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OPERATION DOMINIC, SHOT SWORD FISH

Scientific Director's Summary Report

W. W. Murray, Scientific Director
David Taylor Model Basin
Washington, DC

21 January 1963

NOTICE:
This is an extract of POR-2007 (WT-2007), Operation DOMINIC, Shot Sword Fish.

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Sword Fish was an underwater weapon-effects test and was the first occasion in which the Navy's Antisubmarine Rocket (ASROC) weapon system was used to deliver a nuclear depth charge.

This report describes the overall test effort, provides general information on conditions prevailing at the test site near burst time, and summarizes the project results as understood within a few weeks of test completion.

The primary significance of Sword Fish, from the viewpoint of a ship delivering an ASROC nuclear depth charge is to provide information bearing on: (1) mechanical damage to the ship (caused by underwater shock waves); (2) personnel injuries (caused primarily by gamma-ray sources carried in the base surge); and (3) restrictions on ship maneuvers (due to contaminated water and sonar masking).

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OPERATION DOMINIC

SHOT SWORD FISH

SCIENTIFIC DIRECTOR'S SUMMARY REPORT

W.W. Murray, Scientific Director

David Taylor Model Basin
Washington 7, D.C.

ABSTRACT

Sword Fish weapon effects objectives may be divided into two groups: those connected with onsite efforts and those connected with offsite efforts. The term "onsite" refers to activities conducted within a radius of 12 miles of surface zero on test day.

The short term objective of onsite efforts was to secure weapon-effects information bearing on the establishment of a tactical doctrine for nuclear warhead delivery. Specifically, this information will help to: (1) determine the minimum delivery range at which an ASROC destroyer (DD) can make an attack and retain its capability of mounting an immediate re-attack (from the viewpoint of both equipment and personnel); (2) determine the minimum emergency delivery range at which an ASROC DD can make an attack and retain its mobility with possible weapon system equipment failures and personnel casualties; and (3) determine the restriction which an ASROC attack places on the later tactical maneuvers of a ship because of radiation hazards or deterioration of sonar conditions.

The long term objective of onsite efforts was to enhance the general fund of information on effects on nuclear underwater explosions. Specifically, this information will help to:

(4) determine safe standoffs for delivery of underwater nuclear weapons by submarines; (5) establish reliable procedures for extrapolating to underwater nuclear bursts the statistically significant data on ship equipment damage gained from routine HE shock trials of operational ships.

Objectives of the offsite efforts were concerned with: (1) the effects of the burst upon strategic hydroacoustic detection systems (e.g., SOSUS) and the improvement of long range hydroacoustic theory; (2) the long-time drift and diffusion of radioactive contaminants left in the water after the burst and the effect of these contaminants on marine life; and (3) the detection and identification of underwater nuclear explosions.

Planning guidelines for the test were dominated by the short-term onsite objectives. The distinguishing feature of Sword Fish, as compared to previous underwater nuclear tests, was to be the inclusion of Navy ships, equipped with operational modern weapons, at ranges close enough to the burst to have tactical significance. Three FRAM-1 destroyers, equipped with the ASROC system, were to participate. One of these destroyers, Agerholm, was to launch the weapon from a distance slightly in excess of the minimum firing range. A second, Anderson, was to serve as a standby firing ship. The third, Bausell, was to be placed in tow, unmanned with its main machinery shut down but with selected weapon equipments operating in an unattended condition. The tow line also served the purpose of locating stations used to support underwater pressure gages and to measure surface radiation.

Technical project teams were formed, with DOD and AEC funding support totaling about 2-1/3 million dollars. These projects made their gages and recorders ready and shipped them to the forward area within 2-1/2 months, or less. This performance was possible largely because equipment previously employed in Operation Hardtack was available and could be readied for use. Photographic equipment, however, had to be borrowed from several different Navy sources; most of the cameras had to be modified to provide timing marks on the film.

The major portion of test preparations in the forward area took place in San Diego, California, from 19 April to 6 May 1962. This preparation involved construction of the towed array, shipboard installation of project equipment, ship inspections, modifications, and repairs and rehearsals at sea.

During the preparation period key ships were each subjected to the mildest HE shock trial of the type conducted routinely by the Bureau of Ships under OPNAVINST 09110.2A. A considerable number of shock-damaged items were found in each of the destroyers after these very mild attacks. Though the damaged items were individually insignificant they resulted in considerable impairments of the ASROC system, antiaircraft capability, and conventional ASW capability. Damage was repaired on shipboard prior to the nuclear test. A wide statistical variation in damage to apparently identical ships under identical attacks was demonstrated.

Two Operational Suitability Test (OST) weapons were fired at a range of 4,000 yards, one each from Agerholm and Anderson, as part of the rehearsals. Preliminary estimates of the burst depths are 650 and 675 feet. Missile delivery accuracy was checked in one of these firings: the surface zero position of the burst was about 240 yards beyond the target, roughly along the line of fire.

USS Agerholm launched a nuclear depth charge at the target raft in a lonely spot in the Pacific Ocean about 365 miles west of San Diego, California shortly after 1301 (local time) 11 May 1962. Test conditions prevailing at shot time were determined and are summarized below:

Nearly all measurements attempted during the ASROC test were secured. Information is in hand, at this writing, in most areas: surface phenomena, underwater pressures, ship shock motions, ship damage, base surge radiation, contaminate water pool, onsite sonar. In other areas, marine life and offsite hydroacoustics, a considerable amount of data was secured, but additional study is necessary before an intelligible picture of the results can be drawn. Highlights of the results in hand are summarized in Chapter 5 and, more briefly below.

The most prominent surface phenomena were: the spray dome, the plumes, base surge, and foam patch. The spray dome stretched over a radius of nearly 1,000 yards from surface zero and rose to a maximum height of about 750 feet in 6 seconds. Radial plumes of water broke through the spray dome 7 seconds after burst and reached a maximum height of 2,100 feet in 16 seconds, at which time they covered a radius of 600 yards from surface zero. The base surge, formed as the plumes collapsed, reached a maximum upwind distance of 2,000 yards 110 seconds after burst; at this time it stretched 2,000 yards crosswind and 2,500 yards downwind and was still expanding in these directions. The base surge settled and drifted with the wind; it remained visible for about 10 minutes but lingered as an invisible aerosol up to at least 20 minutes. The foam patch became visible as the base surge dispersed. It attained a radius of about 2,000 yards about 20 minutes after burst and subsequently lost its visible aspects.

Underwater pressure waves consisted of the direct shock wave and pressure waves reflected from the sea bottom. The direct shock wave was typical for an underwater burst and was refracted by the thermal gradient existing in the water. Consequently, its strength near the water surface diminished more rapidly with distance from the burst than it would have in isovelocity water. The bottom-reflected pressure wave had a complex history, undoubtedly due to multiple sea bottom layers. Moreover, it showed some asymmetry with respect to surface zero.

Shock motions were predominantly vertical in the key surface ships. In all cases except Bausell, the response to the bottom-reflected pressure wave was greater than that to the direct wave: in Bausell the responses were about equal. As usual for underwater nuclear bursts the peak vertical velocities measured at ship bulkheads were about equal to the peak bodily velocity. The peak bodily velocities of key ships were: In Bausell about 1 ft/sec after both the direct and reflected pressure waves, in both Agerholm and Anderson about 0.5 ft/sec after the reflected pressure wave.

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Gamma radiation measurements at stations within the base surge indicated intensities of many thousands of roentgens per hour. However, intensities fell off rapidly with distance from the edge of the base surge. Bausell, 2,200 yards upwind, was not enveloped by the base surge, which stretched along a radial line to the ship to within about 350 yards of the fantail: a finger reaching out on the windward side of the ship to about 2,000 yards may have come closer. A recorder on the fantail of Bausell showed a maximum intensity of 44 r/hr and a total dose of about 2 r; at other locations on Bausell, recorders registered much lower values. Bausell was not contaminated.

The water about surface zero was left radioactively contaminated after the collapse of the plumes. For at least 20 minutes, the boundary of this radioactive area is defined by the visible foam patch.

Certain aspects of the onsite results were explored with the aim of generalizing the results, to a limited extent, though not appreciably beyond Sword Fish conditions. Destroyers could have been located closer than 1,700 yards to the burst without sustaining any mobility impairment; however, complete impairment of weapon delivery capability would be anticipated. Destroyers proceeding at 20 knots, or more, could have been located as close as 1,600 yards upwind or crosswind, or 1,800 yards downwind, of the burst and maneuvered so as to remain at least 350 yards beyond the edge of the base surge. Such destroyers would not have been contaminated and their personnel would not have received radiation doses in excess of peacetime test limits. Comparison of the results with Shot Wahoo of Operation Hardtack indicates that the ship damage and radiation results will not be appreciably changed by variations in yield and burst depth within the limits natural to a properly functioning ASROC system.

Sword Fish was executed successfully, in both its operational and technical aspects. The ASROC system demonstrated its capability to deliver a nuclear depth charge. Associated technical measurements of good quality were secured, nearly to the fullest extent planned.

Weapon effects conclusions apply to ASROC burst conditions. These conditions are a slight generalization of the Sword Fish conditions and encompass small variation resulting from a properly functioning ASROC depth charge fuzing system. Specifically, ASROC test conditions apply to vields between

Page 14 deleted.

3.

Personnel exposure to radiation would be less than limits set for peacetime tests.

4. For about an hour after an ASROC burst the contaminated water left about surface zero will pose a radiological hazard of significance even under the exigencies of a wartime situation. In Sword Fish, Sioux entered the pool about 20 minutes after the burst and had to withdraw hastily, though she suffered no serious contamination problems.

3. Sword Fish re-emphasized the role of the base surge as a carrier of radioactivity. A ship which maneuvers, following an ASROC burst, so as to remain at least 350 yards from the edge of the base surge will not subject its personnel to radiation doses in excess of peacetime test limits. In Sword Fish the base surge remained visible for as long as 10 minutes; it settled and dispersed within about 30 minutes.

In Sword Fish, Sioux encountered an invisible aerosol at 20 minutes and personnel on the weather decks were contaminated, though decontamination was easily accomplished.

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2. The contaminated water pool produced by an ASROC burst drifts with the current while it diffuses and decays radioactively. This pool can be tracked for weeks. In Sword Fish the pool was tracked for more than twenty days; twenty days after the burst its center had drifted about 50 miles south of surface zero and maximum surface radiation intensity measured 0.04 mr/hr.

3. Considerable information was acquired, for study,

on the effects of the radioactive wastes on marine life.

4. Information on the long-range hydroacoustic signals produced by the burst was acquired from ship and shore stations. Analysis should enhance ability to detect and classify underwater nuclear explosions.

Several observations were brought to light during the planning and execution of Sword Fish, which bear on the performance of the ASROC system. These observations led to the following conclusions.

Some of the implications of the Sword Fish results for possible design changes in the ASROC system were explored. While any change in present ASROC design must result from a Navy policy decision, three conclusions were drawn which are believed to bear on this question.

1. Sword Fish results suggest that a minimum delivery range as small as 1,600 yards could be employed by a destroyer, if immediate re-attack capability is sacrificed.

2. A reduction in design burst depth is not desirable. Such a reduction will not increase safety to the delivery ships to a sure and significant degree under all operational conditions. Moreover, it appears that any appreciable reduction in design burst depth will lead to a serious degradation of

submarine kill probabilities, especilly in view of probable uncertainties in actually achievable burst depths.

3. Any appreciable reduction in delivery range should be accompanied by detailed reliable weapon-effects information in a form which is readily usable by the fleet under all operational conditions.

PREFACE

Sword Fish was an underwater weapon-effects test executed in the Pacific Ocean off the southwest coast of the United States in May 1962 as part of Operation Dominic. Sword Fish was conducted under the technical and operational cognizance of a JTF-8 Navy task group. This test was the first occasion in which the Navy's Antisubmarine Rocket (ASROC) weapon system was used to deliver a nuclear depth charge.

This report describes the overall test effort, provides general information on conditions prevailing at the test site near burst time, and summarizes the project results as understood within a few weeks of test completion. Details of the results have been published separately by the participating projects. The present report provides a timely evaluation of the significance of the test results. It is inevitable that the evaluation, particularly, reflect the personal opinions of the author; limited time does not permit solicitation of comments from the many participating project officers and their home agencies.

It is not intended to replace the present report with a later updated version. Final results will be published separately by the participating projects. Final conclusions, especially those pertinent to Navy tactical doctrine, can only be developed elsewhere after careful digestion of the results and their synthesis with the results of previous tests and studies.

Sword Fish owes such success as it had to the outstanding devotion to duty of personnel both within and without the Navy task group. To a considerable extent this success was due to the untiring efforts of the task unit commander, CAPT Benjamin R. Petrie. Many individuals freely supplied information which contributed greatly to the preparation of the present report. While it is not possible to give individual credit to each and every one, it is equally impossible to neglect mention of the heavy debt owing to the contributions of two members of the Scientific Director's staff: Mr. D. Schultz of the U.S. Naval Radiological Defense Laboratory and Mr. S. Klingman of David Taylor Model Basin.

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

Sword Fish was a nuclear weapon effects test designed to investigate the effects of a multikiloton yield underwater burst in deep water. The test was designed to maximize the chance of securing information from a shot in which the nuclear weapon was delivered by an operational system: the antisubmarine rocket (ASROC) weapon system. The primary test concept is best understood within the background context of the characteristic features of ASROC and the associated tactical delivery problem.

ASROC provides the Navy with a surface ship antisubmarine weapon system. The weapon system consists basically of a sensing element (primarily sonar), a fire control computer, a launcher, and rocket-propelled missiles. The missile payload may be either a nuclear depth bomb or a torpedo carrying a high-explosive charge.

Further information on ASROC is summarized in Appendix A.

The minimum delivery range, presently built into ASROC nuclear depth charges, undoubtedly reflects a design decision that balanced the tactical need for flexibility in using the weapon against the desire to ensure safety for the firing ship. Re-evaluation of safe standoff requirements, in the light of advances in weapon effects understanding, has resulted in a reconsideration, by the Navy, of the limiting delivery range. Incentive to reduce the minimum delivery range is increased by the fact that, in many ocean areas, restricted sound transmission conditions reduce the sonar maximum range to distances less than the minimum one at which the ASROC nuclear depth charge will arm.

The importance of actual weapons effects information in planning delivery tactics and selecting weapon characteristics for a nuclear weapon designed for close-in tactical defense can be illustrated by a simplified version of an ASROC exercise. Imagine that an ASROC ship, in wartime patrol, has established sonar contact with an enemy submarine. The commanding officer has to decide whether or not to fire a nuclear warhead. Under conditions where the sonar range is 5,000 yards, or less, it is important that he understand the effects upon his own ship, if he fires the warhead. This knowledge will allow the selection of an acceptable attack position from which to launch the ASROC missile without reducing unacceptably either the kill probability or the ship's ability to evade the base surge during an evasion maneuver. After delivery of his attack and completion of his evasion maneuver, the commanding officer will want to verify the kill. The kill must be clearly and quickly established and it is likely, assuming that the firing ship still retains its weapon-delivery capability, that the commanding officer would attempt to re-establish sonar contact with a possibly still-surviving submarine. In the event he has to make a second attack, he will be able to maneuver best with some knowledge of the environmental changes made by his first attack: the lateral extent and depth of the sonar masking region and the lateral extent and radiation intensity of the contaminated water.

Tactical delivery of an ASROC nuclear weapon raises problems which require the establishment of suitable guidance for the commanding officer of the firing ship. In the event that the Navy decides to reduce the present minimum delivery range the need for detailed guidance will increase still further if the commanding officer is to take maximum advantage of his increased weapon delivery flexibility.

1.2 SIGNIFICANCE OF SWORD FISH AS AN EFFECTS TEST

Sword Fish is the fifth underwater nuclear test conducted by the United States. Previous tests were: Shot Baker of Operation Crossroads; Operation Wigwam; and Shots Wahoo and Umbrella of Operation Hardtack. Sword Fish introduced new information that will increase understanding of Navy tactical problems (the major test interest) and of general DOD and AEC problems associated with underwater nuclear bursts.

The primary significance of Sword Fish, from the viewpoint of a ship delivering an ASROC nuclear depth charge, is to provide information bearing on: (1) mechanical damage to the ship (caused by the underwater shock waves, including the direct and bottom-reflected shock waves); (2) personnel injuries (caused primarily by gamma-ray sources carried in the base surge); and (3) restrictions on ship maneuvers (due to contaminated water and sonar masking).

The shock waves arrive at the firing ship within seconds after detonation: their severity at the ship is controlled primarily by range from the burst, burst depth, water depth and bottom characteristics and thermal gradient conditions in the water (a thermocline will tend to reduce the severity of the direct shock wave just as it causes a deterioration in sonar conditions). At ranges of delivery interest, mechanical damage to the ship tends to involve electronic components, light-weight structural gear (e.g., radars, launchers), etc., and to consist of failures which in large part can be repaired on shipboard; only at considerably smaller ranges does damage to major units of the ship's machinery occur. Nevertheless, mechanical damage to be expected at ranges of delivery interest can cause serious (even though largely short-term) impairment of the weapon-delivery capability of the ship.

In Sword Fish, a fully operational ship equipped with a modern weapon system was for the first time placed close enough to the burst to provide verification of previous estimates of shock damage to modern weapon systems.

The base surge is a fine mist of water, carrying radioactive sources, which rolls outward from the collapsing water plumes thrown up into the air by the underwater burst. After a time of about ten minutes, the base surge tends to become invisible and within a slightly longer time, to settle out. The water plumes form the essential mechanism by which the radioactive products of an underwater nuclear burst are brought up to the air and imparted to the base surge. The character of the plumes, in turn, is governed by the pulsation and upward migration of the steam bubble formed in the water after the burst. The base surge, at ranges of delivery interes is greatly influenced by surface winds, extending much further downwind than upwind (or crosswind). It will reach a ship which does not undertake evasive action in a matter of minutes after the burst. However, a ship which remains mobile after arrival of the shock waves can evade the base surge, which carries the high-intensity radiation, under many conditions.

Sword Fish produced a steam bubble probably somewhat different from Wahoo, and, certainly considerably different from Wigwam. It will provide valuable supplementary information on the influence of yield and burst depth on the character of the base surge.

The water about surface zero is left radioactively contaminated to a radius initially about equal to the maximum plume radius after an underwater nuclear burst. This pool of radioactively contaminated water may pose a sufficient personnel hazard, over a period of an hour or more, to inhibit movement of the firing ship in its vicinity.

Sword Fish provided the opportunity to secure measurements of the radioactive pool. This information is expected to be especially valuable because such a complete study was not made in previous tests.

An underwater nuclear burst produces a severe deterioration in sonar conditions, possibly arising from released gas and turbulence as well as reverberations, which may endure for an appreciable time. As a result, the firing ship may be unable to re-establish sonar contact with a submarine possibly left undamaged by the attack.

Sword Fish provided an opportunity to obtain effects information on tactical sonar detection that supplements information previously accumulated (particularly from Shot Wahoo of Operation Hardtack).

Navy interest in Sword Fish was broader in scope than the primary concern with the ASROC tactical delivery problem.

Improved understanding of the general effects of underwater nuclear bursts may be applied to other military problems arising in such diverse areas as: effects on the long-range detection capabilities of land-based hydroacoustic stations, and tactical problems for submarine weapon delivery. It seems likely that the need for more detailed weapon-effects information to answer new questions will be greatly increased with the introduction of improved weapons and ships.

The Navy research program in underwater nuclear-weapon effects is by no means confined to participation in nuclear tests and associated theoretical studies. It includes the extensive employment of such experimental approaches as small-scale model tests, large high-explosive (HE) charge tests of full-scale ships, and HE tests to develop a basic understanding of the mechanism by which the gas bubble (left by an underwater burst) delivers explosion products to the atmosphere. Especially important are the series of routine shock trials conducted by the Bureau of Ships using operating Navy ships of all types. Weapon-effects information accumulated in this program provides the only practical means of determining the statistical variation in ship damage resulting from essentially identical attacks. Extrapolation of the results to underwater nuclear effects can only be based on reliable methods of correlating HE and nuclear test results. Sword Fish data provides some further means of verifying existing methods.

Problems of DOD interest in connection with the detection and classification of underwater nuclear bursts were investigated in Sword Fish under Advanced Research Projects Agency (ARPA) sponsorship. These efforts were associated with studies of interference with the submarine detection capabilities of strategic hydroacoustic detection systems by underwater nuclear explosions.

The AEC accepted the opportunity offered by Sword Fish to investigate the drift and diffusion of radioactive contaminants left in the water after the burst and the effect of this radiation on marine life.

1.3 TEST OBJECTIVES

The overall test objectives are divided for convenience into two groups; those connected with onsite efforts and those connected with offsite efforts. For present purposes the term "onsite" refers to activities to be conducted within a radius of 12 miles of surface zero on test day. Specific project objectives are given separately in the various project reports.

The short-term objective of onsite efforts was to secure weapon-effects information bearing on the establishment of a tactical doctrine for nuclear warhead delivery. Specifically, this information will help to: (1) determine the minimum delivery range at which an ASROC destroyer (DD) can make an attack and retain its capability of mounting an immediate repeat attack (from the viewpoint of both equipment and personnel); (2) determine the minimum emergency delivery range at which an ASROC DD can make an attack and retain its mobility with possible weapon system equipment failures and personnel casualties; and (3) determine the restrictions which an ASROC attack places on the later tactical maneuvers of a ship because of radiation hazards or sonar conditions.

The long-term objective of onsite efforts was to enhance the general fund of information on effects of nuclear underwater explosions. Specifically, this information will help to: (4) determine safe standoffs for delivery of underwater nuclear weapons by submarines; (5) establish reliable procedures for extrapolating to underwater nuclear bursts the statistically significant data on ship equipment damage gained from routine HE shock trials of operational ships.

Objectives of the offsite efforts were concerned with: (1) the effects of the burst upon strategic hydroacoustic detection systems (e.g., SOSUS) and the improvement of long-range hydroacoustic theory; (2) the long-time drift and diffusion of radioactive contaminants left in the water after the burst and the effect of these contaminants on marine life; and (3) the detection and identification of underwater explosions.

1.4 TEST ADMINISTRATION AND HISTORY

Sword Fish was conducted by a JTF-8 Navy Task group, organized as described in Appendix B. Primary technical projects, which formed the hard core of the test proposal, were formulated by the Navy and funded by DASA. Auxiliary projects were generated under AEC and ARPA sponsorship. Project efforts and funding levels, as well as project reporting arrangements, are indicated in Appendix B.

Key events of Sword Fish history are listed below.

12 Jan 1962	ASROC test assigned to CJTF-8 (Code name, Sword Fish) for incorporation into Dominic Series.
2 Feb 1962	Navy Weapon Effects Test Plan (SWET 8) for Sword Fish forwarded to DASA.
2 Feb 1962	Initial Release of DASA funds. Most laboratories responsible for Sword Fish projects started work.
21 Feb 1962	CJTG 8.3 assumed operational and technical cognizance of Sword Fish.
26 Feb 1962	Constitution of ARPA projects.
3 Mar 1962	Formation of Task Unit 8.3.4. Mission: plan and coordinate Sword Fish.

19-26 Mar 1962 Ad Hoc ASROC Safety Committee report.

31 Mar 1962 CJTF-8 selected Wigwam test site rather than Christmas site, based on AEC recommendation.

13 Apr 1962 AEC projects established.

21 Apr 1962 Promulgation of Sword Fish Operation Order 1-62.

25 Apr 1962 Establishment of Task Group 8.9 for operational execution of Sword Fish.

19 Apr to 7 May 1962 Assembly of units, equipment, and personnel at San Diego. Preparations and rehearsals.

4 to 7 May 1962 Sword Fish units departed for test area.

8 May 1962 CTG 8.9 authorized to execute Sword Fish.

11 May 1962 ASROC WR missile launched at 1301 local time.

12-13 May 1962 Sword Fish units arrived back in port.

13 May - 5 June 1962 Rollup at San Diego.

Chapter 2

PLAN DEVELOPMENT

The overall planning guidelines which led to the operational plan are described, together with the reasoning behind their adoption. Attention is concentrated on, though not confined to, matters connected with onsite activities. The onsite efforts stemmed from the primary test objectives and dominated test planning. No effort is made to cover all details of the planning: reference can be made to CTG-8.9 OpOrder 1-62, dated 21 April 1962, and to the individual project reports. It may, however, be helpful to the reader to turn to key figures of Chapter 4 in following the discussion.

2.1 PRIMARY TEST CONCEPT

The primary test concept was created to verify estimates of acceptable minimum delivery ranges for ships using the ASROC nuclear depth charge. The concept was developed not only in the knowledge that the present ASROC system design allows a minimum nuclear delivery range of 3,500 yards but also in light of current discussions concerning the advisability of reducing the minimum delivery range. The test concept duly recognized the key role that technical measurements, including the determination of yield, burst depth, and surface zero would play in such a decision.

Guidelines derived for the primary test plan are indicated in Table 2.1.

2.2 TECHNICAL PROJECT PARTICIPATION

Sword Fish provided the opportunity to conduct a number of investigations concerning the effects of, and the possibility of detecting, underwater nuclear explosions. A list of projects sponsored by DOD (DASA, Navy, and ARPA) and by the AEC is given in Appendix B, together with funding and reporting information. These projects included not only those connected with the primary test objectives but also auxiliary efforts. A brief description of participating technical projects, together with an indication of their general purpose and support requirements, is listed in Table 2.2. The detailed project planning is discussed in the individual project reports; References 1 through 7 cover the DASA-sponsored projects.

2.3 MISSILE LAUNCHING

Key aspects of the firing plan involve questions of: a suitable target, modifications to the delivery ship, and control of the launching time. These aspects are discussed briefly below.

A small wood planked raft (13 feet by 13 feet), floated by six 55-gallon oil drums (each filled with plastic foam),

TABLE 2.1 GUIDELINES ESTABLISHED FOR PRIMARY TEST PLAN CONCEPT

Item	Guideline	Reason
Ship Type	Operable FRAM 1 (ASROC) DD minimum requirement (with more modern ship types desirable)	Demonstrate degree of shock damage on ship-type with weapon system of prime interest -- no reliable means of interpreting results obtained in absence of actual ASROC.
Array Scheme	Tow line for an unmanned operable ASROC ship	Feasible means of placing operable ship close enough to burst without jeopardy to personnel or undue cost.
Number of ASROC Ships	3	One in tow line, one for delivery, and one to act as delivery backup.
ASROC Ship Ranges	Towed DD as close to burst as possible without accepting undue chance of shock damage to major equipment which would involve time-consuming and costly shipyard repair; remaining two ships as close to minimum delivery range as feasible	Demonstrate possibility of reducing minimum delivery range; demonstrate low level of shock damage at present minimum delivery range.
ASROC Ship	Between side-on and stern-on	Likely orientations in tactical situation as result of evasion maneuver following weapon launch.

TABLE 2.1 (CONTINUED)

Item	Guideline	Reason
Test Site	Water depth from 1,500 to 2,200 fathoms with smooth plane bottom	Maximize effects information by using bottom-reflected shock wave to increase shock severity at outermost ASROC ships, making possible a reasonable approach to the borderline beyond which weapon component damage expected.
Technical Project Participation	Determine yield, burst depth, and surface zero; measure surface phenomena, nuclear radiation, underwater pressures, ship responses, radioactive water pool, and effects on tactical sonar transmissions.	Enable comparison of results with other data and enable extrapolation to conditions of general tactical interest
Timing	Employ time command signals as integral part of test.	Provide common time signals to permit correlation of results between projects; provide means of controlling instrumentation sequencing at unmanned stations.

TABLE 2.2 TECHNICAL PROJECT PARTICIPATION AND SUPPORT REQUIREMENTS

Project	Identification	Type of Effort	Support Requirements
1.1 NOL	Underwater Pressure	Measure the pressure waves to 2,000 foot depth.	Two floating platforms and surface ships as available; tow speed less than 1 knot; thermal gradients and salinity to depth; sea bottom depths; sea surface conditions.
1.2 NOL	Surface Phenomena	Analyze technical photographic film to determine yield, burst depth, surface zero, array element positions, and growth of surface phenomena (especially base surge).	Overhead aircraft (at high altitude directly over burst and at low altitude to one side); surface ships as available; cameras and photographers.
1.3 NEL	Hydroacoustic Transmission Effects	Determine masking effects of burst on tactical sonars (employing as targets submarine simulators and sonar transponders), and on shore-based long range detection stations (SOSUS and PMR).	Modern submarine to launch submarine simulators; surface ship equipped with SQS-31 or 32 sonar; ASROC ship as available; submarine at Lorad first convergence zone; extraneous sonar noise (from fast ships, underwater telephones, etc.) held to minimum; thermal gradients.
1.4 NEL	Underwater Nuclear Burst Detection by Hydroacoustic Systems	Determine capability of distant ship-based and shore-based hydroacoustic stations to detect and classify underwater nuclear bursts.	Five surface ships between several hundred and several thousand miles from burst; observation from SOSUS and PMR stations.

TABLE 2.2 (CONTINUED)

Project	Identification	Type of Effort	Support Requirements
2.1 NRDL	Nuclear Radiation	Measure radiation connected with base surge; determine radio-chemical yield.	Surface phenomena data; surface wind and speed; explosive cutters to sever towline just before burst; water samples obtained from near surface zero soon after burst and aircraft to rush them back to laboratory.
2.2 NRDL	Airborne Radiation Monitoring	Measure extent and radiation level of contaminated water.	Low-altitude aircraft.
3.1 DTMB	Ship Response	Measure shock-induced motions on ships; correlate with the associated equipment damage.	ASROC ships and other ships as available.
7.1 BuWeps	Operational ASW equipment	Deploy Julie-Jezabel and other units near burst and observe effects on operation.	Low-altitude aircraft
9.1 BuShips/BuWeps	Ship Shock Damage	Inspect ships for damage; assess significance of shock damage on ship performance; and provide technical support.	ASROC ships and other ships as available.
9.2 EG and G	Command Time Signals and Countdown	Provide common time base for measurements of other projects	Space aboard a ship for control center.

TABLE 2.2 (CONTINUED)

Project	Identification	Type of Effort	Support Requirements
9.3 Navy	Technical Photography	Support Project 1.2 by providing cameras and photographers.	See Project 1.2.
General Atronics	Hydroacoustic Measurements	Employ ship-based hydro-acoustic station to detect and identify underwater nuclear burst.	One surface ship about 40 miles from burst.
NRDL-AEC	Shipboard radio-active pool monitoring	Determine extent, radiation level, and drift of contaminated water for 24 hours after burst.	Surface ship suited to purpose.
AEC Program	Contaminated Water Tracking and Marine Life Effects	Track contaminated water as long as detectable and monitor radiation; provide supporting oceanographic and meteorological data.	Oceanographic ship.

was constructed to serve as a target. Though it was intended primarily to use this raft as a radar target, an SQQ-18 sonar transponder was suspended at a depth of 50 feet below the raft to provide a secondary input to the fire control computers and to enhance the realism of the firing conditions. The small size of the raft and the wood plank construction served the purpose of minimizing both the small chance of the missile striking the target and the chance of disrupting the missile behavior in case of a strike.

A modification was made both to the delivery ship and to the stand-by delivery ship to permit automatic provision of radar target data to the fire control computer. It was felt that the radar data would achieve a more accurate and dependable input (in view of uncertain sonar conditions) than would the normal SQS-23 sonar.

Control of launching time was a key point arising from the problem of ensuring that the high-altitude photographic aircraft were directly over surface zero at burst time. It was decided that the aircraft was in the best position to accomplish this purpose by signalling the delivery ship to launch at an appropriate time when the aircraft was at a predetermined position along its track.

2.4 SAFETY CONSIDERATIONS

Sword Fish was conducted with the attention to personnel safety typical of a peacetime test. A special Safety Committee, convened to determine the overall level of safety, essentially concluded in a memorandum to CJTF-8, dated 26 March 1962, that test plans assured adequate safety. Certain risks, such as a wild missile or a premature burst very close to the firing ship, were so negligible as to simply be accepted. Other risks were minimized in the test plans, as discussed below.

2.4.1 Firing Errors. A record of ASROC firings, made prior to Sword Fish, was compiled from References 8 through 14; a summary is given in Appendix C. It was felt that this record, even though it involved use of sonar inputs to the fire control computer, would lead at least to a conservative estimate of the firing accuracy to be expected in Sword Fish where a radar input was used. An analysis of firing accuracy, presented in Appendix C, indicated that appreciable errors in range and bearing were possible.

It was decided that the risk of such an occurrence would be acceptable if all ships were positioned outside a restricted zone extending from minimum to maximum delivery range and stretching to about 20 degrees on either side of the line of fire.

2.4.2 Premature Air Burst. It was estimated that a chance of less than 3.2×10^{-7} existed that an ASROC depth charge might burst with full yield in the air prior to becoming submerged. Such an airburst might result in personnel hazards stemming from thermal and prompt nuclear radiation, airblast, the rising fireball, and fallout.

Personnel hazards from thermal and prompt nuclear radiation, and airblast, are summarized, from Reference 15, in Figure 2.1. Note that these effects are estimated for yield, a conservative upper limit of expected weapon yield.

Fallout can occur, of course, over widespread areas depending on wind conditions.

The following guidelines were adopted in the test planning to minimize personnel hazards arising from a premature airburst, (firing error was included in the consideration):

1. Shortly before launch all personnel go below decks except those necessary for test conduct.

2. Just prior to launch, topside personnel (unequipped with high-density goggles) turn away and keep eyes closed until depth charge water entry verified.

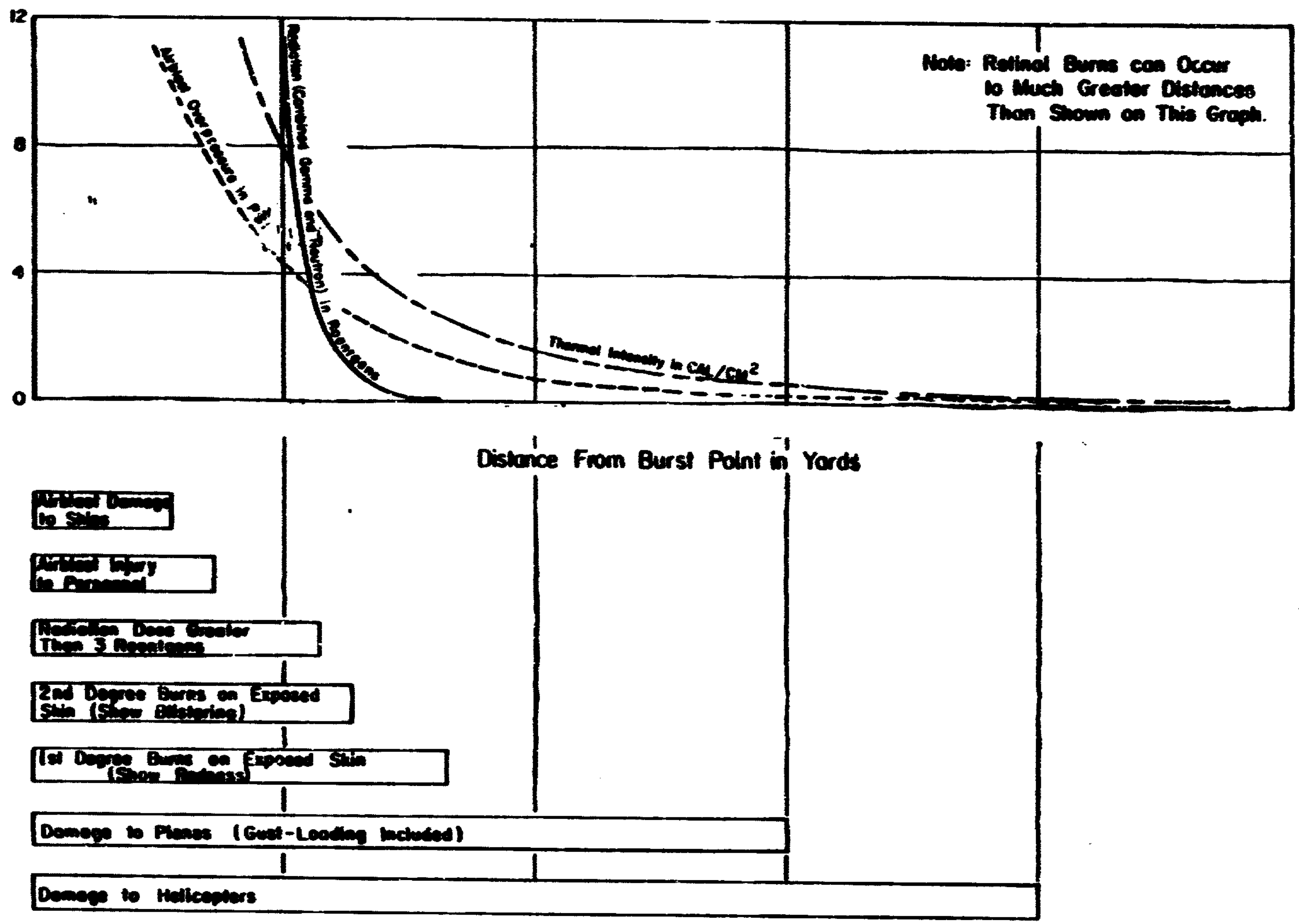

Figure 2.1 Airblast, radiation, and thermal hazards, produced by airburst of a weapon.

3. Helicopters at least 9,000 yards from target raft.

4. Aircraft directly above target raft maintain altitude of at least 18,000 feet.

5. All other aircraft at least 7,500 yards from target raft.

6. A fallout prediction capability to guide ship-escape maneuvers in the event of an accidental airburst.

2.4.3 Radiation from Base Surge. The base surge from an underwater nuclear burst causes a radiation hazard over an area which depends on yield, depth of burst, and the prevailing surface wind. Estimates of the contours about surface zero within which radiation doses would exceed 3 roentgens (the normal Task Force limit for personnel exposure) are presented in Figure 2.2 for varying wind speeds. These estimates were supplied by NRDL on an appropriately conservative basis. In particular,

. It had been estimated that a burst might occur at 300 feet, or less, with a chance of less than 0.2.

The following guidelines were adopted in the test planning to minimize personnel hazards arising from the transit radiation borne by the base surge, (firing error was included in the consideration):

1. No manned units positioned on the surface in the down-wind semicircle from 90° to 270°.

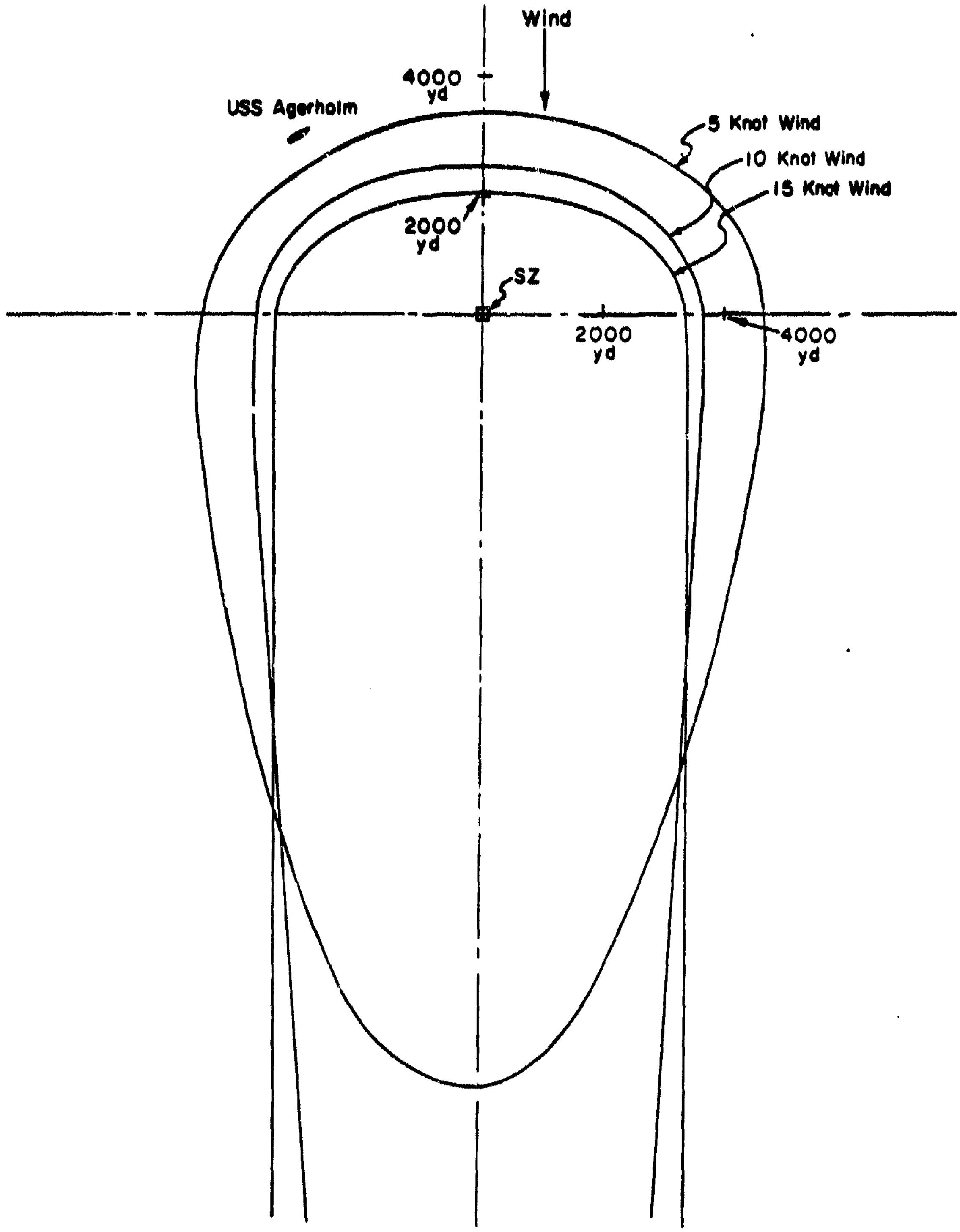

Figure 2.2 Base surge contours in which radiation dose is greater than 3 roentgens for a burst at 300 feet depth and for various wind speeds.

2. No manned stationary units positioned on the surface in the upwind sector closer than 4,000 yards and in the crosswind sector closer than 5,000 yards.

3. In the event of wind speed less than 8 knots, close-in ships would maneuver appropriately.

4. In the event of wind speed less than 3 knots, the test would be delayed.

2.5 PLACEMENT OF TOWED SHIP

The planning choice of horizontal range of the towed FRAM 1 destroyer from the target raft represented a compromise between two conflicting viewpoints.

It had been hoped to place the ship close enough to surface zero to sustain just about as much shock damage as would be sustained under the most severe HE shock test of the type conducted routinely under BuShip's direction of Chief of Naval Operations Instruction 09110.2A. The purpose was to establish correlation between ship damage to be expected with nuclear bursts and that to be expected under HE shock tests. It had been estimated that, with the burst yield and sea depth conditions to be expected in the ASROC test, this purpose would be achieved at a range of about 1,500 yards.

The possibility of producing an undue amount of damage requiring costly and time-consuming shipyard repair, in such a valuable unit of the operational forces posed a real problem because of uncertainties in the ASROC delivery accuracy.

It was decided to come as close to 1,500 yards as possible without accepting more than a negligible chance of producing hull damage or more than a 4-percent chance of causing mobility impairment (damage to heavy machinery items). This decision led to a choice of 1,700 yards as the planned horizontal range from the target raft to the midship section of the towed ship. The placement argument is indicated in Figure 2.3. Circles about the target raft describe hit probabilities as derived in Appendix C. Circular areas about the towed destroyer indicate ranges to which ship damage zones extend. In estimating these damage ranges it was assumed that: yield would be burst depth 700 feet, and thermal layer depth about 300 feet (with gradient typical for test site area in May). The cross-hatched area represents a region within which mobility impairment will occur. A conservative calculation indicates that hit probability within the cross-hatched area is 4-percent: uniform probability distribution throughout each of the zones between the circles about the

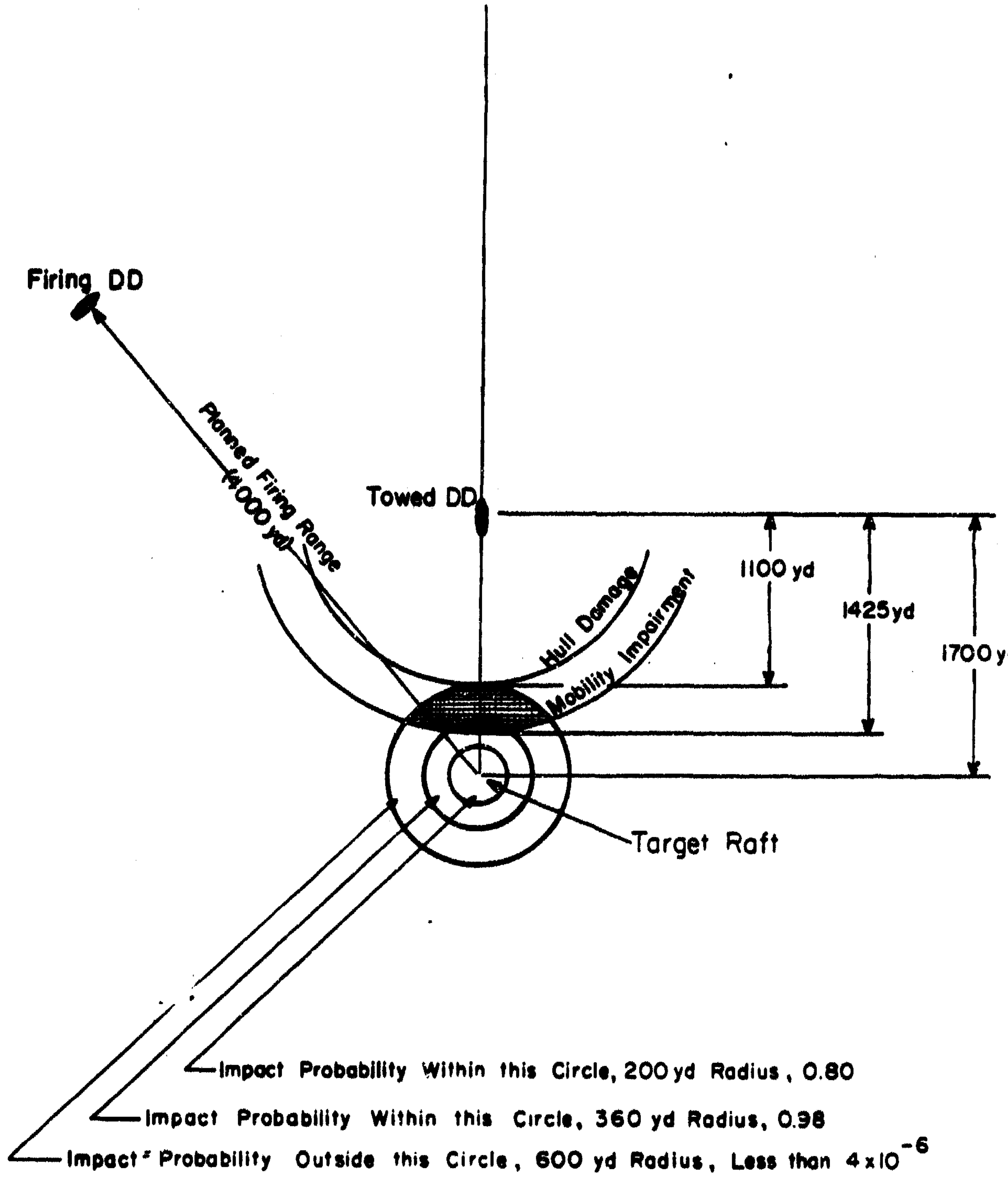

Figure 2.3 Placement consideration of towed destroyer.

target raft was assumed as a conservative simplification. The range of 1,700 yards was considered to offer a reasonable chance of securing the desired information. There was a 90-percent chance of producing shock damage of a severity greater than the least severe routine HE shock but less than the most severe routine HE shock trial. There was a 50-percent chance of producing shock damage of a severity greater than that produced by an HE shock-trial lying midway between the least and most severe routine trials.

2.6 TOWED ARRAY

The towed array stretched over a total distance of 6 miles from the towing ship upwind to a smoke generator downwind. The towline consisted of polypropylene cable, chosen because of its buoyancy as well as its strength. The requirement for buoyancy stemmed from a desire to maintain the positions of the nuclear radiation stations (NRDL coracles) as little changed as possible following the burst. The towline served to position: the towed ASROC ship, 8 coracles, 2 platforms for underwater pressure measurements, and the target raft. Explosive cutters were attached just upwind and downwind of the target raft and activated just prior to the burst to give further insurance that the surface upheaval, following the burst, would not drastically change coracle positions.

The towed array, in addition to positioning key elements of the test, provided flexibility in attempting to line up the coracles in the wind direction. Every effort was made to ensure that the overall array was not only seaworthy but designed to permit ready recovery of the test elements in the event of adverse conditions developing between the time of its deployment and the planned burst time.

2.7 SUPPORT EFFORTS

The operations conducted during an underwater nuclear weapons effects tests are manyfold. Some of the support efforts established for the ASROC test were so intimately related to, and vital for the success of, the technical efforts that they cannot be overlooked completely in the present report. Key support efforts included: deployment of the towed array, weather predictions, rad-safe monitoring, closed circuit television observation, test site surveillance, and documentary photography.

2.7.1 Deployment of Towed Array. The deployment plan, and the requirement for transportation of array elements, called for the services of a Landing Ship Dock (LSD). Deployment of the towed array was accomplished by 4 Landing Craft (LCM's) operating out of the LSD.

2.7.2 Weather Prediction. Vulnerability of the whole operation to unfavorable weather conditions made the creation of a weather prediction capability a matter of prime concern. The following criteria for weather conditions that would permit a successful test were formulated:

Sea Surface: Wave heights less than 8 feet (crest to trough).

Surface Winds: Steady with speed below 18 knots, but not less than 3 knots.

Cloud Cover: Below 5/10 cloud cover up to 20,000-foot altitude.

In addition, safety considerations required that fallout predictions be made to guide ship escape maneuvers in the event of an airburst. This required frequent, planned weather observations up to 20,000 feet.

Required services were supplied by the U.S. Fleet Weather Facility, San Diego, and the U.S. Fleet Numerical Weather Facility, Monterey. Personnel from these activities also assumed responsibility for forecasting such oceanographic data as sea-surface temperature and mixed-layer depth. Details are given in Appendix D.

2.7.3 Radiological Safety Monitoring. The recovery requirements of the ASROC test, plus the need to obtain water samples and to track the contaminated water pool at early times, posed a formidable problem. All phases of the operation were to be completed without exceeding the following radiological safety criteria:

1. The maximum permissible dose for personnel who had not reached their nineteenth birthday was not to exceed 1.25 REM (gamma + neutron) in 13 consecutive weeks.

2. The maximum permissible dose for individuals who had reached their nineteenth birthday was not to exceed 3.0 REM (gamma + neutron) in 13 consecutive weeks.

3. At no time was an individual's cumulative lifetime dose to exceed an amount determined by (N - 18) × 5 REM, where N is the age of the individual in years.

4. No individual without a specific waiver was to be exposed to radiation unless he had reached his eighteenth birthday.

A radiological safety monitoring capability was created within the task unit with the assistance of the U.S. Naval Radiological Defense Laboratory (NRDL). This capability involved the acquisition of experienced personnel and a considerable amount of equipment. Details are given in Appendix E.

2.7.4 Television. A closed circuit television system was installed within each of four key ships. This installation served two purposes: (1) it allowed a definite verification of depth charge water entry, following which photographers (those unequipped with high-density goggles) were permitted to retrain their cameras on surface zero; and (2) it allowed ship personnel inside the ships to view the event on television screens.

On one of the ships with a television installation, a special videotape recorder was employed to secure a documentary record of the event and test activities.

2.7.5 Surveillance. The usual need for surveillance was enhanced in Sword Fish by a decision to test without prior public announcement of a danger zone. Surveillance for surface contacts was to extend to a radius of 50 miles, and, for air contacts, to a distance of 100 miles from the planned point of detonation.

2.7.6 Documentary Photography. The Pacific Fleet Mobile Photographic Unit was assigned the mission of planning and taking photography (still and motion picture) for the preparation of instructional films and historical films.

2.8 DESIGNATION OF SHIPS AND AIRCRAFT

Ships and aircraft were assigned to the ASROC test in response to technical and support requirements. Designations are listed in Table 2.3, for ships, and Table 2.4, for aircraft,

TABLE 2.3 SHIP DESIGNATIONS

Ship	Approximate Location at Burst	Major Mission
USS Agerholm (DD-826)	Up wind	Launch ASROC depth charge.
USS Bausell (DD-845)	Up wind in towed array	Unmanned ASROC ship.
USS Richard B. Anderson (DD-786)	Up wind	Back-up ship for launching ASROC depth charge.
USS Monticello (LSD-35)	Cross wind	Transport and deployment base for towed array elements.
USS Hopewell (DD-681)	Up wind	Track submarine simulators (Project 1.3)
USS Razorback (SS-394)	Cross wind at Periscope depth	Launch and track submarine simulators (Project 1.3)
USCandGS Pioneer (OSS-31)	Up wind near moor (Point Alpha)	Oceanographic ship; measure intensity and size of radioactive pool after the first 24 hours.
USS Molala (ATF-106)	Up wind in towed array	Tow array line.
USS Sioux (ATF-75)	Up wind	Collect radioactive water samples; measure intensity and size of contaminated water pool for the first 24 hours.
USS Yorktown (CVS-10)	Up wind	Provide air surveillance; provide transportation of radioactive water samples to a shore air

TABLE 2.3 (CONTINUED)

Ship	Approximate Location at Burst	Major Mission
USS Preston (DD-795)	Up wind and just outboard of Agerholm	Platform for documentary photography; surveillance.
USS Maddox (DD-731)	Upwind	Surveillance
USS Brush (DD-745)	Upwind	Surveillance
USS Moore (DD-747)	Upwind	Surveillance
USS Cree (ATF-84)	40 miles upwind of site	Platform for hydroacoustic measurements.
USS Sea Fox (SS-402)	28 miles upwind	Platform for hydroacoustic measurements at Lorad first convergence zone.
USS Gannet (MSC-290)	200 miles from site	Platform for hydroacoustic measurements.
USS Tawakoni (ATF-114)	Vicinity of the Hawaiian Islands	Platform for hydroacoustic measurements.
USS Arikara (ATF-98)	Vicinity of the Hawaiian Islands	Platform for hydroacoustic measurements.
USS Lipan (ATF-85)	Vicinity of the Hawaiian Islands	Platform for hydroacoustic measurements.
Chilean Yelco (ATF)	Off Santiago, Chile	Platform for hydroacoustic measurements.

TABLE 2.4 AIRCRAFT DESIGNATIONS

Aircraft Type	Approximate Location from SZ at Burst	Major Mission
A3D-2P	20,000 foot altitude over SZ	Overhead technical photography (lead aircraft)
A3D-2P	20,000 foot altitude trailing lead A3D-2P by 2,000 feet.	Standby aircraft for lead A3D-2P
R5D-3	265° True at 10,000 yard range and 10,000 foot altitude	Platform for technical photography.
R5D-3	310° True at 10,000 yard range and 10,000 foot altitude	Platform for documentary photography
P2V	Well away at burst. Area of radioactive water at approximately H + 3 hours	Measure intensity and size of radioactive pool.
P2V-5	Upwind - approximately 24,000 yards.	Airborne ASW systems.

Note: Two helicopters were airborne upwind between 14,000 and 20,000 yards.

together with general locations at burst time and missions.

2.9 TIMING SYSTEM

Time signals just prior to, and just after, launch of the nuclear depth charge formed a critical feature of the test. Instrumentation equipment on the unmanned stations had to be operated at a suitable sequence of times. A fiducial signal had to be provided to give project measurements a common time base. A partial summary of the timing signals, provided in response to project requirements, is given in Table 2.5. This table includes only those stations which used automatic operations. Additional operations took place, manually, at some of these stations and on other ships and aircraft.

The plan to implement timing requirements was formed from the following guidelines: (1) the signal for launching the missile was to be given by the lead photographic A3D to ensure that this aircraft was positioned directly overhead at burst time (as mentioned in Section 2.3); (2) a backup control center was to be placed in USS Anderson to ensure timing signals in the event that USS Agerholm (with the primary control center) was unable to deliver the missile; (3) zero time was to be provided by the burning of a wire stretched in back of the missile rocket to prevent the running of project recording tapes in the event of a missile

TABLE 2.5 COMMAND TIME SIGNALS

Station	Project 1.1		Project 3.1		Project 9.1	
	Signal Time	Signal Use	Signal Time	Signal Use	Signal Time	Signal Use
USS Anderson			Fiducial: +35s; (a,c)	Common time base	Zero time	Activate photoflash equipment to photograph ASROC computer panel.
USS Bausell	H - 10m (a)	Provide power to warm up electronic equipment	H - 10m (a)	Provide power to warm up recorder equipment.		
	Zero time	Start tape	Zero time	Back-up for H - 10m. Start tapes through delay (27 sec) sequence timer.		
			H + 27 s (b)	Back-up zero time. Start high-speed cameras through delay (8 sec) sequence timer.		
	Fidu: +35.5s (a,d)	Common time base	Fidu: +35.5s (c)	Common time base		

TABLE 2.5 (CONTINUED)

Station	Project 1.1		Project 3.1		Project 9.1	
	Signal Time	Signal Use	Signal Time	Signal Use	Signal Time	Signal Use
USS Agerholm	H - 10m	Provide power to warm up electronic equipment.			Zero time	Activate photoflash equipment to photograph ASROC computer panel.
	Zero Time	Start tape				
	Fidu: +35.5s (a,d)	Common time base	Fidu: +35.5s (c)	Common time base		
USS Molala	H - 10M	Provide power to warm up electronic equipment.				
	Zero time	Start tape				
	Fidu: +35.5s (a,d)					

TABLE 2.5 (CONTINUED)

Station	Project 1.1		Project 3.1		Project 9.1	
	Signal Time	Signal Use	Signal Time	Signal Use	Signal Time	Signal Use
Platforms 1 and 2	H- 10m	Provide power to warm up electronic equipment.				
	Zero time	Start tape	H + 27s (b)	Provide power to start recorder equipment through delay (5 sec) timer.		
	Fidu:+35.5s (a,d)	Common time base	Fidu:+35.5s (c)	Common time base		
Target Raft					Zero Time	Activate flare
					+34s	Cut towline

Notes: (a) "s" denotes time after launch in seconds; "m" in minutes.
(b) H + 27 signal was transmitted to arm the fiducial receivers in addition to functions listed.
(c) Four additional fiducials (+36.5s; +37s; +37.5s; +38.5s) were transmitted.
(d) Only the +35.5s fiducial was recorded. The four additional fiducials were blanked out.

failure to ignite; (4) the control-center power was to be drawn from the same source as that for the ASROC system so that any possible power failure would affect both systems; and (5) receivers at unmanned stations were to be doubled in number and paralleled to minimize the consequences of receiver failures.

Further detailed description of the timing system is given in Appendix F, which also discusses the voice countdown, and the world time of launch.

2.10 TECHNICAL PHOTOGRAPHY

Technical photography was, from the commencement of test planning, considered an essential feature of the test. Superficially, photographic coverage was required to provide basic raw material for the Project 1.2 efforts. In a broader sense, every project depended on photographic information, if only for such simple purposes as determining station position from the actual surface zero. Every effort was made to secure the desired coverage with generous use of backup cameras, which previous test experience had demonstrated was essential.

A key problem to overcome was the safety requirement of photographers not looking at the target raft until water entry of the depth charge was verified. Considerable fear was felt that high-speed cameras could not be retrained in time to catch the initial phenomena. Successful experience in the rehearsals with the television installation (discussed in Section 2.7) helped to allay this fear. Additional measures involved the installation of flares on the target raft, designed to light up on the zero time signal, and provision of high-density goggles to key photographers.

Technical photography was largely accomplished, in response to the objectives of Project 1.2, by Navy photographers with borrowed cameras. NADC APEL modified the cameras to include a timing base and installed cameras, on specially made mounts, on the photographic aircraft. Detailed discussion is given in Appendix G.

2.11 CHOICE OF TEST SITE

At an early stage in the test planning it was envisioned that Sword-Fish would be conducted in the Pacific Ocean in the water about Christmas Island and Johnston Island. These regions had been selected by JTF-8 as operating areas for other tests of the Dominic Series. Objection to the choice was made on the ground that these waters abounded with fish life and that an underwater nuclear test would very likely lead to catches of commercially valuable fish, such as tuna, with detectable, though not hazardous (in terms of permissible levels for continued human consumption), radioactivity.

Consequently, it was decided to conduct the test in the general area of the Wigwam site, a known marine desert. It was, moreover, clear that radiation hazards to populated shores (either from fallout or contaminated water drift) would be entirely negligible for any site in this general area so long as the test was conducted more than several hundred miles from shore.

General conditions for achieving a successful test, with a bearing on the selection of a site, are listed below:

Sea Bottom: Smooth hard bottom at depth between 1,500 and 2,200 fathoms and plane (within about 5 percent) to an extent laterally of at least 3 miles. Bottom could not be such as to focus the bottom-reflected shock wave at ship positions (i.e., any concave dishes should not have radius of curvature at all close to water depth). The top of a flat-topped sea mount or a sea-mount slope was preferred, inasmuch as either would be less likely to have a thick sediment layer (which would undesirably distort the bottom-reflected shock wave).

Water Currents: Less than about 1 knot and fairly uniform with depth (i.e., within less than 1 knot) down to 2,000-foot depth.

Distance from Staging Area: Close enough to airport to allow A3D aircraft at least 2 hours on-site time.

On the basis of the above conditions and certain general considerations, the region of interest was narrowed to the cross-hatched area shown in Figure 2.4. Arguments went as indicated below.

1. Operating guidance used for Wigwam was adopted. This guidance amounted (Reference 16) to confining consideration to a general sector 200 to 600 miles from San Diego, bounded between west and south directions from San Diego, but excluding areas within 50 miles of land. This sector is bounded by dashed lines in Figure 2.4. A distance from San Diego of less than 600 miles allowed the A3D aircraft an on-station time of at least 2 hours.

2. It was decided to place the test closer to the U.S. coast than to the Mexican coast. That is, it was decided to confine attention to the north of the dashed straight line drawn in Figure 2.4 radially from San Diego.

3. It was decided to find a site at least 50 miles south of the commercial shipping lane from Los Angeles to Honolulu. The solid curve shown in Figure 2.4 indicates this northern limit.

4. Thermal-layer-depth data for this region of the ocean are sparse but some information is given in Reference 17 for the April-May season. The layer tends to be shallow inshore but increases with distance off shore. Location of the 200-foot layer in April is shown by the shaded curve

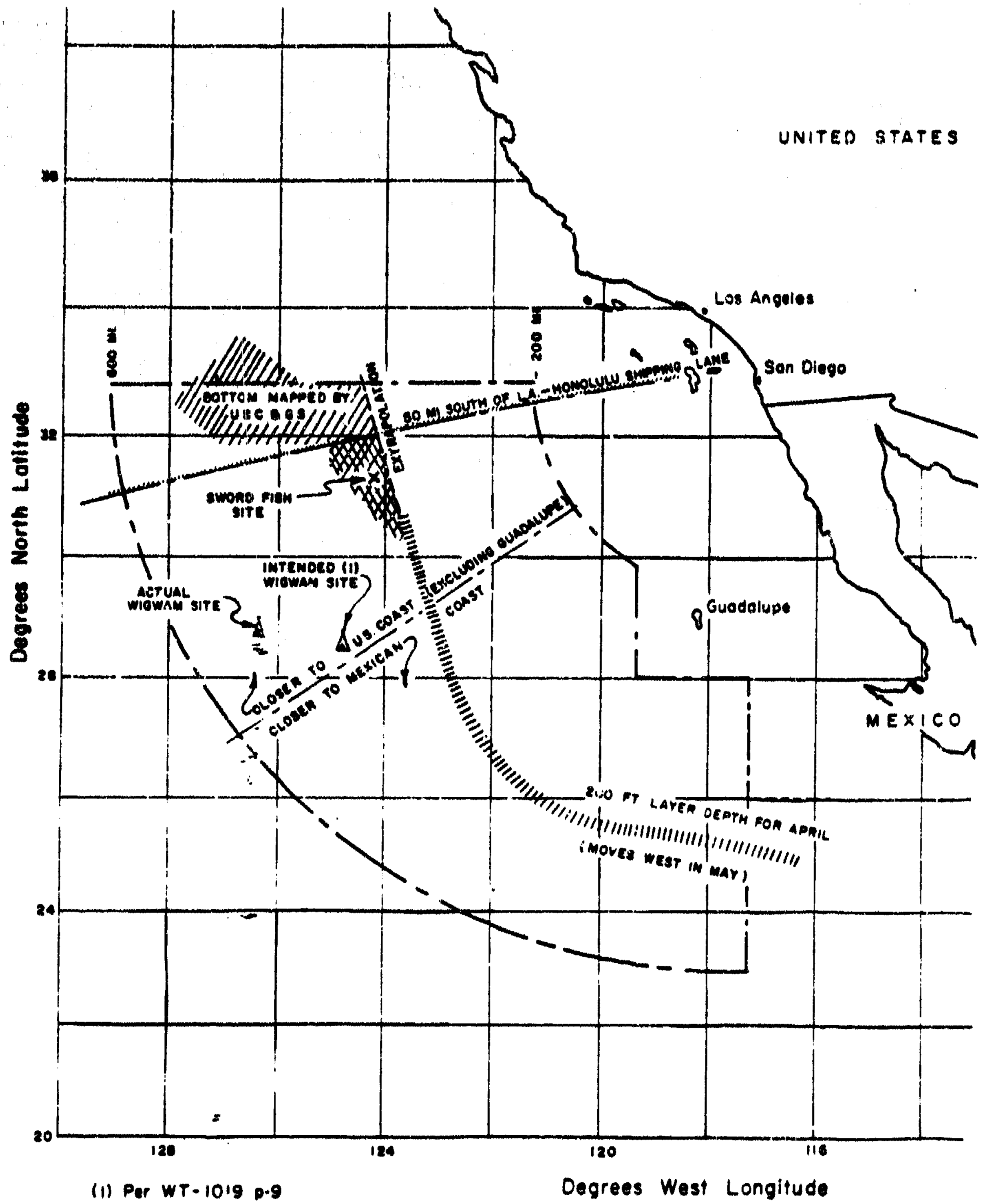

Figure 2.4 Selection of Sword Fish site.

in Figure 2.4. In May the location is shifted further westward as the surface water heats up, though the increased surface temperature is less at more northern latitudes. The change in May is so considerable that the chance of satisfying the criterion anywhere in the area is lessened (Reference 17 suggests a maximum depth of 150 feet). However, specific measurements near the Wigwam site have shown greater depths (e.g., Reference 16 gives one such measurement taken on May 12)

5. The best chance of achieving the desired type of sea bottom appeared to be by confining attention to a region whose depth had been determined in considerable detail. Coastal surveys with requisite depth and geographical positioning accuracy had been conducted by the United States Coast and Geodetic Survey in the north of the region as shown in Figure 2.4. Information to the south and west appeared to be considerably less detailed and accurate.

6. Within the cross-hatched area of Figure 2.4 several possible test sites appeared to exist.

Final demarcation of the test area was made by the Pioneer. Examination of a possible sea mount showed it to be unsatisfactory. Subsequently, Pioneer planted a marked buoy (which came to be known as Point Alpha) at a flat-level bottom area some 2,000 fathoms deep. She charted the bottom throughout a region extending west of the marker buoy 10 miles, south 12 miles, and north 10 miles.

Chapter 3

PRETEST ACTIVITIES AND RESULTS

The preparation effort in the forward area took place in San Diego, California from 19 April 1962 to 7 May 1962. San Diego served as the staging area for the task group with headquarters located at the Naval Repair Facility. Modifications to the aircraft to permit the installation of cameras were carried out at the Naval Air Development Center in Johnsville, Pennsylvania between the period of 4 April 1962 through 14 April 1962, as discussed in Appendix G. On 19 April 1962 the aircraft arrived at San Diego. Special efforts connected with auxiliary projects took place elsewhere.

Two types of pretest activity occupy a special place of importance because they provided information which has an intimate bearing on the evaluation of results from the nuclear tests. These activities were the high explosive (HE) shock trials of the ships and the OST firings.

Preparation at San Diego and the results obtained from the HE shock trials and the Operational Suitability Test firings are described below.

3.1 PREPARATION

Throughout the pre-test period, numerous briefings were held to weld together into a working team the many diverse elements of the task group which had newly come together. Special attention was given to problems connected with operational coordination of ships and aircraft with radiological safety.

Preparation at San Diego involved four major efforts: (1) construction of the towed array; (2) shipboard installation of project equipment; (3) ship inspections, modifications, and repairs; and (4) rehearsals at sea.

The towed array was constructed of polypropylene line, to a total length of more than six miles. The line was ordered and assembled with shackles in suitable length sections to permit the attachment of instrumentation stations at proper locations. Two platforms were constructed from standard pontoon sections. Several target rafts were constructed. Detailed information on the towed array is provided in Reference 7.

The various participating projects installed their equipment aboard ships and platforms as planned. These installations are covered in References 1 through 7.

A number of inspections, modifications, and repairs were made aboard the ships. Shipboard modifications included the installation aboard the ASROC ships of ordnance equipment to permit radar information to be fed automatically into the ASROC fire control computer system. Suitable provisions were made to permit unattended operation of selected equipment during the test. The washdown systems of Bausell, Anderson, Agerholm and Hopewell were checked and repaired. The sonar gear on these four ships was calibrated. Complete checks of the ASROC system including sonar inputs were carried out. These matters are discussed in detail in Reference 7. In addition, closed circuit television equipment was installed aboard the Agerholm, Anderson, Hopewell, and Monticello. On the Anderson, arrangements were made to record on video tape.

A number of partial and complete rehearsals were carried out prior to the ASROC test in order to verify the seaworthiness of the towed array, to train the ships in the planned maneuvers, to check the time command signals, to proof-test the scheme for coordinating overhead aircraft positioning with ship firing readiness, and to verify the readiness of both Agerholm and Anderson to fire an ASROC missile.

On 10 May 1962, an attempt was made to fire a nuclear depth-charge. However, a sequence of unfortunate events, involving both the firing ship and the overhead aircraft, led to an abort. Since key recording capability (especially, cameras on the overhead aircraft and the underwater pressure recording equipment) had been compromised, it was decided to retrieve elements of the array and place them back aboard the Monticello for a shot on the following day. This abort provided the Task Group with the most complete rehearsal carried out.

3.2 HIGH EXPLOSIVE SHOCK TRIALS

In order to proof-test their readiness to participate in the ASROC test, Bausell, Agerholm, Anderson, Hopewell and Razorback were each subjected to the mildest routine shock test of the type conducted by BuShips under OPNAVINSTR 09110.2A.

The results of these shock trials are discussed in References 6 and 7. Attention here is confined to the destroyers; Razorback had only secondary interest from the viewpoint of shock damage.

The shock motions experienced by Agerholm were undoubtedly representative of those undergone by all the destroyers. Motions were predominantly vertical. Peak vertical velocities measured on bulkheads, a useful location at which to characterize ship response, ranged from 1.2 to 3.1 ft/sec, averaging about 2 ft/sec.

Pages 82 through 85 deleted.

the ship and which would have an effect lasting for more than a few minutes. As remarked in Reference 7, nearly all significant damage concerned ordnance gear. Note that in Table 3.1, for convenience, damage is separated into two categories: (1) damage affecting the ASROC system, and (2) damage affecting conventional weapons systems.

Damage listed in Table 3.1 shows some similarity among the three ASROC destroyers. More significantly, however, Table 3.1 demonstrates the considerable statistical variation in damage to be expected if apparently identical ships are subjected to attacks of essentially identical severity.

Both Tables 3.1 and 3.2 demonstrate the impairment to be expected in conventional weapon-delivery capability under very mild shock.

3.3 OST FIRINGS

Anderson and Agerholm each launched an Operational Suitability Test (OST) weapon as part of the rehearsal for the nuclear test. The weapons were launched on 3 May 1962 about 10 miles west of San Diego within the operational area designated as Sierra-Sierra 4578 on Hydrographic Chart No. 15461. Agerholm launched its missile at the target raft from a range of about 4000 yards at 1929:31 (GMT) at 117° 34'W, 32° 19° N; Anderson at 2215 (GMT) at 117° 37' W, 32° 19' N. Key ship positions at the time of launch are shown for the Agerholm OST shot in Figure 3.1. Positions for the Anderson shot were similar.

Efforts were made during these shots to measure the burst depth and the missile delivery accuracy. For these purposes hydrophone (Project 1.1) and aerial photographic data were accumulated. Data concerning depth of burst wei also taken by the General Atronics project on Cree.

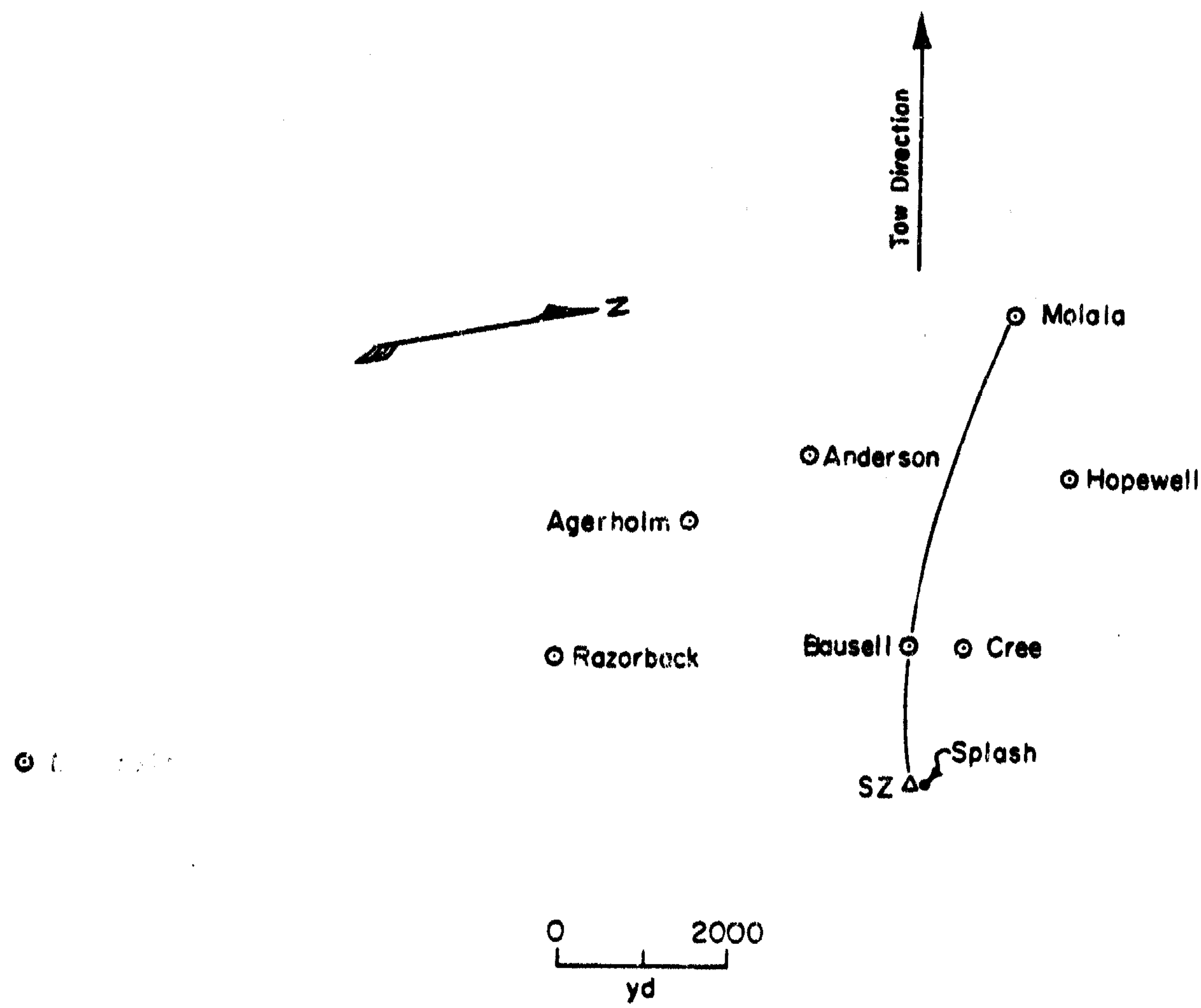

Figure 3.1 Array for OST firings.

Missile delivery accuracy could not be determined during the Anderson's firing; no aerial photographs were taken.

Chapter 4

TEST CONDITIONS

Shortly after 1301 (local time) 11 May 1962, USS Agerholm launched an ASROC nuclear depth charge at the target raft in the test array. The underwater burst occurred at a lonely spot in the Pacific Ocean about 365 miles west of San Diego, California.

The test was conducted without prior public announcement of a danger zone. Surveillance units detected only one merchant ship close to the limits set for the danger zone. Two hours prior to burst, this contact was about 40 miles to the west heading toward the northwest. She cleared the area well prior to burst time.

General conditions prevailing at test time were documented. Specific results are summarized in Chapter 5. Aspects of the results with a common interest, together with information on meteorological and oceanographic conditions, are described below.

4.1 BURST DEPTH

The depth of the nuclear burst is estimated to be

based on information presently available.

Primary means of determination were based on underwater shock wave measurements (Reference 1) and on aerial photography of the shock wave slick (Reference 2).

Project 1.1 (Reference 1) estimated the depth of burst to be . This conclusion was derived from data obtained at pressure gages located along the length of a 2,000 foot cable suspended from the platform closest to surface zero. Gage depth was plotted as a function of the absolute time (i.e., with respect to an EG&G fiducial signal) of shock wave arrival at each gage. The resulting curve, together with a measurement of the platform distance from surface zero (obtained from aerial photography), allowed determination of: depth of burst, time of burst, and angle of gage string inclination to the vertical.

Project 1.2 (Reference 2) estimated the depth of burst to be about . This estimate was obtained from high speed photographic film records made by cameras in the overhead aircraft. The radial growth of the slick (visible surface evidence of the shock front) about surface zero was plotted as a function of time and the results matched to theoretical computations for various burst depths. These results do not depend critically on burst yield.

The directly measured burst depth may be compared with an inference from the total sinking time of the warhead. Available aerial photography indicates that the time from warhead splash to the first surface effect of the detonation was seconds. This time is essentially the total sinking time from water entry to detonation: shock wave travel time from the burst depth to the surface cannot be more than about 0.1 second. The method of Appendix C gives a computed burst depth of   The close agreement with the direct measurement of burst depth indicates that the method of Appendix C will produce a reasonably reliable burst depth estimate based on the warhead sinking time.

Secondary means of determining the depth of burst are potentially available from measurements of the spray dome. (Project 1.2) and hydroacoustic travel path times (General Atronics). Reliable information from these sources must await further analysis and can be expected in the final project reports.

4.2 TIME OF BURST

The time of burst was determined, primarily by Project 1.1 (Reference 1), to be   second after the EG&G zero time signal. The zero time signal was probably within a few milliseconds of the time the wire behind the rocket motor was burned through and within about one-third second of actual missile launch. Thus, the absolute time of burst was   Greenwich Meridian Time. Burst time was a by-product of the burst depth determination, described above.

A rough check on burst time is provided by adding the missile airflight time and the warhead sinking time. The most accurate determination of airflight time comes from the difference between the time of warhead splash and the time at which the flares on the target raft were lighted. These flares were lighted at zero time which, as stated above, was essentially the time of missile launch. Cameras on Bausell (Project 3.1) indicated that the airflight time was . This measurement is somewhat greater than the computed flight time of recorded on the ASROC fire control console dial at launch. Sinking time, as described in Section 4.1, was . Total time from launch to burst, was therefore, ; the agreement with the previous more exact determination is apparent.

4.3 SURFACE ZERO

Surface zero was located at a distance of about yards beyond the target raft approximately along the line of fire.

Aerial photography (Project 1.2) indicated that the warhead splashed in the water at a distance of beyond the target raft approximately along the line of fire. The first surface disturbance, surface zero, was noted on the photographs to be about yards beyond the warhead splash. This distance between splash point and surface zero indicates the amount of underwater forward travel of the warhead prior to burst. Such travel distance is in fair agreement with the estimate of 80 yards ordinarily given for this weapon: see Appendix A.

4.4 YIELD

The burst yield is estimated to be , based on preliminary information from Projects 1.1 and 2.1.

Underwater pressure measurements secured by Project 1.1, Reference 1, allowed a hydrodynamic determination of the yield as This estimate was derived from measurements of peak shock wave pressure at deep gages suspended from close-in stations. Limited measurements of the shock wave decay time constant tended to verify it.

Radiochemical analysis of the burst products (Project 2.1) indicated that the yield was .

The measured yield is in close agreement with the yield predicted on the basis of the : see Appendix C.

Other means of determining the yield are potentially available and the results will be given in final project reports. An independent check will be secured by Project 1.2 by analysis of the spray dome. Another hydrodynamic determination is expected from the General Atronics project.

4.5 ONSITE UNITS AT SHOT TIME

Positions of onsite units at shot time are shown in Figure 4.1. For convenience, the major stations at which measurements were obtained are indicated by showing project numbers in parentheses after the station identification.

All ships shown in Figure 4.1 were essentially stationary

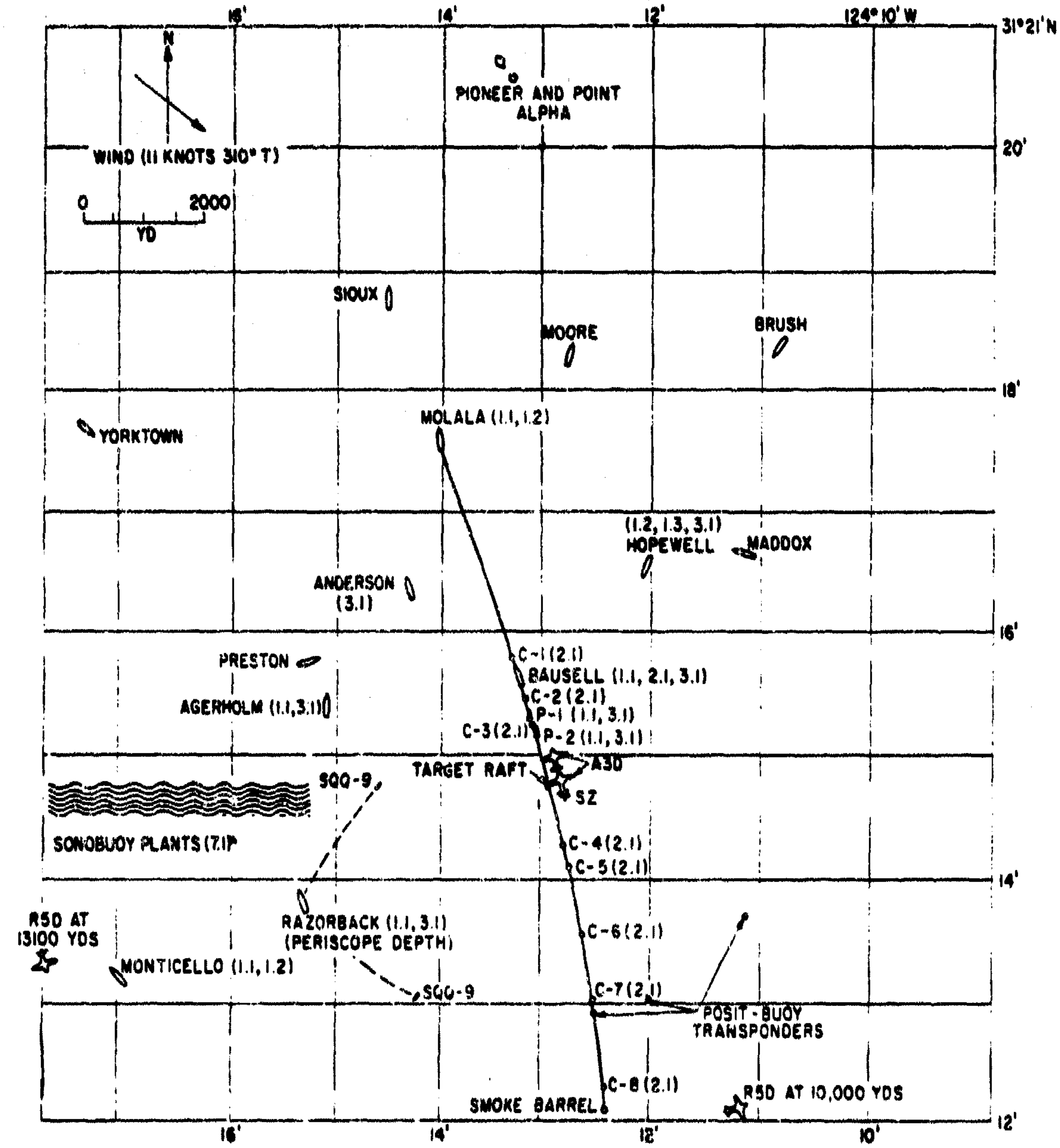

Figure 4.1 Sword Fish array at shot time.

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(i.e., speeds about 1 knot) at shot time, except for Hopewell, which was proceeding at about 4 knots. Verification of this statement is indicated by the Project 1.1 finding, deduced as discussed in Section 4.1, that the 2,000 foot underwater pressure gage line suspended from the platform closest to surface zero was inclined to the vertical by only about 5°.

The towed array, shown in Figure 4.1 by a solid curve, may be approximated by two straight line segments hinged about the target raft. The upper segment was about 344°T; the lower segment about 349°T.

Ship headings shown in Figure 4.1 are tabulated in Appendix H. Various aspects of the entire array are discussed in more detail below.

Positions of major onsite surface elements at shot time were mainly determined from: (1) ship radar tracks, (2) aerial photography, and (3) shock wave arrival times. Comparison of data obtained by all three methods is shown in Table 4.1. Detailed discussion of the derivation of positions from the radar tracks and shock wave arrival times is given in Appendix H.

Positions listed in Table 4.1 as determined by aerial photography were derived by Project 1.2 from film taken by aircraft directly overhead at burst time. However, as indicated in the table, confirming evidence for Bausell and both platforms was obtained from an aerial photographic

TABLE 4.1 POSITION OF SURFACE ARRAY ELEMENTS AT SHOT TIME

Array Element	By Radar[(a)]		By Aerial Photography[(a)]		Shock Wave[(a)]	Remarks
	Range (Yards)	Bearing (deg)	Range (Yards)	Bearing (deg)	Arrival Time Range (Yards)	
Bausell (DD-845)	2,200	338	2,209	338	2,180	Photo mapping run 1/2 hour before shot gave result in close agreement.
Agerholm (DD-826)	4,348	298			4,328	
R. B. Anderson (DD-786)	4,150	325	4,505	327	4,249	Photo range determination probably high.
Hopewell (DD-681)	4,200	021	4,108	19.5	4,014	
Razorback (SS-394)	4,600	251			4,488	
Monticello (LSD-35)	7,940	250	7,860		7,936	
Molala (ATF-106)	6,250	341	6,358	338		
Platform 1			1,427	335	1,383	Photo mapping run 1/2 hour before shot gave result in close agreement.
Platform 2			1,040	332	1,040[(b)]	Photo mapping run 1/2 hour before shot gave result in close agreement.
Target Raft			348	306		
Coracle 1			2,475	337		
Coracle 2			1,771	337		
Coracle 3			1,393	335		
Coracle 4			810	181		
Coracle 5			1,190	176		
Coracle 6			2,297	171		
Coracle 7			3,447	169		
Coracle 8			4,930	168		
Smoke Generator			5,230	167		

TABLE 4.1 (CONTINUED)

Array Element	By Radar[a] Range (Yards)	By Radar[a] Bearing (deg)	By Aerial Photography[a] Range (Yards)	By Aerial Photography[a] Bearing (deg)	Shock Wave[a] Arrival Time Range (Yards)	Remarks
Pioneer	12,600	356				
Preston (DD-795)	4,700	300				
Yorktown (CVS-10)	9,850	309				
Brush (DD-745)	8,050	026				
S. N. Moore (DD-747)	7,170	001				
Maddox (DD-731)	4,800	036				
Posit.-buoy	3,120	126				Submerged to 50 feet from float.
Posit.-buoy			3,447	169		Attached to Coracle 7, submerged to 50 feet.
Posit.-buoy	3,250	157				Submerged to 50 feet from float.

Notes: (a) Ranges are measured horizontally from surface zero to the center of the ship, and bearings are measured clockwise from true north.
(b) Correction of 2-percent made to translate slant distance given in Appendix H to horizontal range.

mapping run one-half hour prior to burst. Ranges and bearings taken with respect to the target raft agreed very closely in the two independent determinations: ranges within 1-1/2 percent, bearings within 1/2 degree.

Agreement in determining positions, as among the various methods shown in Table 4.1, is quite good considering the approximations used. In particular, values for ranges agree within about 3 percent, except in the case of Anderson. To be sure, range determination from wave arrival times depends on the prior accuracy of estimating the burst time. However, differences in arrival time with respect to a well established object (such as Bausell) provide a determination of range differences independently of burst time. It may be noted in Table 4.1 that range differences determined from shock wave arrival times are in good agreement with range difference determined by other means.

The range of Bausell from surface zero was 2,200 yards. This distance was considerably in excess of the planned range of 1,700 yards. Part of the excess distance was due to the overshooting of the warhead. Part, however, was due to the Bausell being at a greater distance from the target raft than planned. Bausell's distance from the target raft as determined by radar (see Appendix H) was 1,975 yards; this measurement was closely confirmed by aerial photography which gave 1,950 yards (see Reference 2). Apparently the tow line had stretched about 15-percent. This supposition is to some extent confirmed by observation, from aerial photography, that both platforms were also at distances in excess of those planned by about the same percent.

Surface elements of the array shown in Figure 4.1 but not listed in Table 4.1 are the Project 1.3 submarine simulators and the Project 7.1 sonobuoys.

The submarine simulators were submerged to from 50 to 100 feet and held courses indicated by the dashed lines of Figure 4.1 to positions at burst time as shown.

The Project 7.1 sonobuoy positions are indicated schematically in Figure 4.1. They stretched along a line running due west of the target raft. The SSQ-41 sonobuoys had their hydrophones at a depth of 300 feet and were planted in pairs at four positions: (1) just west of the target raft, (2) about 1 mile, (3) about 2 miles, (4) about 4 miles. The SSQ-28 sonobuoys had their hydrophones set at a depth of 90 feet and were planted in pairs in four positions: (1) about 8 miles from the target raft, (2) about 15 miles, (3) about 30 miles, and (4) about 60 miles.

Aircraft positions at burst time, shown in Figure 4.1 but not in Table 4.1, were determined only roughly from sparse information presently in hand. Deductions from their own camera films indicated that the two A3D's were approximately over surface zero at burst time at an altitude of 20,000 feet proceeding on a course of 345°T at a speed of 200 knots. The leading A3D was about 670 yards beyond surface zero; the lagging A3D about 370 yards beyond surface zero. The two R5D's were tracked by Hopewell's radar with some difficulties (see Reference 2). They were both at 10,000 feet altitude proceeding counter clockwise about surface zero at a speed of 120 knots. The leading R5D was at a range of 10,000 yards and a bearing of 150°T at burst time. The lagging R5D was apparently at a range of 13,100 yards and a bearing of 253°T at burst time.

4.6 POST SHOT POSITION CHANGES

Determination of position changes of onsite elements occurring up to, say, 15 minutes after burst time has considerable importance, especially for analyses of base surge radiation measurements. Of key importance are the position changes in the radiation measurement stations (i.e., coracles) themselves and in the camera platforms (Monticello, Molala, Hopewell, the two A3D's and the two R5D's). Information presently in hand is rather sparse but it is hoped that later careful study of the evidence will enable the prosecution of project analysis with the needed degree of accuracy. Existing preliminary information is summarized below.

Hopewell moved appreciably after the burst; Monticello and Molala did not. Movement of these ships is detailed in

Appendix H. Other ships in the array, with the exception of Sioux, are understood not to have moved very much during the 15 minute period following the burst. In particular, Bausell and the upwind section of the tow continued to be towed by Molala.

Aircraft positions following the burst will be difficult to determine (see Reference 2) and will for the most part, have to be found indirectly from photographic film obtained from their own cameras.

General observations on the position changes of radiation-measurement stations are given in Reference 5. Coracle 3 remained attached to the upwind section of the cut towline, but was washed eastward before falling into place behind Coracle 2 as the tow moved upwind. The entire downwind section of the towed array drifted with the current. Coracle 4 broke loose from the downwind section of the cut towline, and was washed downwind after which it drifted with the current. Coracle 5 overturned at an early but undetermined time. However, it remained attached to the downwind section of the cut towline.

The submarine simulator positions following the burst are not well known (see Reference 3). One unit was not recovered and apparently sank some time after the burst. One unit was recovered at a position which suggested that it was shock damaged, shut off, and surfaced immediately following the burst.

4.7 GEOGRAPHIC LOCATION OF SURFACE ZERO

The geographic position of surface zero was 124° 12.7' ± 0.5' West longitude and 31° 14.7' ± 0.5' North latitude.

Surface zero was located geographically by taking radar ranges and bearings of Pioneer with respect to the target raft as described in Appendix H. Pioneer was standing close to Point Alpha (see Figure 4.1) during the test; Point Alpha's geographic position was known to better accuracy than that of any other object.

Point Alpha was marked by an anchored buoy placed by Pioneer during the pre-shot phase of Sword Fish activities. The longitude and latitude of the buoy were determined by Pioneer by a series of star fixes and loran readings. All readings agreed within about a quarter of a mile. The geographic position of Point Alpha was 124° 13.3' ± 0.3' West longitude and 31° 20.6" ± 0.3' North latitude.

4.8 SEA BOTTOM

Water depths at the test site were measured by Pioneer prior to the test, and locations were systematically determined with respect to Point Alpha. Bottom samples were secured. Seismic measurements of the bottom characteristics were also made, using high explosive charges.

The water depth at surface zero was 2,190 fathoms.

Depth at instrumented-ship locations did not vary from this value by more than 50 fathoms. Figure 4.2 charts the test-site bottom. Inaccuracy of the depths shown is estimated to be less than 10 fathoms.

Information on the bottom characteristics is tentative. Bottom core samples showed a red clay and sediment composition. Depth soundings, taken by exploding HE charges, indicate the clay layer is not thicker than 200 feet. Depth soundings also indicate deeper layers.

4.9 METEOROLOGICAL CONDITIONS

Meteorological conditions are given in detail in Appendix D. A summary of the meteorological data at shot time is given below:

Cloud coverage (total skydome)	0.6
Cloud coverage (over surface zero)	0.2
Visibility	15 miles
Barometric pressure	30.3 in Hg
Air temperature - dry bulb	65°F
Air temperature - wet bulb	53°F
Surface wind at target raft	10 to 11 knots from 310°T

The direction of the surface wind given above is based on aerial photographs of smoke from the flare on the target raft.

4.10 OCEANOGRAPHIC CONDITIONS

Sea waves at the test site at shot time were less

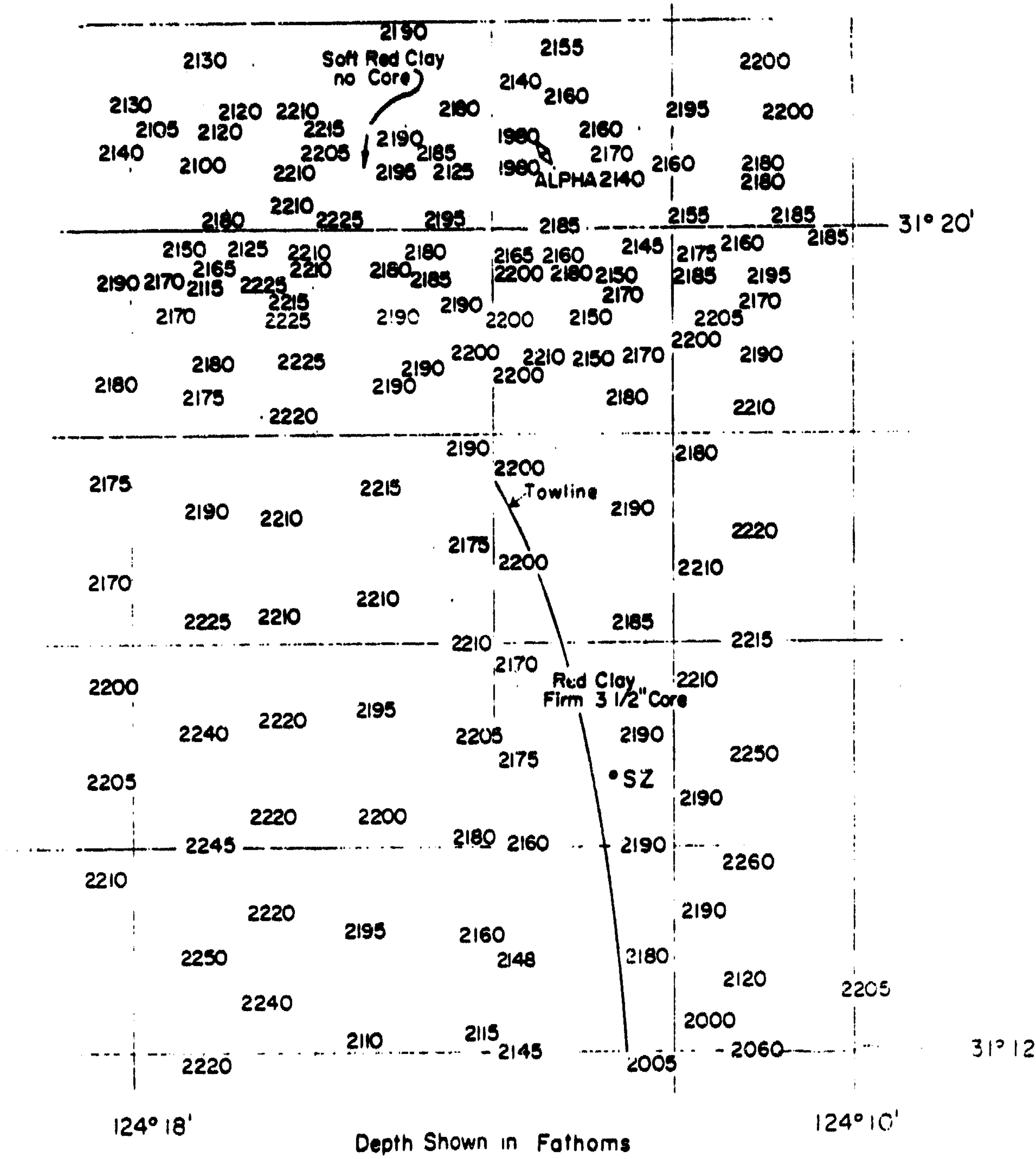

Figure 4.2 Chart of test site bottom.

than 3 feet high, crest to trough, and from the Northwest. Swells ranged 1 to 6 feet from the North by Northwest. The surface current was about 0.5 knots from 338°T. Details are given in Appendix D.

Bathythermographs close to shot time were made by Agerholm, Anderson, Hopewell and Pioneer; a few of the measurements made closest to shot time are given in Appendix H. A comparison of measurements made close to shot time at various ships is shown in Figure 4.3. These measurements together with those given in Appendix H, suggest that the thermal gradient at shot time was fairly independent of ship position.

Salinity data, taken by Pioneer on 26 April 1962, is reproduced in Figure 4.4 and probably represents a good approximation to conditions at shot date.

Sonar ranges reported by Anderson, Agerholm, and Hopewell close to shot time suggest that a submarine at periscope depth could have been detected: (1) by SQS-23 sonar at a maximum range of about 7,500 yards, (2) by SQS-32 sonar at a maximum range of about 5,000 yards.

4.11 LOCATION OF OFFSITE STATIONS

Approximate locations of off-site stations are shown in Figure 4.5. For simplicity, Figure 4.5 omits a ship stationed off the coast of Chile: no measurements were

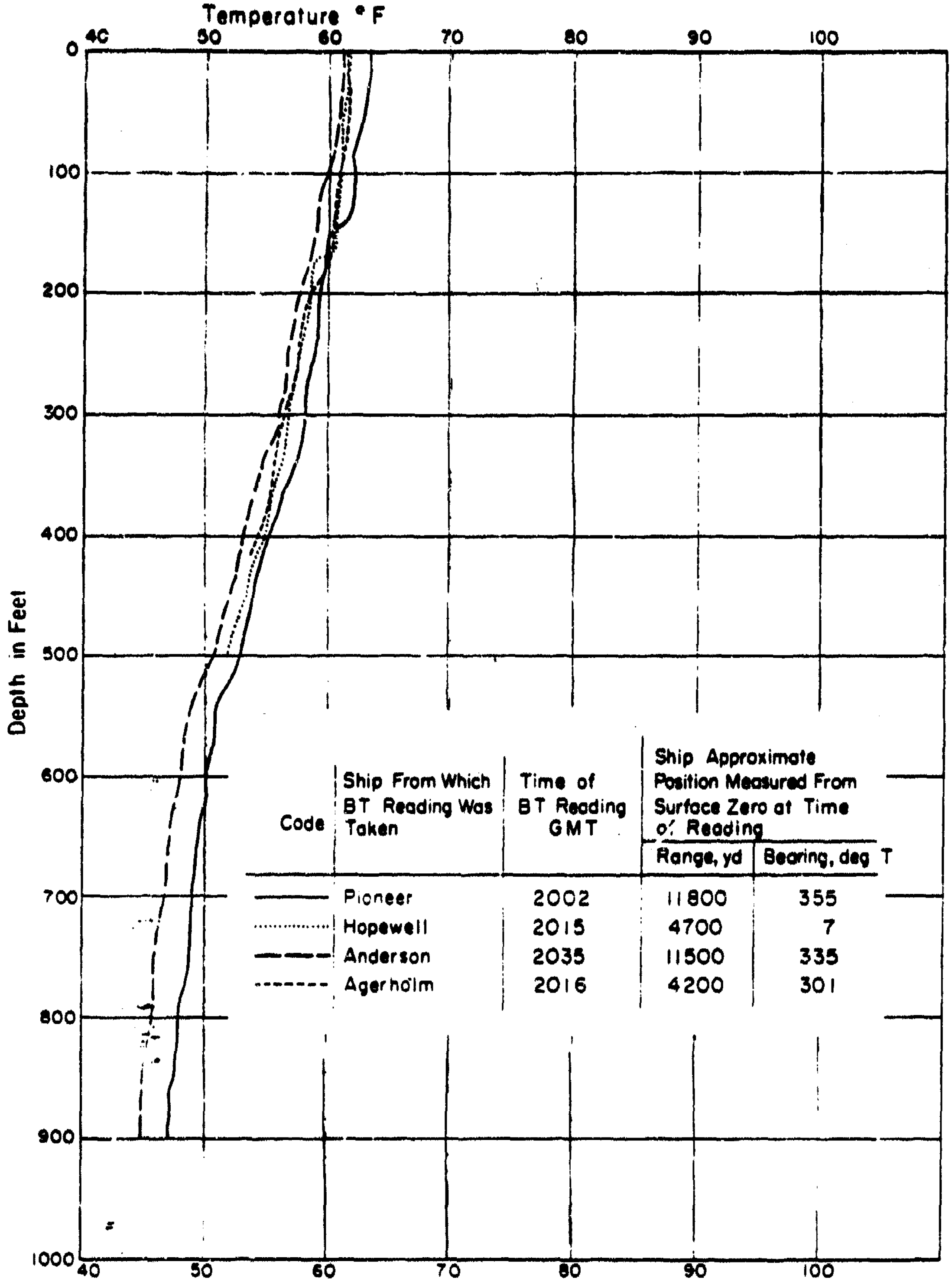

Figure 4.3 Bathythermographs near shot time at various ship positions.

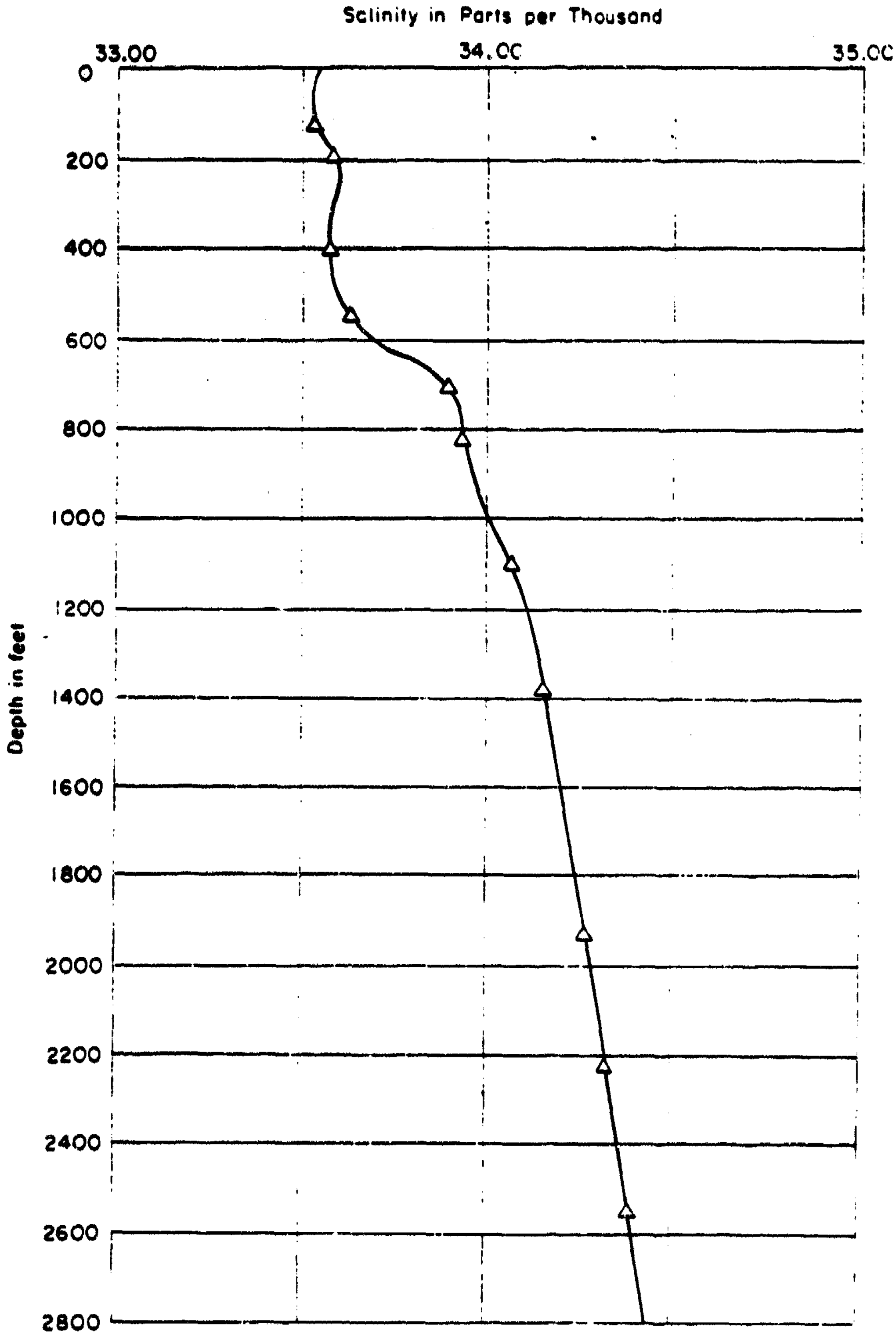

Figure 4.4 Salinity data at test site. (Triangles indicate depth at which data was taken on 26 April 1962.)

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secured there. Moreover, Figure 4.5 omits the positions of a number of submarines which reported general observations of the effects of the burst on their sonars. Detailed information may be found in Reference 4.

Chapter 5

RESULTS

Sword Fish was conducted successfully, with safety to personnel and with achievement of its purposes.

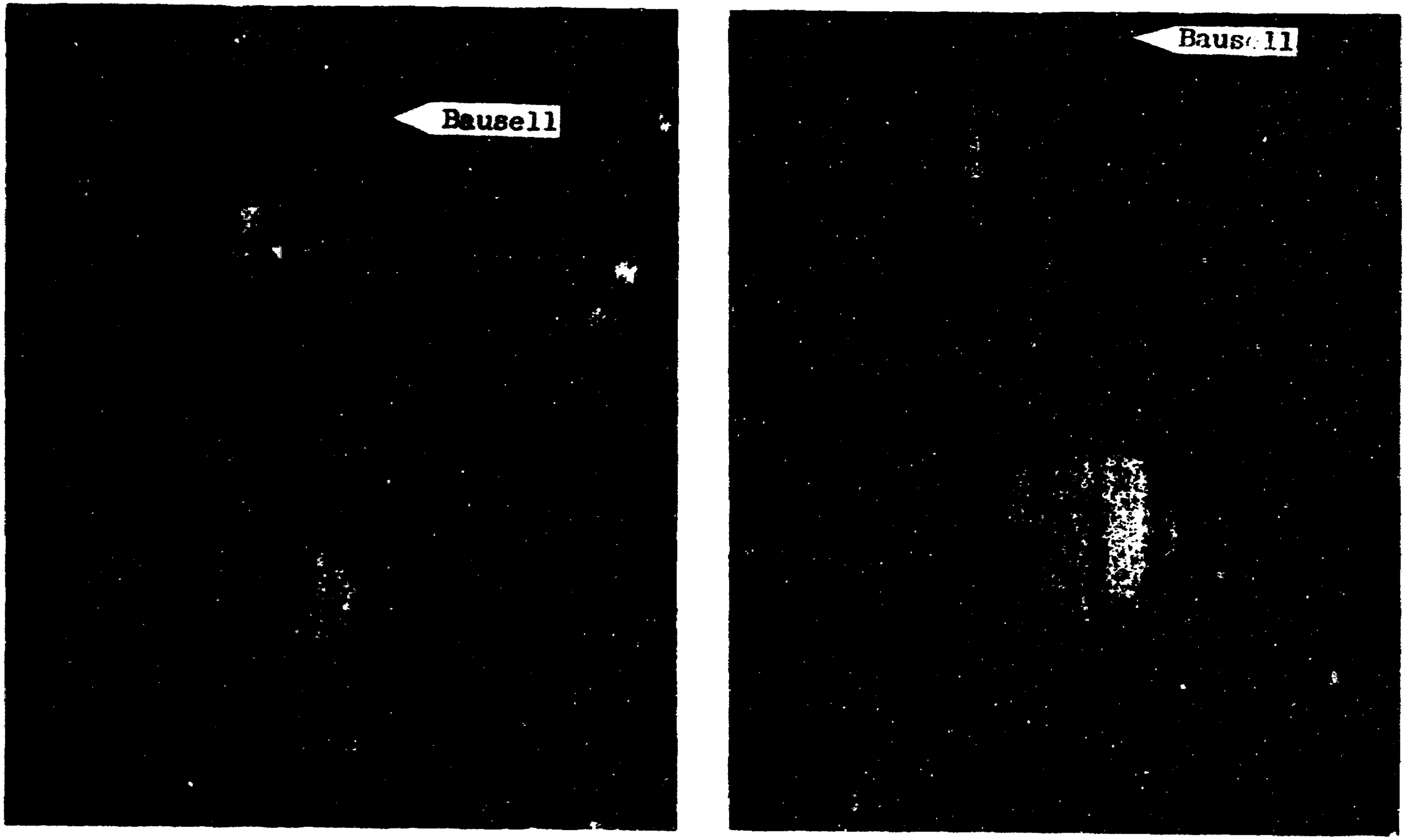
Test operations were completed without serious injury to anyone. Radiation dose limits were not exceeded except for six men who received doses up to 6 r while aboard Sioux. This ship entered the radioactively contaminated pool at about 20 minutes after burst time in order to obtain water samples.

Nearly all of the measurements attempted during the ASROC test were secured. Many months of painstaking analysis by the participating projects will be required before these results become available in reliable detail. Meanwhile, much information is given in the project preliminary reports, References 1 to 7, or in the informal reports of various types.

A selected summary of the highlights of the preliminary results is given below.

5.1 SURFACE PHENOMENA

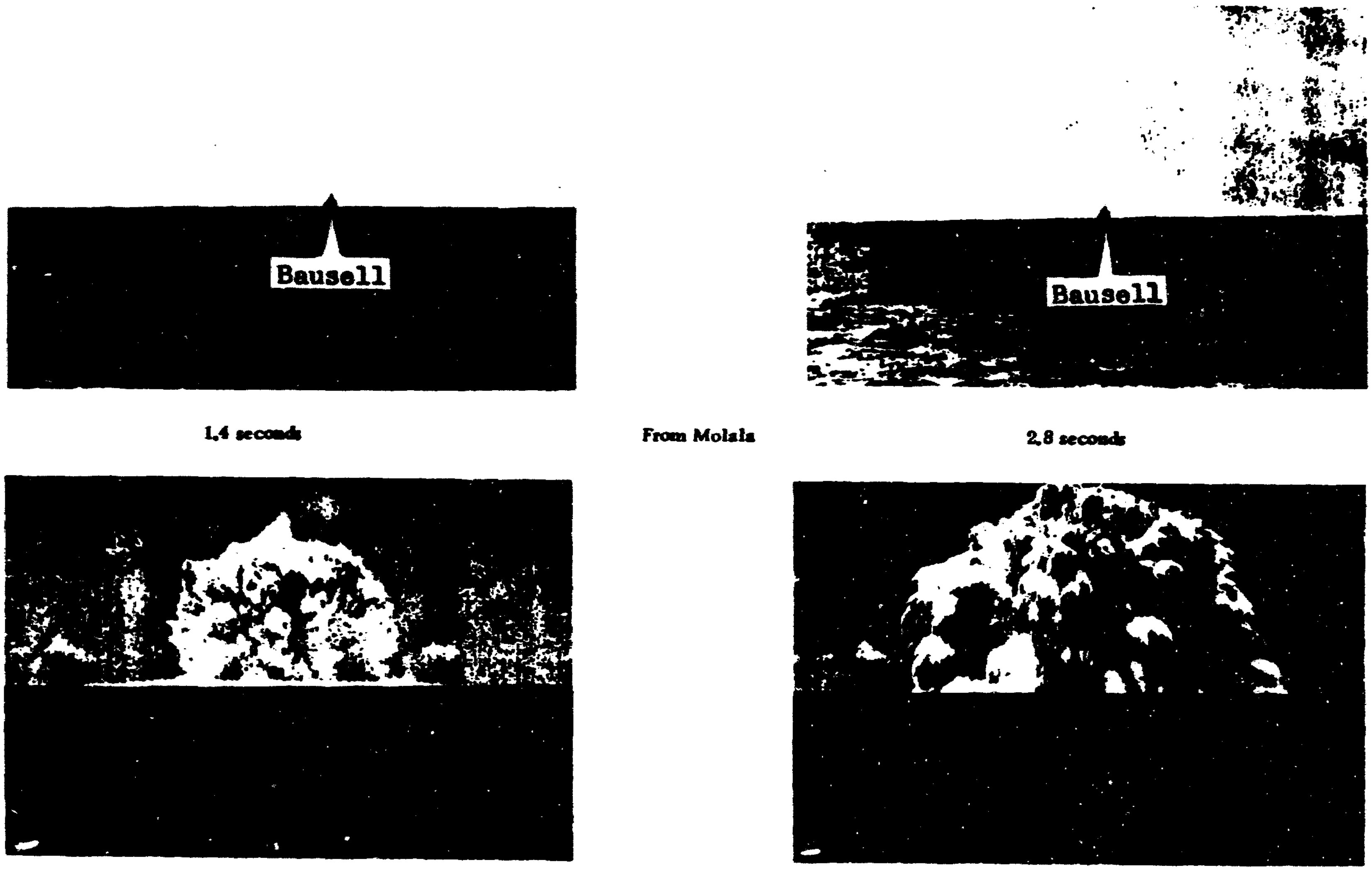
The main features of the surface phenomena described by Project 1.2 (Reference 2) are illustrated in Figures 5.1 to 5.5. Times marked below each print are times after burst, neglecting the small time interval (about 0.1 sec) from burst to the first effect visible at the surface.



0.70 second

0.17 second

Figure 5.1 Slick and spray dome as seen from the air.



1.4 seconds

From Molala

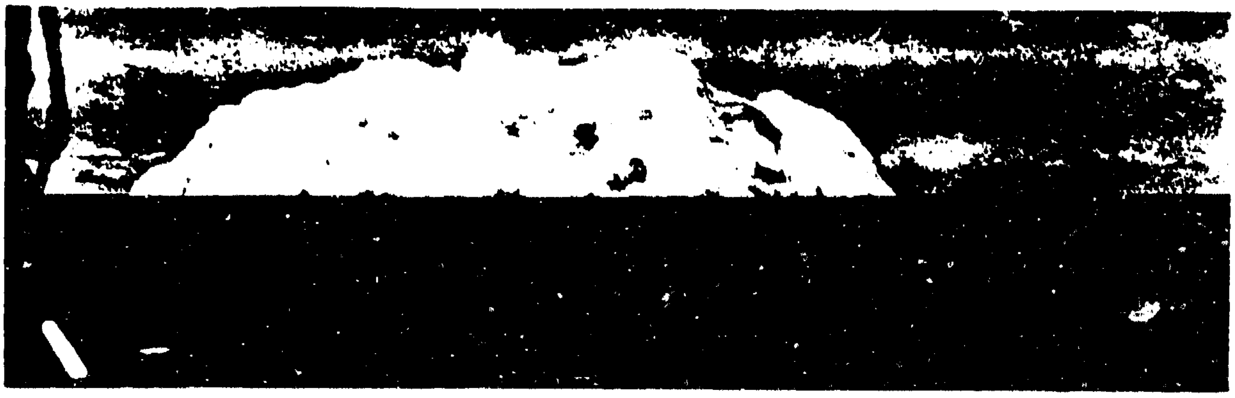
2.8 seconds

12 seconds

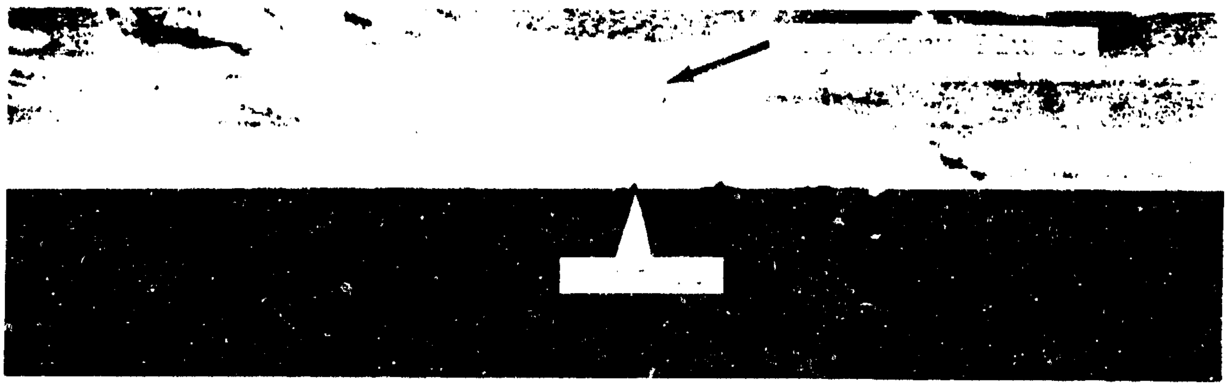
From Hopewell

18 seconds

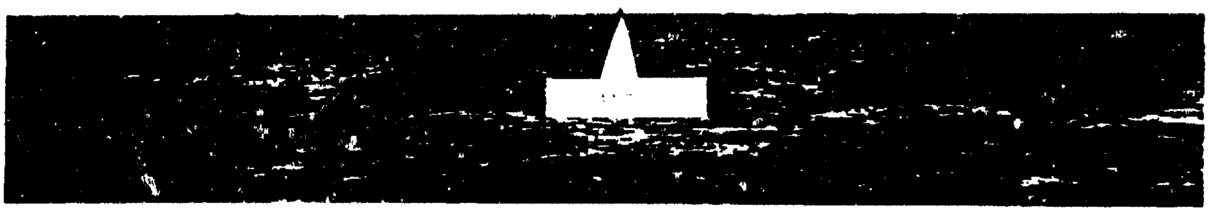
Figure 5.2 Spray dome and plumes.



From Hopewell 25 seconds

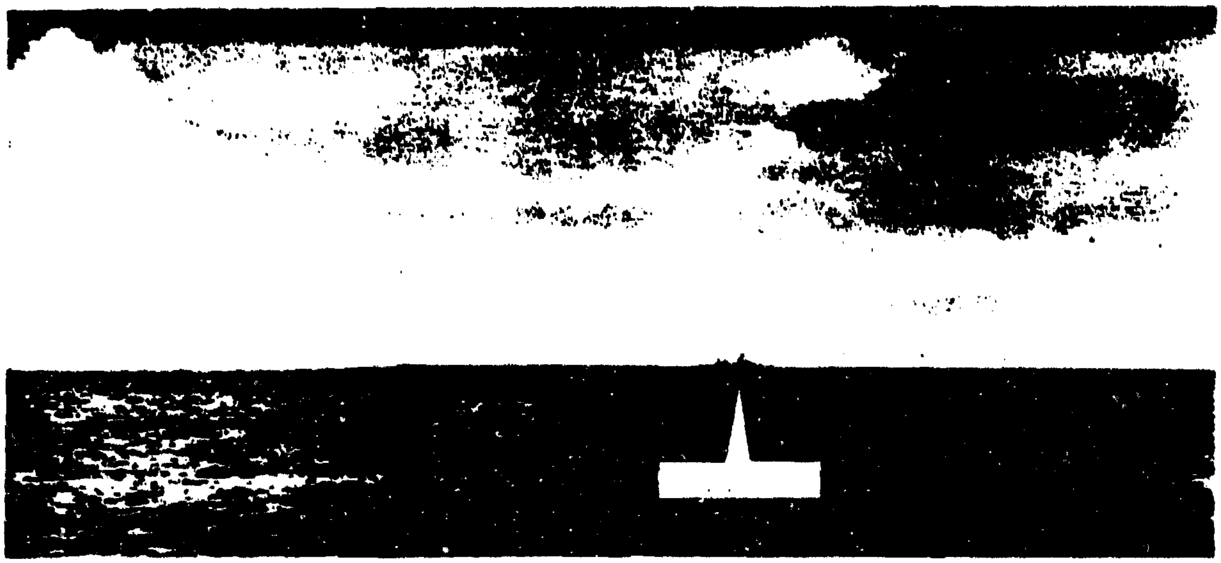


From Molala 46 seconds

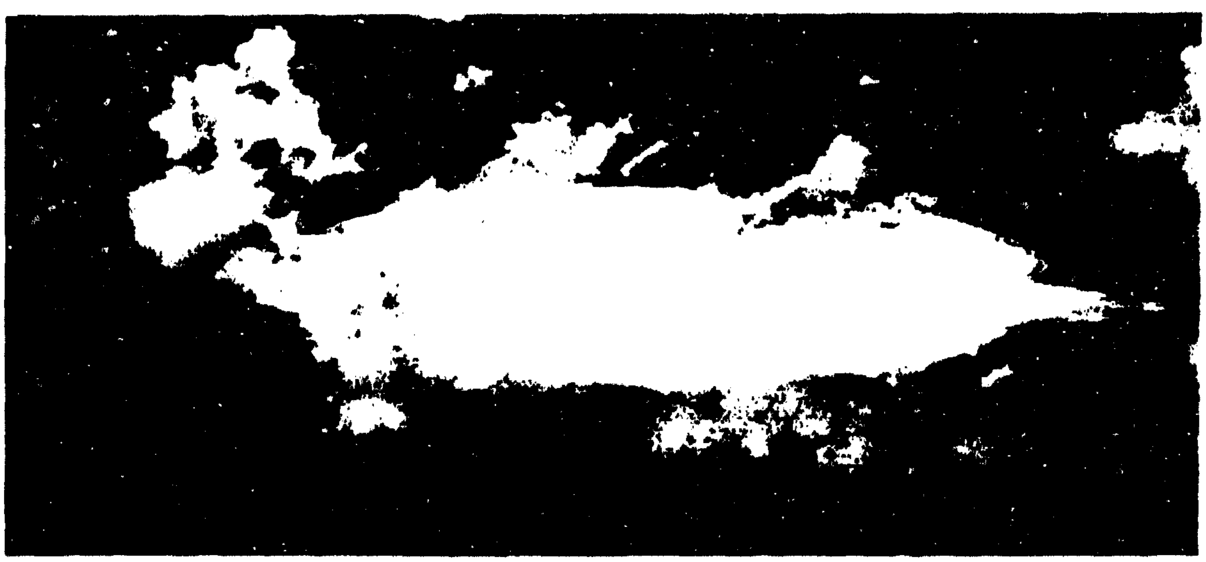


From Molala 58 seconds

Figure 5.3 Base surge.

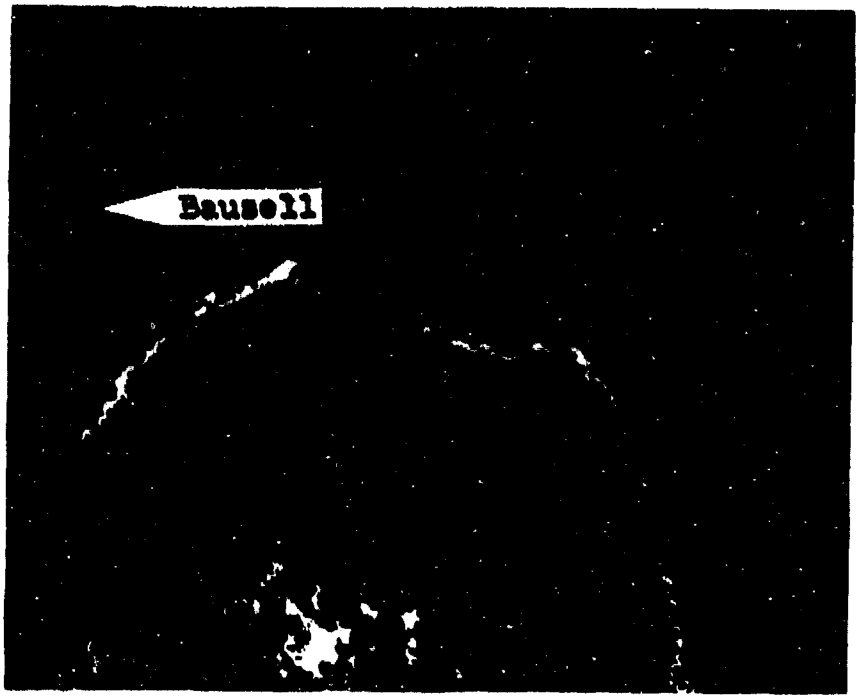


From Hopewell 87 seconds

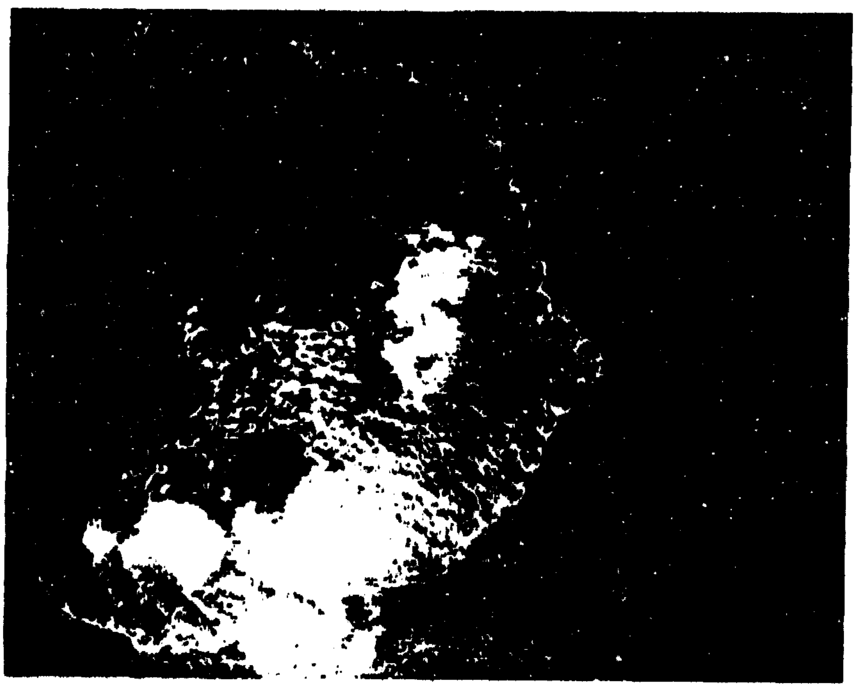


From the air 153 seconds

Figure 5.4 Base surge and foam patch.



267 seconds



11 seconds

Figure 5.5 Foam patch as seen from the air.

The slick (the outer boundary of the dark ring shown in Figure 5.1) is the first evidence of the underwater burst visible at the water surface. The light from the underwater fireball was not detected by human eye or by camera. The slick represents a change in the optical properties of water caused by the shock wave and indicates the outward spread of the shock front at the water surface. Measurements of the slick led to an estimate of the burst depth given in Chapter 4. Secondary slicks, not shown in Figure 5.1, were also observed and these offer clues as to the nature of other pressure waves.

The spray dome (the white central areas shown in Figure 5.1 and the white mound of water shown in the upper two prints of Figure 5.2) is a mass of water spray thrown up into the air as a result of the shock wave interaction with the water surface.

Radial plumes of water (shown in the lower two prints of Figure 5.2) broke through the spray dome at about 7 seconds. These plumes are powerful jets of water produced by the contracting and upwardly migrating steam bubble left to pulsate in the water after the burst. They represent the first appearance of radioactive products above the water surface.

Secondary plumes (shown in the center print of Figure 5.3) arose to a smaller height at a later time: they are discussed below in connection with gravity waves.

The base surge (shown in Figures 5.3 and 5.4) consists of small water droplets formed when the plumes collapse. These water droplets surge outward from the base of the collapsing plumes carrying radioactive products of the nuclear burst. The visible base surge started to form

The base surge pushed outward rapidly at first; at early stages it was roughly circular. As the base surge slowed, it came more and more under the influence of the wind and lost all claim to circular symmetry. The visible base surge reached a maximum upwind

. Faint clumps of mist were still visible, however, up to at least 10 minutes. An invisible aerosol lingered even beyond this time as discussed in Section 5.5. More detailed information on the base surge is given at the end of this section.

A foam patch (shown in Figures 5.4 and 5.5) at the surface of the water became visible as the base surge dispersed. The edges of this patch probably mark the boundaries of a pool of radioactively contaminated water. Roughly circular in shape, the foam patch had attained a radius of about 2,000 yards when its visible aspects disappeared more than 20 minutes after the burst.

A train of gravity waves produced by the burst is to some extent visible in Figure 5.5. Gravity waves are produced by the collapse of the cavity left at the water surface by the erupting plumes; the same mechanism is responsible for the formation of the secondary plumes seen in the central print of Figure 5.3. A few observations of these water waves are reported in Reference 6.

Detailed description of the surface phenomena is given in Reference 1. For present purposes, some additional information on the base surge is given in Figures 5.6 and 5.7. Figure 5.6 shows some rough estimates of the base surge contours at a succession of times. These estimates came from a combination of aircraft and surface ship photographic film read by Project 1.2. Gaps in the contours indicate the presence of clouds or lack of visible aspect from the photographic positions. Figure 5.7 shows distance-time relations of the boundary of the base surge along various bearings from surface zero. These relations represent interpolations of readings made from Figure 5.6

Pages 120 and 121 deleted.

Attention is called to the fact that slopes of the curves indicate that the rate of base surge advance in the upwind and downwind directions is about equal to the wind speed after 2 minutes. The crosswind rate of advance is comparably slow after this time.

5.2 UNDERWATER PRESSURE

Measurements of pressure histories were made by Project 1.1 at depths extending from 25 feet below the water surface down to 2,000 feet, using floating stations located between 1,000 and 6,000 yards from surface zero. Both the direct shock wave and the sea-bottom-reflected pressure waves were recorded. No evidence of a bubble-pulse pressure has been noted at the present stage of data reduction.

Detailed description of the results is given in Reference 1. These results led to estimates of burst depth, yield, and time, which are summarized in Chapter 4. For present purposes, attention is concentrated on pressures near surface ship positions.

Estimates of the peak shock-wave pressures near the water surface were made from Project 1.1 measurements presently available and are given by points in Figure 5.8. The direct shock wave, whose peak pressures are given by squares, was characterized by a steep front followed by an exponential decay: the decay time constant was about 30 msec. The sea-bottom-reflected pressure wave, whose peak pressures are given in Figure 5.8 by circles, had a slowly rising front followed by a complex history. The reflected pressures were apparently not symmetrical about surface zero: this is noted in Section 5.3.

 Page 124 deleted.

Two computations were made for the direct shock-wave peak pressure at the surface and the results are shown in Figure 5.8. The dashed line represents the peak pressure to be expected, according to Reference 18, in isovelocity water as a result of the Sword Fish burst.

. The solid line in the upper portion of the figure represents a more refined computation in which allowance was made for refraction effects The computational scheme was based on acoustic ray theory in the manner described in Reference 19. A thermal gradient similar to that measured in Sword Fish was used for a computer input prior to the test itself; the thermal gradient used for computing was sufficiently similar to the actual test condition that the effort of another calculation did not seem warranted. The degree of agreement between the measured points and the computation which allows for refraction justifies use of this method to extend the range interval covered by the measurements. The difference between the two computed curves of Figure 5.8 indicates the significance of refraction for influencing direct shock-wave strengths.

The solid curve shown to the bottom of Figure 5.8 merely connects the measured bottom-reflected pressure peaks, with the extended dashed portion representing an arbitrary extrapolation. Existing information does not justify a theoretical comparison; this must await further analysis.

5.3 SHOCK MOTIONS

The motion histories of ship hulls and selected equipments were measured by Project 3.1 (Reference 6). Information included the response to the direct shock wave and sea-bottom-reflected pressure waves of Bausell, Agerholm, Anderson, Hopewell and Razorback.

The response to the bottom-reflected wave was more severe than that from the direct shock wave in every ship but Bausell. At Bausell the responses to the two types of input were about equal.

Velocity motions recorded on the ships were predominantly in the vertical direction, with the single exception of Razorback. For example, on Bausell the vertical peak velocities were several times as great as those in other directions. Razorback was submerged to periscope depth; the vertical and horizontal velocities were about equal.

Vertical motions were distributed fairly uniformly throughout each ship. This was true even for the motions produced in Bausell by the direct wave: a situation in which a pressure wave travelling at a small angle with respect to the water surface struck from the stern.

The main features of the vertical shock motions are given in Figure 5.9. The experimental points shown in this figure represent average peak vertical velocities measured at various locations on the ship bulkheads. This type of location is representative of the ship structure; motions at bulkheads are considered to be characteristic of the basic shock input. Actual ranges for peak vertical velocities at bulkheads were: (1) 0.8 to 1.3 ft/sec for Bausell in response to the direct shock wave, (2) 1.1 to 1.2 ft/sec for Bausell in response to the bottom-reflected wave, (3) 0.4 to 0.6 ft/sec for Agerholm in response to the bottom-reflected wave, (4) 0.4 to 0.6 ft/sec for Anderson in response to the bottom-reflected wave (5) 0.8 to 1.0 ft/sec for Hopewell in response to the bottom-reflected wave.

Curves shown in Figure 5.9 represent computed vertical peak bodily velocities. Previous experience (References 19 and 2 indicates that average peak vertical bulkhead velocities represent the vertical bodily velocity of the ship fairly closely. Computations were actually based on approximating the vertical bodily velocity by the vertical water-particle velocity at the water surface: this is an excellent approximation for underwater nuclear explosions (see Reference 19). Two computations were made for the direct shock wave: one (dashed curve) for isovelocity water and one (solid curve) for refraction conditions similar to those prevailing at test time. These computations employed the peak pressure curves given in Figure 5.8 and attack angles given by geometry (isovelocity calculation) or by refraction theory. One computation was made for the bottom-

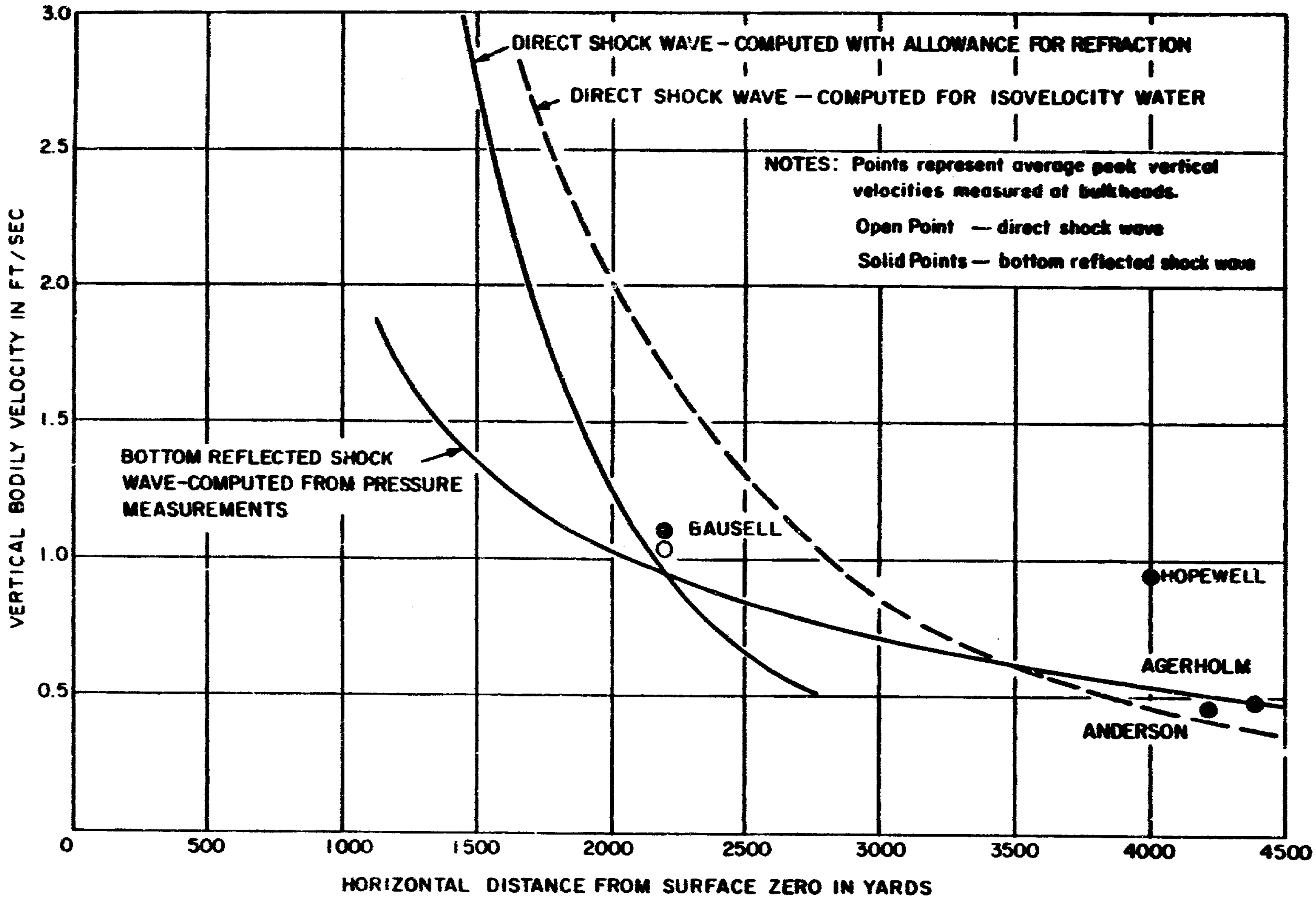


Figure 5.9 Peak vertical bodily velocities of surface ships.

reflected shock wave. This employed the peak pressure curve given in Figure 5.8 and attack angles given by geometry.

The degree of agreement shown in Figure 5.9 between the measured values and the curves computed for the direct shock wave and bottom-reflected pressure wave is generally good. Note, however, that Hopewell received more severe shock motion than did Anderson and Agerholm at about the same distance but on a different bearing from surface zero. This observation suggests that the bottom-reflected pressures were not symmetri about surface zero; unfortunately, no underwater pressure measurements were made on Hopewell's bearing to confirm this point. The difference between the two curves computed for the direct shock wave indicates the significance of refraction under Sword Fish conditions.

The main features of the shock motions sustained by Razorback may be summarized briefly. Peak vertical velocities in response to the bottom-reflected pressure wave ranged from 0.4 to 0.7 ft/sec at bulkhead locations. Peak athwartship velocities in response to the bottom-reflected pressure wave were about 0.5 ft/sec at bulkhead locations.

Pages 130 through 134 deleted

5.5 BASE SURGE RADIATION

A number of observations were made of the nuclear radiation associated with the base surge. For the most part these observations consisted of gamma ray intensity histories recorded by Project 2.1 at eight coracle stations located up- and downwind of surface zero and at Bausell located upwind (roughly 35 degrees off the wind line). Some measurements of the size and rainout rate of water droplets in the base surge were secured, as were water samples from the base surge. Samples of the water about surface zero were also obtained after the burst for the purpose of determining the radiochemical yield. Attempts to secure gas samples apparently failed.

Existing information consists largely of gamma ray intensity histories and is reported in Reference 5. Basic questions concerning
the nature and distribution of the radioactive products, and the fraction of radioactive sources carried by the base surge must await further study. More immediately apparent aspects of the results, together with various observations on the base surge and ship contamination, are summarized below.

Key results from the gamma ray intensity histories measured at exposed surface locations are presented in Table 5.3. It should be realized that the radiation histories were complex in nature: for example, the peak dose rate given in

TABLE 5.3 TOTAL GAMMA RAY DOSE AT EXPOSED SURFACE LOCATIONS

Station	Distance from SZ (yd)	Total Dose (r)	Time to Accumulate 90% of Total Dose (min)	Remarks
C1 (Upwind)	2,500	0.4	2	Not in base surge or pool.
Bausell	2,200	0.70-2.1	2-3	Not in base surge or pool, values recorded on weather decks.
C2 (Upwind)	1,800	23	3	Not in pool or base surge.
C3 (Upwind)	1,400	880	20	In windward edge of pool
C4 (Downwind)	800	4,240	12	Adrift in leeward edge of pool.
C5 (Downwind)	1,200	210	20	Coracle overturned.
C6 (Downwind)	2,300	330	55	Probably drifted into the pool sometime after 30 min.
C7 (Downwind)	3,450	39	6	Not in pool, toward edge of base surge.
C8 (Downwind)	4,950	17	4	Not in pool, toward edge of base surge.

Note: (a) Radiation reached 4 out of 5 stations where this could be determined by about 7 to 8 sec. An exceptional station was C6 where it apparently took 13 sec.

(b) Stations 1, 2, 7, 8 essentially stationary while dose was accumulating.

Table 5.3 measurements are not necessarily the first dose-rate maximums to occur on the record. The time over which 90 percent of the dose was accumulated, as listed in Table 5.3, is measured from the time at which radiation intensities first became appreciable; it is not time from burst. Coracles enveloped by the base surge and washed by the contaminated water pool are indicated under the "remarks" column of Table 5.3. These determinations were made on the basis of photographic coverage of the visible base surge, the character of the radiation histories, and the type of contamination found on the coracles when they were recovered.

The intimate connection of the radiation measurements with the surface phenomena is easily seen by reviewing Table 5.3 with reference to information in Section 5.1. Radiation was first noted about 7 seconds after burst time at 4 out of the 5 stations where absolute time could be determined; at this time the plumes first erupted through the spray dome. Radiation intensities were relatively low at stations which remained outside of the base surge and the contaminated water pool. There is little doubt that most of the radioactive products from the burst erupted above the water surface with the plumes and that a portion settled back to form the contaminated water pool within a few minutes while a portion remained in the air as base surge for at least 20 minutes.

but the Sioux encountered invisible aerosol, which contaminated ships and personnel, at about 20 minutes just after she entered the contaminated water pool: see Appendix E. Arrival times of the base surge at the radiation stations have an obvious importance and these times are also listed in Table 5.3.

Radiation intensities and total doses, measured at exposed surface recorders and listed in Table 5.3, are plotted as a function of distance from surface zero in Figure 5.10. Some portion of the radiation was contributed by sources in the base surge and some by sources in the contaminated water pool.

Most of the radiation recorded by the three upwind stations (Bausell, Coracles 1 and 2) shown in Figure 5.10

. These stations stayed outside the contaminated water pool which, at the early times of interest, could not have made an appreciable contribution. The radiation intensity dropped off too sharply across the edge of the pool to permit much contribution from the pool: see Section 5.6. The base surge itself did not reach any of these stations, though coming very close to Coracle 2; a finger of the base surge actually reached out on the windward side to a greater distance than Coracle 2. The rapid drop in intensities and total doses shown in Figure 5.10 by these three stations

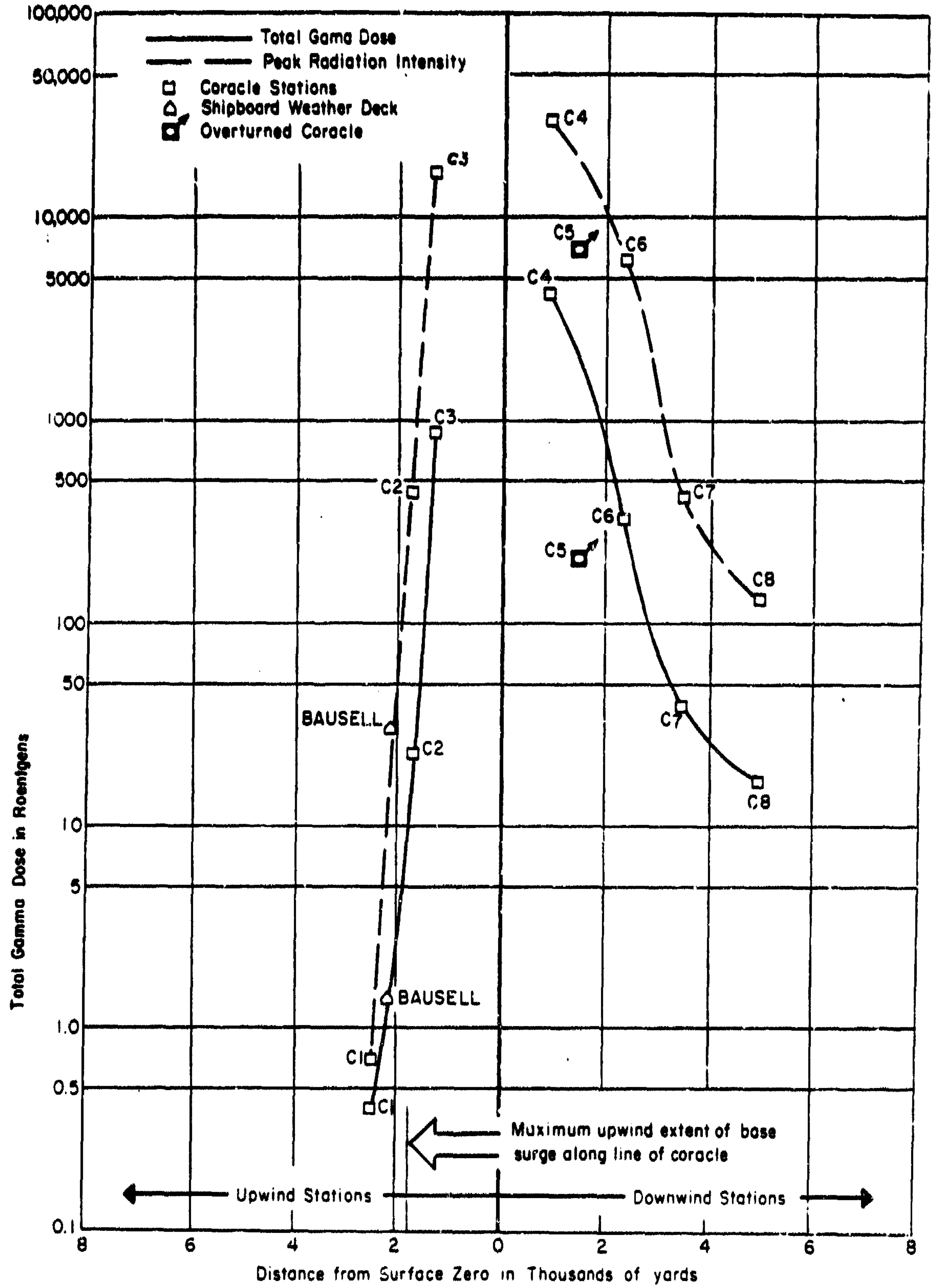


Figure 5.10 Total gamma dose and maximum radiation intensity as functions of distance.

clearly suggests the decrease in radiation hazard with distance from the edge of the base surge. Note that beyond a distance of about 350 yards from the edge,

total doses less than 3 r.

The situation for the two stations shown in Figure 5.10 farthest downwind (Coracles 7 and 8) is not so clear. These stations undoubtedly recorded radiation largely from the base surge: they were definitely not washed by the contaminated water pool. Nevertheless, the geometry of these stations with respect to the base surge has not yet been determined.

The four interior coracles shown in Figure 5.10 received their radiation from both the enveloping base surge and the contaminated water pool. Relative contributions cannot be apportioned without further study. Nevertheless, it seems clear that envelopment by the base surge produced a large portion of the total. Individual radiation histories measured at these interior stations show early peak intensities as high as tens of thousands of roentgens per hour.

Some interesting observations from an airborne monitoring expedition are made in Appendix E. An R5D aircraft flew directly over the base surge at an altitude of 3,000 feet 15 minutes after the burst.

though the aircraft was not contaminated. Additional flights were made at 1,500 feet altitude at 50 and 60 minutes.

Bausell, stationary at 2,200 yards upwind of surface zero, remained several hundred yards beyond the maximum upwind extent of the base surge and was not contaminated. When she was re-boarded about an hour after the burst, radiation intensities were at background level. Gamma time-intensity recorders aboard Bausell showed and a maximum dose of about 2 r: see Figure 5.10. These values were measured on the fantail. At a bow location on the weather decks, the radiation was less: and total dose 0.7 r. Gamma ray intensities within the interior of Bausell were less than 1/10 of those measured on the weather decks.

5.6 CONTAMINATED WATER POOL

The water about surface zero was radioactively contaminated by the underwater burst. After the subsidence of the visible base surge, a number of projects secured measurements of the extent of the contaminated pool, its surface and subsurface radioactivity, and its drift. This mapping and monitoring effort was made by: several projects in the AEC program using Sioux for the first 24 hours, Pioneer from about 25 hours after the burst to many days later, and Project 2.2 using an aircraft from one to seven days after the burst.

Surface measurements of the contaminated water pool indicated that radiation intensities were not uniform throughout the pool area. Intensities within the pool boundaries, defined by contours of constant radiation intensities, varied as much as tenfold over distances as small as a few hundred yards. Nevertheless, the various measurement efforts permit an overall picture of the pool behavior to be drawn. As the radioactive products diffused and decayed the pool grew in size and maximum radiation intensity diminished. Simultaneously the entire pool drifted with the current. At first the pool drifted toward the southeast, then toward the south, and still later toward the southwest. Twenty days after the burst Pioneer reported the maximum surface intensity to be 0.04 mr/hr and the pool center to be about 50 miles due south of surface zero.

Subsurface radiation intensity measurements down to at least about 400 feet were obtained by Sioux and Pioneer. These measurements appear to suggest that, by at least one day after the burst, radioactive material was essentially confined to the water layer above the thermocline, at about 200 feet depth.

Radiation intensities at the surface of the pool are especially interesting within a few days of the burst. Available measurements of the maximum intensity are plotted, as a function of time after burst, in Figure 5.11. These measurements were obtained from Project 2.1 gamma time-intensity recorders during the early forays of Sioux into the pool to obtain water samples (Reference 5), from the 24-hour monitorin by Sioux, and from the aircraft monitoring accomplished by Project 2.2. In the latter case the P2V aircraft flew over the pool at an altitude of about 500 feet; the aircraft measurements were multiplied by a factor of 4 to convert them to surface readings prior to entering them in Figure 5.11.

Measurements of maximum surface radiation intensity shown in Figure 5.11 indicate fair agreement among sets of values obtained from the various sources. This agreement is emphasized by drawing a solid line faired through the measurement points. These measurements suggest a method of extrapola ting back to conditions existing a few minutes after the burs possible extrapolations are indicated by the dashed lines. Such matters obviously require further study. Note that in tl

Page 144 deleted.

figure the earliest measurement might include a contribution from the aerosol. All that seems apparent at the moment is that surface radiation intensities were considerably in excess of 1,000 r/hr a few minutes after the burst.

The field from the pool appeared to contain a large fraction of low energy gamma radiation. Radiation levels inside the wheel house of the Sioux were less than 1/100 of those outside on the weather decks despite the minimal shielding provided by the ship structure. The monitoring aircraft (Project 2.2) reported that the spectrum was heavily weighted toward energies equivalent to 100 KEV.

The Sioux, which made several passes through the contaminated water, did not have its machinery or piping contaminated to a significant degree except for the lube-oil coolers which read 3 mr/hr five days after the test. The weather deck contamination resulting from early-time aerosol was easily decontaminated by fire hoses.

The four coracle stations that were in the oontaminated pool were found to be contaminated by an alpha emitter, probably unfissioned plutonium. The contamination was confined to a belt 8 to 12 inches wide around the water line of these stations and was extremely difficult to remove.

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5.8 MARINE LIFE

About 53 dead fish were counted after the burst. A portion of this fish count may represent redundant observations. Fish were reported to be less than 3 feet in length.

A number of studies of the effects of the underwater nuclear explosion products on marine life were made by Wood Hole Oceanographic Institute (WHOI) under AEC sponsorship. In the main, these studies involved pre- and post-shot surveys aimed at documenting changes in the physical and chemical composition of the water and its biological content down to a depth of several hundred feet. Samples of plankton were collected at various times to investigate their concentration, their excretion rates and their accumulation of fission products. A considerable amount of data was obtained but an intelligible assessment of the results must await laboratory analysis.

5.9 OFF-SITE HYDROACOUSTICS

A number of observations connected with the long range transmission of hydroacoustic signals generated by the underwater nuclear burst were made from ship and shore stations. Measurements were secured by Projects 1.3 and 1.4, with preliminary results reported in Reference 4. Records must be studied over many months to permit overall evaluation of the effects of an underwater nuclear burst on the capabilities of surveillance stations to continue to function and of the possibilities of using hydroacoustic methods to detect and classify underwater nuclear bursts. Meanwhile, information presently in hand concerns the effects of the burst and is summarized below.

Sea Fox, submerged to periscope depth, was stationed about 30 miles north of surface zero at about the first LORAD convergence zone. Pressure histories were obtained from hydrophones placed at depths between 150 and 1,000 feet. Pressure spikes, with a duration of a few milliseconds, were recorded with peak pressures up to nearly 40 psi at the deeper depths and less than 20 psi at the shallower depths. Reverberations were recorded over a longer time.

Pressure recordings were also obtained successfully from other ships shown in Figure 4.5. A notable result was that the two ships behind the Hawaiian Islands received much weaker signals than did the ships located so as to permit an unobstructed ocean path to the burst.

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5.10 SPECIAL OBSERVATIONS

A number of miscellaneous results of Sword Fish deserve mention.

An extensive photographic coverage of the test, in addition to the technical photography, was secured by the Pacific Fleet Mobile Photographic Unit. This film is of excellent quality and will provide the basis of several documentary films. Though the film lacks timing marks it is anticipated that considerable technical information can be secured from it.

A video tape recording of pre-test activity at the site and the early stages of the surface phenomena was secured from the television installation aboard the Anderson. Unfortunately, the later stages of the surface phenomena were missed because of a power failure caused by the bottom reflected shock wave.

The burst did not have any noticeable effect on radio transmission and reception at the test site. The voice countdown continued for about 20 seconds after burst. It was transmitted from Agerholm on 243 Mc/sec and on 2772 Mc/sec and received, without any effects from the burst, by the ships. Radio teletype transmissions were received on several ships through burst time, on a frequency of 112.85 kc/sec, without any effects being noted.

Chapter 6

DISCUSSION

Information presently in hand appears to warrant an effort to generalize the test results slightly beyond conditions pertaining to Sword Fish. Certain aspects of the onsite results are discussed with the aim of exploring: (1) the dependence of ship damage on range from the burst, (2) the significance of the radiation hazards for ship maneuvers (3) the effects of small changes in yield and burst depth natural to an ASROC nuclear depth charge, (4) the implications of possible malfunctions of the ASROC system, and (5) the significance of the test results for possible ASROC system design modifications.

6.1 SHIP DAMAGE

The short-range test objectives associated with ASROC safe delivery problems require an extrapolation of the ship damage results to ship ranges and orientations somewhat different from those which actually occurred in the nuclear test. Prior to making this extrapolation a background discussion of the nature of the ship damage and its connection with the shock loading is given.

All the significant ship damage noted in Sword Fish, both in the nuclear test and in the preparatory HE shock trials, concerned the capability of the ships to deliver their weapons effectively against possible enemy submarine or aircraft targets. In no case was the capability of the ship to maneuver significantly degraded.

Ship damage was produced by the shock motions induced in the ship by the pressure waves generated by the underwater explosion. The vertical component of the shock motions produced in the surface ships was more severe than any other component. In the nuclear test the bottom-reflected pressure waves produced vertical motions which were more severe than those produced by the direct shock wave in all ships except Bausell: in Bausell the responses were about equal. In the nuclear test, thermal gradients in the water refracted the direct shock wave and caused a diminution of the shock motions produced in the surface ships with respect to those that would have been produced in isovelocity water. In the HE shock tests only the direct shock wave produced noticeable shock motions and the effects of refraction were insignificant.

A gross measure of the severity of the vertical shock motions induced throughout a ship by the pressure waves is the peak vertical bodily velocity of the ship. This quantity can be easily computed, either for a nuclear burst (Reference 21) or for an HE burst (Reference 22). The bodily velocity can be related to measurements (e.g., see References 19 and 23) but in a more simple manner for a nuclear attack than for an underwater HE attack. An alternate measure of shock severity for surface ships attacked by HE bursts is the vertical shock factor. The vertical shock factor can be directly related to the bodily velocity in HE attacks but not for nuclear attack; the vertical shock factor is not an adequate measure for nuclear bursts. Predictions of ship damage (Reference 24) have suggested that weapon delivery impairment commences when peak vertical bodily velocity approaches and is complete at as bodily velocity increases beyond about mobility impairment is produced.

In Sword Fish, the preparatory HE tests (vertical shock factor of 0.08 or vertical peak bodily velocity of 1 ft/sec) produced somewhat more damage to the ASROC ships than did the nuclear test itself. Nevertheless the attack severities, as measured by peak bodily velocity, were about equal in the three ASROC ships subjected to the HE tests and in Bausell at her location in the nuclear test. This result does not necessarily contradict the use of vertical bodily velocity as a measure of attack severity. The fact that the HE tests produced greater damage to the ships than did the nuclear test is primarily ascribed to: (1) variations in ship conditions as indicated especially by noting that of the three ASROC ships Bausell received least damage in the HE trials, (2) replacement of weak items uncovered in the HE tests prior to the ASROC test.

Both the preparatory HE shock tests and the nuclear test, itself, demonstrate the wide statistical variation in weapon delivery impairment sustained by apparently identical ships under identical attack. The HE shock tests subjected three FRAM 1 destroyers to identical attacks, yet the damage differed widely among the ships.

Ship orientation to the burst plays no significant role under Sword Fish conditions. For example, had Bausell been placed side-on rather than stern-on, the same results would have been secured. She received two separate shock inputs of about equal severity; one from the direct shock wave and one from the bottom-reflected wave. The bottom-reflected pressure wave struck the ship from below, making an angle with respect to the surface normal of about 15 degrees. Under such conditions, ship orientation can have no great significance.

6.2 RADIATION HAZARD

The short-range test objectives associated with ASROC safe delivery problems require an extrapolation of the radiation results to ship ranges, bearings (especially, with respect to wind direction), and maneuvers somewhat different from those which actually occurred in the nuclear test. This effort requires consideration of the radiation hazards associated with the base surge and the contaminated water pool.

Sword Fish re-emphasized the importance of keeping out of the base surge. Envelopment of a ship by the base surge would subject personnel to gamma ray intensities of many thousands of roentgens per hour and would contaminate both personnel and ships. Outside the confines of the base surge, radiation intensities drop off rapidly. The traditional rule of thumb to stay at least about 350 yards away from the edge of the base surge was confirmed.

Key observations on the base surge are that: (1) it moves outward with great initial rapidity but its advance is soon slowed to rates comparable to ship speeds, (2) its spread is soon greatly influenced by surface wind speed and direction, (3) it disperses and becomes invisible within 10 minutes and settles within about 30 minutes or less. Ship escape maneuvers are therefore quite possible from close-in positions, whether upwind or downwind. Suitable escape maneuvers are covered in existing tactical doctrine in case of nuclear weapon detonation. For example, the USN Addendum to ATP-1 (Sec. 530.2) states: "Since the base surge expands from ground zero at decreasing speed, the correct procedure is to turn away from ground zero and proceed at maximum speed."

The possibilities for ship evasive maneuvers under Sword Fish conditions are spelled out in Figure 6.1.

it is assumed that ships are moving at the conservative speed of 20 knots. Positions of the tracks prior to burst time assume a foreknowledge of the burst of 30 sec; this time would be the approximate time from launch to burst if the ASROC delivery range were reduced as discussed in Section 6.5. For present purposes this amount of foreknowledge is conservative; in Sword Fish the time from launch to burst was about 40 sec. Notice that tracks have been deliberately chosen to go through fingers of the base surge which stretch out to a maximum extent.

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Comparison of the ship tracks with the position and speed of the base surge indicates that each of the three ships shown in Figure 6.1 would have remained at all times at least 350 yards from the base surge. Personnel on these ships would have received total radiation doses distinctly less than the 5 r dose which might be considered a reasonable limit under wartime conditions (Reference 27.) In Sword Fish, destroyers could have been placed 1,600 yards upwind, 1,600 yards crosswind, and 1,800 yards downwind and maneuvered in a manner that would have limited personnel radiation doses to peacetime test standards. Gamma time-intensity recorders on Bausell, 2,200 yards upwind, registered a total dose of only about 2 r on the fantail, and much less elsewhere in the ship despite the lack of any evasive action whatsoever.

Sword Fish demonstrated that the radioactively contaminated pool left by an ASROC burst would restrict ship maneuvers within the confines of its boundary, although very close approach could be made to its edge without radiation hazard.

Key observations on the contaminated pool are that: (1) it drifts with the current, (2) it expands in size while maximum radiation intensities decline, (3) its boundary, though at first visible as a foam patch, becomes invisible in about 20 minutes.

Ship maneuvers through the contaminated pool appear feasible if necessary due to wartime exigencies. Consider the extreme case of a traverse across the pool diameter. At 60 minutes after the burst the Sword Fish contaminated pool was not much greater than 4,000 yards in diameter and exhibited maximum surface radiation intensities of, at most, A ship traversing the entire diameter at 20 knots at this time would have subjected some of its personnel to an acceptable total dose of 5 r. Suitable precautions to minimize ship contamination due to water intake could probably be accomplished for the short time involved in the traverse. In Sword Fish, Sioux was not appreciably contaminated even though she entered the pool about 20 minutes after burst.

6.3 EFFECTS OF ASROC YIELD AND BURST DEPTH VARIATIONS

Available information suggests that the ASROC nuclear depth charge can have yields varying between and burst depths varying between Variation from Sword Fish conditions within these limits can not be expected to change the Sword Fish results to any consequential degree.

Ship damage will not be altered to a degree noticable within the normal statistical scatter of damage. Peak bodily velocity at, say, a range of 2,200 yards would vary only between 0.9 ft/sec and 1.1 ft/sec.

Radiation hazards can hardly be altered significantly by such variations. Base-surge dimensions, which have key importance for this question, probably vary about as the cube root of the yield and are insensitive to change in the depth. Direct comparison with Shot Wahoo of Operation Hardtack (References 28 and 29) illustrates the effects.

6.4 COMMENTS ON ASROC PERFORMANCE

Sword Fish provided a unique opportunity to evaluate the performance of the ASROC system: a nuclear depth-charge firing was made for the first time. Two aspects of the system were brought to light and caused some concern as to the operational readiness of the system.

During the deliberations of the ASROC special safety committee, estimates were received from NOTS, Pasadena, of the probabilities of a premature burst due to fuzing system malfunctions. Application of these estimates (which were made only for a launching range of 4,000 yards) to longer launching ranges (up to the maximum of 10,000 yards) is discussed in Appendix C. Straightforward interpretation suggests that the best existing assessments of premature burst possibilities are that:

Two of the three missile launchings made during Sword Fish gave opportunity for accurate measurements of missile delivery accuracy.

likely, that these results were coincidental.

[redacted]

6.5 IMPLICATIONS FOR ASROC DESIGN CHANGES

Changes to the present ASROC system are presently under consideration within the Navy. The following recommendations have been made.

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The comparison of radiation hazards as between a burst depth of feet and feet is not certain. No specific information exists for a depth of feet. Indeed, radiation estimates for feet, supplied by NRDL for Sword Fish safety studies, indicated that the range at which personnel radiation doses could be received might be increased by one-third over that at which an equal dose would be received in the deeper burst.

The decision on how much to reduce the minimum delivery range, if any, will be a Navy policy decision. However, it is felt that any reduction in delivery range implies acceptance of the concomitant responsibility to supply the fleet with more detailed and reliable weapon-effects information in a form that can be readily used in all operational conditions, not just Sword Fish.

Chapter 7

CONCLUSIONS

Sword Fish was executed successfully, in both its operational and technical aspects. A shipboard ASW weapon system (ASROC) demonstrated its capability to deliver a nuclear depth charge. Associated technical measurements of good quality were secured, nearly to the fullest extent planned. No personnel were injured and only six participants received radiation doses in excess of peacetime limits: these six men received doses of less than 6 roentgens. No damage in excess of planned levels was caused to Naval equipment.

Conclusions were formed on the basis of presently available information. The test conditions, discussed in Chapter 4, were derived with a sufficient number of independent checks to give confidence that later analysis will produce only refinements in accuracy. Test results, summarized in Chapter 5, are believed to give a gross picture of the surface phenomena, underwater pressures, shock motions, ship damage, base surge, radiation field, contaminated water pool, and on-site sonar. Of course, many important implications will be apparent only after further study. In other cases (off-site hydroacoustics and marine life) a meaningful picture must await further analysis. A few generalizations of the test results were explored in Chapter 6 to approach those objectives concerned with ASROC delivery problems.

No doubt refinements, modifications, and supplements to the present conclusions will result from further analysis of the data. However, it is believed that present conclusions are substantially correct. The conclusions were formulated in four general areas: (1) test conditions, (2) weapon effects, (3) ASROC system performance, and (4) ASROC system modifications.

7.1 TEST CONDITIONS

Sword Fish test conditions were established with good accuracy despite the special difficulties associated with an operational delivery of the warhead. Test conditions were:

7.2 WEAPON EFFECTS

Sword Fish provided a substantial increment to previously existing information on the effects of underwater nuclear explosions. The unique feature of Sword Fish, as compared to previous nuclear tests, was the placement of operational ships, equipped with a modern weapon system, at ranges of tactical significance.

Weapon effects conclusions apply to ASROC burst conditions. These conditions are a slight generalization of the Sword Fish conditions, listed above in Section 7.1, and encompass small variations resulting from a properly functioning ASROC depth charge fuzing system.

Conclusions which pertain to short-term on-site objectives are listed below:

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Conclusions which pertain to long-term on-site objectives are:

1. Sword Fish re-emphasized the important role that sea-bottom-reflected pressure waves play in establishing surface ship safe delivery ranges. In Sword Fish the sea-bottom-reflected waves produced a stronger shock loading than did the direct shock wave in all ships except Bausell. At Bausell the bottom reflected shock wave produced a shock about equal to that of the direct shock wave.
2. Sword Fish re-emphasized the role of thermal gradients in the water in causing refraction of the shock wave. Surface ship damage ranges tend to be reduced by refraction as long as they are controlled by the direct shock wave.
3. Sword Fish re-emphasized the role of the base surge as a carrier of radioactivity. A ship which maneuvers, following an ASROC burst, so as to remain at least 350 yards from the edge of the base surge will not subject its personnel to radiation doses in excess of peacetime test limits. In Sword Fish the base surge remained visible for as long as

; it settled and dispersed within about 30 minutes. In Sword Fish, Sioux encountered an invisible aerosol at 20 minutes, and personnel on the weather decks were contaminated, though decontamination was easily accomplished.

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2. The contaminated water pool produced by an ASROC burst drifts with the current while it diffuses and decays radioactively. This pool can be tracked for weeks. In Sword Fish the pool was tracked for more than twenty days; twenty days after the burst its center had drifted about 50 miles south of surface zero and maximum surface radiation intensity measured 0.04 mr/hr.
3. Considerable information was acquired, for study, on the effects of the radioactive wastes on marine

life.

4. Information on the long-range hydroacoustic signals produced by the burst was acquired from ship and shore stations. Analysis should enhance ability to detect and classify underwater nuclear explosions.

7.3 ASROC SYSTEM PERFORMANCE

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3. Any appreciable reduction in delivery range should be accompanied by detailed reliable weapon effects information in a form which is readily usable by the fleet under all operational conditions.

Appendix A

ASROC SYSTEM

A.1 OVERALL SYSTEM

The ASROC Weapon system provides surface ships an anti-submarine weapon capable of delivering either an

Attention is primarily given to the nuclear depth charge. The major ASROC system groups are: (1) an active sonar, AN/SQS-23, or later model, with the ship's gyrocompass, a pitometer log, wind-indicating system, and dead-reckoning analyzer; (2) a fire control group, Mk 111 Mod 1; (3) a launching group, Mk 112 Mod 0; and (4) a rocket-thrown depth charge, Mk 2 Mod 1, or a rocket-thrown torpedo, Mk 2 Mod 0.

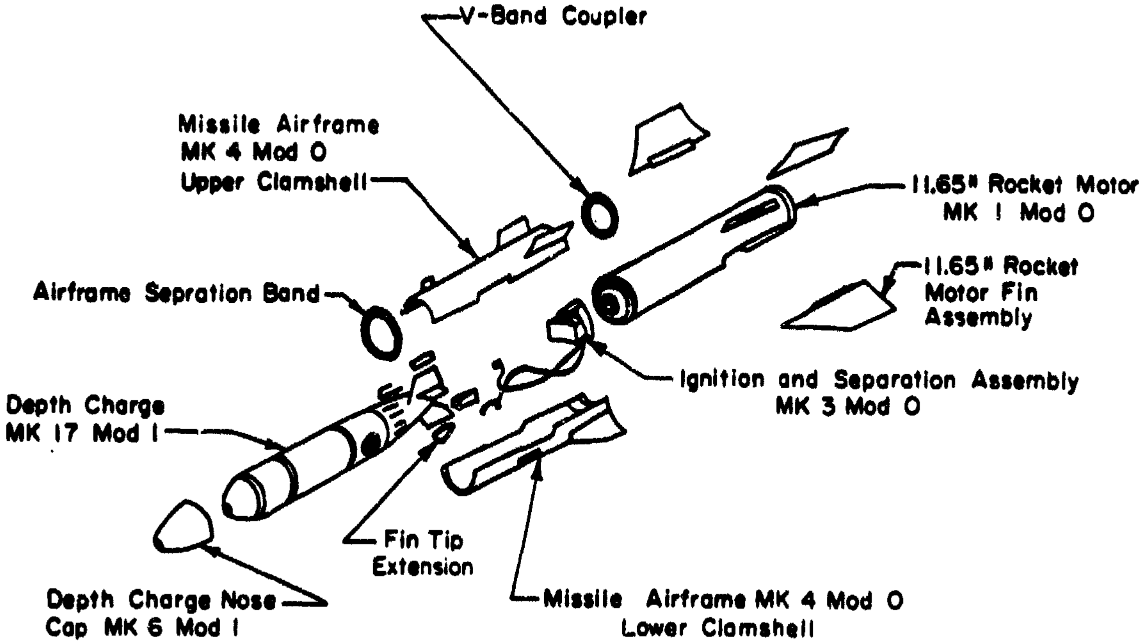
Normally, the sonar provides target range and bearing information directly to the fire control group. The fire control group is also designed to accept radar target-position information. Information on wind speed and direction and on own-ship's speed and course is fed to the fire control system directly from the ship's anemometers, compass, and log.

The fire control group computes and feeds information on elevation and bearing automatically and continuously to the launcher.

The ASROC launcher is a 2-axis stabilized mount which can stow and fire 8 missiles. The launcher is installed amidships in FRAM 1 destroyers. Limits of train in these installations are from about 078 to 128 degrees and from about 228 to 283 degrees relative. Limits of the launcher elevation are from 3 degrees below the deck plane to 85 degrees above.

An exploded view of the missile is shown in Figure A.1. The missile accepts either a torpedo or depth-charge warhead. A comparison of the torpedo and depth-charge dimensions is also shown in Figure A.1.

Environmental conditions beyond which there may result a reduced ASROC system capability are: (1) roll angle during firing, (2) pitch angle during firing, (3) relative wind, and (4) water temperature



	Depth-Charge Configuration	Torpedo Configuration
Total Length	155"	180"
Diameter	13"	13"

Figure A.1 Exploded view of ASROC missile.

Pages 185 through 187 deleted.

A.3 MISSILE TRAJECTORY

When the firing switch is thrown into firing position the rocket motor ignites and the missile leaves the launcher. Total time from closing the firing key to missile launch is seconds.

The missile is launched at a fixed true elevation of When it has accelerated to the predetermined velocity, A forward underwater travel by the depth charge of about is accounted for in the fire control system. This is the estimated amount of forward travel for a burst in water.

The missile trajectory expected for delivery range is indicated in Figure A.3. Times shown in Figure A.3 refer to a trajectory which has been computed (at the Naval Weapons Laboratory, Dahlgren, Virginia) under the assumption of a 14-1/2-knot crosswind relative to the firing ship. Key steps in the fuzing sequence are also shown in Figure A.3 in such a way that they can be readily correlated with the history of the missile along its trajectory.

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Appendix B

ADMINISTRATIVE INFORMATION

Sword Fish plans were formulated by a special task unit under the overall direction of CJTG 8.3, organized as shown in Figure B.1. Actual conduct of the operation was accomplished by the same group, under the same direction, but reconstituted as JTG 8.9 for administrative reasons.

Technical projects are listed in Table B.1. This table provides information on the project funding levels and sponsoring agencies. Actual cost information must await final accounting process. The project reporting arrangements are also indicated in Table B.1 by listing the agency through which each report is processed.

TABLE B.1 PROJECT FUNDING AND REPORTING

Project	Identification	Funding[a] ($1,000)	Sponsor	Reports
1.1 (NOL)	Underwater Pressures	205	DASA	FCDASA
1.2 (NOL)	Surface Phenomena	25	DASA	FCDASA
1.3 (NEL)	Effects on Hydroacoustic Propagation	93	DASA	FCDASA
1.4 (NEL	Nuclear Burst Detection	150	ARPA	ARPA
2.1 (NRDL)	Base Surge Radiation	242	DASA	FCDASA
2.2 (NRDL)	Radioactive pool Airborne monitoring	30	ARPA	ARPA
3.1 (DTMB)	Ship Response	210.84	DASA	FCDASA
7.1 (BUWEPS)	Effects on ASW Sonar Equipment Operation	In-house Navy-effort	Navy	Navy
9.1 (BUSHIPS BUWEPS)	Ship Damage Assessment and Technical Assistance with Test Conduct	398.742	DASA	FCDASA
9.2 (EG&G)	Time Command Signals	47.2	DASA	Scientific Director's Report
9.3 (Navy)[b]	Technical Photography	28.218[b]	DASA[b]	Scientific Director's Report
ONR (Gen. Atronics)	Nuclear Burst Detection	330	ARPA	ARPA
AEC Program (USC&G, WHOI NRDL, NOL, Texas A M College)	Radioactive Pool Monitoring by Ships, Oceanographic and Meteorological Efforts, Effects on Marine Life	581	AEC	AEC

Notes: (a) Funds provided in FY'62, not actual costs. In many cases, however, indicated funding is not sufficient to permit FY'63 efforts to complete analysis and prepare final report.

(b) Technical photography was largely accomplished by an in-house Navy effort, borrowing existing cameras and using military photographers. The equivalent cost of this effort, under commercial contract, has been estimated at $210,000.

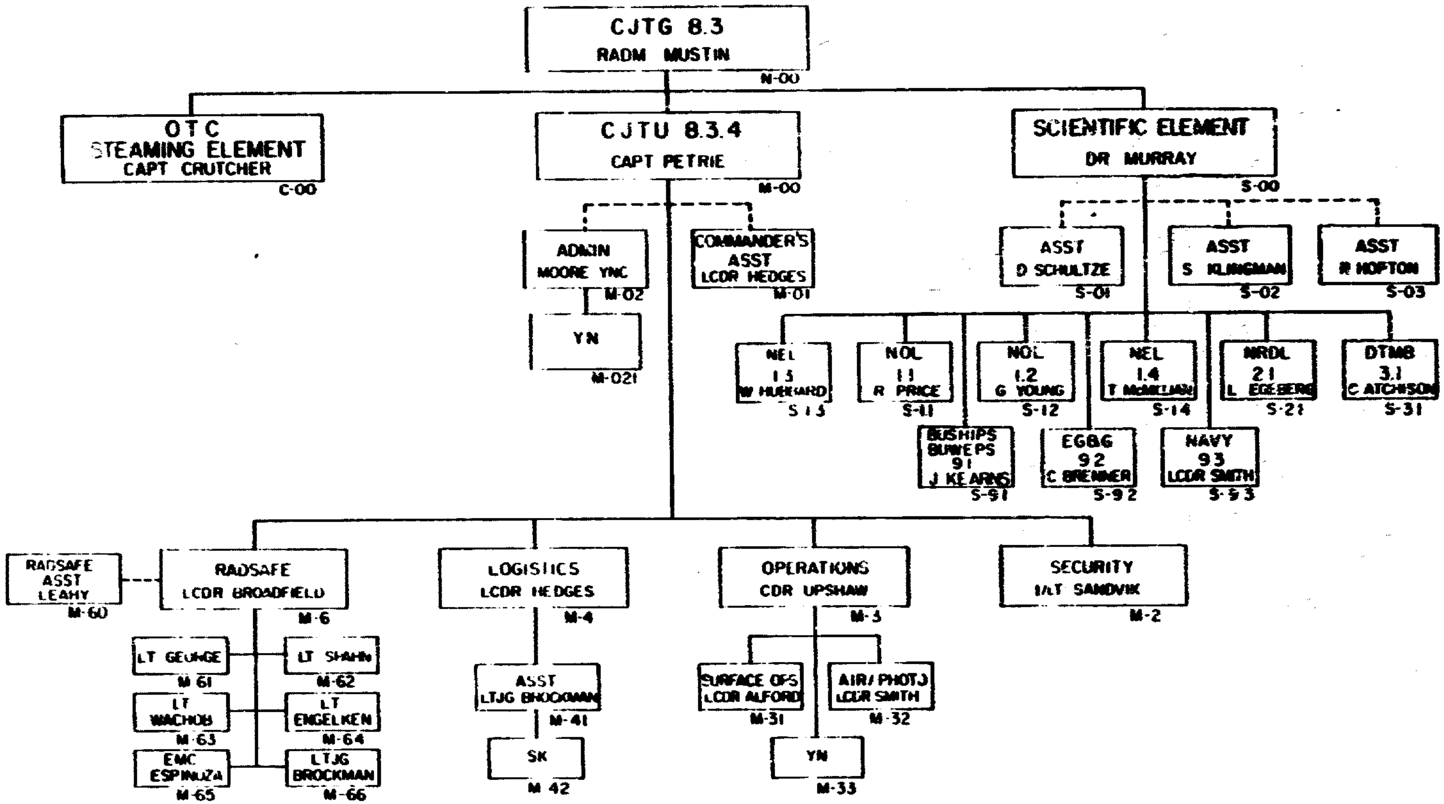

Figure B.1 Sword Fish Task Unit organization chart.

Appendix C

ASROC FIRING ACCURACY AND MALFUNCTIONS

This appendix summarizes the accuracy of the ASROC system in placing a nuclear underwater burst at a desired location and indicates possible malfunctions. The assessment is based on information available prior to Sword Fish. Topics of concern are: yield, range and bearing accuracy, burst depth, and significant malfunction possibilities.

C.2 RANGE AND BEARING ACCURACY

The best source of information on accuracy of missile delivery to a water-surface aim point is the record of previous firings. Prior to Sword Fish, the ASROC missile was fired: (1) 208 times during its development under Naval Ordnance Test Station (NOTS) management, (2) 154 times (including the Golden Bear Shot and 11 other non-nuclear depth-charge firings) during evaluation (up to March 1962) by the Operational Test and Evaluation Force (OPTEVFOR) with NOTS assistance, (3) 23 times in ship qualification trials up to 1 February 1962; and (4) 10 times in fleet training firings up to August 1961. Of these firings only the OPTEVFOR tests are considered pertinent, except when unusual events occurred in the other tests. The pre-OPTEVFOR firings involved special devices attached to the missile, and the prototype fire-control and launcher equipments were developmental rather than production types. Ships in qualification and training firings are not equipped to take measurements of the distance between the aimpoint and the splashpoint.

The OPTEVFOR firings were conducted off Key West, Florida in 5 phases, A through E. The purpose of the Phase A tests was to compare the ASROC system performance and operability with design requirements. The purpose of Phases B through E was to determine the effectiveness of the ASROC system against conventional and fast nuclear submarines when various escape maneuvers were permitted. In Phases A, B, C, and D, firings were from USS Norfolk, which has the launcher installed at the stern, and, in Phase E, from USS Perry which has the launcher installed amidships. All firings were made in sea states less than sea state 4 using the SQS-23 sonar for input.

Data on the OPTEVFOR firings are recorded and analyzed: Phase A, B, D, and E by NOTS in References 8, 9, and 10; Phases C, D, and E by OPTEVFOR, in References 11, 12, and 13. Methods of data analysis and definitions of the various ranges and errors involved in the firings differ. Both sets of data are combined in this appendix in order to obtain a complete picture of the firings.

Of the several types of error discussed in References 8 through 13, only the missile-delivery error, which excludes sonar-input error, is analyzed. The missile-delivery error is defined indirectly in terms of the total-system error. The total-system error is the distance between the weapon water-entry point and the target's position at the time of weapon water entry. The total-system error in the OPTEVFOR tests was based on aerial photographs of the warhead splash and a smoke float released by the target submarine. When this method failed, the total-system error was based on radar range and bearing to a helicopter that hovered first over the splash point and then over the smoke float. The missile-delivery error is essentially the difference between the aimpoint and the water entry point, obtained for each firing by reconstructing on a plotting board the target and firing-ship paths relative to the splash point and by vectorially subtracting errors arising from sonar input and from the fire-control prediction. The fire-control-prediction error was generally negligible. Needless to say, the method of measurement is subject to many experimental uncertainties.

Detailed lists of the OPTEVFOR firing errors are given in Tables C.1 (depth charge) and C.2 (torpedo firings). The torpedo firing results are considered relevant to depth charge firings, because essentially the same system is used to deliver the torpedo and the depth charge.

An overall summary of ASROC firing accuracy is given in Table C.3. This table combines OPTEVFOR infomation given in Tables C.1 and C.2 with unusual events in non-OPTEVFOR firings.

C.3 DEPTH OF BURST

No direct information on the depth of burst existed prior to Sword Fish. Estimates were based on indirect inferences from the time between splash and burst or the time interval consumed by the nominal 12-1/2-second timer and from observations of depth-charge sinking speeds. The formula used is:

$$D = D_o + s(t - t_o) \qquad \text{(C.1}$$

Where: D = depth of burst

D_o = depth at which the hydrostats close

s = sinking speed, assumed constant from time of hydrostat closure to time of burst

t = time from water entry to detonation

t_o = time to reach the depth at which the hydrostats close.

Pages 198 through 205 deleted.

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Estimates of hydrostat-closure depths are based on static tests of the hydrostat itself. No published description is available but it is understood, from NOTS personnel, that 168 tests using a number of different hydrostats were completed by February 1960.

Sinking-speed estimates are based on observations made during missile firings. A sound source was placed in the missile head and tracked through the water by use of hydrophone strings and triangulation methods. Firings took place, for the most part, in water   deep. Available information (Reference 14) suggests that:

1. Terminal velocity is reached by the time the missile has reached a depth where the hydrostat should close.

2. Time, t_o, to reach the depth at which the hydrostats should close varies between   (for maximum missile range) and   (for minimum missile range).

Terminal-velocity estimates, in addition to marginal observations as indicated above for shallow-water missile firings, are based on drop-rig tests. The warhead was attached to a cable and allowed to drop through the water with the cable still attached. The rate of descent was measured by noting the rate at which the cable payed out from its reel. Corrections were made to eliminate the influence of cable drag. Information on the results, as obtained from NOTS personnel, indicates that depth charge terminal sinking rate, s, is

Prior to Sword Fish, five OST tests were conducted in which the time from water entry to detonation was measured. The measurements are summarized in Table C.4. The burst depths in this table were computed from Equation C.1. In

 Page 208 deleted.

this computation, values of D_o, s, and t_o were employed as given above.

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Appendix D

SITE METEOROLOGY AND OCEANOGRAPHY

(Prepared by CDR F. G. Robinson, Staff Meteorologist, U.S. Fleet Weather Facility, San Diego, California, except for such deletions as seemed desirable to avoid repetition of matters covered elsewhere and for editorial changes).

D.1 SERVICES

Weather services required to support Sword Fish were provided by the U. S. Fleet Weather Facility, San Diego, and the U. S. Fleet Numerical Weather Facility, Monterey, California.

Services provided by the U. S. Fleet Weather Facility, San Diego, consisted of: 1. A daily 24-hour forecast, based upon the 1800Z synoptic data and the detailed debriefing of the weather reconnaisance observer issued at approximately 2100Z. This forecast included the synoptic situation at 1800Z and a detailed forecast of all parameters including sea and swell. Additional 12-hour forecasts were transmitted at 1200Z on 10 and 11 May 1962. These included the H-hour forecast and were used to determine if conditions remained satisfactory for planned operations. 2. Canned map analyses (coded weather maps), prepared and transmitted daily. Weather reconnaisance (recco) flights commenced 30 April and were made daily for the duration of the operation.

Services provided by U. S. Fleet Numerical Weather Facility, Monterey, California, consisted of a daily forecast of conditions expected at Point Alpha on planned D-day (10 May), transmitted commencing 5 May 1962. On 10 May, 20-hour and 28-hour forecasts were provided. These forecasts included normal weather parameters, including upper winds to 50,000 feet, plus oceanographic data consisting of sea-surface temperature, sea condition, swell height and direction, and the mixed-layer depth.

Services provided by the USC & GS ship (Pioneer) consisted of making and transmitting 3-hourly surface and 12-hourly radiosonde and pilot balloon (pibal) observations from Point Alpha commencing 4 May 1962. The radiosonde and pibals were transmitted in standard code, utilizing Point Alpha for the location identifier. Latitude and longitude were not transmitted in any message. The Pioneer commenced transmitting normal weather messages, including latitude and longitude, at noon on 12 May 1962.

Services provided by USS Sioux (ATF-75) were: One Aerographer's Mate 3/c was ordered to the Sioux for the purpose of making and transmitting weather reports. The Sioux arrived at Point Baker (34°N latitude and 126°W longitude) on 6 May 1962 and made and transmitted 3-hourly surface weather reports until 090000Z, then departed to join the task group at Point Alpha.

Services provided by USS Monticello (LSD-35) were: 1. The task group weather service unit, consisting of one Commander, one AG2, and one AG3, was based aboard and provided detailed forecasts as required. The operational forecasts were based upon the data provided by the weather facilities, the Tecco summaries, Pioneer and Sioux reports, and local observations; 2. Equipment was aboard the Monticello to permit making radar wind balloon (RAWIN) observations. This was not necessary, however, since the USS Yorktown assumed this duty after joining the task group on 9 May 1962.

D.2 CLIMATOLOGY OF POINT ALPHA

The area at this time of the year is under the influence of a relatively dry oceanic climate with little precipitation but a high incidence of lower clouds. The area has partly cloudy to cloudy skies approximately 95 percent of the time, the clouds being mostly stratus or cumulus types. The diurnal variation of cloudiness is small, amounting to a few tenths, with a decrease of the cloud cover occurring near sunrise.

Tropical cyclones in the Southeastern Sector of the North Pacific Ocean, 100° to 150° west and from the equator to 30° north, are rare from January to April, having a season of development from May to December with the maximum activity occurring in September.

The tropical cyclones affecting this area have their source region primarily in the Pacific Ocean near the land masses of Mexico and Central America, the Gulf of Tehuantepec (15°N, 95°W) being one of the more prolific source regions. They may move parallel or perpendicular to the coast, or may curve and travel westward over the ocean.

Storms moving perpendicular toward the coast are usually the most intense and hazardous since they often strike with little forewarning. These storms are generally small in diameter, sometimes less than 50 miles, but are accompanied by high winds and heavy rains.

Cyclones moving westward over the area generally travel in the vicinity of 15°N, usually curve north or south at about 120°W and dissipate rapidly. Because of wind and cool ocean-current patterns, most cyclones are either driven inland or dissipated at sea south of 30°N; none have traveled farther than 35°N in the last 50 years.

The average number of extratropical storms entering the area of Point Alpha for any month is less than one in four years and the occurrence of tropical storms in May is relatively rare, thus the probability was small that a storm of either type would be a factor influencing operations. During June and July the probability of tropical storms increases slightly.

During the period of this operation, Point Alpha area was under the influence of a large, high-pressure air mass which covered most of the Eastern Pacific Ocean area. The center of the air mass was near 44°N and 156°W on the 9th, moving slowly to the southeast, reaching a position near 37°N and 148°W by 111800Z. At 111800Z, a minor trough extended southwestward from the Seattle, Washington area through 32°N 126°W or approximately on a line one hundred miles NW of Point Alpha. Recco aircraft reported numerous showers in this area. The morning radiosonde from Point Alpha indicated considerable moisture to 7,000 feet with the air mass below that level being conditionally unstable. Frequent rain showers occurred in the vicinity of Point Alpha from near sunrise until noon. Shower activity became widely scattered by late forenoon with only three- to four-tenths lower-cumulus-type clouds remaining at noon. At H-hour the immediate area was nearly clear with only a few scattered cumulus clouds remaining. By mid-afternoon, cloudiness had increased to five- to six-tenths with scattered showers being observed at 1600T. The pressure gradient remained relatively weak with NW 16 knots being the highest wind observed until early on the 12th, when the gradient increased as a low-pressure area began to develop over the western United States.

Comparison of climatological data for Point Alpha with data observed during the test period is given in Table D.1.

TABLE D.1 CLIMATOLOGICAL DATA

	May	June	July	Observed 10-11 May
Precipitation (percent of time)	5	5	5	Trace
Average air temperature	59	61	63	59
Average maximum temperature	66	67	68	64
Average minimum temperature	55	57	59	58
Prevailing wind direction	NW	NW	NW	NW
Wind velocity (percent of time)				
0 to 3 knots	3	8	6	0
4 to 10 knots	27	33	35	59.3
11 to 16 knots	28	26	23	40.7
16 to 27 knots	38	31	33	0
Equal to or greater than 28 knots	4	2	3	0
Visibility (percent of time)				
Less than 5 miles	10	15	20	0
Fog (percent of time)		Less than 5		0
Cloudiness (percent of time)				
Total cloud cover 0 to 2-tenths	10	20	15	24.2
Total cloud cover 3 to 7-tenths	50	30	25	66.7
Total cloud cover 8 to 10-tenths	40	50	60	9.1
Total low cloud cover 6 to 10-tenths	50	70	65	24

D.3 OCEANOGRAPHIC DATA FOR POINT ALPHA

The area near Point Alpha is located in the California Current, a sluggish current setting southeast along the California Coast. During the spring and summer months, the north-northwest winds prevailing off the coast give rise to intense upwelling. This initiates a pattern of low temperature currents setting in a southerly direction away from the coast, interlaced by tongues of higher temperature currents setting north toward the coast. The cool water of the California Current and cooler waters in upwelling regions are a major factor in the formation and persistence of the low clouds.

The prevailing northwest wind in the area and along the California coast induce a prevailing northwest sea and swell.

The theoretical tidal range for this open ocean area is approximately 4-1/2 feet.

The more typical bathythermograph traces of 325 soundings taken during May and August indicate the Mixed Layer Depth (MLD) is generally at 75 to 125 feet, the depth decreasing from May to August.

During the period of this operation, the sea and swell conditions were as expected. The persistent northwesterly wind flow made the forecasting of these parameters a relatively easy problem. The mixed-layer depth was deeper than climatological data indicated, averaging about 200 to 250 feet. It was variable, however, and a definite diurnal change with minimum depths occurring in the midafternoon hours was observed.

Comparison of oceanographic data for Point Alpha with data observed during the test period is given in Table D.2.

D.4 OBSERVED DATA

Wind observations on the test date, 11 May 1962, are listed in Table D.3. These soundings were the only ones taken from midmorning until early evening. The 1100T sounding is considered quite representative for conditions existing at 1300T. The winds both surface and aloft began increasing after 1600T.

It will be noted, from values listed in Table D.3, that observed surface winds were variable. This is normal and can be expected when convective type activity is occurring. The general wind flow throughout the area was from the northwest (315°T) with an average velocity of approximately 11 knots. This overall direction and velocity was verified very closely by the observed travel distance of the water "pool" tracked by the USS Sioux. Using a value for wind current of 4 percent of observed surface wind, the Weather Facility calculated 10.6 nautical miles per day. The USS Sioux reported the "pool" traveled approximately 11 miles per day on a bearing of 135°T.

The surface wind determined from photos of the smoke flares at the target raft was 310°T at 10.5 knots. It is

TABLE D.2 OCEANOGRAPHIC DATA

	May	June	July	Observed 10-11 May
Average sea surface temperature (^{o}F)	60	63	64	63
Prevailing sea direction	NW	NW	NW	NW
Sea Heights (percent of time)				
Calm (less than one foot)	4	4	5	0
Less than 3 feet	38	35	34	100
3 to 5 feet	25	28	27	0
5 to 8 feet	22	25	24	0
8 to 12 feet	9	7	8	0
Greater than 12 feet	2	1	2	0
Prevailing swell direction	NW	NW	NW	NW
Swell Heights (percent of time)				
Calm	7	7	8	0
1 to 6 feet	35	39	41	97
6 to 12 feet	46	47	46	3
Greater than 12 feet	12	7	5	0
Surface current				
Set	SE	SE	SE	SE
Speed (knots)		0.1.to 0.3		0.4 to 0.5

TABLE D.3 WIND OBSERVATIONS FROM VICINITY POINT ALPHA 11 MAY 1962

Surface wind observations (direction-velocity)

Time	Monticello	Yorktown	Pioneer
0800T	315-09	315-09	315-14
0900T	315-04	335-08	
1000T	315-04	358-07	
1100T	360-09	330-10	360-14
1200T	340-08	286-04	
1300T	315-11	319-10	
1400T	280-06	300-09	360-14
1500T	315-12	300-12	
1600T	315-13	304-12	
1700T	315-12	302-12	360-13

Upper wind observations

	1100T		1700T	
Height feet	Dir	Vel	Dir	Vel
1,000	350	07	310	15
2,000	320	08	304	15
3,000	310	10	304	15
4,000	290	10	301	14
5,000	270	09	290	17
6,000	260	12	300	19
7.000	260	15	304	21
8,000	260	15	304	21
10,000	250	21	287	31
12,000	220	30	276	29
14,000	320	45	273	32
16,000	230	49	262	57
18,000	220	55		
20,000	230	60		

recommended that these values be considered constant for 5 minutes and be used for base-surge calculations. For the next 20 to 30 minutes an average wind should be used, with 310°T being a suggested value. The velocity should be assumed constant at 11 knots for the period from H + 5 to H + 60 minutes. Possibly overhead time-interval photos of the base surge and associated mist cloud could be used to determine more accurate wind directions.

D.5 REMARKS

1. Forecasts provided by Fleet Weather Facility, San Diego and Fleet Numerical Weather Facility, Monterey, were quite accurate. The overall verification was 90 to 95 percent.

2. The area west and south of San Diego is quite suitable for this type operation. Weather conditions are seldom severe, and sea conditions are favorable 60 to 75 percent of the time. The major difficulty is the predominant low cloud cover. Areas within 200 miles of San Diego have numerous days when low cloud covers average 6/10 to 8/10 overcast conditions. This condition occurs all year and limits the operational suitability of this area considerably. Beyond 200 miles, less cloud cover and less restriction to visibility can be expected. Frontal systems occasionally affect the area but are not of serious concern.

Severe weather from tropical depressions is infrequent. It is recommended that future operations of this type be conducted in the area west of 123°W longitude and south of 31°N latitude. The threat from tropical storms can be minimized by remaining north of 25°N latitude. The late spring and summer months are best to avoid the threat of high swell from the northwest.

Appendix E

RADIOLOGICAL SAFETY

(Prepared by CDR W. Broadfield, USN, JTG 8.9 Radiological Safety Officer and by Mr. E. Leahy, USNRDL, except for such deletions as seemed desirable to avoid repetition of matter covered elsewhere and for editorial changes)

E.1 BUILDUP PHASE

During the buildup phase, the following tasks were accomplished: preparation of a radiological safety (rad-safe) annex for the Sword Fish Shot Operation Order, procurement of instrumentation and equipment, selection of qualified radiological safety personnel, and indoctrination and training of task unit personnel.

E.1.1 Preparation of Rad-safe Annex. The rad-safe annex to JTG 8.9 Op-plan 1-62, as prepared, was adequate for the Sword Fish shot and might serve as a guide for future shots of this type.

E.1.2 Procurement of Instruments and Supplies. A nuclear test such as Sword Fish is conducted under radiological criteria suited to peacetime industrial operations rather than a wartime military situation. As a result, instrumentation and supplies are required to control radiation exposure and contamination to low levels. Some of the instrumentation and supplies required for this task are not available in the military supply system. Those items that are available are not carried in sufficient quantities by ships or units to meet the demand of a test organization and its additional efforts and personnel. Even if such items were available in the required quantity, a ship or unit could not be expected to expend its operating gear -- much of which would be lost because of the radiological contamination, or the high cost of decontamination to peacetime acceptable limits.

For Shot Sword Fish, the JTF 8 Rad-Safe Organization was to supply a majority of the items required. Location of the shot away from the immediate vicinity of Christmas Island made it impossible for JTF 8 to supply the required items and still meet their other shot commitments. Thus, all rad-safe items other than the low-range radiacs (AN/PDR-27) and 300 pair of coveralls were purchased or borrowed locally. All items required other than 0-to-5 and 0-to-10 r dosimeters and hi-density goggles were available through normal supply channels. The dosimeters and goggles could not be purchased from commercial suppliers because of the short delivery time requested. A marginal supply of dosimeters was collected by borrowing from the Nevada Test Site and on a future BuShips program. A minimum number of hi-density goggles were also obtained from the Nevada Test Site. Both items are an absolute necessity for a test operation such as Swor

Fish but are not normally carried in military supply channels.

E.1.3 Film Dosimeters. Film dosimeters, supplied by JTF 8 and required for each individual, were issued. This is a time-consuming, although not difficult, task that could be simplified by the use of a punch card or IBM type of issue card to replace the log sheets used in this operation.

E.1.4 Rad-Safe Personnel. Competent radiological safety personnel were required to monitor each phase of the recovery operation. Such persons are not available from ships or operating units. For Sword Fish, officers and enlisted instructors from Navy Radiological Training Activities were obtained as assistants for the recovery operation and to carry out the required training and indoctrination programs. A radiological safety consultant (health physicist) from NRDL was obtained to aid in the technical matters and procurement of equipment. This consultant was invaluable in obtaining hard-to-get items, since he knew the types of equipment needed, where they might be located, and who to contact at the location. He also provided much help and advice on the technical procedures to be followed.

E.1.5 Task Unit Indoctrination and Training. Prior to shot time, it became apparent that many of the task group personnel were apprehensive of the radiological effects. To allay any fears, a series of unclassified indoctrination sessions of 4-hours duration were conducted at times convenient to task units. A special 3-hour classified indoctrination course was conducted for all ship and unit officers.

A special decontamination team of 24 men supplied from task group ships was trained in a 5-day course conducted by JTU 8.3.4 rad-safe group. This course was presented in addition to that available at Fleet schools, to organize the men into operating teams, to provide them the methods of operation and decontamination to be used, to familiarize them with the equipment to be decontaminated, and to impress them with their mission and the industrial exposure and contamination limitations imposed on them.

E.2 OPERATIONAL PHASE

The radiological safety aspects of the operational phase consisted of an aerial survey of the contaminated water area, entry into the contaminated water area to obtain water samples, recovery of the target array, tracking of the water pool and return to port. The operational phase was completed without a serious radiological incident. All scientific equipment was recovered, and no data was lost because of actions of the rad-safe group. Approximately six persons of the USS Sioux exceeded the established dose of 3.0 r with the maximum dose (estimated by pocket dosimeter readings) of 5.4 r. These exposures were received during the penetration of the contaminated water pool to obtain water samples for yield analysis.

E.2.1 Aerial Radiation Monitoring Survey. After the shot,

The radiation dose rate observed exceeded 50 r/hr. Additional flights

indicated dose rates of 800 mr/hr.

attenuation, does not correlate with predicted values and later measurements made aboard the USS Sioux. The reason for the lack of correlation is not known but could be due to the aircraft's not being positioned over the pool, improper reading of the radiac, or lack of a proper altitude-attenuation correction factor. As will be noted later, the radiation above the water appeared to consist of a large quantity of low-energy gamma rays estimated at about 100 kev.

Upon return to base the aircraft was monitored, and no contamination was noted. No person on the aircraft approached the exposure limit of 3.0 r.

E.2.2 Early Time Entry Into Water Pool.

the USS Sioux (ATF-75) entered the contaminated water pool from an upwind position while proceeding at a speed of 3 knots. Radiation dose rates as monitored from the starboard wing of the bridge were observed to rise rapidly from 40 mr/hr to 300 mr/hr in one minute. At the 300 mr/hr dose rate, the ship was advised to turn out of the patch. During the time the turnout maneuver was executed, the dose rate rose to 75 r/hr and then to greater than 500 r/hr at a point estimated to be about 200 yards inside the edge of the water pool. One water sample was collected during this entry which read 5 r/hr at contact with the 5-gallon container.

Upon clearing the water patch, contamination was noted on the weather decks. Since the ship's speed did not cause a water spray and the area was clear of base surge, it appears that a contaminated mist existed above the water surface. This contamination was subsequently reduced to a nondetectable level by a washdown of the ship's weather surfaces.

Following the initial entry, eight of the personnel on the Sioux had pocket dosimeter readings indicating exposures between 2.5 and 5.0 r. Permission was requested of CJTG 8.9 to continue the water-sampling mission and allow exposures of up to 7.0 r.

With permission granted to proceed with water sampling, two additional entries were made into the pool at

A water sample was collected on each entry. The second and third water samples indicated 1 r/hr and 200 mr/hr respectively when measured at contact. The maximum exposure received for the additional two entries was 0.6 r. The maximum total exposure (as indicated by pocket dosimeter) for all entries was 5.4 r. (A non-task force film badge indicated an exposure of 8.0 r.)

Radiation dose-rate readings taken on the wing of the bridge and within the closed bridge indicated shielding factors of 100 to 1,000. Since the shielding in the area is minimal (approximately 1/2 inch of steel) it appears that the early-time radiation field consisted of a large fraction of low-energy gamma rays.

Crews were changed on the Sioux at about H + 6 hours and efforts made to determine the radiation contour and early-time path of the water pool. At approximately , the maximum dose rate noted above the pool surface was 240 mr/hr. The maximum exposure noted for all passes made during the contour mapping and pool tracking was 100 mr. Specific entry times, entry positions and gamma dose rates will be found in Reference 5.

E.2.3 Recovery of Target Array. The following portions of the target array were recovered:

USS Bausell. The towed DD, USS Bausell, was not engulfed in the base surge and when boarded at H + 1 hour was found to be free of contamination. Doses received at various locations on the Bausell from the approach of the base surge will be found in Reference 5.

Submarine Simulators. One submarine simulator, fired from the USS Razorback and recovered by the USS Hopewell, presented no radiological problem. Although the simulator was found in the vicinity of the contaminated water, it apparently did not operate in the contaminated pool.

NOL Platforms (Barges). Two platforms were used to support NOL pressure gages. Platform 1, located the farthest from surface zero, was boarded at . Dose rates (measured at 3 feet from surfaces) of 600 mr/hr average and 1,000 mr/hr maximum were noted. Washdown by fire hose at reduced the dose rates to 250 mr/hr, thus allowing gage recovery to proceed. Platform 2 was boarded at and dose rates of 1,000 mr/hr average and 2,000 mr/hr maximum were noted. , fire hosing reduced these dose rates to approximately 300 mr/hr.

Following raising of the gage strings, the platforms were towed to the LSD and stored in the well deck until the ship returned to port. Additional work on the barges was delayed until the ship reached port to allow additional dose-rate reduction by decay.

In port, alpha contamination was noted on the barge at the water line. The alpha contamination was probably caused by unfissioned weapon material. Efforts are to be made to remove the alpha contamination before the platforms are re-used.

NRDL Coracles. The eight NRDL coracles posed no radiological problem. General dose rates were 200 mr/hr on those units engulfed in the base surge. Decontamination efforts by fire hose were not successful. The contamination appeared to be lodged in the rubber bumper and gasket material used between the upper and lower sections of the unit.

<u>Towline</u>. Recovery of the towline proved to be both an operational and a radiological problem. As sections were recovered that had been in the contaminated water patch, dose rates commenced to increase, and removable contamination was noted. Ship personnel on the LSD required protective clothing including plastic or rubber-covered gloves to prevent personnel contamination. Approximately 200 feet of towline between Platforms 1 and 2, when retrieved, produced a dose rate of 2.5 r/hr. This line was cast free to float until D + 1 at which time it was again recovered and carried to port in the well deck of the LSD. The recovered line was found to be contaminated with alpha activity as well as fission products. Decontamination was not effective.

Operationally, the line recovery along with the approach of the LCM to the LSD resulted in several boats' fouling screws in the line. Return of the line to the Naval Repair Facility presented a handling and ultimate disposal problem. A method of sinking the line at sea is desirable in future operations.

Operations on the LSD-35. The facilities for personnel decontamination were barely adequate. A much larger facility could have been used. The increased background from recovered items hampered personnel monitoring and demonstrated the need for a monitoring facility up forward away from the stored items. The limited beta capability of the AN/PDR-27 (beta sensitive on 0-to-0.5 and 0-to-5 mr/hr ranges only) also hampered the process of personnel monitoring and required the use of side-window Geiger-Mueller radiacs (IM 133A) with a 0-to-20 mr/hr beta range.

Clothing supplies, consisting of 500 pairs of coveralls, 300 towels, 300 pair of shoes, 200 sets of underwear, and 100 pairs of gloves, were nearly exhausted at the conclusion of the operation.

Tracking of Contaminated Water Pool. Following the early-time operations of the USS Sioux the contaminated water pool was tracked for approximately three weeks by both surface ship (Pioneer OSS-31) and aircraft. No radiological problems were encountered during the surveys.

E.3 ROLLUP PHASE. Upon return to port, all contaminated items were removed from the ship and properly packaged for shipment or turned over to the Naval Repair Facility for disposal.

Monitoring survey of all ships indicated no significant contamination, except for the USS Sioux. Monitoring of the Sioux upon return to port (D+5) revealed no contamination except for the lube-oil coolers, which measured 3 mr/hr at 3 inches. Instructions were given to the engineering officer to monitor the units when it became necessary to perform repairs.

All material borrowed for the operation was returned to the original owners. The remaining rad-safe gear purchased was packaged and sent to NRDL for storage.

Appendix F

TIMING SYSTEM

(Prepared by Claude W. Brenner, Edgerton, Germeshausen and Grier, Inc., except for such deletion as seemed desirable to avoid repetition of matters covered elsewhere and for editorial changes.)

Timing signals for Sword Fish were provided by Edgerton, Germeshausen and Grier, Inc. (EG & G). The main elements of the timing system were: (1) a control point located in the firing destroyer, USS Agerholm (DD-826), and (2) radio-tone and fiducial-zero receivers located in the several ships and floating platforms of the array where instrumentation was placed.

The primary users of the timing signals were the U.S. Naval Ordnance Laboratory (NOL), Project 1.1, and David Taylor Model Basin, Project 3.1. A secondary user was the joint Bureau of Ships-Bureau of Naval Weapons Project 9.1. In addition to the timing signals provided the above users, in the form of relay closures (radio-tone receivers) and time-reference pulses (fiducial-zero receivers), an audio countdown was given for all ships participating.

F.1 DESCRIPTION OF EQUIPMENT

F.1.1 Control Point. The control point in USS Agerholm was located in the ship's helicopter hanger. It consisted of five cabinets of electronic equipment necessary for the generation of an accurate time base and for the transmission, monitoring and recording of signals at times in the countdown sequence specified by the users. Audio information was provided by direct link from the control point to the ships' communication systems. In addition to the timing signals furnished users at remote stations by radio link, users aboard the Agerholm were provided timing signals by hard-wire link to the control point. Finally, signals were taken by hard wire from the ASROC firing sequence to initiate certain events in the countdown sequence as will be described below.

The central feature of the control point is the World Time System using an extremely stable crystal-controlled quartz oscillator as the primary frequency standard.

The 1-Mc oscillator frequency is amplified and divided to provide a 100-kc output to the local time clock where it is in turn divided down to lower frequencies to provide pulses for the Signal Distribution System and a visual time readout on a nixie tube display. The local time clock is calibrated daily to the standard given by the National Bureau of Standards over radio station WWV, for which a receiver is installed in the control point, together with an oscilloscope for visual calibration.

A world time event clock driven by the local time clock provides time readout information through a digital recorder for a permanent printed record to a tenth millisecond of when signals were transmitted or events occurred. The local time clock also drives the countdown clock which gives a backward counting visual readout for the operator on a nixie tube display.

The Signal Distribution System, as noted, is driven by the World Time System. Its primary components are a Command Post coder that establishes at what times in the countdown sequence signals are sent, a signal decoder that determines where the signals are sent, and a signal distribution control panel that is employed for test and monitoring purposes. For a countdown commencing at minus 1 hour, signals may be sent every half minute during the first 58 minutes and every half second thereafter.

The remainder of the control point is comprised of: two dc power supplies; the 60-watt VHF transmitters for radio signals; various test, monitoring and recording equipment additional to that already described; the audio distribution system; and the control console. The latter contain repeaters of the local time and countdown clocks together with the appropriate control necessary to the operation of a countdown.

Power was supplied to the control point directly from the ship's power distribution switchboard,in the after engine-room, which also supplied ASRCC power. This direct power transmission avoided the possibility of parallel power users causing surges in the line that might, in turn, burn out various electronic elements integral with and essential to the operation of the control point.

The five cabinets comprising the control point were bolted together and mounted on a foundation welded to the hangar deck and braced from the hangar port bulkhead. Rubber shock mounts were placed between the cabinets and the foundation bracing. These served the dual purpose of protecting the equipment mechanically from the shock of the nuclear detonation and isolating it electrically from the ship.

Four whip antennas (6 feet 7 inches long) for the two transmitters, the EG & G Net transceiver, and a radio-tone monitor were mounted in a vertical finger array fore-and-aft on a stub mast above the Electronic Counter Measures (ECM) shack directly over the hangar. Height above mean waterline was approximately 60 feet. The folded dipole antenna for WWV reception was mounted at an angle of approximately 30° to the deck from the after end of the hangar deck forward to a railing above the ECM shack. This installation was readily dismountable so that helicopter operations were able to continue during the exercise.

F.1.2 Radio-Tone Receivers. The radio-tone receiver, Type RC-8, consists of three subassemblies — namely, a transistorized radio receiver, a tone-sensitive relay section

w/

and a power supply (battery pack); all were contained in a single watertight splash-proof case. This receiver, tuned to the frequency (148.89 Mc) of the appropriate VHF transmitter in the control point, provides a means for controlling remote functions by radio-activated relay closures. Each receiver has the capability of providing a relay closure at three distinct instants of time during the countdown sequence.

Radio-tone receivers were installed in the various ships participating in Sword Fish as shown in Table F.1. It may be noted that in those cases where two receivers are shown (USS Bausell and the two instrumentation platforms) the receivers were paralleled for reliability, as those stations were unmanned during the shot. Where more than one user was employing a relay closure at the same time, EG & G 27-QA relays were employed in series with the receiver relay to provide the required number of contacts. These relays are four-pole, double-throw, drawing 60 ma at 1000 ohms.

F.1.3 Fiducial-zero Receiver. The fiducial-zero receiver Type RT-4 consists of three subassemblies, namely, a transistorized radio receiver, a pulse shaping and emitting network, and a power supply (battery pack), all contained in a single watertight, splash-proof case. This receiver, tuned to the frequency (150.45 Mc) of the appropriate VHF transmitter in the control point, accepts a transmitted square pulse of

TABLE F.1 DISTRIBUTION OF RECEIVERS

Station	Event Signal	Project User
USS Richard B. Anderson (DD-786): One receiver located in after torpedo stowage room, port side alongside hangar.	Zero time + 27 sec [a]	NOTS EG & G
USS Bausell (DD-845): Two receivers located in oil storage racks in helicopter hangar. Three 27-QA relays.	- 10 min Zero time + 27 sec [a]	1.1 and 3.1 1.1 and 3.1 3.1 and EG & G
USS Hopewell (DD-681): One receiver located in Radio 3.	+ 27 sec [a]	EG & G
USS Molala (ATF-106): One receiver located in enclosed upper-deck access ladder, starboard side.	- 10 min Zero time + 27 sec [a]	1.1 1.1 EG & G
Platforms 1 and 2: Two receivers mounted on side of instrument support frame. One No. 27-QA relay.	- 10 min Zero time + 27 sec [a]	1.1 1.1 3.1 and EG & G
Surface Zero Platform: One receiver mounted on side of antenna mast.	Zero time + 34 sec	9.1 9.1
USS Agerholm (DD-826): Hard-wire link	-10 min Zero time + 27 sec [a]	1.1 1.1 and NOTS EG & G

[a] The signal taken at + 27 seconds by EG & G was for the purpose of arming the fiducial-zero receiver, as described in Section F.1.3.

100-msec duration, reshapes it and provides a square-pulse output of 1.5-msec duration with a 15-μsec rise time and an amplitude of 12 volts. Four outputs are provided on each receiver, so that four users may take the fiducial signals simultaneously.

Because of the sensitivity of these receivers to noise, and because of the relatively noisy electrical environment obtaining in the operation, it was considered desirable to keep these receivers quiescent for as long as possible and arm them just before the fiducial pulses were transmitted. Accordingly, the fiducial-zero receivers employed in Sword Fish were specially modified by EG & G to accept a ready closure from a radio-tone receiver which in turn closed an internal relay in the fiducial receiver, permitting the pulse-emmitting circuitry to function. A switch was also provided on the receiver to permit local arming for check-out purposes.

Fiducial-zero receivers were installed adjacent to the radio-tone receivers in Anderson, Bausell, Hopewell, Monticello and Molala, on the two instrumentation platforms, and in Agerholm (armed by hard-wire link) and Razorback (armed manually). The fiducial-zero receivers were armed at +27 seconds in the countdown sequence. The fiducial pulses themselves were transmitted at +35.5, +36.5, +37.0, +37.5, and +38.5 seconds.

F.1.4 Antenna Installations. Receiving antennas for the radio-tone and fiducial-zero receivers were Mark Products Model CV-3160 whips, approximately 6 feet 7 inches long. In all cases of multiple installation, the antennas were arranged fore-and-aft in vertical finger array, spaced 39 inches apart. The locations of the antennas in each ship were:

Anderson: Four antennas on a stub mast above the ECM shack.

Bausell: Three antennas on a stub mast above the ECM shack.

Hopewell: Two antennas on a stub mast attached to the forward wall of the after smokestack.

Molala: Two antennas attached to the highest point of the after mast.

Platforms 1 and 2: Three antennas attached to a telescoping mast placed nearly amidships and giving an antenna height above mean water line approximately 25 feet.

Surface Zero Platform: One antenna attached to a telescoping mast amidships.

In Razorback, the single fiducial-zero receiver was patched into the existing 150-Mc antenna on the submarine. The antenna installations in Agerholm have already been described in Section F.1.1.

F.1.5 Remote Signal Station. Signals were taken by hard wire from the ASROC firing sequence to initiate certain events in the countdown. In the overall planning for Sword Fish, provision had been made to fire the nuclear depth charge from the USS Richard B. Anderson (DD-786) in the event of an aborted firing from USS Agerholm. In order to meet this eventuality, therefore, EG & G found it necessary to install a remote manned signal station in Anderson capable of accepting the desired signals by hard wire from the Anderson ASROC system and transmitting them by radio link to the control point in Agerholm. Accordingly, one cabinet of electronic equipment was installed in Anderson's after torpedo stowage room port side alongside the helicopter hangar. This cabinet contained a 28-volt dc power supply, a 60-watt VHF transmitter, a radio-tone generator, two radio-tone monitors (one for monitoring the two ASROC signals transmitted from Anderson, the other for monitoring all radio-tone signals transmitted by the control point in Agerholm), an EG & G Net transceiver, and the chassis for accepting and monitoring the hard-wire ASROC signals. As in the case of the Agerholm installation, the cabinet was installed on shock mounts for the purposes of mechanical protection and electrical isolation. Power was again drawn directly from the after engineroom switchboard (also serving the ASROC system) through an isolation transformer.

This station was employed for an Operational Service

Test (OST) firing from Anderson during one of the later rehearsals, but failed to transmit its signals. Investigation revealed that NOTS personnel had inadvertently connected one of the EG & G signal lines to the wrong relay in the ASROC Mk199 launch control console. The error did not reveal itself during earlier simulated firings (when signals were transmitted by Anderson and received by Agerholm perfectly) for reasons that are beyond the scope of this report. The proper connection was made prior to the final exercise, but, of course, this station was not used.

F.2 COUNTDOWN PROCEDURE

F.2.1 Audio System. An audio countdown was given from the control point in Agerholm whence it was transmitted to all participating vessels and aircraft. The primary countdown circuit assigned was (243.0 Mc). Radio silence was maintained on this circuit during the countdown. A patch was made from the audio distribution panel in the control point to a remote unit, RHMS 8, at the port lookout station on the hangar deck, which was in turn patched into the primary countdown circuit transmitter in radio central. This circuit was used both for the EG & G countdown and for the brief period when the lead photographic A3D took over the count as explained in the following section.

Because the two participating submarines, Razorback and Sea Fox, could not receive the primary countdown circuit when submerged, and because the USS Cree (ATF-84) could not receive the circuit either, countdown was also transmitted directly over the secondary tactical circuit (SECTAC), (2772 Mc). For obvious reasons, radio silence was not maintained on this circuit during countdown. A patch was made from the audio distribution panel in the EG & G control Point to a remote unit in the pilot house, which was in turn patched into the SECTAC transmitter in radio central.

Aboard Agerholm, the countdown was carried throughout the ship over the 1-Mc (public address) system by means of a patch from the audio distribution panel in the EG & G control point paralleled into the output of the 1-Mc microphone on the afterdeck. (Because the topside 1-Mc speakers aboard Agerholm had to be silenced as a result of severe audio feedback to the control point microphone, scientific and documentary photographic personnel who needed to be topside during the countdown heard it relayed over sound-powered phones.)

In most of the other ships, the countdown was heard directly by ship's personnel over the 1-Mc system by means of a patch from the primary countdown circuit or SECTAC receivers paralleled into the output of the nearest 1-Mc microphone (generally that at the pilot house). In certain instances it is understood that the countdown was relayed by an officer talking into the 1-Mc system.

F.2.2 Countdown Sequence. The audio countdown in Sword Fish commenced nominally an hour before the event, with zero time designated as the instant of launch of the ASROC missile. Events occurring thereafter, including the detonation of the weapon, thus occurred at plus times. Time announcements were made at 15-minute intervals for the first 45 minutes, and at 1 minute intervals until minus 1 minute. Safety announcements were made at minus 10 minutes, minus 5 minutes, and minus 1 minute.

Because of the criticality of coordinating the position of the two photographic A3D aircraft with the ASROC firing and weapon detonation, the countdown was transferred from EG & G control to the lead A3D at minus 30 seconds. After a hold for a brief period (necessary for the two aircraft to reach the correct position over the array for accurate, overhead, high-speed photography of the burst point), the lead aircraft resumed the countdown. Time announcements were made over the primary countdown circuit at 5-second intervals to minus 10 seconds and at 1-second intervals thereafter to zero. Upon receipt of the lead A3D's zero, the gunnery officer aboard the Agerholm launched the ASROC. The countdown was then returned to EG & G control, with time announcements at 1-second intervals to plus 40 seconds, and at 5-second intervals thereafter to plus 1 minute, at which time the countdown was complete. Safety announcements were made at plus 27 and plus 40 seconds.

It must be noted that the establishment of an accurate zero time referenced to the instant of launch of the ASROC was critically important to the instrumentation projects in Sword Fish. To provide this accurate time reference, EG & G first modified the CP coder so that the signal stepping sequence and countdown clock would automatically stop and hold at minus one-half second (the shortest time increment achievable with the coder). With the aircraft holding for several seconds at minus 30 seconds prior to resuming the count, as noted above, the clock and sequence stepper were run out and holding before the aircraft gave zero.

In order to restart the clock and sequence stepper so that the vital zero signal could be transmitted at ASROC launch, two hard-wire signals were taken from the ASROC firing sequence, as noted earlier. The coder restart signal itself was obtained by replacing an insulated wire across the after end of the launching tube. This wire completed an electrical circuit in the EG & G control point and held the restart relay closed. When this wire was burned through by the rocket blast, the circuit was opened, releasing the relay that held the clock and the sequence stepper stopped.

To prevent the coder from restarting prematurely as a result of the vital wire's possibly breaking accidentally prior to launch, the restart circuit was protected by an arming circuit. This circuit was activated by the K-12 relay in the Mk 199 launch control console, which closed when the ASROC firing switch was thrown from Standby to Fire. The time elapsed between the closure of the K-12 relay and rocket ignition, ie., burning of the restart wire, was a matter of milliseconds. The two signals were to all intents and purposes received simultaneously.

It must be noted that in spite of the demonstrated high reliability of the ASROC weapon system, a small probability existed that the missile would not launch when the firing switch was thrown. If the closure of the K-12 relay had been taken alone as the EG & G coder restart signal, and the missile had not launched, the critical zero signal activating high-speed data recorders would have been sent but no data would have been taken. This would have resulted in considerable delay for the purpose of reloading tape, oscillographic and photographic recorders, particularly those at unmanned stations in the towed array. In all probability, the exercise would have been aborted for the day. Accordingly, it was decided that the burning through of the wire was a more positive indication that the missile would launch. Thus, receipt of either signal alone, i.e., closure of the K-12 relay or breaking of the wire, would not restart the EG & G coder. Both signals were necessary.

A special chassis was built by EG & G to indicate the status of the restart sequence. Test switches were incorporated that also permitted manual override in the event of failures up the line. This chassis was incorporated in both the control point in Agerholm and the remote signal station in Anderson. In addition, the control point in Agerholm had an identical second chassis installed for the purpose of monitoring the signal status in Anderson, in the event that the missile was launched from that ship.

During both the OST firing and the final Sword Fish event, this coder restart sequence functioned perfectly with the zero signal transmitted at the instant of rocket ignition.

F.2.3 Event Times. The times at which the critical events took place in the final Sword Fish event are given below as reproduced from the printed record given by the control point.

Event	Local Time
- 60 min. Commence countdown	12:00:00
- 10 min. Relay closure	12:50:00.0918
- 0.5 sec. Coder stopped	12:59:59.5931
Zero Relay closure	13:01:26.1004
+ 27 sec. Relay closure	13:01:53.0949
+ 34 sec. Relay closure	13:02:00.0991
+ 35.5 sec. Fiducial pulse	13:02:01.5812

Event	Local Time
+ 36.5 sec. Fiducial pulse	13:02:02.5859
+ 37.0 sec. Fiducial pulse	13:02:03.0884
+ 37.5 sec. Fiducial pulse	13:02:03.5911
+ 38.5 sec. Fiducial pulse	13:02:04.5825

The 1-min. 27 sec. elapsed time between the -0.5 second and zero time indicates the approximate aircraft hold before resuming the count.

F.3 SUMMARY

Participation of EG & G in Sword Fish involved the provision of timing signals and an audio countdown. The EG & G control point was established in Agerholm and manned by three EG & G personnel. A remote signal station was placed in Anderson and manned by two EG & G personnel. Radio-tone and fiducial zero receivers, together with appropriate antennas and relay boxes, were installed in Anderson, Bausell, Hopewell, Razorback, Molala, and two towed instrumentation platforms and the surface zero platform. Two EG & G personnel sailed in the USS Monticello (LSD-35), for the purpose of maintaining the EG & G equipment in the towed array and other ships not manned by EG & G personnel, replacing batteries every three days as required. In the final Sword Fish event, timing signals were received and relay closures given on time at all instrumented stations, except for a premature closure of the + 27 second relay which occurred at Platform 1. Similarly, fiducial signals were received at all stations except at Molala. Spurious fiducial signals were received at Bausell, but they did not prevent detection of the five true signals.

Appendix G

TECHNICAL PHOTOGRAPHY

(Prepared by LCDR G. Smith, with deletions deemed desirable to avoid repetition of matters covered elsewhere.)

The general objective of the technical photography was to make possible the analysis of surface phenomena (to be undertaken by Project 1.2). Tasks involved were as follows: (1) to obtain the required photographic equipment and film; (2) to obtain the required photographic aircraft; (3) to train and brief both aerial and surface photographic crews; and (4) to record photographically the surface events.

G.1 PREPARATION

All photographic equipment was obtained on a loan basis by the Bureau of Naval Weapons (BuWeps) from Naval activities, for a period of 90 days, at no cost to the project.

The Naval Air Development Center (NADC) Aeronautical Photographic Experimental laboratory (APEI), Johnsville, Pennsylvania, was utilized to overhaul, repair, modify, and store all cameras for the project. APEI modified all cameras possible to a timing system of 120 cps and 500 cps without a common fiducial mark. Each camera station was provided with at least one camera with a clock installed which could be matched with other camera stations to utilize the known time of burst.

Because of the short time allowed to prepare for Sword

Fish, APEL did not have time to calibrate each camera lens; therefore, the lenses were calibrated to infinity and all cameras were returned to APEL for a focal-length calibration upon completion of Sword Fish.

APEL removed most of the original NCCS-4 camera control system from the A3D-2P, and modified the electrical system to operate the required high-speed motion-picture cameras.

Heavy Photographic Squadron Sixty-Two (VAP-62) provided two A3D-2P aircraft, flight crews, and ground maintenance crews. Cameras were installed by APEL as shown in Table G.1.

Third Marine Air Wing provided two R5D aircraft, flight crews, and ground maintenance crews. Cameras were installed by APEL. The cameras, which are listed in Table G.2, were divided between two R5D aircraft. The second aircraft was provided for backup.

Three surface ships were utilized as camera stations, USS Molala (ATF-106), USS Hopewell (DD-681), and USS Monticello (LSD-35); each ship was equipped with seven cameras as shown in Tables G.3, G.4 and G.5. Four Automax 35-mm recording cameras were installed on the USS Hopewell's Mark 25 and 37 Fire directors to obtain a tracking record of the R5D aircraft.

G.2 OPERATION

The A3D-2P aircraft flew over the array at 20,000 feet altitude, ground speed 200 knots, during the nuclear detonation,

(Text continues after Table G.5)

TABLE G.1 A3D-2P TECHNICAL CAMERA INSTALLATION

Camera No.	Camera	Film Size	Amount of Film	Camera Speed	Length of Record	Lens Focal Length	Camera Field Width	Camera Field Length
			feet	fr/sec	sec	mm	yards	yards
A-1-1	FASTAX	16 mm	400	1,000	16	50	1,370	990
A-1-2	MILLIKEN	16 mm	400	200	80	25	2,770	1,990
A-1-3	KF-8	35 mm	1,000	96	160	18.5	9,000	5,760
A-1-4	KF-8	35 mm	1,000	24	670	25	6,670	4,270
A-1-5	CINE-SPECIAL	16 mm	100	24	175	15	4,630	3,330
A-1-6	KA 46	5 in	250	2	250	152	5,530	5,530
A-1-7	X70	70 mm	50	1/8	1,920	75	5,550	5,000
A-1-8	CA-13	9 in	370	9/16	419	914	3,330	1,660
A-1-9	KF-8	35 mm	1,000	96	160	50	3,330	2,130
A-1-10	KF-8	35 mm	1,000	24	670	50	3,330	2,130
A-1-11	T-11	9 in	370	1/3	1,320	152	10,000	10,000

TABLE G.2 R5D-3 TECHNICAL CAMERA INSTALLATION

Camera No.	Camera	Film Size	Amount of Film feet	Camera Speed fr/sec	Length of Record sec	Lens Focal Length mm	Camera Field Width yards
A-2-1	FASTAX	16 mm	400	1,000	16	100	1,100
A-2-2	MILLIKEN	16 mm	400	200	80	75	1,450
A-2-3	MITCHELL	35 mm	1,000	96	167	50	5,200
A-2-4	MITCHELL	35 mm	1,000	24	670	25	10,500
A-2-5	FILMO	16 mm	100	16	250	15	7,300
A-2-6	F-56	7 in	125	1/3	630	508	3,500
A-2-7	P-220	70 mm	50	1/4	960	75	8,700

TABLE G.3 USS MOLALA (ATF-106) TECHNICAL CAMERA INSTALLATION

Camera No.	Camera	Film Size	Amount of Film feet	Camera Speed fr/sec	Length of Record sec	Lens Focal Length mm	Camera Field Width at 5,000 yards yards
S-1-1	MILLIKEN	16 mm	400	400	40	50	1,150
S-1-2	MITCHELL	35 mm	1,000	96	160	100	1,380
S-1-3	MITCHELL	35 mm	1,000	96	160	35	3,920
S-1-4	MITCHELL	35 mm	1,000	48	330	152	580
S-1-5	MITCHELL	35 mm	1,000	24	670	18.5	7,450
S-1-6	FILMO	16 mm	100	16	250	15	3,810
S-1-7	F-56	7 in	125	1/3	630	210	4,400

TABLE G.4 USS HOPEWELL (DD-681) TECHNICAL CAMERA INSTALLATION

Camera No.	Camera	Film Size	Amount of Film (feet)	Camera Speed (fr/sec)	Length of Record (sec)	Lens Focal Length (mm)	Camera Field Width at 4,000 yards (yards)
S-2-1	MILLIKEN	16 mm	200	200	40	40	1,040
S-2-2	MITCHELL	35 mm	1,000	96	160	50	2,000
S-2-3	MITCHELL	35 mm	1,000	96	160	25	4,000
S-2-4	MITCHELL	35 mm	1,000	48	330	25	8,400
S-2-5	MITCHELL	35 mm	1,000	24	670	18.5	5,400
S-2-6	FILMO	16 mm	100	16	250	10	4,380
S-2-7	F-56	7 in	125	1/3	630	210	1,600

TABLE G.5 USS MONTICELLO (LSD-35) TECHNICAL CAMERA INSTALLATION

Camera No.	Camera	Film Size	Amount of Film	Camera Speed	Length of Record	Lens Focal Length	Camera Field Width at 10,000 yards
			feet	fr/sec	sec	mm	yards
S-3-1	MILLIKEN	16 mm	400	400	40	102	900
S-3-2	MITCHELL	35 mm	1,000	96	160	152	1,500
S-3-3	MITCHELL	35 mm	1,000	96	160	50	4,500
S-3-4	MITCHELL	35 mm	1,000	48	330	25	9,200
S-3-5	MITCHELL	35 mm	1,000	24	670	25	9,000
S-3-6	FILMO	16 mm	100	16	250	15	6,200
S-3-7	F-56	7 in	125	1/3	630	508	3,000

and the R5D's flew in a circular flight path at 10,000 feet, one at a horizontal range of 10,000 and the other at 13,100 yards from surface zero. A3D-2P No. 1 was utilized as a timing aircraft and gave the final countdown, using an optical viewfinder with a special timing grid. The array was photo-mapped at 7,000 feet before and at 10,000 feet after the shot by the A3D-2P's. R5D No. 2 was utilized to obtain radiological readings at 3,000 feet and 1,500 feet, and to drop smoke bombs in the radioactive water patch.

G.3 DISPOSITION OF FILM

The wide aerial film was processed by VAP-63 photographic laboratory, NAS Miramar, San Diego, California, and prints made for local use, evaluation, and preliminary measurement. The remaining film was forwarded to APEL for controlled processing. NOL received custody of all technical films.

G.4 CONCLUSIONS

The technical photographic coverage was accomplished in accordance with CJTG 8.3 Operation Order 1-62. Fifty-four technical cameras were utilized successfully.

Appendix H

DETAILED DATA ON TEST CONDITIONS

Detailed information on test conditions near shot time was compiled. Items of concern are array-element positions determined by radar, array-element ranges from surface zero determined by shock-arrival times, ship headings, and bathythermograph measurements near shot time.

Agerholm, Anderson, Hopewell and Yorktown tracked various elements of the array by radar. The radar-track positions at shot time relative to the target raft are summarized in Table H.1 along with Pioneer's reading of her own position relative to the target raft. From these data, an average position was determined as shown in the last column of Table H.1. Agerholm's range, both as deduced from her own radar track and as averaged from all radar tracks, was in good agreement with the input to the ASROC firing console. Agerholm's range from the target raft as displayed on the ASROC attack console at shot time was 4,025 yards. The average positions of all ships as shown in Table H.1 were redetermined relative to surface zero before being carried forward to the summary given in Table 4.1.

Ship movements for the critical 15 minutes after the burst are given for the most part by radar tracks made by the ships. The best radar tracks were made by Agerholm, as a cursory perusal of TablesH.1 and 4.1 indicates. Information

TABLE H.1 SHIPS' RADAR DATA ON ARRAY POSITIONS(1)

(1) Ranges are measured with respect to target raft. Bearings are measured clockwise from true north.

Ship or Other Array Element	Measured By											
	Agerholm		Anderson		Hopewell		Pioneer		Yorktown		Averages	
	Range yd	Bearing deg	Range yd	Bearing deg	Range yd	Bearing deg	Range yd	Bearing deg	Range yd	Bearing deg	Range yd	Bearing deg
Agerholm	4,050	299	3,800	291	4,150	303					4,000	298
Anderson	3,850	327	3,550	323	4,140	331					3,847	327
Hopewell	4,100	026	2,950*	52*	4,150	028					4,125	027
Razorback	4,550	247	4,580	241	4,200	257					4,443	248
Monticello	7,780	249									7,780	249
Bausell			1,880	339	2,070	350					1,975	344
Pioneer			12,500	353	12,750	362	11,800	355			12,350	357
Posit.-buoy	3,460	121	9,850**	134**							3,460	127
Posit.-buoy	3,560	155	10,300**	154**							3,560	155
Molala	6,000	343									6,000	343
Yorktown									9,500	309	9,500	309
Brush									8,000	028	8,000	028
Moore									7,000	003	7,000	003
Maddox									4,900	040	4,900	040
Preston									4,400	300	4,400	300

*Data discarded in taking averages.

**Data discarded. Helos stated the Posit.-buoys were dropped at H - 30 min within 3,000 to 4,000 of the target raft as planned. Drift is assumed to be small.

from this source covers the movements of Hopewell, Monticello, and Molala and is summarized in Table H.2. In addition, information on Hopewell's movements from its own DRT is included in Table H.2. Hopewell moved appreciably after the burst while the Monticello and Molala did not. Other ships in the array, with the exception of Sioux, are understood not to have moved very much during the 15 minutes following the burst. In particular, Bausell and the upwind section of the tow continued to be towed by Molala.

Shock arrival times recorded by the Project 1.1 and 3.1 gages were also used to determine ship ranges from surface zero. Table H.3 summarizes the times and the computed ranges from the burst.

Table H.4 summarizes available information concerning ship headings at shot time. The ship radar tracks give the direction of the target at shot time; headings were assumed to be along the direction of motion. Shock wave arrival times at gages located along the length of a ship produced the estimates of heading given in the table under "shock arrival" The last column of Table H.4 indicates the overall estimate of ship headings.

Figure H.1 compares the bathythermograph record taken by Hopewell at 2015 GMT with that taken by Hopewell at 1945 GMT. Similarly, Figures H.2 and H.3 compare bathythermographs taken near shot time by Anderson and Agerholm. The comparisons

(Text continues after Figure H.3)

TABLE H.2 SHIP POSITIONS AFTER THE SHOT

Positions relative to target raft

Time	Hopewell[a]		Hopewell[b]		Monticello[b]		Molala[b]	
	Range (Yards)	Bearing (deg T)	Range (Yards)	Bearing (deg T)	Range (Yards)	Bearing (deg T)	Range (Yards)	Bearing (deg T)
1302	4,125	027	4,125	027	7,780	249	6,000	343
1303	3,540	030			7,800	250	6,180	016
1304	3,170	032	3,475	032				
1305	3,000	041						
1306	3,230	049						
1307	3,970	050	4,000	034	7,740	251	6,240	015
1308	4,390	044						
1309	4,550	036						
1310	4,240	031	4,050	028	7,680	251	6,340	016
1311								
1312	4,020	021						
1313	4,190	016						
1314	4,380	011						
1315	4,630	007	4,150	015	7,600	250	6,425	014

Notes: (a) From own DRT-(initial position corrected to conform to that given by Agerholm's radar plot.)
(b) Agerholm radar surface plot.

TABLE H.3 SUMMARY OF SHOCK-ARRIVAL-TIME DATA ON ARRAY POSITIONS

(a) Frame 93-1/2 is approximately the midship's station.
(b) Times are accurate to ± 1 msec, relatively, and ± 10 msec, absolutely.
(c) Burst time is taken as 39.810 sec after launch. See Chapter 4.
(d) Shock wave velocity was taken as 4950 ft/sec, except for Platform 2 where a correction of 4-percent was made to account for the finite amplitude of the shock wave.

Array Unit	Arrival-Time Recorded by	Arrival Time[b] After Burst[c] (sec)	Distance from Burst[d] (Yards)
Platform 2	Project 1.1 pressure gage average at surface; Project 3.1 velocity meter.	0.612	1,060
Platform 1	Project 1.1 pressure gage at 30-foot depth.	0.838	1,383
Bausell	Project 3.1 velocity meter on keel at Frame 93-1/2[a].	1.320	2,180
Agerholm	Project 3.1 velocity meter on keel at Frame 93-1/2[a].	2.623	4,328
Anderson	Project 3.1 velocity meter on keel at Frame 93-1/2[a].	2.575	4,249
Hopewell	Project 3.1 velocity meter on keel at Frame 93-1/2[a].	2.433	4,014
Razorback	Project 3.1 velocity meter on keel at Frame 47-1/2.	2.718	4,488
Monticello	Project 1.1 hydrophone at 200-foot depth.	4.809	7,936

TABLE H.4 SHIP HEADINGS AT SHOT TIME

(1) Heading with respect to true north.
(2) Values measured from shock arrival first choice, from photographs second, and from radar tracks third. Figures rounded off.

Ship	Source of Data for Ship Heading (1)							
	Radar Track by Anderson (deg)	Radar Track by Hopewell (deg)	Radar Track by Agerholm (deg)	Track by Razorback (deg)	Track by Yorktown (deg)	Aerial Photographs (deg)	Shock Arrival (deg)	Ship Heading Value Chosen (2) (deg)
Agerholm			359				4 ±5	5
Anderson	342		329				350 ±5	350
Hopewell	198	210	190				201 ±10	200
Razorback	338			340				340
Monticello			325					325
Bausell	338					334	338 ±10	340
Pioneer	334							335
Molala			12			355		355
Yorktown					134			135
Brush					213			215
Moore					148			150
Maddox					290			290
Preston					15			15

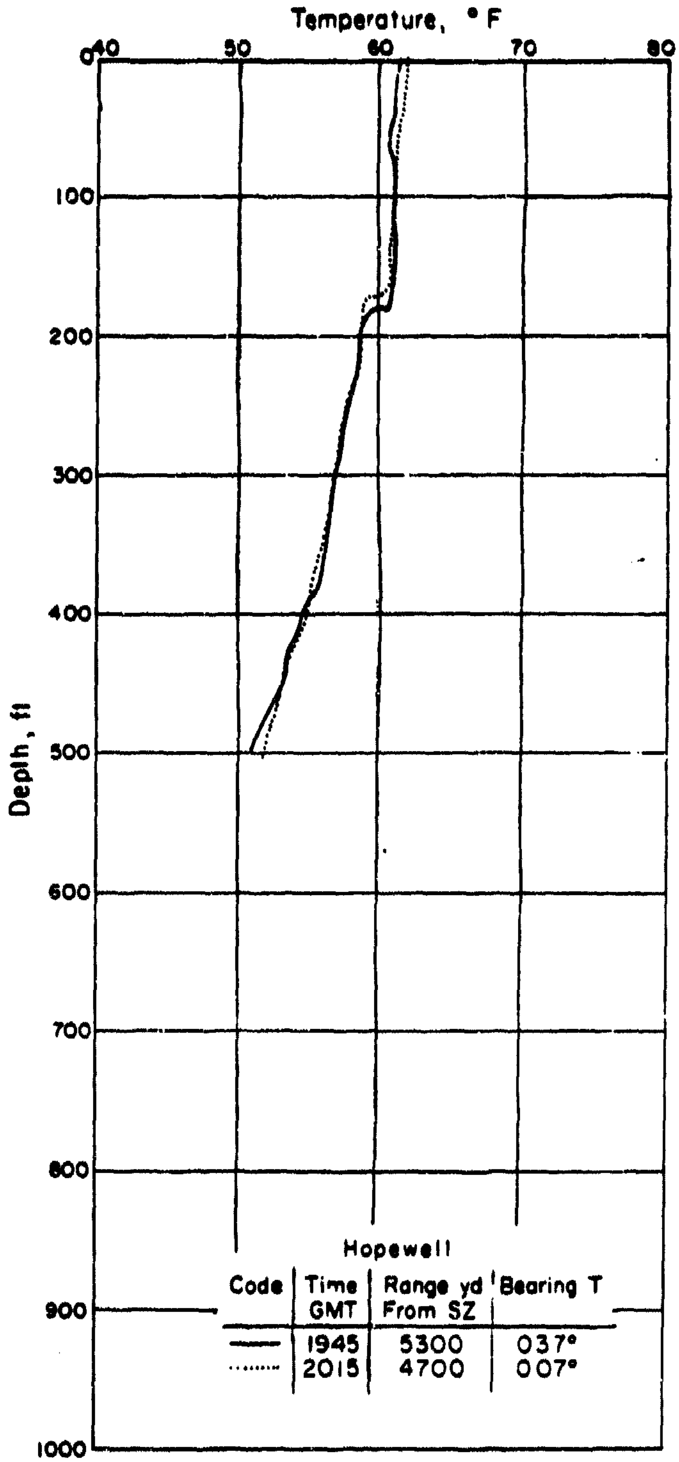

Figure H.1 Hopewell bathythermographs near shot time.

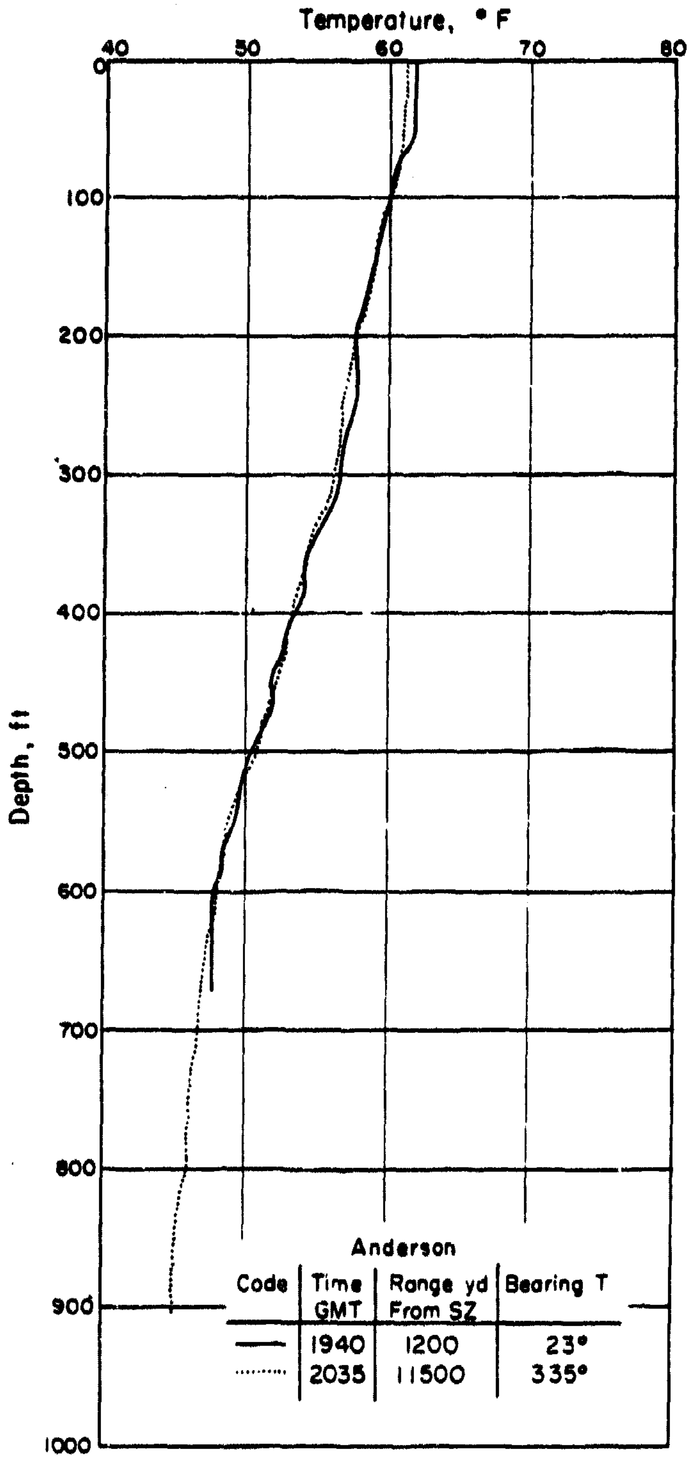

Figure H.2 Anderson bathythermographs near shot time.

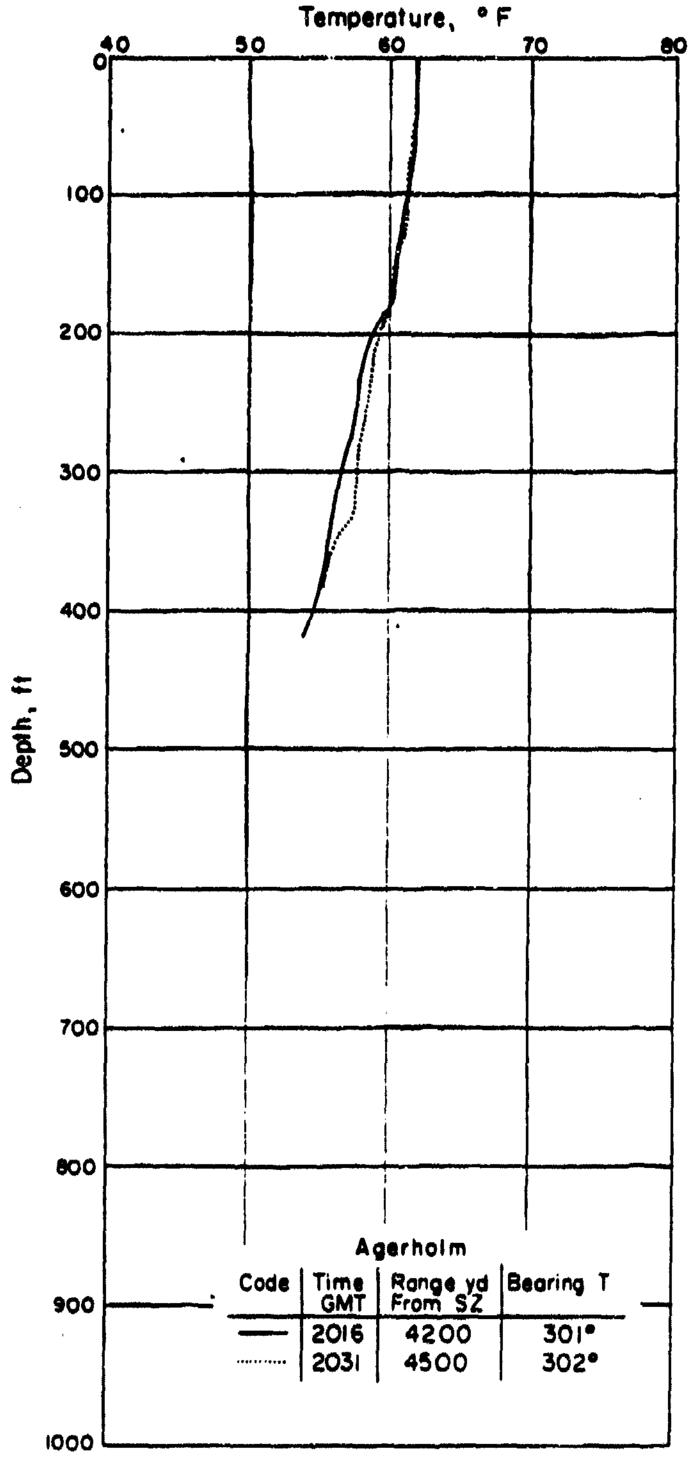

Figure H.3 Agerholm bathythermographs near shot time.

tend to indicate that there was little change in the thermal structure of the water from about 15 minutes before to 15 minutes after the shot at a given ship location.

 Pages 272 through 274 deleted.

21. W. W. Murray; "Interaction of a Spherical Acoustic Wave With a Beam of Circular Cross Section"; UERD Report 1-55, January 1955; Underwater Explosions Research Division, Norfolk Naval Shipyard, Portsmouth, Virginia.

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