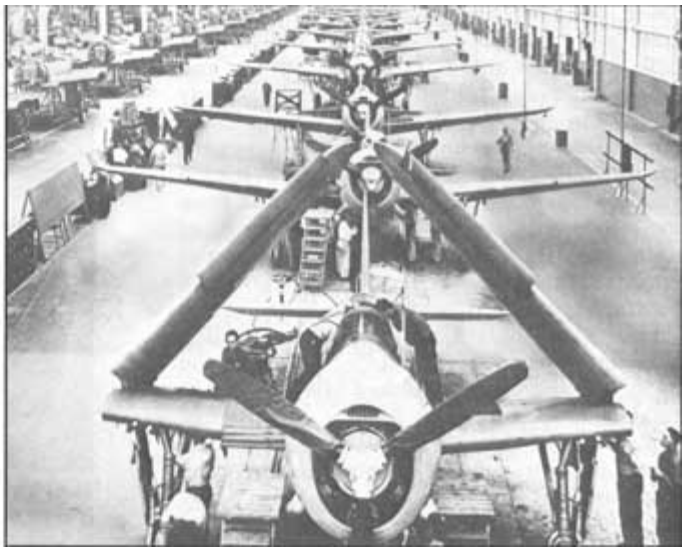




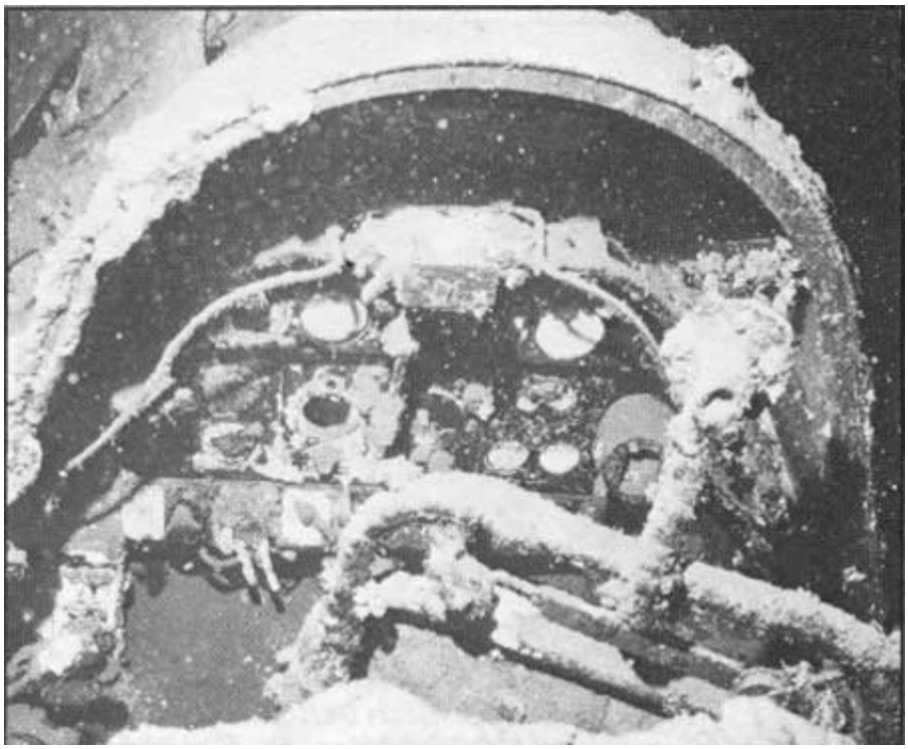


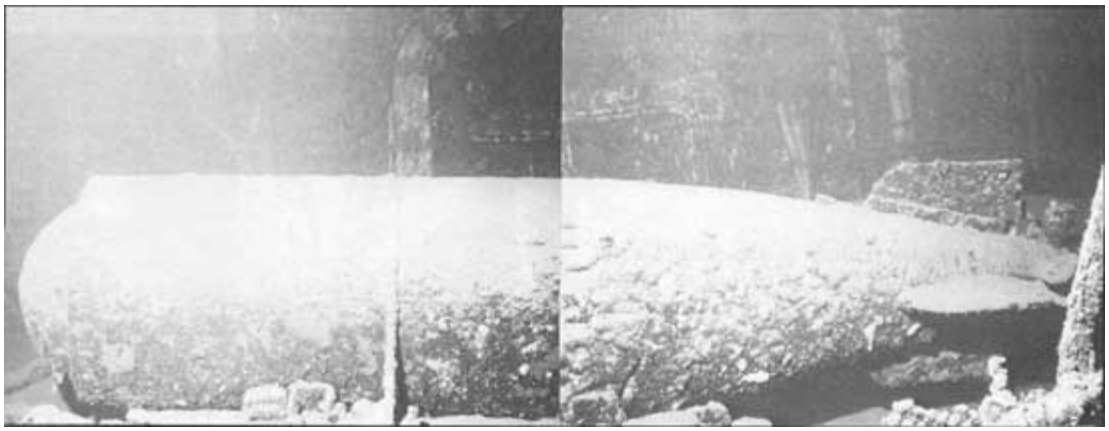



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68



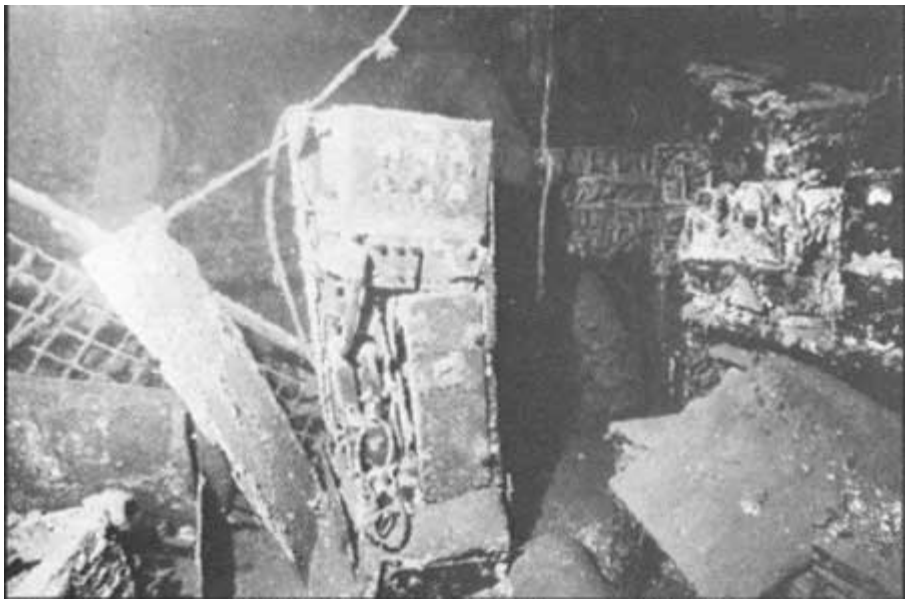


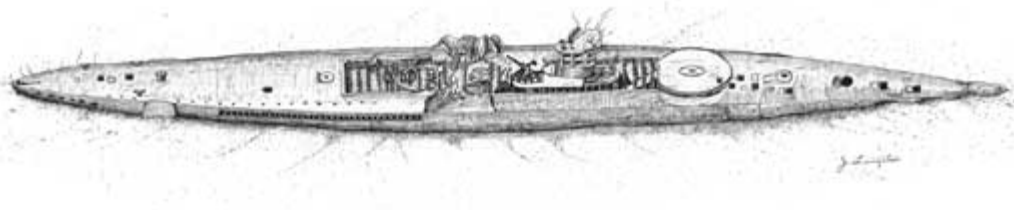








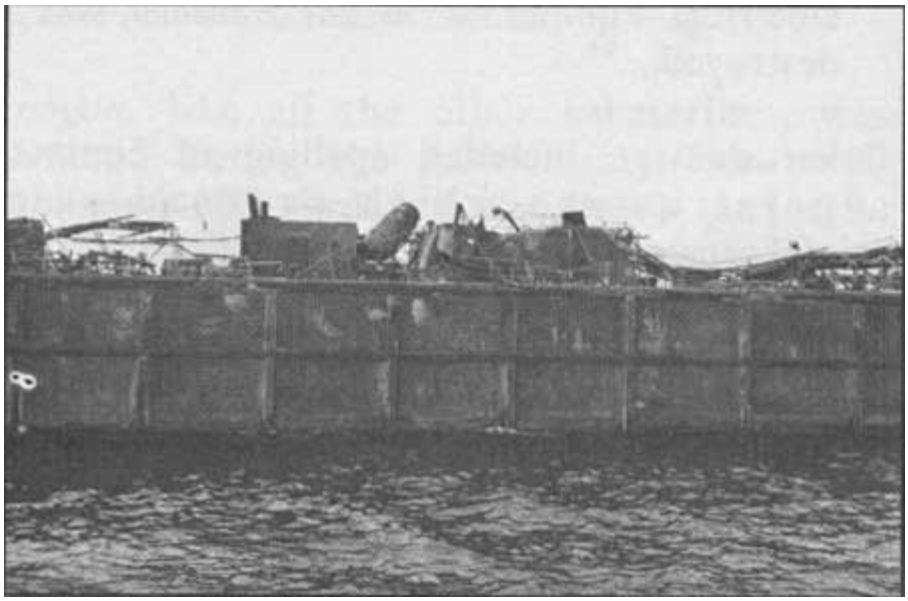






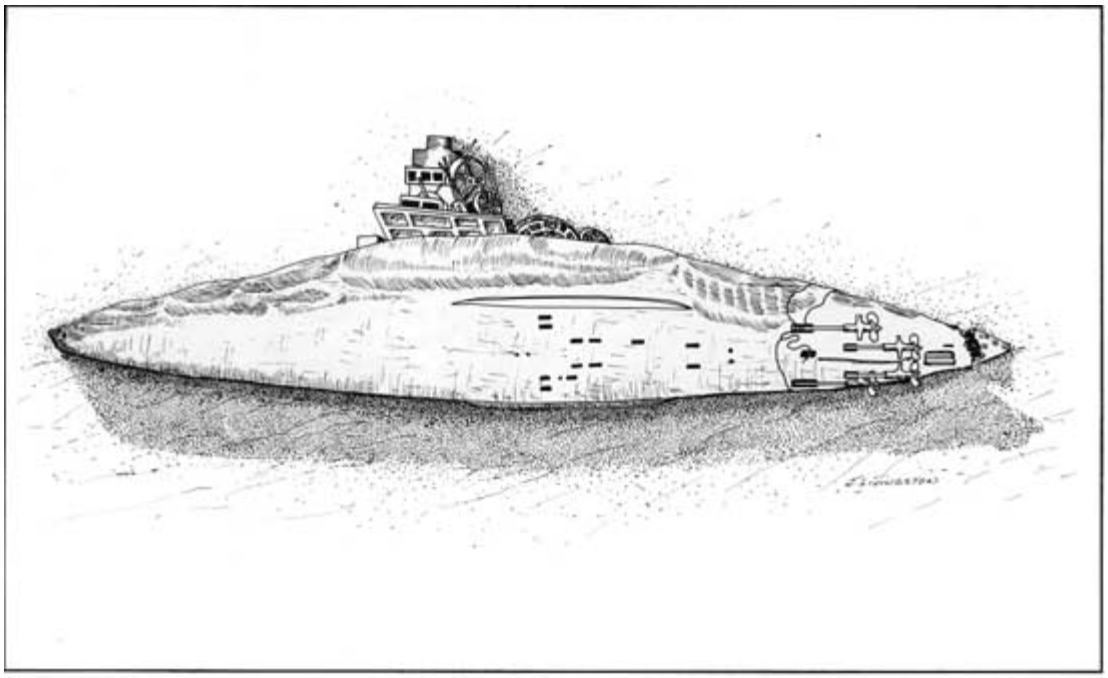

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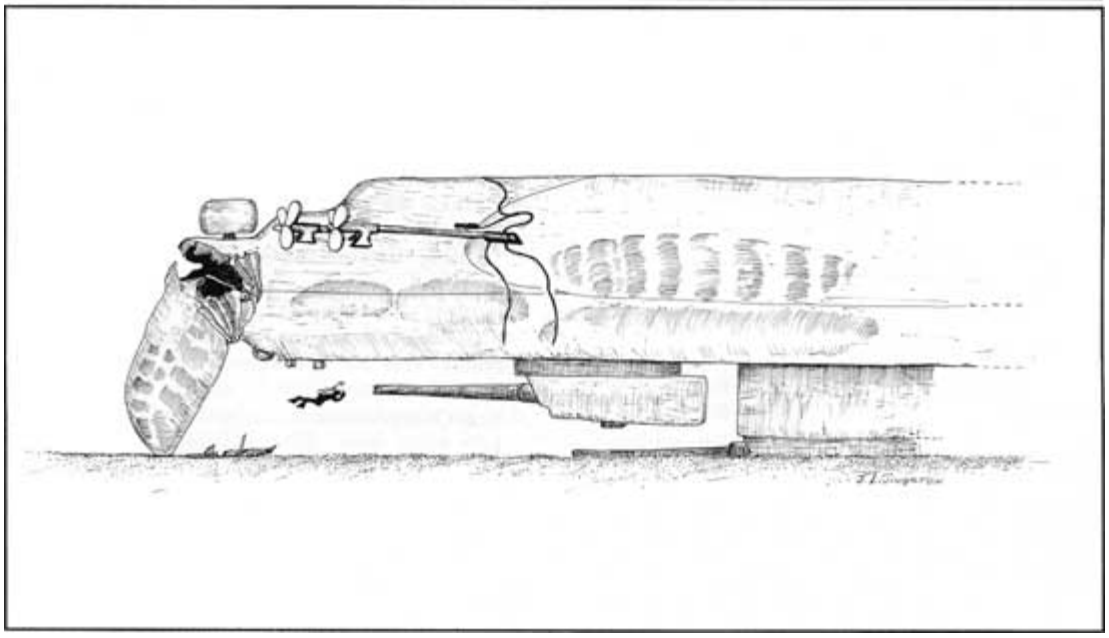

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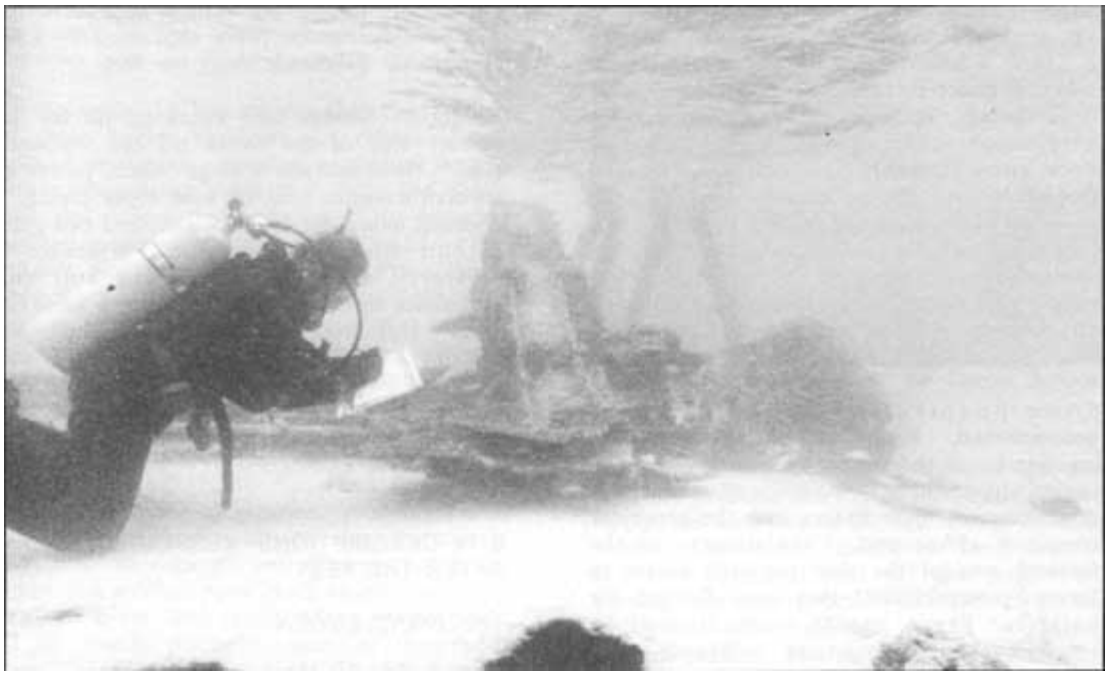


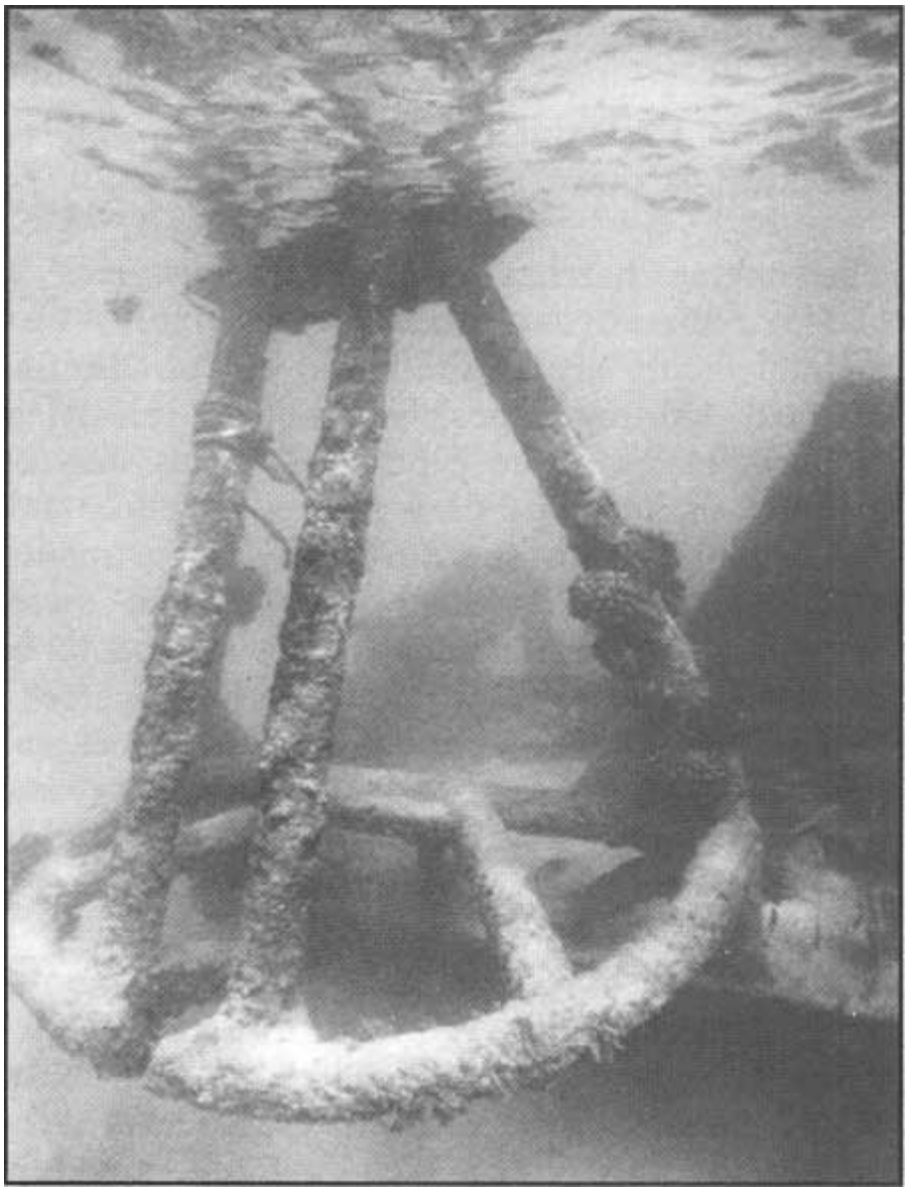


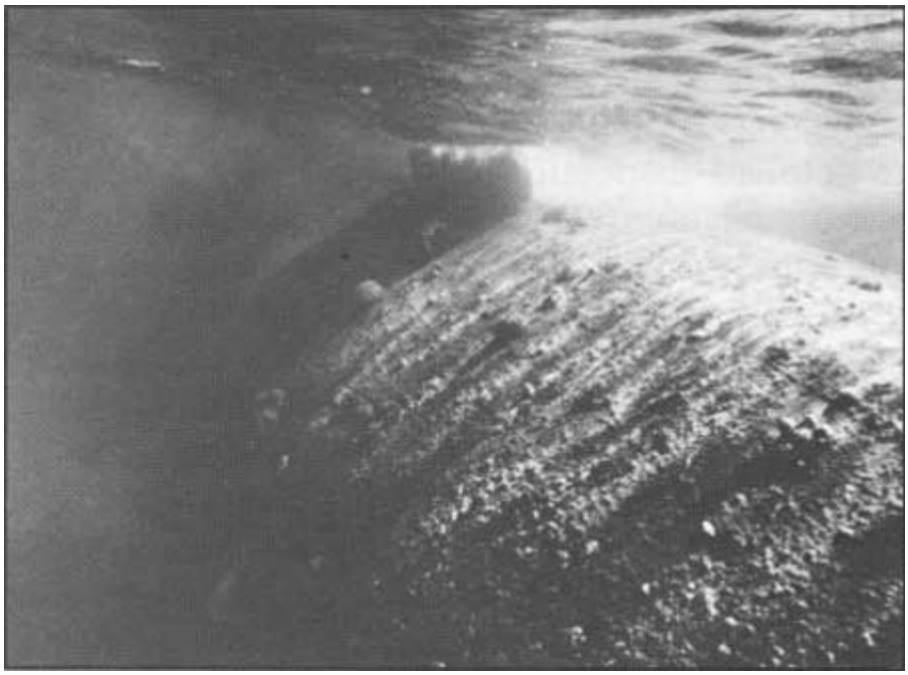




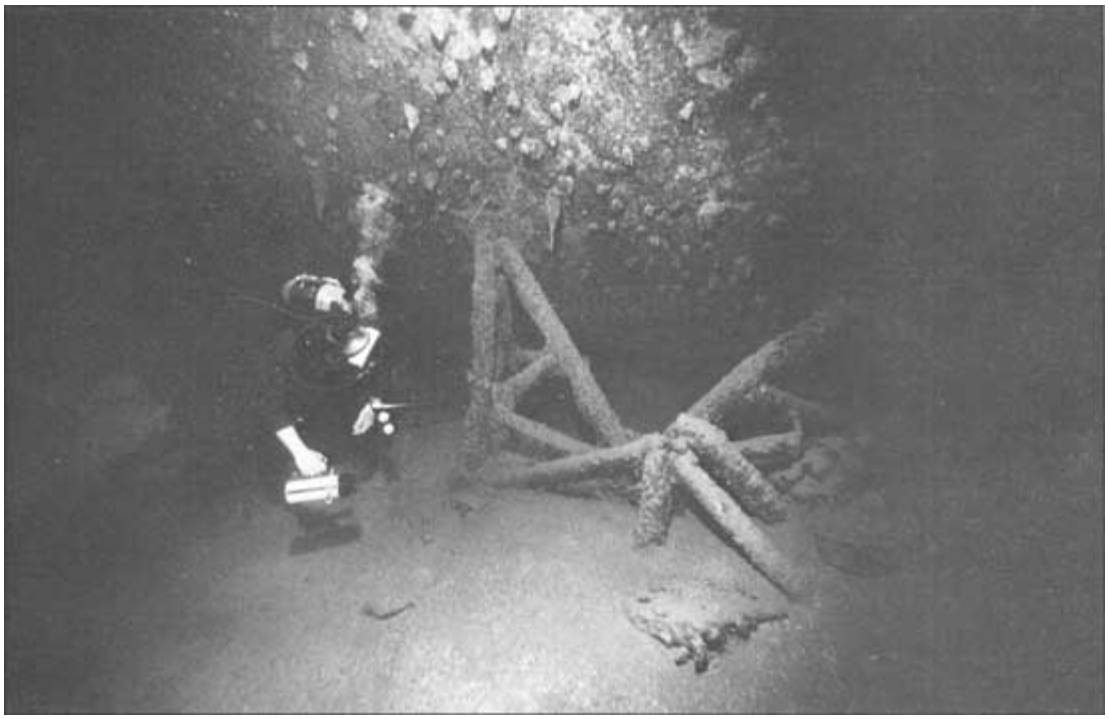








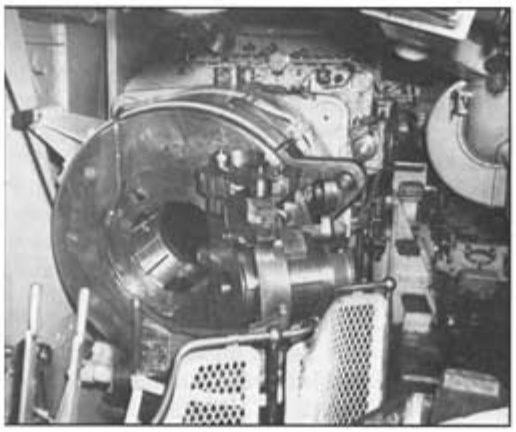


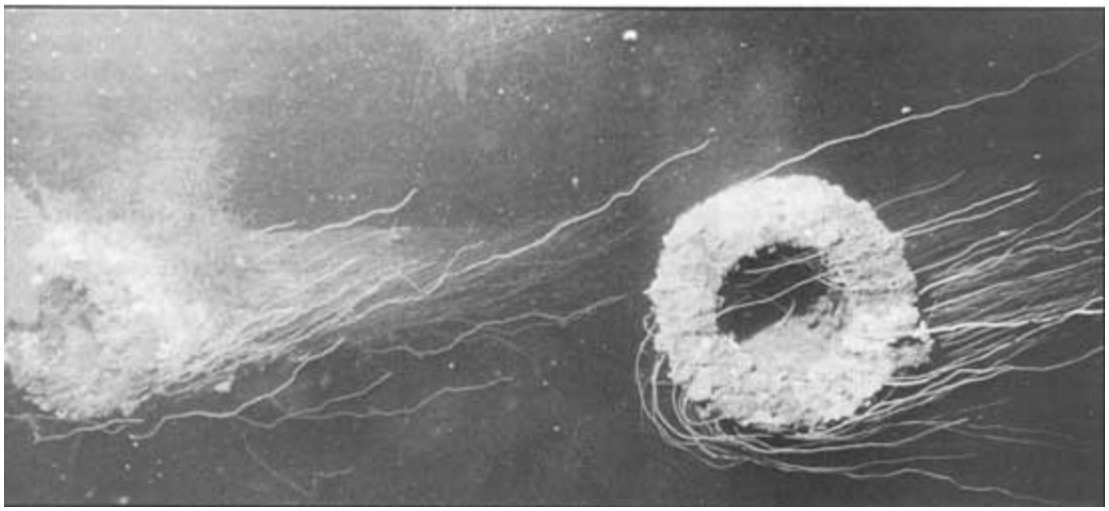



KEEP CLEAR
DANGER!
VERY RADIO-ACTIVE



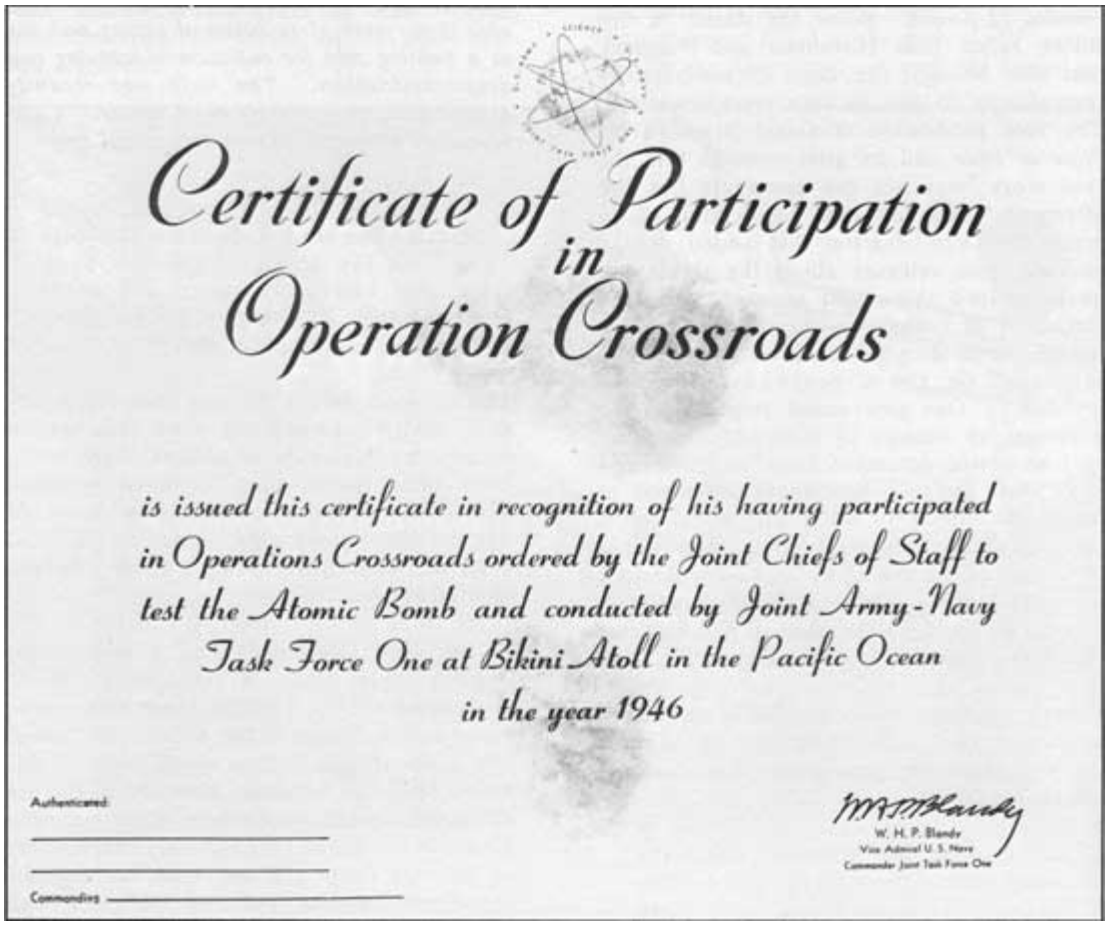












Certificate of Participation in Operation Crossroads

is issued this certificate in recognition of his having participated in Operations Crossroads ordered by the Joint Chiefs of Staff to test the Atomic Bomb and conducted by Joint Army-Navy Task Force One at Bikini Atoll in the Pacific Ocean in the year 1946

Authenticated:

_____

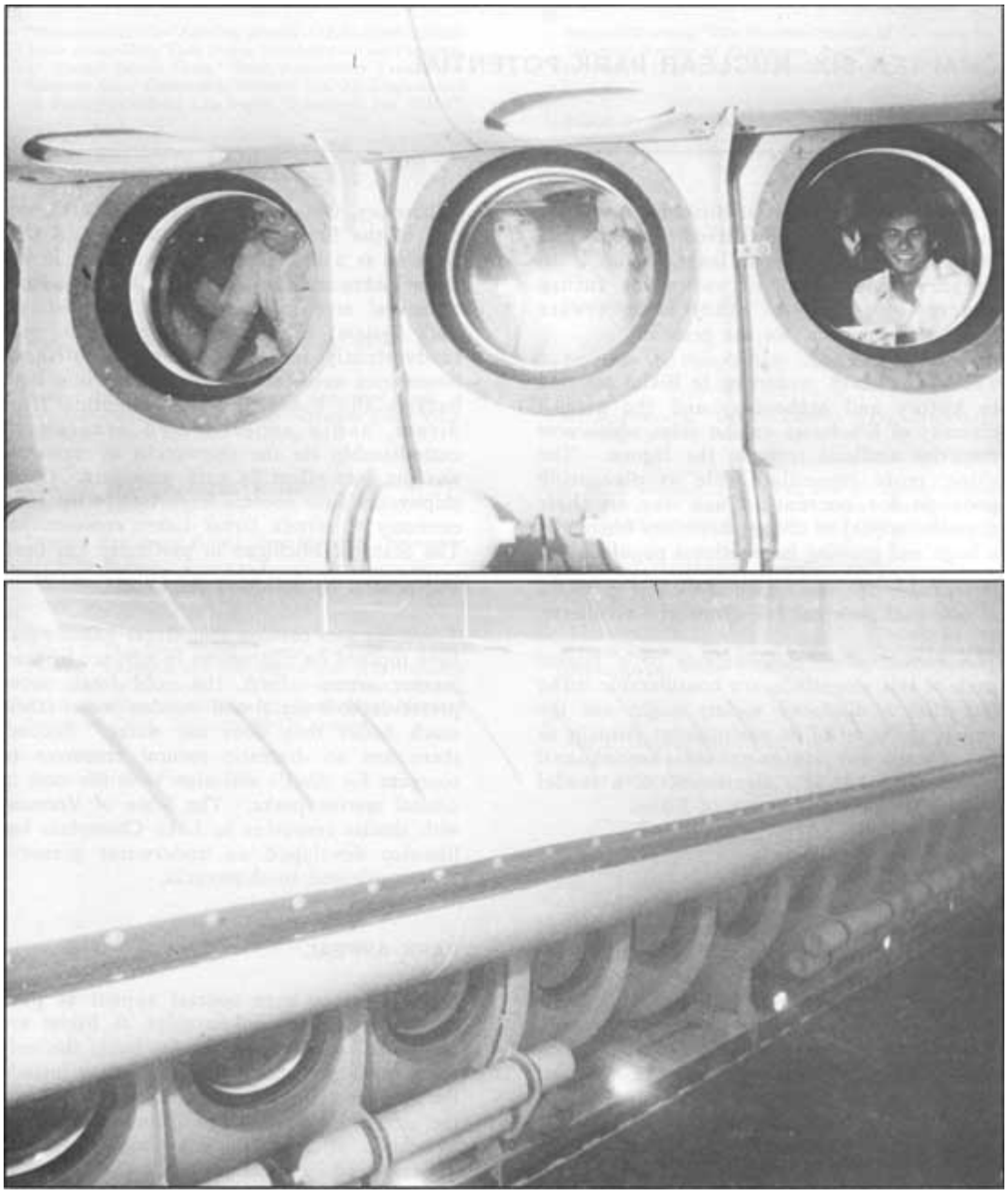
_____

Commanding _____

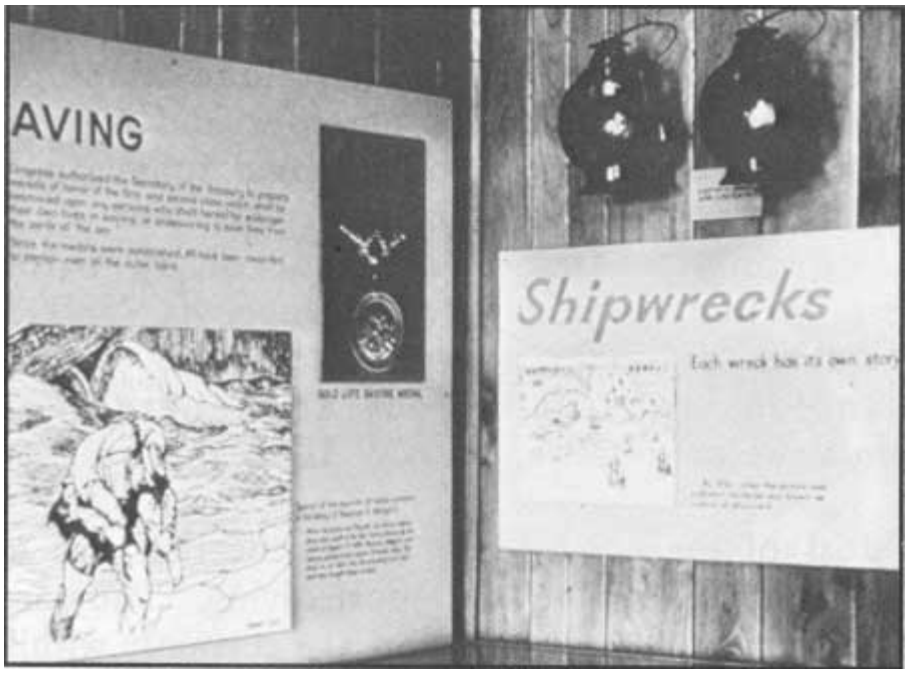
W. H. P. Blandy
Vice Admiral U. S. Navy
Commander Joint Task Force One

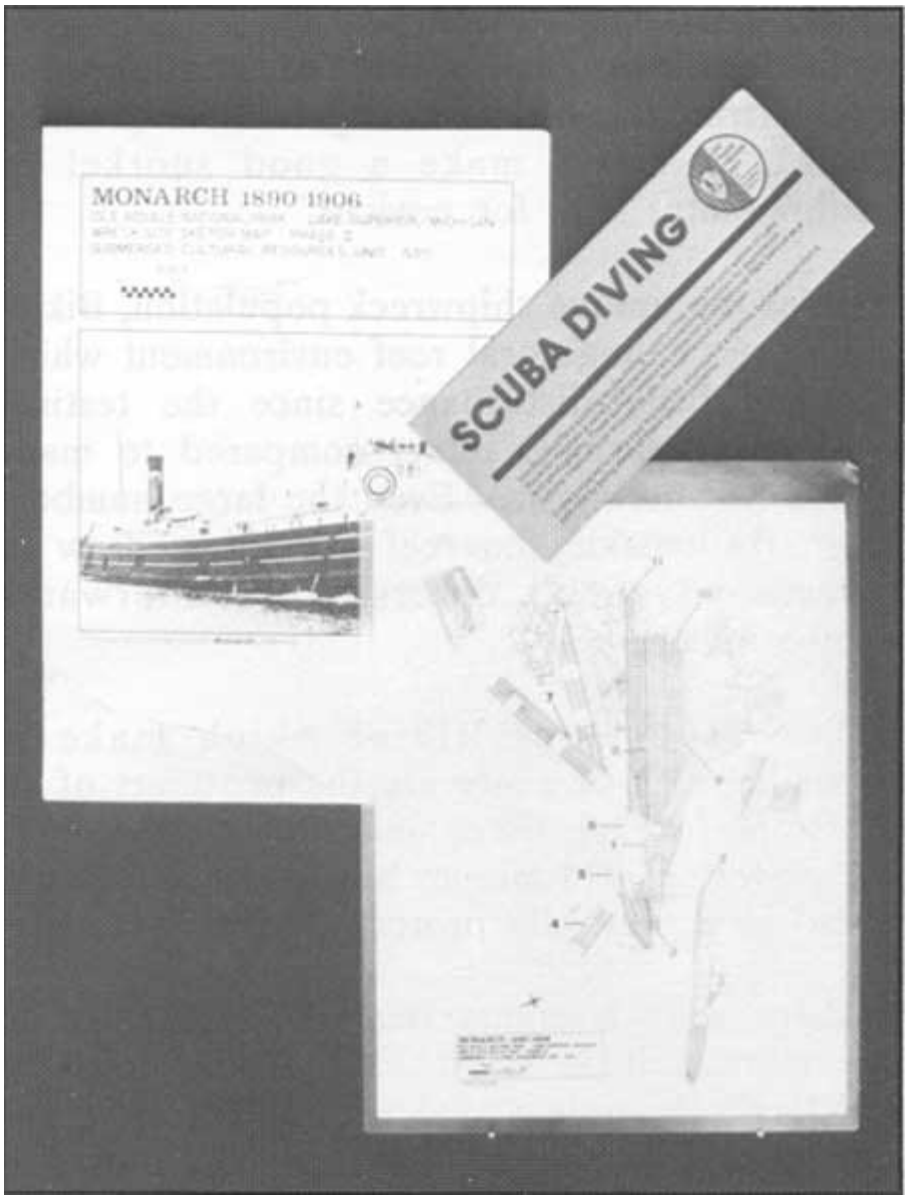
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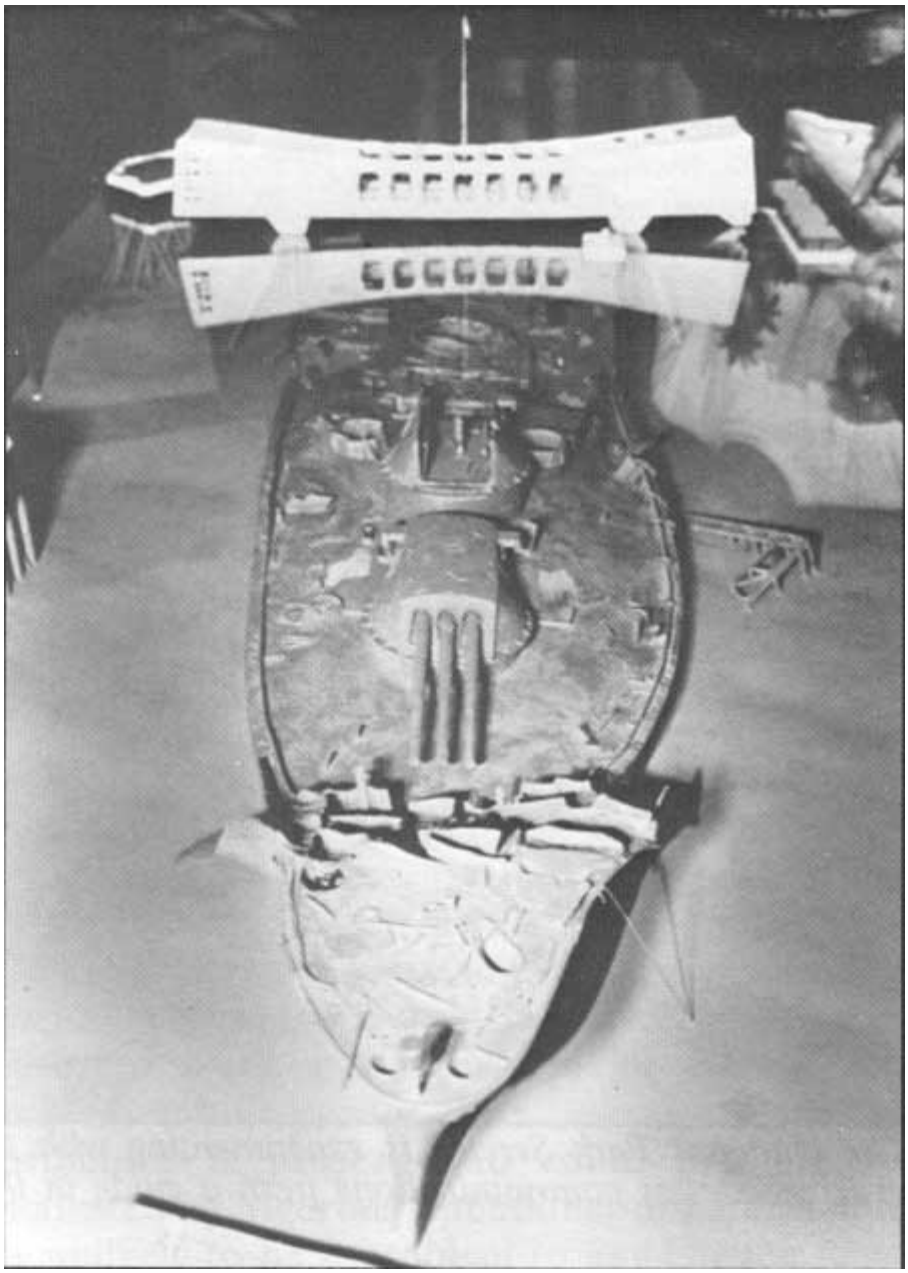



DESTRUCTION
Storms, boring organisms, and
some fishes break down coral
colonies into fragments.

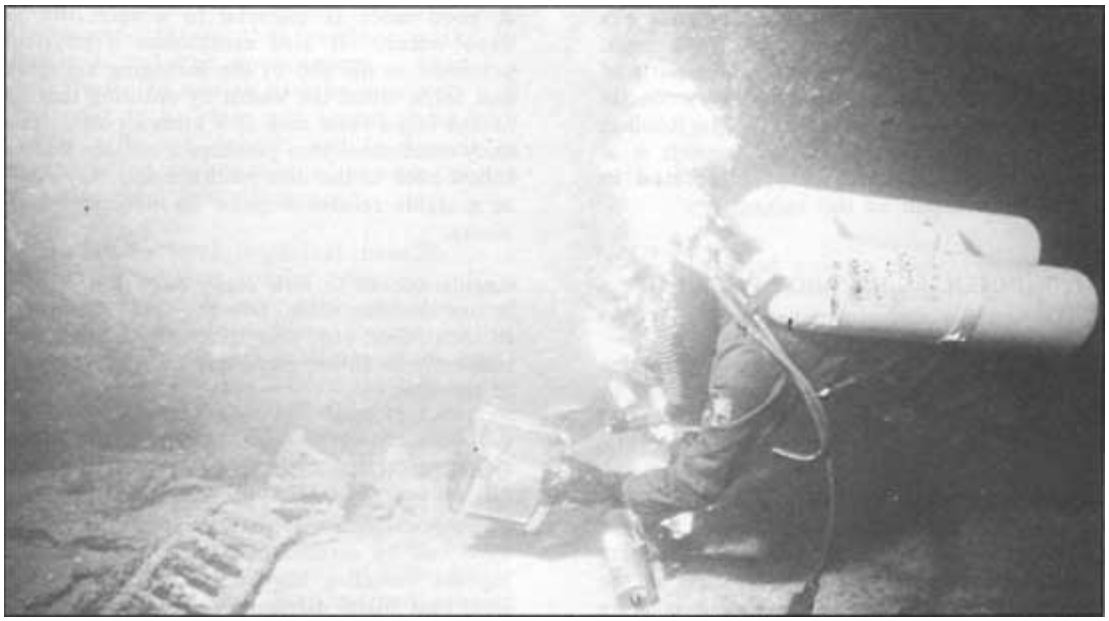

AVING
Shipwrecks


MONARCH 1890 1906
SCUBA DIVING

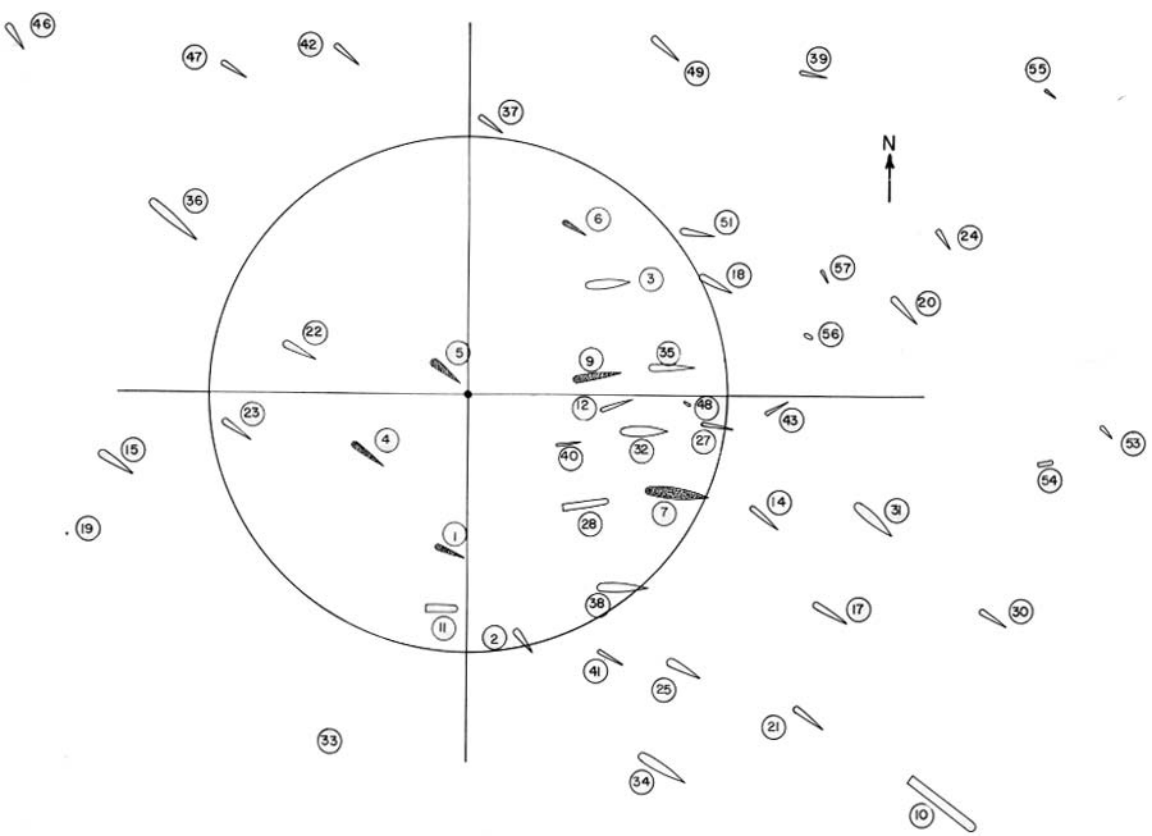

MONARCH

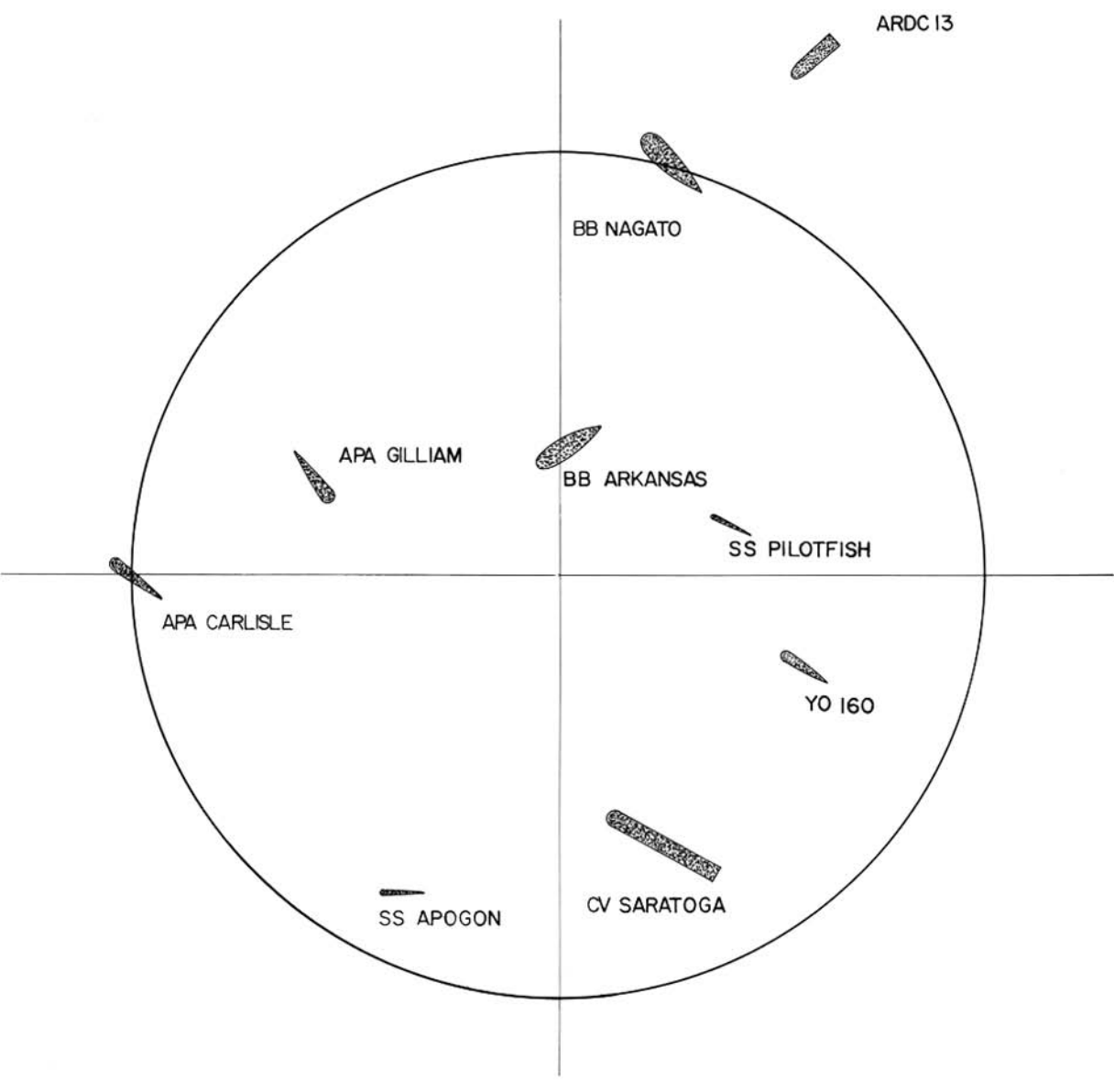




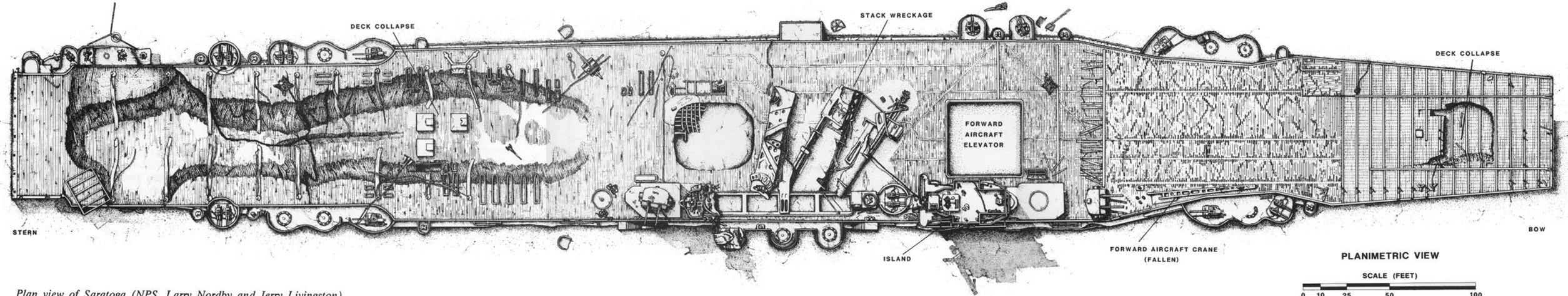



ISLE ROYALE NATIONAL PARK
NOTICE
This mooring was installed to provide safe diving and to minimize damage to submerged cultural resources by eliminating anchoring within the shipwreck area.
1. All divers must pre-register at any Ranger Station.
2. At least one capable operator should remain on the dive boat at all times.
3. Use of this mooring buoy is limited to registered divers during actual dive operations; not to be used overnight, during rough seas, high winds, or while fishing.
4. No more than three (3) boats at any one time on the mooring.
5. Check mooring lines and hardware during descent.
6. All shipwreck features, parts, artifacts, and debris are protected by Federal law. Please leave these for others to enjoy.
7. Report all diving accidents or illnesses immediately to park rangers. They can provide emergency care and arrange for transport to recompression chambers.

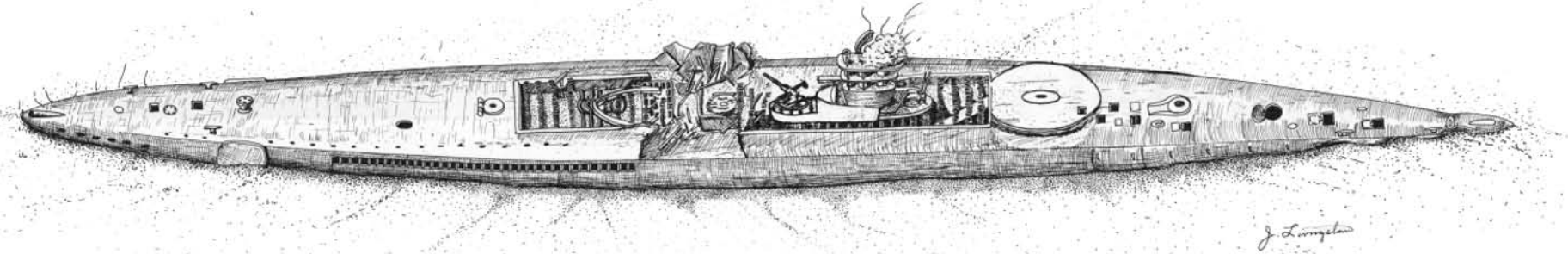

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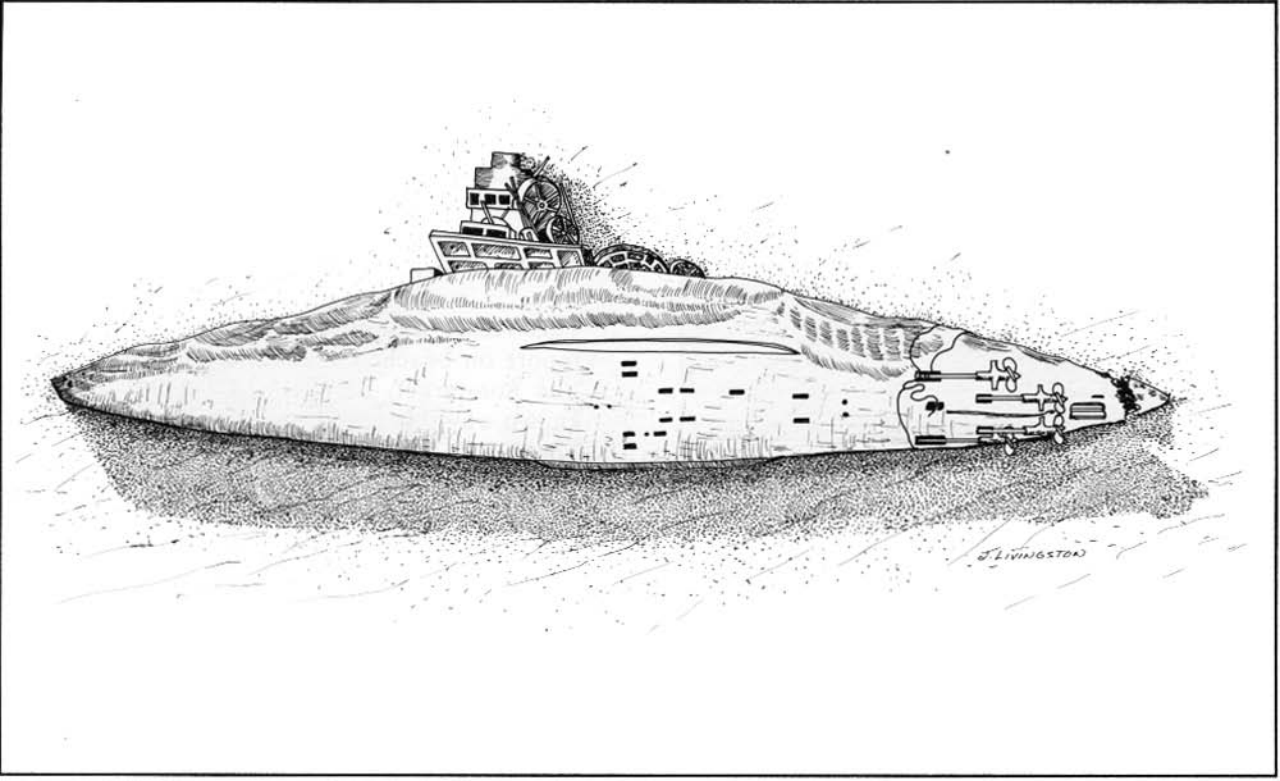

ARDC 13
BB NAGATO
APA GILLIAM
BB ARKANSAS
SS PILOTFISH
APA CARLISLE
YO 160
CV SARATOGA
SS APOGON

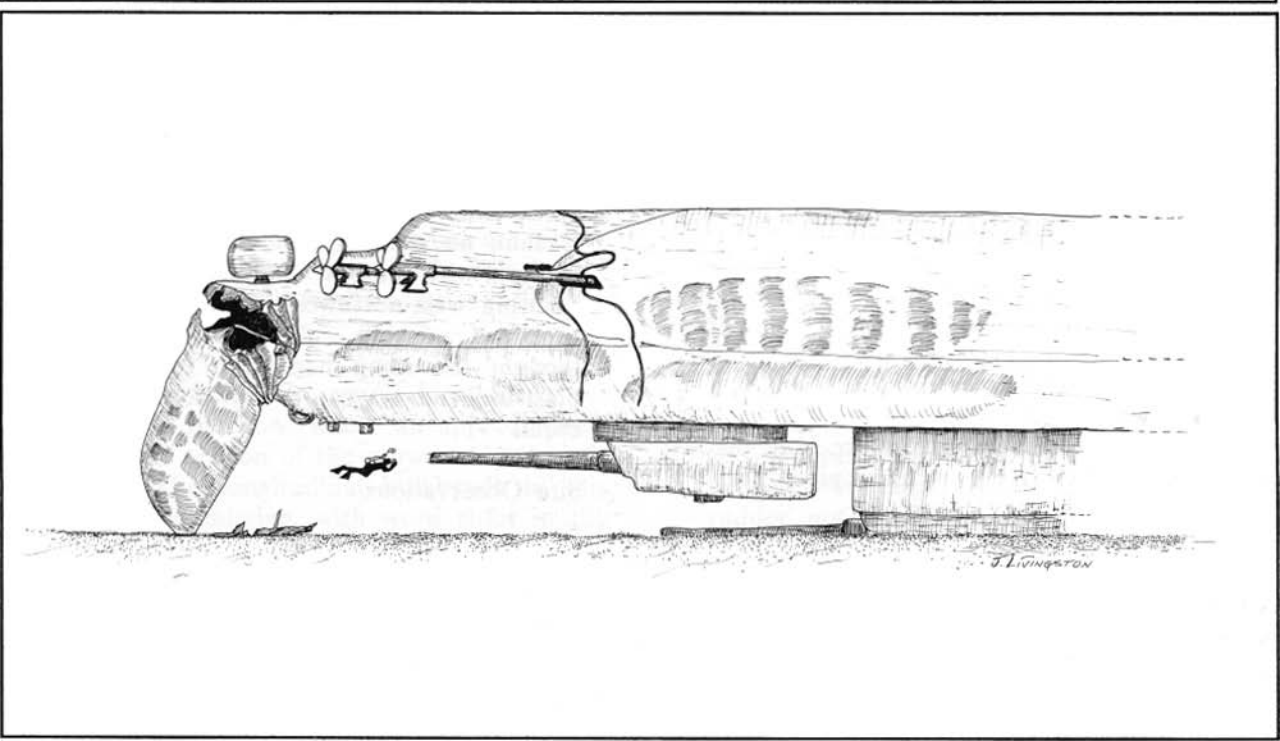




Plan view of Saratoga (NPS, Larry Nordby and Jerry Livingston)




J. LIVINGSTON


J. LIVINGSTON