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:
A SUBMERGED CULTURAL RESOURCES ASSESSMENT OF THE
SUNKEN FLEET OF OPERATION CROSSROADS
AT BIKINI AND KWAJALEIN ATOLL LAGOONS
REPUBLIC OF THE MARSHALL ISLANDS

Prepared for:
The Kili/Bikini/Ejit Local Government Council

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Submerged Cultural Resources Unit
National Maritime Initiative
United States Department of the Interior
National Park Service

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FOREWORD

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.

[Signature]

July 8, 1991
ACKNOWLEDGEMENTS

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 “Alma” Brown, Holmes and Narver representative on Kwajalein, and its resident 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 Natrass, Fred Hansen, Warren Shilton, Edward Malteba, John Lapan, Roger Joel, Thompson Johnson, Harry Hudson, Wilma Riklon, and Kane Izno provided invaluable assistance. The 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 George Ferris, Deputy Assistant Director Rowland T. Bowers, Chief Anthropologist Doug Scovill, and Chief Historian Edwin C. Beaus 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. Philip 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 Beatty, commander of the Eleventh Ordnance Disposal Unit One, Detachment 63, at Pearl Harbor, as well as by the men of MDSU 1 and BOD Mobile Unit One in locating the target ships, buoying them, rendering 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—a critical piece of information. In 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" Headerson, Albuquerque, New Mexico, the third engineer of the Los Alamos Group at Crossroads; Leon D. Smith, also of Albuquerque, the "Able" weaponer; 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 Pueblo. B. J. Dorman, Museum Director, and Jeffrey L. Crawford, Assistant Museum Director for the Pacific Fleet Submariner Memorial Association, provided material on Pueblo, Pacific,aine-class submarines, JP mine, and 20 and 40mm weapons, as well as an informative tour of USS Beaufort (SS-287) in Honolulu, Hawaii. Sue Moss and Carolyn Schaller 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 Shipyards 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, now a survivor of the Independence-class carriers, shares a common origin with Arkansas—both were built at the same yard, and more importantly, were converted from cruiser hulls. Timothy Romano, master of USS Attaol (DD-641) in Baton Rouge, Louisiana, provided a tour of his destroyer that greatly assisted our understanding of Arkansas and Lamson; among the bonuses of the tour was a greasy but informative tour of 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 Diamante, Superintendent, White Sands National Monument, Harry 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 Jackson 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 ship prior to the tests, such as Arkansas' 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 Pueblo, who put us in touch with the other skippers of the target submarines at Bikini. Joe Petersen, one of Saratoga's ship's photographers, loaned his postwar "mugbook" and history of Saratoga and several original photographs of Saratoga'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 are 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 trials 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 West 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.
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. 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 natural 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, represented 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 by 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 residing from the U.S. nuclear testing program in the northern Marshall Islands between June 30, 1946, and August 1, 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 determined. 

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 weapon 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 Test Site.

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 cables 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 remain 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 midship 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 historic significance.

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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 Scion 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 historic significance, marine park potential, and diving hazards associated with the sunken
Commander David McCampbell, USN (left), led the Navy effort to locate and plot the wreck locations. (NPS, Larry Murphy)

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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 expertise 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.

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 Archaeologist Larry E. Murphy; Archivist 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 Pn"nz 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 capsize and sinking of Pn"nz 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) in Bikini; a lesser degree of documentation was achieved for the battleships Nagato and Arkansas (BB-35), the submarines Pigeon (SS-91) and Proteus (SS-399), VO 160, LCT 1375, LCM-A, and the attack transports Gillow (APA-57) and Cerfia (APA-49) at Bikini, as well as the cruiser Pawi Fugue at Kwajalein. In every case, the NPS found sufficient cause to determine that these vessels are indeed historically and archaeologically significant.

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 showing Saratoga's last pre-Crossroads refit at Bremerton Naval Shipyard in May 1945 were 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 obtained 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 these conjectural drawings were carried on each dive by the illustrators and altered to fit the archaeological 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 utilized with a microphone that permitted the diver to speak directly onto a videotape as he panned the site with the camera. This permitted on-site 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 processes. 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.

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 reliability 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 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 advantages obtained in the dives was taken principally as 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.

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 decompression chamber. During the 1990 field session no Navy medical facilities or chamber were available, so evacuation to Kwajalein would have been necessary.

![Image of divers](image.png)

The depth at which the wrecks lie, and the amount of time required for successful observation and documentation compelled lengthy oxygen decompression times. (NWS Larry Murphy)
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.
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 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 reconnaitered 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 examined the more intact port side of the battleship at the 150-foot level and the bow at the 140-foot level.

August 23: A dive was made on Pueblo, 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 bow. 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 Prince Roger 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: Post-dive work was 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 launching ramp (depth of 120 feet). Fire-11-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, windlass and emergency radio compartments were penetrated.

May 3: Documentation of Saratoga continued. Arkansas was dived on and port casemate penetrated by Lenihan and Murphy at a depth of 175 feet. Wreck of LCM-4 snorkeld and
The Bikini Council used a dive team to participate in the documentation of the ships. Here, the team takes measurements to the corner of the blast gauge tower near Saratoga's division. (NPS, Larry Murphy)
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 dove 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 a car battery and oxygen. Lenihan was able to meet briefly with Bikini elders and Jack Niedenthal (Bikini Liaison) during layover of AMI flight on Enyu. Some of the project results including drawings were reviewed.
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 10:15 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
The 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.

The tests involved assembling a fleet of 242 ships, 42,000 men, 156 airplanes, and tons 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. 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.

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 specter 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 fear chills to the Cold War. General H. H. "Hap" Arnold, head of the U.S. Army Air Forces, was the first to publicly prophesy 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 1944, 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 probably well demonstrated the basic fact that the atomic bomb is too powerful a weapon to be left outside the confines of international control and that Operation Crossroads will simply underline this truth..." The commander of Joint Task Force One which conducted Operation Crossroads was Vice Adm. William Henry "Pappy" 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."
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 unequaled importance of the atomic bomb...shakes the very foundations of military strategy.

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 30, 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 anti-air attack against ships and to determine the effect of the atomic bomb upon military installations and equipment."

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:

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." 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 power 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.

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. 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. 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 for 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."

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 hulls, captured enemy vessels, and United States Navy combatant ships about to be stricken from the active list." 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. 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, Secretary Forrestal 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 prophesied 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 battlecruisers, for, if the atomic bomb works this way, they want to know it."

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 plan of the Underwater Explosion Program staff. 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." It was not until December 30, 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." 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 warships would lie in the unprecedented scale and world-wide importance of the tests." 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 expand three (the original number of planned detonations) of those 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 noted. 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 animals and inanimate things on it in the event that war comes again." 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
The Able Target Array, showing the actual point of detonation. Shaded vessels sank as a result of the blast.
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.
from secondary factors such as fires, and floods, and lack of food, over-exertion, and lack of medical attention.21

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 weapon 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."2a

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 (auxiliary), 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

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—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, 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, 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, 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, fuel oil, gasoline, water...Ships were loaded as closely as possible to the battle or operating
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. Other preparations included the establishment of vertical and horizontal reference lines for list and twist determination, installation of deck compression gages, 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." 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 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 watertightness to high-level decks and incorporate principles of longitudinal framing. Therefore, the final target array included the most post 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. 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. Four cruisers—two U.S., one German (Prinz Eugen), and one Japanese (Sakawa)—were included. The American-built ships were "excellent examples of proven riveted construction, with structure somewhat heavier than any cruiser 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." Sakawa was intended to sink, as was Nagato; both vessels were moored within a 1,000-yard perimeter of the designated zero point 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, was 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 extending 50 percent of the length. Few watertight platforms existed here and aft of the machinery spaces. The underwater protection was very similar in arrangement to that of modern battleships and large carriers. A laser bottom about the bottom shell was fitted between the innermost torpedo bulkheads for about 80 percent of the length. 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." 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." Three reinforced concrete vessels were used—ARDC-23, VO-160, and VO-83. These three vessels were selected for disposal 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. 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. Some vessels were individually selected because of age, previous battle damage, and, occasionally, to replace ships selected but not available. LCT-703 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." The selection of "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.

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. 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." 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 fullsize 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." 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 sold "the cost for at least 90 percent would be only their scrap value," which the admiral estimated at $100 million. 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 obsolete 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, and be towed back to the United States and sold as scrap. Still others may be placed back into service. . . . One letter writer wanted to place target ships in personal service: 15-year-old Max Ledewasser "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." 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, could be converted into temporary homes for veterans." 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 fullsize 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." 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 sold "the cost for at least 90 percent would be only their scrap value," which the admiral estimated at $100 million. 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 obsolete 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, and be towed back to the United States and sold as scrap. Still others may be placed back into service. . . . One letter writer wanted to place target ships in personal service: 15-year-old Max Ledewasser "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."
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....

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 prophesied 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 unreadied 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.

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." One writer suggested that "
Considerable protest arose over the exposure of animals aboard the target ships. Two goats aboard USS Ek?IZQZ (National Archives) 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

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 zero point 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 LCPs, one LST, one LSM, sixteen LCTs, seven LCUs, 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 notwithstanding, 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
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." The vessels were closely grouped together near the center of the array "because of the increase of pressure with increase in distance from the zeropoint." The test area 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." 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 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." 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 "Gilds" for the recent Rita Hayworth motion picture of that name, and stenciled 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 zero point, Nevada, probably because of, according to some experts, poor aerodynamics caused by its high-drag tail fin structure, detonating instead 2,130 feet directly above and 50 yards off the bow of the attack transport Gilliam. 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. 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 zero point along with destroyers (DD-410), which was among the more damaged destroyers and later required beaching to avoid its sinking, the bathyscaphes Aleutian and Nageo, ARDC-13, and VO-160, all badly torn and battered. The fears of the physicists opposed to the tests—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. The foreign observers were unimpressed, reported the press; the Russian observers shrugged their shoulders and the Brazilian observer said he felt "so so."

![Image of Able test bomb](Image)
about the blast. Of the 114 press representatives at Bikini, only 75 stayed for the Baker test.

Following the Able detonation, Navy teams moved in to fight fires, refuel 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." The first dives were made on July 1, 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 zero-point for the blast), and underwater photography continued until July 14, when attention turned to the preparations for the Baker test. 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." News reports and military and public interest focused on blast effect. The effect of radiation was largely ignored; a short news item filed by the Associated Press on July 13 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..." The scarcely noted account was a harbinger of the future.

![Image of a ship](image-url)
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 one of the test observers, the caisson was suspended 90 feet below the well in the steel landing ship LSM-60. 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, while 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 soil, pulverized coral and mud up to his armpits. The Baker blast—or the two million tons of displaced water from the cloud that fell back into the lagoon—sunk 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, recorded at a depth of 95 feet in a 100-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 San Jacinto, 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 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 Faison, 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 dismal means that would enable him to regain his sense 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." Laurence himself, as well as nearly everyone else involved in the tests, failed to realize or report the insidious effect of the bomb. For less than the actual blast, in that time of "limited and nuclear weapons, was the lasting effect of radiation, continuing once again the story and progress of the nuclear scientists that even seemingly "undamaged" vessels could and would suffer from radioactive contamination. Decontamination by scrubbing the ships "clear" 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, failing the intensity to vary a great deal in a matter of feet. One got the impression that fission products had become most fined in the Terry making of the plumbing...and even spots in the metal plates. When the survey was complete the Chief turned his boot, swearing, profane and laughing crew loose with brushes, water, and a barrel of lys. Yet when the hydrants were done and the deck rinsed clean again, another survey showed the invisible emanations to be present... The petty 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?"

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 Faison, which were sinking, but both vessels were radioactive to the extent that taking them in tow required fast work. The Sarcophagus, for example, had a tolerance time of about eight minutes. 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! 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."78

Radioactive material adhered to the ships' wooden decks, paint, tar, curves, 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 boiling brass and copper with salt water. 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."78

"Lightly" contaminated ships—Conyngham,
Wainwright, Carteret, and Salt Lake City—were the first vessels subjected to "detailed decontamination" on July 30.

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 decontaminated 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 were one of the most poisonous chemicals known, their presence was considered a serious and indeterminate menace." The priority of work shifted "toward recovery of instruments and clearance of those ships designated for use in Test Charlie." 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 "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. Botta, 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."

Gross decontamination efforts continued that enabled the Navy to complete the renewal of test instruments and records, technical inspections, and salvaging operations; however, the report on radiological decontamination concluded that these efforts, "although successful to a certain extent in the limited applications they received, revealed conclusively that removal of radioactive contamination of the type encountered in the target vessels in Test Baker cannot be accomplished satisfactorily."

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." 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 destructor 

Some of the 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. 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 aimed 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, focused nuclear deterrence through the adoption of and subsequent escalation of use of nuclear weapons at sea as a defense.

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.

A confidential memorandum from the Commander in Chief, Pacific Fleet, (CINCPAC), dated September 4, 1946, authorized the sinking of contaminated vessels at Kwajalein. The same day, Admiral Blandy, back in Washington, reported that "only 9 of 92 ships escaped at Bikini," noting that "93 but nine...were either sunk, damaged or contaminated by radioactivity, naming the submarines 

31
Parche, and the transports Godfrey, Niagara, Blake, 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

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 that they 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 1946 all these were towed to sea and sunk as targets in deep water. Fifty of the target vessels were sunk as targets for conventional weapons (fierce bombardment and aerial attack); 56 were sunk in the vicinity of Kingkini. New York and Nevada were sunk off Hawaii in deep water. Hughes and Pensacola were sunk off the Pacific coast of Washington, and Independence, Casablanca, 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—Currituck, Wilmington, Geneva, and Niagara—were transferred to the Maritime Commission and ultimately scrapped by them. The fate of 13 landing craft (five LCMs, three LCMS, and five LCVPs) is unknown. 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 fleet 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 poorer 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.

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 radiative contamination. Blast effect, while impressive, paled next to radiation effects. "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, atomic bombs not only can nullify any nation's military effort, but can annihilate its social and economic structures and prevent their re-establishment for long periods of time. With such weapons, especially if employed in conjunction with other weapons of mass destruction, it is quite possible to depopulate vast areas of the earth's surface, leaving only vestigial remnants of man's material works.

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 fleet of ghostly radioactive ships..." 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 sharpened as gross
outlines...the real problem; nevertheless, these outlines show pretty clearly the shadow of the colossus which looms behind tomorrow. Bradley also was drawn to the analogy of the target ships at Kwajalein, including "the beautiful Prinz Eugen, once the pride of the German fleet 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." 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 65 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." 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 wrecks from the nuclear test 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 Rongelip 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 universe they are no different from us all." 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." 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." 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. 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."
The Bikini Scientific Resurvey team lands at Bikini, 1947. (U.S. Navy photograph)

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 Pilotjish 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." 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 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." More than 600 dives were made to study blast effects and damage on the wrecks of Saratoga, Apogon, and Nagato. In addition, a recovery inspection was made of the ex-Japanese battleship Nagato. The first dives made were on July 77, 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..." 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." Radiation levels recorded ranged from "two times background (gamma) to 6 R/hr. (gamma), and up to 6 R/hr. (beta and gamma)." 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 usual powder from the smashed ships and sand from the lagoon bottom."

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." 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, "post 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 add materially to the information at hand concerning the air blast in shot Baker. 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." 

At the end of August, packing of equipment began for departure. Laboratories ashore were closed and packed by August 27, and the buildings 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 finished the 10th.

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.

NOTES
4 Shurcliff, Bombs at Bikini, p. 36.
5 Ibid., p. 3.
8 Daly, Ibid., p. 70.
9 Ibid., p. 7.
10 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. Signed on July 1, 1946, the bill was signed into law by President Harry S. Truman on August 1.

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, Marahau, and Nagasaki came as soon as active material and other components were ready—no earlier detonation was ever possible.

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.


43 The New York Times, April 17, 1946, p. 3.
44 Letter, Brig. Gen. T. J. Betts, USA, to Alexander White, April 1, 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.
47 Letter, Brig. Gen. T. J. Betts, USA, to Peter Brambir, March 21, 1946, filed in Protest Answers, National Archives Record Group 374.
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.
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.
57 Ibid., pp. 44-45.
59 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 human-like process that began with the "Fat Man" and continued with "Fat Boy" and "Fat Cat."" The name for the female bomb was the result of a contest sponsored by Hollywood, and the title "Helen of Bikini" was chosen for its potential to "humanize" the bomb through romantic associations. The name "Bikini" was used to "humanize" the bomb further, and the famous原子泳衣 "Atome" (quickly dubbed the "Bikini" when introduced in 1946) and the 1947 pop song "Atom Bomb Baby," which became popular due to its catchy and memorable title.
60 Shurcliff, "Technical History," p. 6.7. Also see "Helen of Bikini," Time Magazine, August 5, 1946, p. 27.
61 Hansen, U.S. Nuclear Weapons, p. 31. The commander of the Composite 509th Group, which dropped the bomb, blamed the late run on crew error. See Paul Tibbets, The Tibbets Story (New York: Stein and Day, 1978), p. 140. 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 bombmaker, Harold Wood, and post-Abel tests with the same crew and bomb that consistently dropped "Fat Man" except close to the target.
63 Ibid., p. 3.
65 Ibid., pp. 44-45.
67 The New York Times, July 1, 1946, p. 3.
69 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 human-like process that began with the "Fat Man" and continued with "Fat Boy" and "Fat Cat."" The name for the female bomb was the result of a contest sponsored by Hollywood, and the title "Helen of Bikini" was chosen for its potential to "humanize" the bomb through romantic associations. The name "Bikini" was used to "humanize" the bomb further, and the famous atomic swim suit "Atome" (quickly dubbed the "Bikini" when introduced in 1946) and the 1947 pop song "Atom Bomb Baby," which became popular due to its catchy and memorable title.
70 Shurcliff, "Technical History," p. 28.7. Also see the Washington Star, August 22, 1946.
73 Director of Ship Material, "Technical Inspection Report: Radiological Decontamination of Target and Non-Target Vessels," Vol. I, p. 44. 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

74 "Radiological Decontamination of Target and Non-Target Vessels," Vol. II, No. 4, Fall 1988, p. 50.

75 Ibid., p. 51.

76 Ibid., p. 52.

77 Ibid., p. 53.

78 Ibid., p. 55.

79 Ibid., p. 56.

80 Ibid., p. 57.

81 Ibid., p. 58.

82 Ibid., p. 59.

83 Ibid., p. 60.

84 Ibid., p. 61.

85 Ibid., p. 62.

86 Ibid., p. 63.

87 Ibid., p. 64.

88 Ibid., p. 65.

89 Ibid., p. 66.

90 Ibid., p. 67.

91 Ibid., p. 68.

92 Ibid., p. 69.

93 Ibid., p. 70.

94 Ibid., p. 71.

95 Ibid., p. 72.

96 Ibid., p. 73.

97 Ibid., p. 74.

98 Ibid., p. 75.

99 Ibid., p. 76.

100 Ibid., p. 77.

101 Ibid., p. 78.

102 Ibid., p. 79.

103 Ibid., p. 80.

104 Ibid., p. 81.

105 Ibid., p. 82.

106 Ibid., p. 83.

107 Ibid., p. 84.

108 Ibid., p. 85.

109 Ibid., p. 86.

110 Ibid., p. 87.

111 Ibid., p. 88.

112 Ibid., p. 89.

113 Ibid., p. 90.

114 Ibid., p. 91.

115 Ibid., p. 92.

116 Ibid., p. 93.

117 Ibid., p. 94.

118 Ibid., p. 95.

119 Ibid., p. 96.

120 Ibid., p. 97.

121 Ibid., p. 98.

122 Ibid., p. 99.

123 Ibid., p. 100.

105 Ibid., p. 2.
106 Ibid.
### TABLE ONE: SHIPS LOST DURING OPERATION CROSSROADS TESTING AT BIKINI ATOLL LAGOON

<table>
<thead>
<tr>
<th>CLASS</th>
<th>SHIPS Lost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIRCRAFT CARRIERS</strong></td>
<td></td>
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<tr>
<td>BAKER TEST:</td>
<td>USS <em>Sumfoga</em> (CV-3), <em>Lexington</em> Class</td>
<td></td>
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<tr>
<td><strong>BATTLESHIPS</strong></td>
<td></td>
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<tr>
<td>BAKER TEST:</td>
<td>USS <em>Arkansas</em> (BB-33), <em>New York</em> Class</td>
<td></td>
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<tr>
<td></td>
<td><em>HiJMS Nagato</em>, <em>Nagato</em> Class</td>
<td></td>
</tr>
<tr>
<td><strong>CRUISERS</strong></td>
<td></td>
<td></td>
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<tr>
<td>ABLE TEST:</td>
<td><em>HiJMS Jisshu</em>, <em>Agnus</em> Class</td>
<td></td>
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<tr>
<td><strong>DESTROYERS</strong></td>
<td></td>
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<tr>
<td>ABLE TEST:</td>
<td>USS <em>Anderson</em> (DD-411), <em>Shio</em> Class*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USS <em>Lexun</em> (DG-907), <em>Mahan</em> Class*</td>
<td></td>
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<tr>
<td><strong>SUBMARINES</strong></td>
<td></td>
<td></td>
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<tr>
<td>BAKER TEST:</td>
<td>USS <em>Apogon</em> (SS-388), <em>Relco</em> Class</td>
<td></td>
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<tr>
<td></td>
<td>USS <em>Pingfish</em> (SS-536), <em>Relco</em> Class</td>
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<td><strong>TRANSPORTS</strong></td>
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<tr>
<td>ABLE TEST:</td>
<td><em>Gilliam</em> (APA-87), <em>Gilliam</em> Class</td>
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<tr>
<td></td>
<td><em>Carlisle</em> (APA-59), <em>Gilliam</em> Class</td>
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<tr>
<td><strong>AUXILIARIES AND LANDING CRAFT</strong></td>
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<td>BAKER TEST:</td>
<td>ARDC-13 LCM-4</td>
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<tr>
<td></td>
<td>LCT-414 (scuttled after)</td>
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<tr>
<td></td>
<td>LCT-312 (scuttled after)</td>
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<tr>
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<td>LCT-314</td>
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<tr>
<td></td>
<td>LCT-1175</td>
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<tr>
<td></td>
<td>LCT-1357 (scuttled after)</td>
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<tr>
<td></td>
<td>LCT-1257 (scuttled after)</td>
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</tr>
<tr>
<td></td>
<td>LCM-01 (completely destroyed)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>YO-100</td>
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TABLE TWO: VESSELS LOST INSIDE KWAJALEIN ATOLL LAGOON IMMEDIATELY AFTER THE CROSSROADS TESTS CURRENTLY AT DEPTHS ACCESSIBLE TO SCUBA

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

LANDING CRAFT
LCI-327

Boldface indicates this vessel was documented by NPS SCUBA 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.*