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FINAL REPORT
RESEARCH AND DEVELOPMENT EFFORT ON AN UNDERWATER SOUND SIGNAL

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FOREWORD

This report covers the development of a shallow-functioning underwater sound signal by the U. S. Naval Ordnance Laboratory, Corona. The work described herein was authorized by the Bureau of Naval Weapons under Task Assignment 340-664/46037/07063 for Fiscal Year 1960 and WepTask RUDC-5B607/211-1/F001-13-005 for Fiscal Year 1961. The design objectives required by both task assignments were specified in NAVORD OS 10135, Description and Requirements for Underwater Sound Signal.

The specifications required that the underwater sound signal have a selectable dual-depth capability for functioning at water depths of 21 ± 4 feet and 800 ± 100 feet. Only the first phase of the design effort was completed by NOLC before termination of the project. This phase included completion of the design for the shallow-functioning unit and limited tests of the unit. Hydrodynamic characteristics desirable for the deep-functioning operation were incorporated into the unit.

The limited test results indicate that further development effort would be needed if all the requirements of OS 10135 are to be met.

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ABSTRACT

An underwater sound signal that functions at a water depth of 21 ± 4 feet has been designed for antisubmarine warfare training exercises. The device incorporates a new concept: the use of air retardation to solve the problem of cavitation at water entry. With air retardation, the velocity of the device can be stabilized to a point at which hydrostatic forces can be successfully applied within the shallow depths specified. In addition to air retardation, other improvements in basic design promise to upgrade the safety, accuracy, and reliability of the device and to make it available for shallow functioning after a 350-knot launching speed.

Although the device described herein is capable only of shallow functioning, a hydrodynamic configuration required for deep-depth operation was included in this interim model. Further development effort in which the remaining deep-firing characteristics are incorporated into the design, plus a reasonable evaluation program, should result in a safer and more reliable fleet-exercise signal than is presently available.

CONTENTS

INTRODUCTION

This report covers the design and development of a shallow-functioning underwater sound signal (SUS) for use in antisubmarine warfare (ASW) training exercises. The device, which is designed to function at a water depth of 21 ± 4 feet, also incorporates a hydrodynamic configuration that would permit adaptation to deep-depth (800 ± 100 feet) functioning. The SUS described herein is primarily designed for launching at speeds up to 350 knots from aircraft equipped with SUS launchers. In addition, it can be adapted to hand-launching from surface vessels or helicopters. Only limited tests were conducted on the device before work was terminated. However, it is believed that further development effort in which all the deep-firing characteristics are incorporated into the design, along with a reasonable evaluation program, would make a safer and more reliable fleet-exercise SUS than is presently available.

Underwater sound signals are used for submarine detection by explosive echo-ranging methods. The signals contain a fuze, which is armed at a designated depth—usually as a result of hydrostatic pressure. They also incorporate a small quantity of high explosive, which produces an underwater sound signal when detonated. The resulting sound waves strike the target submarine, return as echoes, and are received by the sound equipment of the target-seeking aircraft or surface vessel. Signals of existing design employ a blunt-nosed configuration to conform with dispensers presently installed in ASW aircraft and to prevent skipping at water entry. The fuze may provide out-of-line safety prior to arming, or other safety methods may be used.

Signals of existing design present several problems, particularly when they are used for ASW training exercises. As described in detail in the next section of this report, training exercises cannot be held under realistic conditions because the present units are not sufficiently reliable. The lack of reliability, coupled with the explosive nature of the signal, means that special precautions must be taken to prevent damage to the training submarine. In addition, even when precautions are taken, accidents might cause damage to the submarine in shallow-depth tests. Finally, the safety of present designs is deficient in two respects: use of only one mechanism to arm and fire the unit, and use of pull pins, which are removed prior to launching, to prevent premature arming.

Consequently, an improved sound signal was needed so that accidents could be avoided, better methods of training could be implemented, and operational safety could be increased. Development of an improved sound signal was therefore undertaken by the Naval Ordnance Laboratory Corona (NOLC). The device, which was to meet the requirements specified in OS 10135,[1] was intended to be safe, to function reliably at shallow depths, and to be inexpensive.

In the next section of this report, background information covering the problems in existing designs and the requirements for an improved design are discussed. Theoretical considerations on which a new design was based are then explained, followed by descriptions of the design, the method of operation, and the further development necessary to complete the unit.

BACKGROUND

In its preliminary approach to the design of a safe, reliable, inexpensive SUS unit, NOLC first analyzed the features in present designs that preclude safe, reliable operation. The detailed design requirements were then established.

ANALYSIS OF PRESENT DESIGNS

Training Aspects

Since the explosive contained in an underwater sound signal may cause damage to a submarine hull, a problem exists when SUS's are used for ASW training exercises. To achieve the most effective ASW training in explosive ranging, the training crew should not know the location of the exercise submarine. Furthermore, the submarine should be free to take any evasive action required to avoid detection without danger of possible major hull damage from any echo-ranging device used by the ASW crew. However, present practice depth charges (PDC's) and sound signals are loaded with sufficient explosives to cause considerable hull damage if detonated in contact with the pressure hull, and they do not function reliably at shallow depth. Hence, for safety reasons it is a required exercise procedure that the location of the submarine be known by the aircraft before any drops are made. To indicate its location, the submarine tows a sail during daytime training and uses a light for night exercises. If the present sound source units were reliable

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[1] Bureau of Ordnance, Navy Department, Description and Requirements for Underwater Sound Signal, NAVORD OS 10135, 6 August 1959 (CONFIDENTIAL).

and would fire at a set depth, the exercise submarine could operate freely within an underwater floor and ceiling; such devices as sails or lights could be omitted; and realistic training exercises could be conducted.

At the present, a problem also exists in connection with shallow-depth operation of a training submarine. When the submarine is operating at periscope depth, the water depth to the deck is less than the firing depth of the presently used signals. If a signal should land and lodge on the deck, it could function when the submarine dived to a lower level and could cause hull damage.

Reliability Problems

The erratic behavior of existing SUS devices, particularly with respect to detonation depth, is a result of several factors:

1. Firing is accomplished by hydrostatic pressure triggering a firing mechanism. Accurate depth cannot be sensed by hydrostatic means until the cavitation bubble that envelops the unit on water entry has collapsed. The altitude and speed of the launching craft affect the magnitude and duration of the entrained cavity. With present systems, effective adjustments for cavitation cannot be made.

2. The requirements of the present launching racks dictate the use of a blunt-nosed SUS design. Such an external configuration aggravates this condition of cavitation. In addition, it is one of the major factors contributing to the erratic underwater trajectory of some of the present SUS units.

3. A part of the firing system employs a sliding watertight seal for the hydrostatic-sensing mechanism. These seals are subject to a certain degree of seizure after prolonged storage. This effect introduces serious errors in firing depth and in severe cases can cause dudding of the signal.

Safety Problems

The present PDC and SUS designs also present problems of safety deficiency. First, all units were found to be lacking to some degree in safety, as judged by Navy standards of good safety-arming device design. In all units studied, hydrostatic pressure is used to align the explosive train or to fully arm the device, or both, in combination with the use of hydrostatic pressure to fire the device. However, good safety design requires that separate environments be used to arm and fire the unit. A second problem is created with the older units (PDC's), because they use a precocked firing pin. This stored spring energy can be released by impact as well as hydrostatic pressure. Third, the safety measure used to prevent premature arming in present designs is a pull wire or pin. Either this pin must be removed before the sound source is loaded into the launching rack; or, as in the later models, slipstream air or water force must be used to remove the pull wire after launch. The unit is no longer safe after the pull wire is removed, and may arm and fire with the application of sufficient hydrostatic pressure. The seriousness of this safety problem is verified by a history of premature firings of PDC's upon aircraft ditching.

Operational Problems

To acquire a more complete knowledge of SUS handling, stowage, and use problems in the explosive echo-ranging system, NOLC personnel visited service activities engaged in this program and studied the various ASW aircraft (S2F, P5M, P2V, and P3V). Problems encountered with the use of the existing PDC's and SUS's were discussed with operating personnel at FAETUPAC, Naval Air Station, North Island, San Diego, and at VS-37, Naval Air Station, Los Alamitos. These visits revealed that:

1. All SUS devices must have an external configuration compatible with four different launching racks.
2. Safety in shipboard stowage is a problem. At present, inadequate safety features dictate that the arming and firing section be assembled to the explosive section before use and disassembled and restowed in separate areas if not expended.
3. The most satisfactory signal returns are obtained from SUS units that use a 1.8-pound TNT charge.
4. A more reliable sink rate is needed to determine which signal is being received when several signals have been dropped sequentially.

DESIGN REQUIREMENTS

Based on the study of deficiencies in present designs, a set of requirements for an improved design was established. The task assignment included the following capabilities for the NOLC design:

1. A SUS design that will incorporate dual-depth functioning capabilities at 21 ± 4 feet or 800 ± 100 feet.

2. Two basically different design approaches, which would result in:

    a. A device that uses hydrostatic capability combined with an air-retardation device to control the water entry velocity.

    b. A device that does not have the air-retardation feature but that uses delay fuzing for initiation.

3. A design adaptable to variations in launch environment from the maximum condition of an air drop at 350 knots to the minimum condition of hand launch from a surface vessel.

4. A design with inherent safety features that provide complete safety in all conditions of manufacture, assembly, inspection, shipping, testing, handling, stowage, and use.

5. A design that provides a safe separation distance from the launching craft before becoming fully armed.

6. A design that is safe from initiation by shock, vibration, acceleration, and inadvertent water immersion of the launching craft and that does not detonate on impact with a submerged submarine except within normal firing limits.

To meet the requirements of the broad scope of the task, and to establish an orderly procedure for the accomplishment of the task within the limited time and funding available, NOLC divided the design effort into phases, as follows:

1. Phase 1—design and development of an air-retarded shallow-depth SUS.

2. Phase 2—incorporation of selectable deep-depth capability into the design.

3. Phase 3—provision, by a different approach, of a device without air retardation but with delay fuzing.

Emphasis under the task assignment was placed on the Phase 1 effort. In addition, hydrodynamic characteristics desirable for the Phase 2 design were incorporated.

THEORETICAL CONSIDERATIONS

Before a design was attempted, problems of velocity and cavitation, safety, and hydrodynamic characteristics were considered, and solutions were determined, as described below.

VELOCITY AND CAVITATION

Since hydrostatic energy was chosen as one of the environments to be used in arming the SUS, studies were needed to determine the effects of velocity and cavitation. The launching speed was specified as 350 knots maximum; consequently, a means of retardation was needed to provide a lower water entry velocity. Only in this way could cavitation be reduced so that hydrostatic energy would be available at shallow depths. A survey of present devices was made to determine the extent of the cavitation problem.[2,3,4] This survey revealed that cavitation is a definite problem at shallow depths and that some units do not detonate reliably at depths of less than 65 feet.

An existing contract (NOrd 15520) with the Alden Hydraulic Laboratory of Worcester Polytechnic Institute (AHL/WPI) authorized that organization to act as consultants and perform certain laboratory tests in connection with the SUS design. AHL/WPI was requested (1) to determine the maximum water entry velocity that would allow hydrostatic devices to function within the shallow-depth limits specified for the design, and (2) to establish the time for a signal to reach a depth of 20 feet after launching at speeds from 140 to 350 knots without variations in release altitude from a base of 300 feet.

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[2] U. S. Naval Ordnance Test Station, Pasadena, California, Mk 50 Mod 0 Sound Signal Shallow Depth Firing Tests, by R. Larson, 21 March 1960.

[3] Alden Hydraulic Laboratory, Worcester Polytechnic Institute, Worcester, Massachusetts, Characteristics of Water Entry and Underwater Travel, Signal Depth Bomb, Ex 12 Mod 0, by Lawrence C. Neale and Howard K. Steves, Report No. 50, April 1960 (CONFIDENTIAL).

[4] U. S. Naval Ordnance Test Station, Pasadena, California, NUOS Ex 12 Mod 3 Shallow Depth Firing Tests, by R. Larson, 15 December 1960.

From information furnished by AHL/WPI in answer to these requests, a velocity of 25 ft/sec was established as the approximate rate of descent required to utilize the hydrostatic source of energy for shallow-depth operation.

Several means of air retardation were then considered, and a parachute was chosen as the best solution. A research and development contract was then negotiated with the Irving Air Chute Co., Inc., for the design of a parachute capable of retarding a 6-pound SUS to a water entry velocity of 25 ft/sec from a maximum air-launch velocity of 350 knots. With this approach, the SUS velocity would be decreased to a point at which hydrostatic forces would be successfully applied at shallow depths.

SAFETY CHARACTERISTICS

To avoid the safety deficiencies previously mentioned, NOLC established, as a design requirement, that at least two independent environmental forces be used for the arming and firing sequence. The forces considered were the slipstream energy available after launch and the hydrostatic energy available after water entry. In keeping with the Navy philosophy on safety, an interrupted explosive train, wherein the firing of the most sensitive elements in the out-of-line position would not initiate the main charge, was chosen. In the safe position, a positive lock was included on this interrupter. Finally, a sterilizing feature was incorporated to prevent detonation after the unit had reached the lower limit of specified shallow-firing depth.

The following arming and firing sequence was chosen:

1. After air launch, slipstream energy is used to release the parachute; the opening shock of the parachute is then used to unlock the firing pin used to prevent premature arming. Thus, the most sensitive elements of the firing train are unlocked. Parachute opening shock is also used to energize the relaxed firing spring and the timing device.

2. The energy from water impact is applied to start the timer assembly. When the timer has completed its cycle, the assembly is released to fire.

3. Hydrostatic pressure is used for two functions and would be used for three with the incorporation of the deep-depth setting. Water pressure at a depth of 14 feet aligns the firing train to complete arming. In the case of malfunction, hydrostatic

pressure sterilizes the unit at a depth of 25 feet. For deep-depth operation, hydrostatic pressure would be used to fire the unit.

HYDRODYNAMIC CHARACTERISTICS

For deep-depth operation, the most important consideration is time to firing depth. Time depends on a steady sink rate, which is influenced by hydrodynamic shape, properly distributed weight, and buoyancy. A study of the test reports on the existing SUS and PDC units had, however, disclosed a wide variation in sink rates and underwater characteristics.

This wide variation is due primarily to the nose configuration of existing SUS and PDC units (see Figure 1). The extremely blunt nose of these devices is dictated by the nature of the various aircraft launching equipment. The hydrodynamic shape employing this blunt nose is inherently difficult to stabilize through its water trajectory, and this instability contributes to the long, erratic path of some of the present SUS and PDC designs.

Basic hydrodynamic configurations, which were determined with the cooperation and advice of AHL/WPI, indicated that an ogive-shaped nose would provide the required hydrodynamic characteristics for deep-depth operation. This nose shape was to be accompanied by a long tail configuration for better hydrodynamic shape of the afterbody. For weight distribution, the dense fuze assembly was to be located forward of the tail section; hence, the explosive was to be contained in the tail section.

These conflicting requirements (a blunt nose for the launching equipment and a more optimum hydrodynamic nose for deep-depth firing) were solved by a design with a removable parachute container. The blunt-nosed container that houses the air-retarding parachute is mounted over the ogive of the hydrodynamic configuration. Subsequent separation of the parachute container after launch, and parachute separation after water entry, provide the SUS with optimum characteristics (see Figure 1). For reasons of simplicity and low cost, slipstream energy was chosen as the means of opening this rigid parachute container.

DESCRIPTION OF DESIGN

In its final form, the NOLC-developed SUS incorporated all the features deemed necessary for optimum reliability and safety. Physically, it consisted of three principal sections:

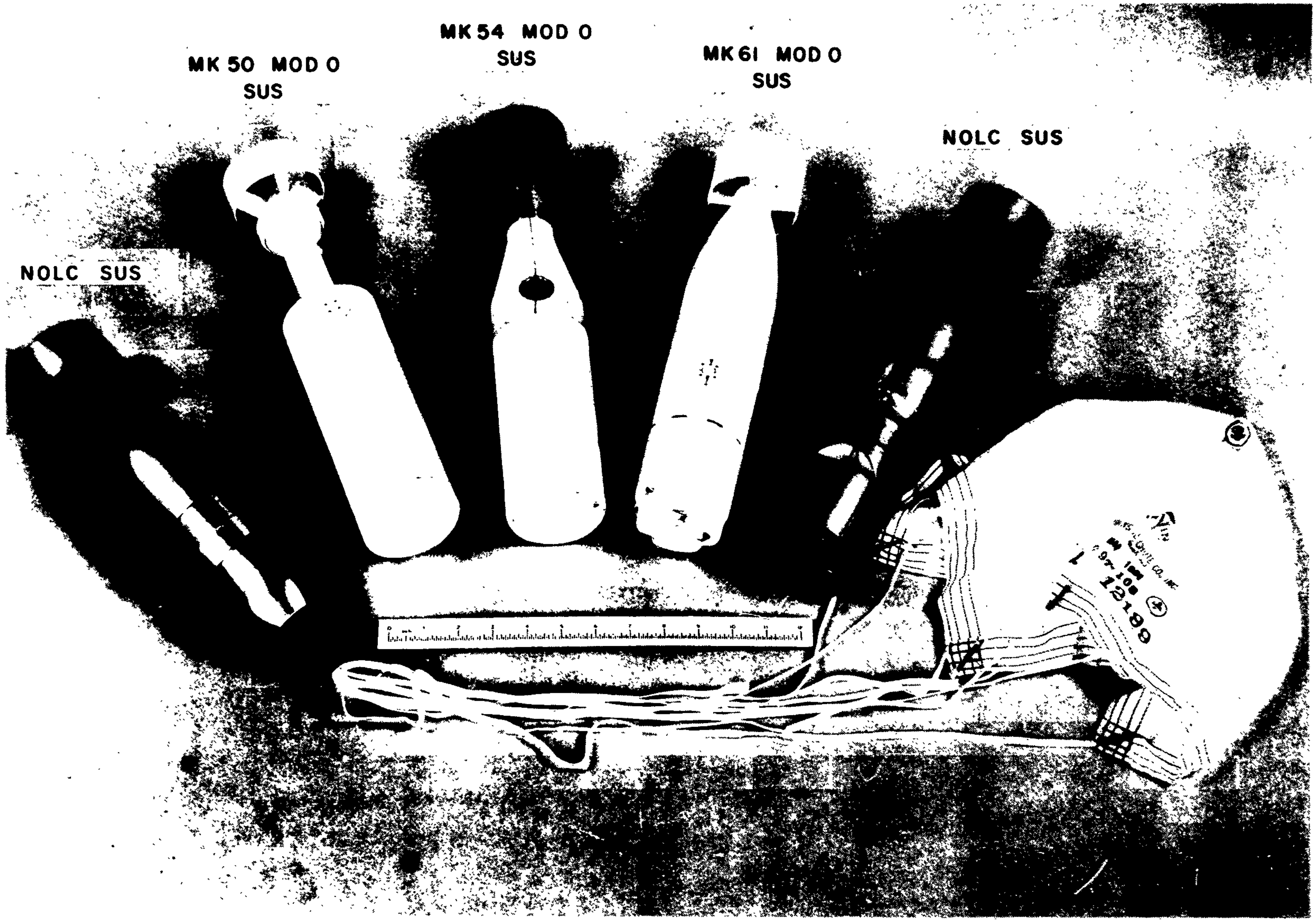

FIGURE 1. Aircraft-Launched Underwater Sound Signals

1. The forward section, which comprises the parachute, parachute container, and ogive-shaped nose fairing.

2. The fuze assembly, which is located in the nose cone and in the central section and which comprises the timing, arming, firing, and sterilizing components.

3. The afterbody, which includes the booster and explosive charge.

Photographs of the unit are shown in Figures 2 and 3, and an exploded view is given in Figure 4. Detailed descriptions of these three sections are given below.

FORWARD SECTION

Parachute

Several parachute designs were devised and tested before a final design was chosen. A 3.9-foot-diameter parachute delivered the 6-pound SUS at a velocity of 21 ft/sec. In tests at the Naval Parachute Unit, El Centro (NPU), it operated satisfactorily at speeds up to 200 knots. In a second design, the diameter was reduced to 3.3 feet. This parachute gave a stabilized rate of descent of 27 ft/sec and was successfully flown at the 350-knot design speed.

A third parachute, 2.0 feet in diameter, was designed to retard the velocity of the SUS in both air and water. With this design, the stabilized velocity in air was increased to approximately 65 ft/sec, and the retardation process was completed in water. Since this design produced a stabilized sink rate in water of 1 ft/sec, a reliable time element to firing depth was provided, regardless of the type of launch used (aircraft, helicopter, or hand launch from a surface vessel).

This design was a standard six-gore parachute made from 1.1-oz/yd nylon with an open crown. It used 250-pound shroud lines. After this standard parachute had been developed to satisfy the specified launching speeds, effort was applied to effect product improvement and cost reduction.

The final design consists of a 21-inch-square, one-piece parachute (see Figure 5) fabricated from 2.25-ounce nylon. The edges are folded to form a stitched skirtband for the attachment of eight 250-pound discontinuous shroud lines. In this simplified design, standard parachute construction has not been followed. The shroud lines are not continued over the crown, and the gores have been eliminated to effect a saving of both labor and material. The lines are threaded through a lug attached

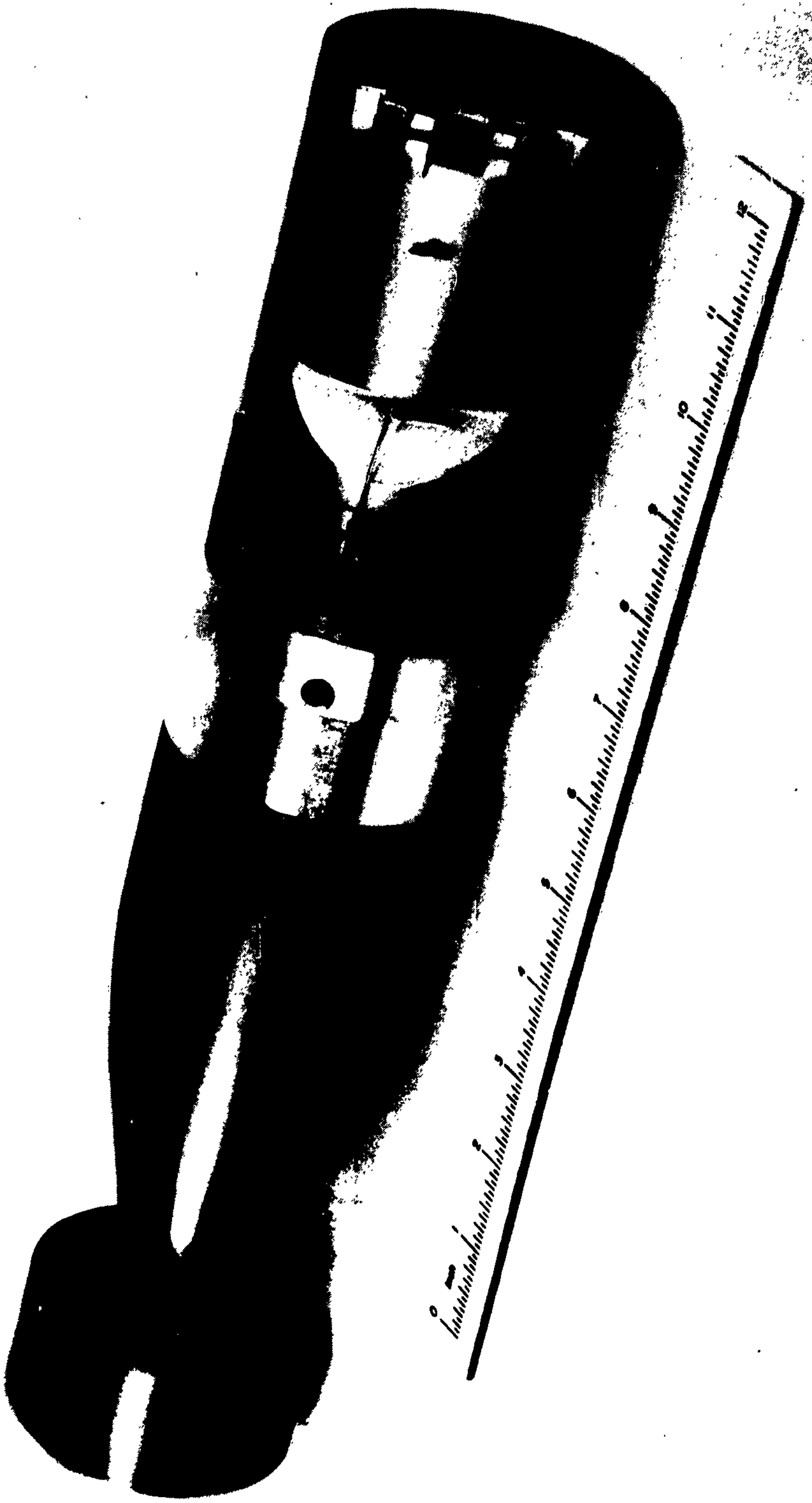

FIGURE 2. NOLC-Designed SUS—Assembled

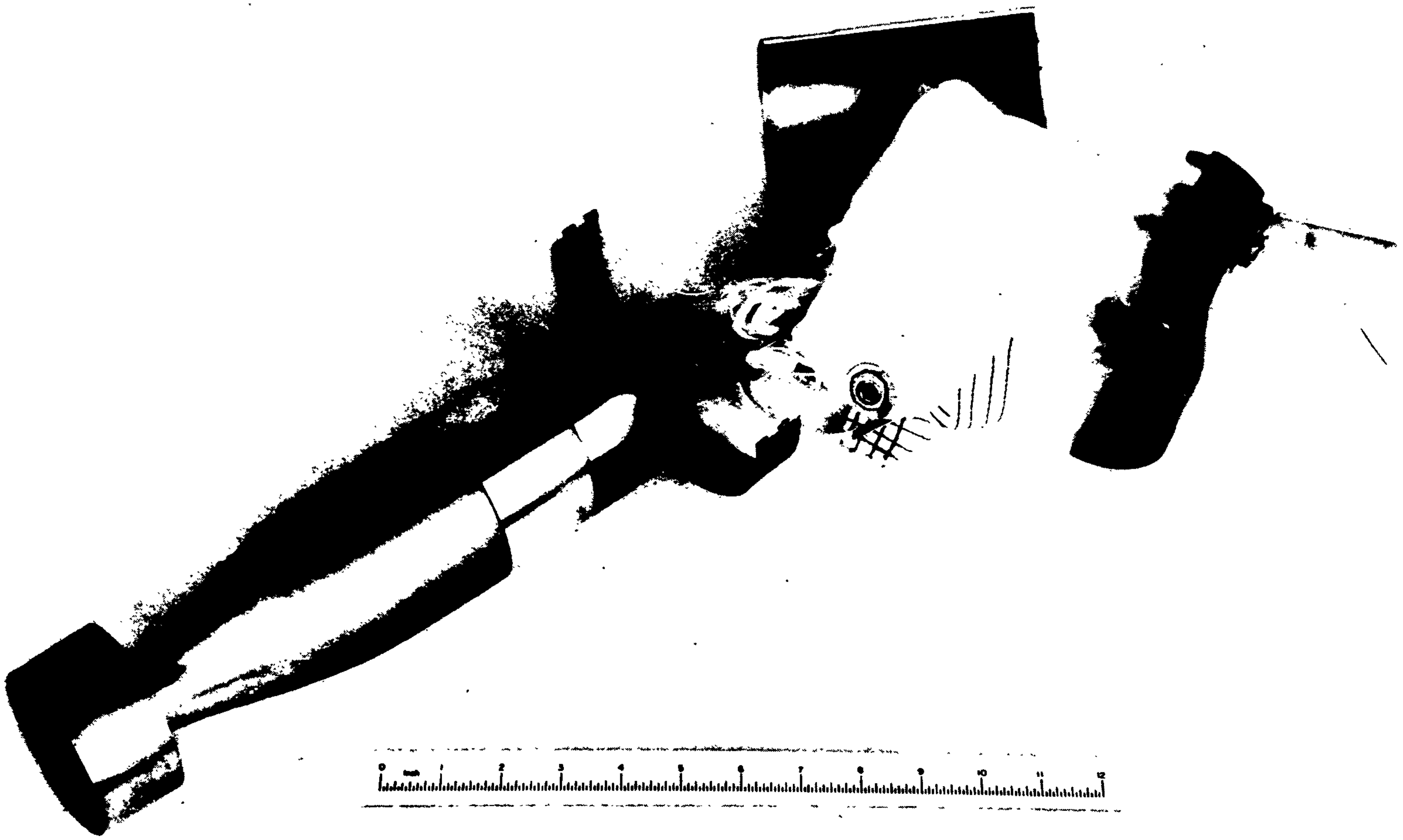

FIGURE 3. NOLC-Designed SUS—With Parachute Container Released

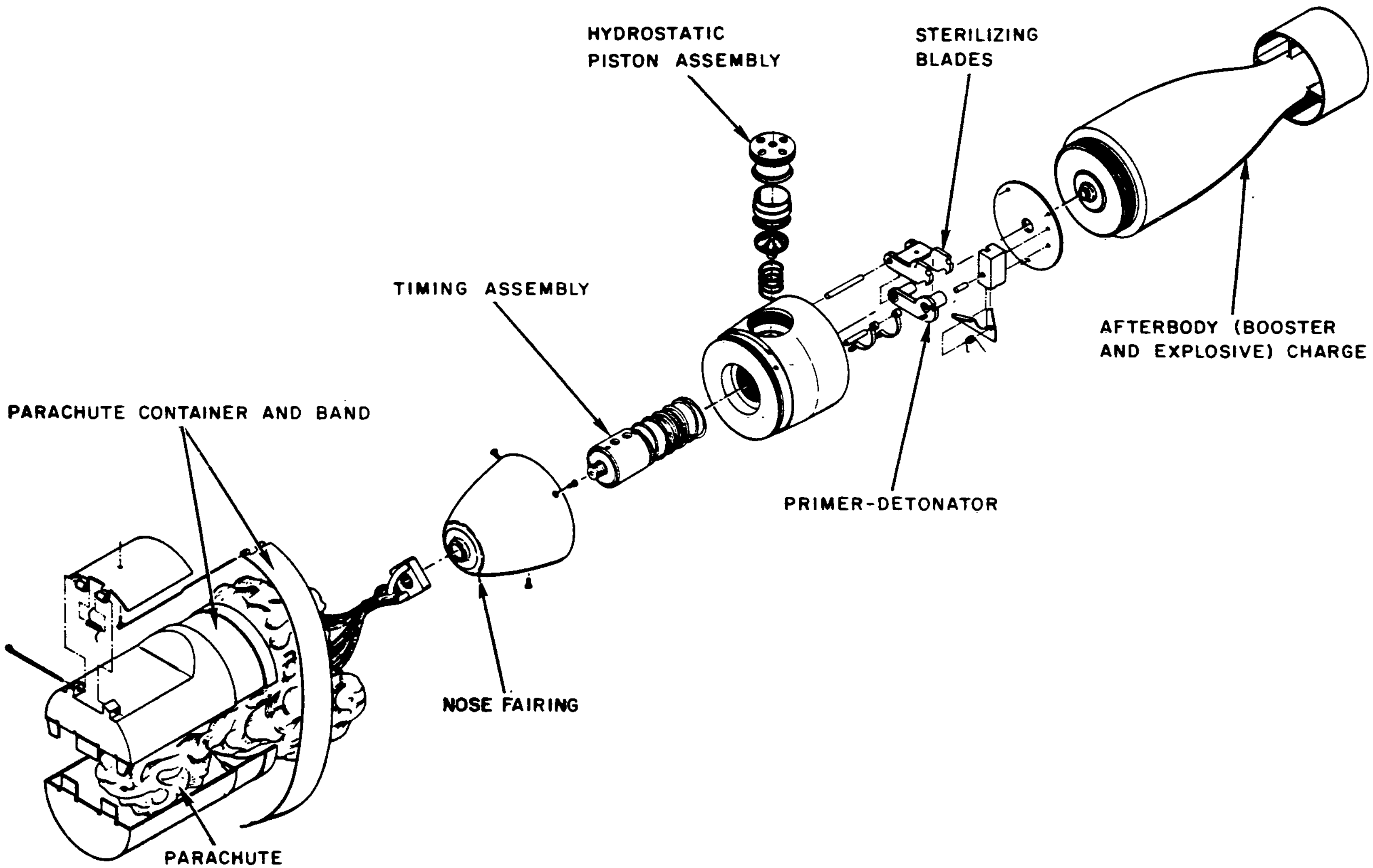

FIGURE 4. NOLC-Designed SUS—Exploded View

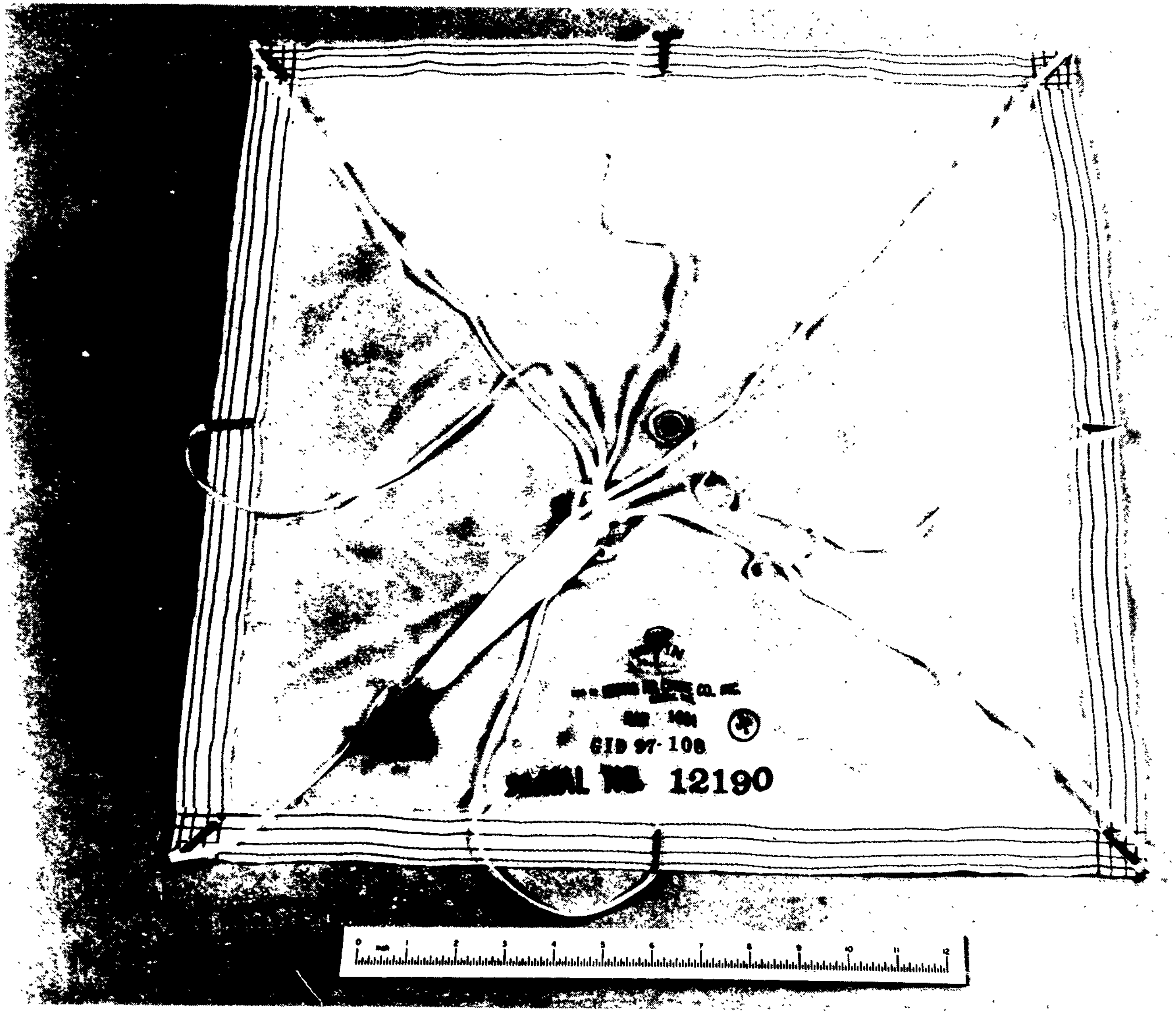

FIGURE 5. Final Parachute Design

to the firing and arming shaft, so that the shock at parachute deployment can be used to cock the relaxed firing spring. This design used "shroud-first" deployment, wherein the lines are used to delay canopy opening and therefore to reduce the opening shock to a feasible level. A small grommet (Size 00) in the crown of the parachute was incorporated to spill entrapped air and thus prevent inconsistent parachute flotation and surface delay. This design has been flown more than 25 times without failure at maximum launch speeds.

During the parachute design phase, the possibility of causing the parachute to float was considered, since the sound signal could thus be maintained at a given depth by means of a measured line. It was decided to cause parachute flotation by entrapping air in the inflated canopy at water entry. A parachute that provided low or zero porosity was therefore necessary. Either the standard parachute material could be treated with a watertight compound, or a plastic liner could be inserted in the canopy crown. After several tests of different materials, a parachute constructed of a Mylar/nylon-bonded material was successfully test flown at 200 knots. Tests conducted at greater speeds were not successful, since the low-porosity material could not overcome the opening shock at high velocities. As a result, the flotation approach was finally abandoned. However, the idea is feasible and probably can be accomplished with further development.

Parachute Container

Several parachute container designs were fabricated at NOLC and tested at NPU in an effort to obtain a design that would meet the following requirements:

1. Provision of launch rack bearing in three of the four in-service launch racks.

2. Complete self-containment (that is, the container cannot depend on attachment to the launch rack for initiation of opening).

3. Provision of an adequate separation distance from the launching craft before deployment of the parachute.

4. Rigid and sturdy construction, so that the container can withstand normal shipping, handling, and stowage without opening easily and allowing parachute deployment.

5. Inexpensive production.

The final container design (see Figures 3 and 4) met all these requirements. It consists of two aluminum half-shells, which are slip-hinged at the top and held together at the bottom by a retaining band. A spring-loaded releasing vane is mounted on the outside of one of the half-shells. One end of a locking wire, or pin, is attached to the vane, and the other end extends through the joint in the retaining band. As the container is subjected to the slipstream, the vane acts as a lever arm to withdraw the pin from the retaining band around the half-shells and open the parachute container. The entire unit is held securely in place by two lips, which engage a mating groove in the fuze body. This design thus provides a rigid assembly that will withstand normal handling and launching.

The final container design was flown more than 25 times at NPU, at drop speeds of 100 to 350 knots, without a functional failure.

FUZE ASSEMBLY

The fuze assembly consists of the components necessary for timing, arming, firing, and sterilizing the SUS. Particular effort was applied to the design concept for these components, since all the existing PDC or SUS units are lacking to some degree in the desired safety.

In accordance with basic ordnance design, two mechanisms were chosen for arming and firing the unit: the shock from parachute opening, which is activated by slipstream energy, and the hydrostatic energy available on water entry. Use of the parachute solved the problem of uniform water-entry velocity, and thus permitted the application of hydrostatic energy at shallow depths.

Design Concept

The first problem considered was the timing. Since flotation of the SUS at firing depth had been rejected, accurate timing to the required detonation depth of 21 ± 4 feet was necessary. In this regard, the concept of using the parachute as a stabilizing element in both air and water was adopted. This method produced a reliable time to firing depth, since the parachute continues to act as a retarding device underwater with a stable sink rate of approximately 1 ft/sec.

With this concept established, the next problems to be solved were the initiation of timing and the design of a simple timing mechanism to delay firing. Since water impact appeared to be the simplest available means of initiating the timing cycle, the magnitude of water impact was tested at the Morris Dam facility of the U. S. Naval Ordnance Test Station. These tests led to the design of a simple g-weight trip to initiate timing at water entry.

Requirements for an inexpensive, reliable timing mechanism with a minimum number of components led to the choice of an orifice assembly or dashpot as the timing mechanism. Prototype dashpot timers were built and tested, and these models were found to be reasonably reliable after several cycles of operation. A maximum error of 16% in repeatability of set time was obtained. For the set times tested, the total variation was less than 2 seconds, which represents a variation of 2 feet in water depth at detonation.

Parachute opening shock was chosen as the method of removing the firing pin used to prevent premature arming and of initiating the arming function by cocking the relaxed firing spring. Concurrent with parachute development tests at NPU, El Centro, experiments were conducted on the magnitude of the parachute opening shock at various launch speeds. The tests showed that the level of energy was sufficient to cock the firing spring.

A new and different method was chosen for utilizing hydrostatic energy to perform the arming and sterilizing functions and also for eliminating the problems associated with a sliding surface moving through a watertight seal. A diaphragm was used to avoid the "sticking seal" problem. With this approach, better watertight integrity was achieved, along with a smoother transmission of the change in hydrostatic pressure with increasing depth. The diaphragm was secured to the body by a gland nut, which is forced to a tighter seal with increasing water pressure.

With this approach, however, came the disadvantage of limited motion. The motion caused by hydrostatic pressure was transmitted through the diaphragm to a spring-loaded piston in a guide. A snap-acting spring was used to produce a sizable movement from a minimum motion, so that levers and linkages would not be needed to multiply this small movement. As in the ordinary toggle light switch, a small movement causes a quick positive action after the spring-loaded arm passes a balanced point in its radial travel.

This principle was applied to both the primer-detonator carrier and the sterilizing blades. At a water depth of 14 feet, hydrostatic pressure causes sufficient movement of the spring-loaded piston to push the primer-detonator carrier past the center point. The primer-detonator is thus snapped to a fully armed condition in line with the cocked firing pin. If the SUS has not fired at prescribed depth, the increasing water pressure and continued motion of the piston cause a similar snap action to occur at a water depth of 25 feet, and sterilization is then effected by a double-bladed barrier that covers both ends of the most sensitive elements in the firing train.

Final Design

The final fuze assembly design consisted of the following components:

1. A firing pin and relaxed firing spring positioned along the side of the primer-detonator carrier and sterilizing device. These components lock the most sensitive elements of the explosive train in a safe position (see Figure 6).

2. A g-weight that is activated on water impact and thus initiates the timing cycle. This device is also in a locked condition until the firing pin and dashpot timer assembly have been withdrawn and the firing spring has been energized by parachute opening shock or manual operation of the unlocking and cocking shaft (see Figures 7 and 8).

3. A dashpot timer that releases the firing latch at the end of the time cycle (see Figure 9).

4. A spring-loaded piston, covered by a silicone rubber diaphragm, that transmits hydrostatic pressure to the primer-detonator carrier and the sterilizing blades.

5. A spring-loaded snap-acting primer-detonator carrier blade that is moved to a snap-through position by the piston at 14 feet of water depth (see Figures 9 and 10).

6. A spring-loaded snap-acting double-bladed sterilizing device that is moved to a snap-through position at 25 feet of water depth (see Figure 11).

7. An antishock lever that keeps the explosive train from being aligned by a side shock after it has been unlocked by withdrawal of the firing pin.

8. A Mk 125 Mod 1 stab primer and a Mk 59 Mod 0 detonator.

9. A window that permits a visual inspection of the condition of the SUS unit. (The armed and sterilized positions are indicated by the appearance of a red marker or a red and green marker, respectively.)

AFTERBODY

Hydrodynamic considerations dictated the use of a long tail section, and weight-distribution problems dictated that the more dense fuze

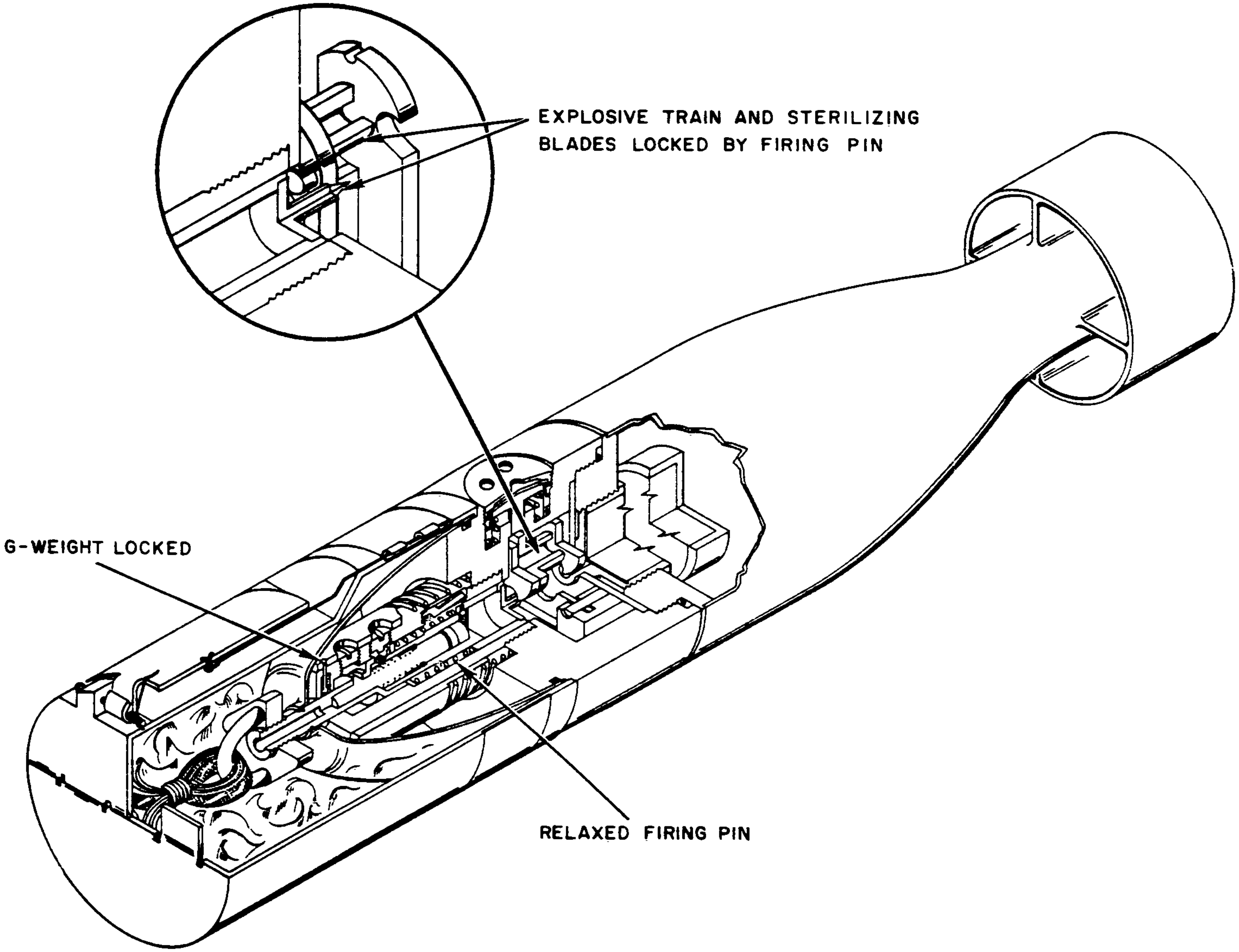

FIGURE 6. SUS—Assembled and Ready for Use

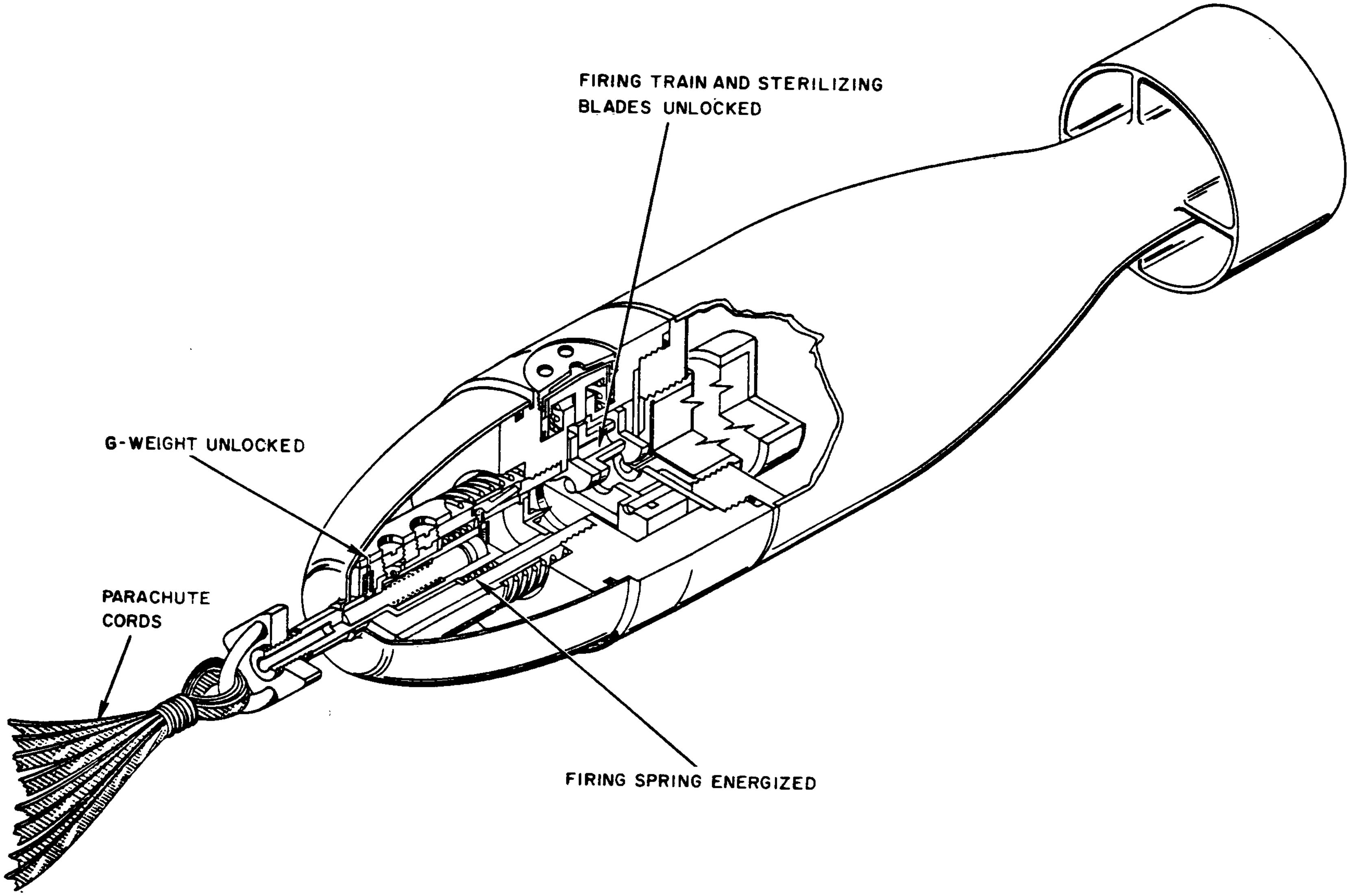

FIGURE 7. SUS Operation—After Air Launch

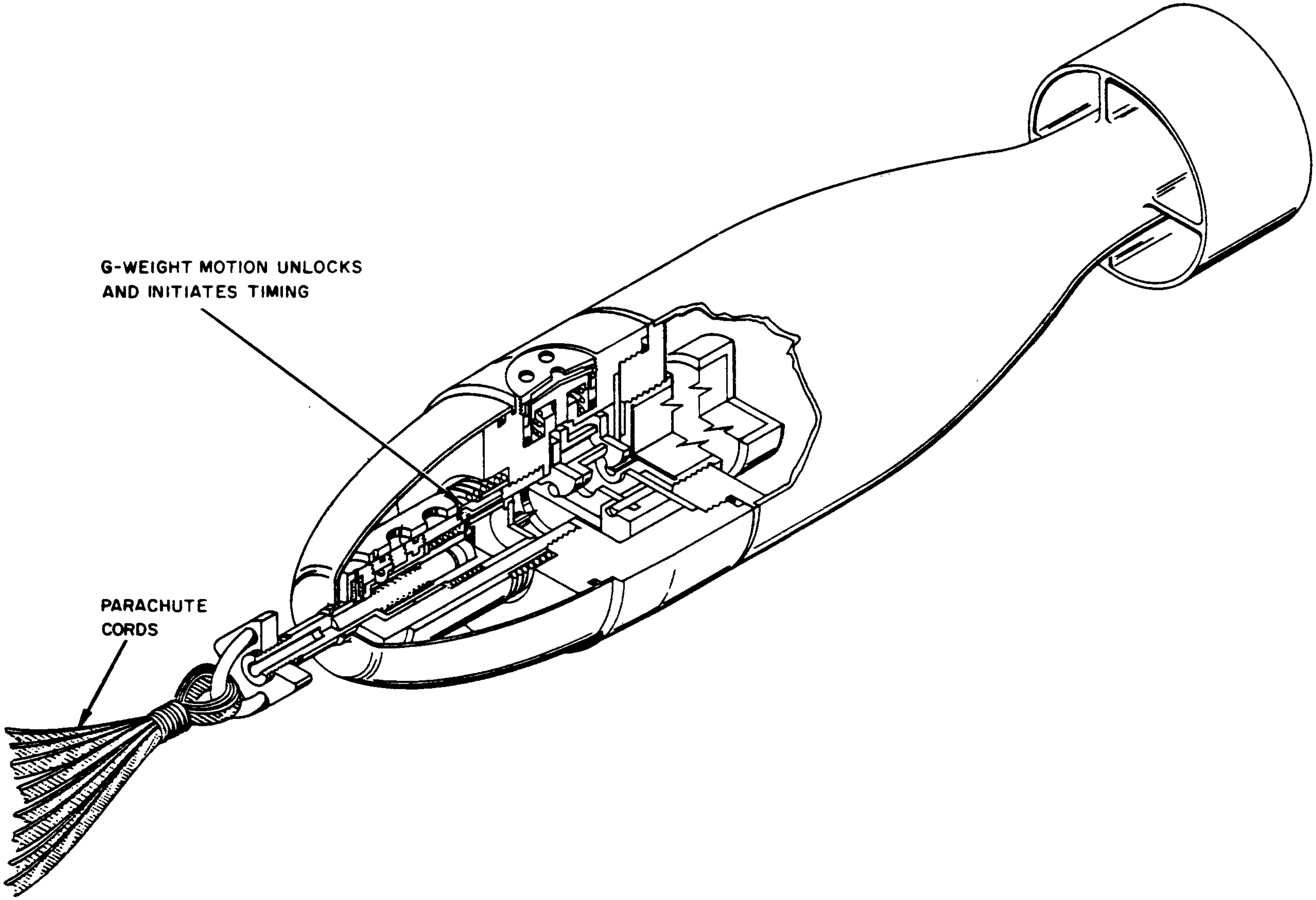

FIGURE 8. SUS Operation—On Water Impact

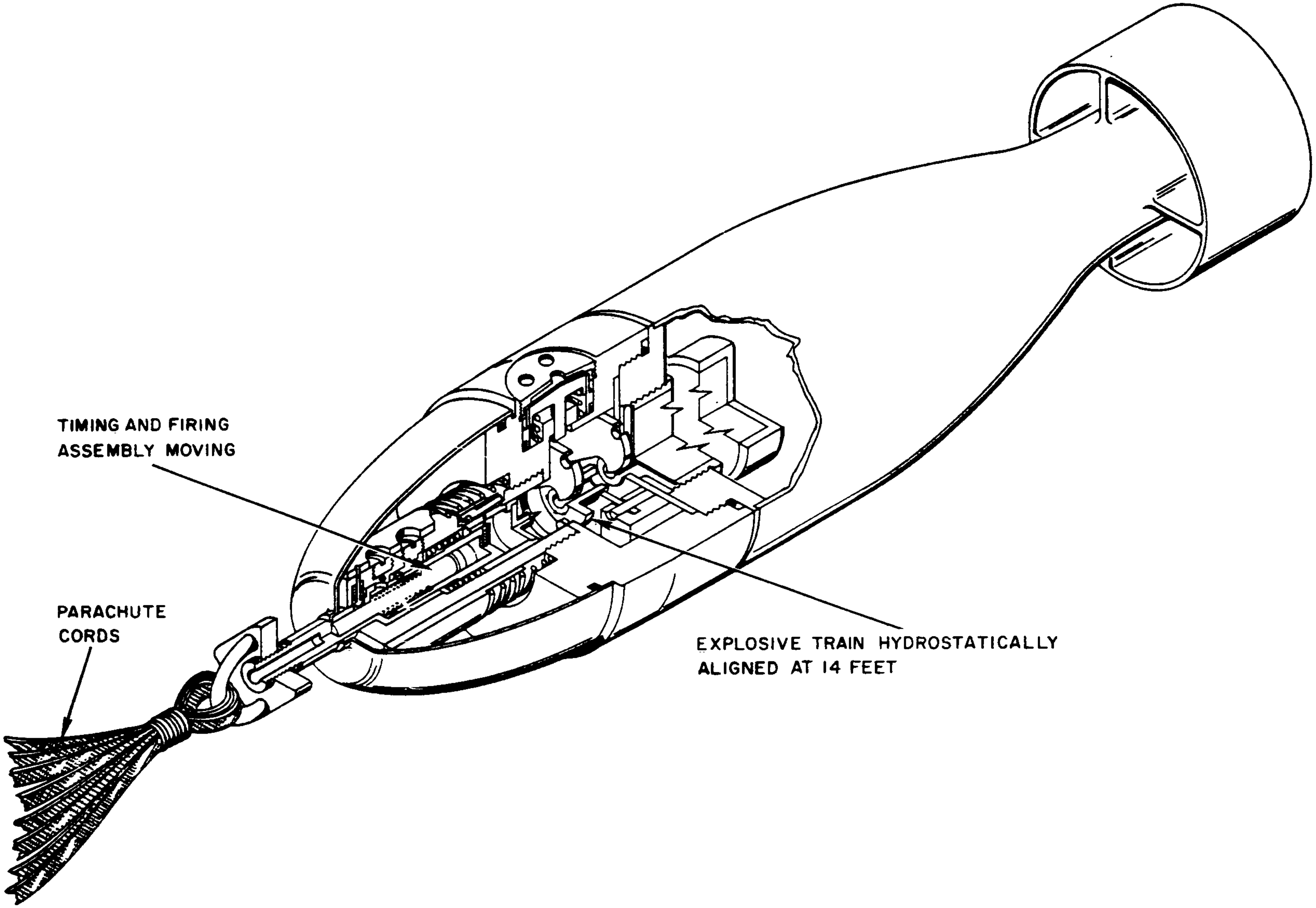

FIGURE 9. SUS Operation—Armed Condition

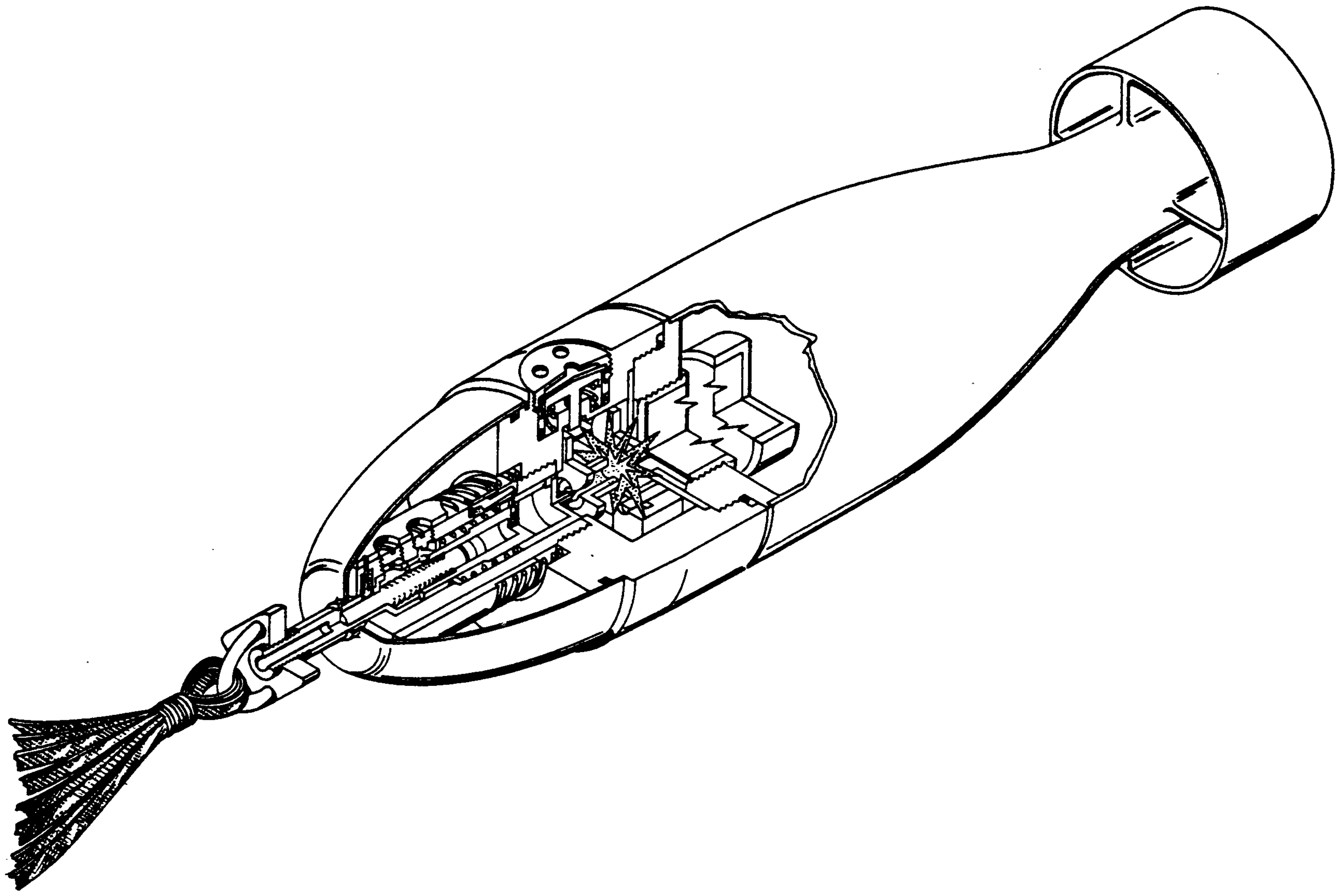

FIGURE 10. SUS Operation—At Detonation

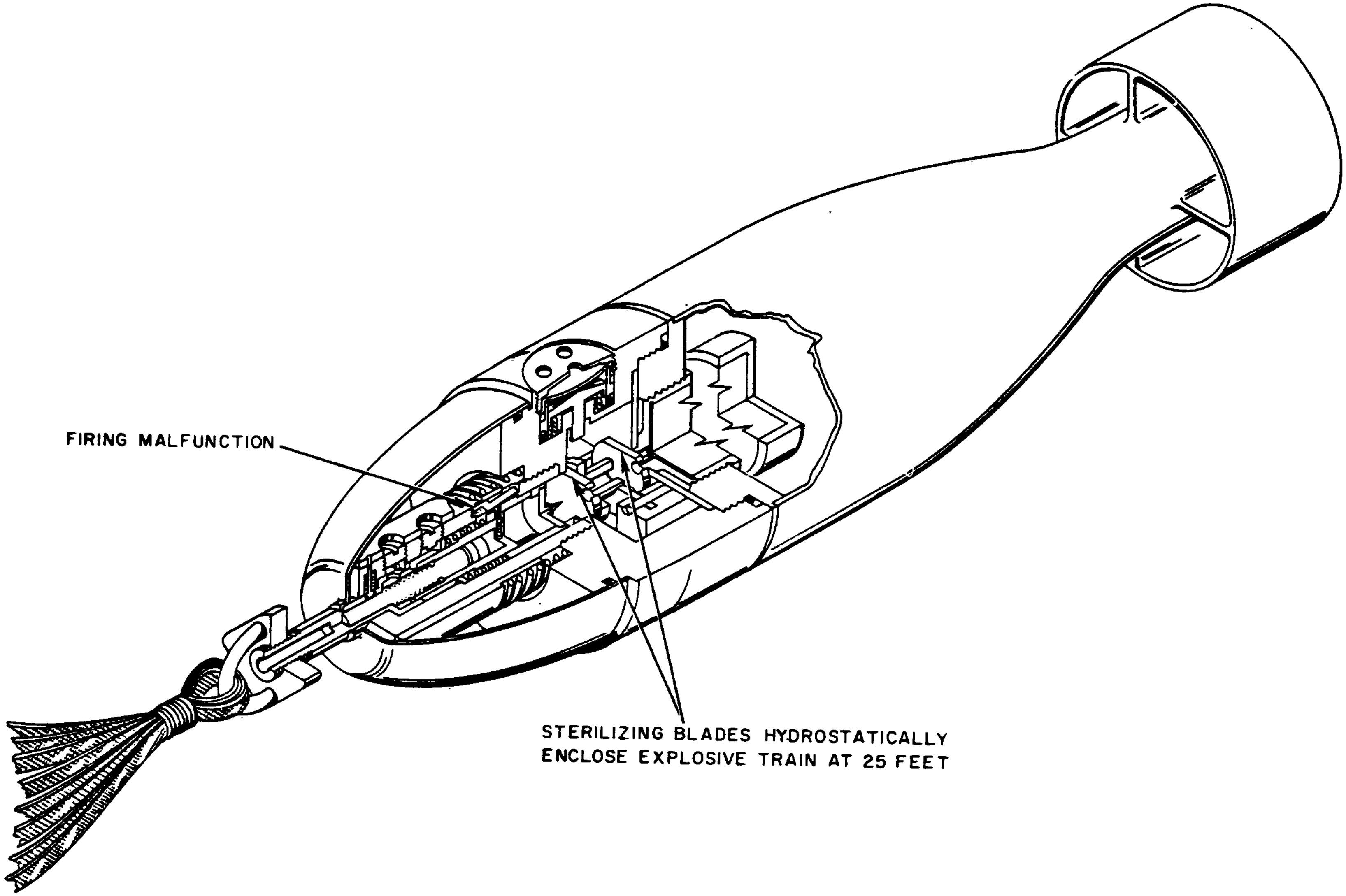

FIGURE 11. SUS Operation—At Sterilization

assembly be located in the forward section of the SUS unit. Hence, the decision was made to locate the less dense explosive charge in the afterbody.

In an effort to simplify some of the design and tooling problems, it was desired to use an explosive section now available on a production SUS. Both the Mk 3 Mod 0 and the Mk 4 Mod 0 explosive sections had the desired explosive content (1.8 pounds). However, the Mk 3 Mod 0 explosive section, which is used in the Mk 54 Mod 0 SUS, fits onto the front of the unit. It therefore does not satisfy the requirement for a long tail configuration. The Mk 4 Mod 0 explosive section, which is used in the Mk 61 Mod 0 SUS, employs the entire tail fairing to contain the explosive charge. An afterbody similar to that used in the Mk 4 Mod 0 was therefore chosen for the NOLC-designed SUS.

DESCRIPTION OF OPERATION

The sequential functions that will occur under conditions of air launch and shallow-depth operation are as follows:

1. Upon air launch the force of the slipstream acts under the releasing vane. This vane then exerts a lever action that withdraws the pin in the retaining band and releases the split-shell parachute container (see Figure 3).

2. The parachute deploys in a shroud-first opening action. This action reduces opening shock and provides a short delay. As the parachute deploys, the cocking and releasing shaft is withdrawn. This motion accomplishes three functions (see Figure 7):

    a. The relaxed firing spring is energized.

    b. The firing pin is withdrawn from a locking position in front of the primer-detonator carrier and sterilizing blades.

    c. The water impact g-weight is unlocked.

    (In the event that the parachute fails to open, the unit will "dud," because the firing spring will not have been cocked and the firing pin will still lock the explosive train out of line.)

3. The parachute retards the velocity of the SUS to a stable rate of about 65 ft/sec and lowers it into the water in a tail-first position. The impact of water entry forces the g-weight to

travel past the time start latch; thus, dashpot action is allowed to start the timing cycle (see Figure 8).

4. At 14 feet of water depth, the hydrostatic pressure transmitted to the piston through the diaphragm causes the spring-loaded piston to move against the primer-detonator carrier arm. The carrier passes the center of its travel and snaps into an aligned position. At this point, the red marker, which is visible at the Safe-Arm window, indicates that the unit is armed (see Figure 9).

5. At firing depth, the timing cycle is completed, a sear is released, and the firing pin therefore strikes the primer. This action initiates the detonator. The detonator initiates the lead, which in turn initiates the booster and finally the 1.8-pound charge of TNT (see Figure 10).

6. In the event of firing malfunction, at a depth of 25 feet the piston moves the double-bladed sterilizing device past its center point of travel, and it snaps to a position at which the blades cover both ends of the primer-detonator carrier. The unit can no longer fire even if the firing pin is subsequently released or the detonator is initiated from some other source. When sterilization has occurred, both the red tape and a green tape can be seen through the Safe-Arm window (see Figure 11).

In a deep-depth firing, the following additional steps would occur:

1. After the unit reaches a depth of more than 25 feet, a parachute release device separates the parachute from the SUS, so that the SUS will now sink at an estimated rate of more than 20 ft/sec.

2. Firing at the deep setting would be controlled by hydrostatic energy acting on a shear pin. The pin would automatically move into position when deep-depth operation is selected.

RECOMMENDATIONS FOR FURTHER DEVELOPMENT

The following suggestions represent this Laboratory's recommendations for further development of the SUS described in this report. It is estimated that this work, followed by an evaluation program on the overall device, should result in a satisfactory unit costing approximately $12 in production quantities.

FORWARD SECTION

There appears to be little need for further improvement and cost reduction of the parachute. However, a complete product-improvement program is needed for the parachute container, with emphasis on an item suitable for mass production. It is contemplated that the half-shells and vanes would be produced as die-formed parts. A mass-produced container can be manufactured at a fraction of the cost of the present hand-made prototype.

FUZE ASSEMBLY

A complete safety and reliability evaluation program on the arming, timing, firing, and sterilizing components is recommended. Design modifications as needed to complete the development of the shallow-operating SUS should then be made. After the shallow-depth design is completed, the selectable deep-depth capability should be incorporated and evaluated.

In particular, the following effort is recommended:

1. An escapement-type timer should be investigated, tested, and compared with the dashpot timer in terms of reliability and cost. The better method should then be used as the means of timing to the shallow-firing depth.

2. Instrumented drop tests should be made to determine the arming-depth and timer-firing-depth relationships as well as the reliability of the arming and timing components.

3. The fuze explosive train should undergo a comprehensive safety evaluation program so that live testing, such as air drops from the present service aircraft, can be made.

4. A parachute-release mechanism should be designed and evaluated for use with the deep-depth unit. The use of a parachute-release mechanism that is triggered by the action of the sterilization blades should be investigated.

HYDRODYNAMIC CHARACTERISTICS

A model of the entire unit, including the planned continuation of the nose ogive, should be made and tested by AHL/WPI to determine the exact sink rate. The AHL/WPI effort should include any recommended improvements in the shape of the nose and afterbody for best performance of the unit within the physical limitations.

MISCELLANEOUS

A final suggestion, of indirect concern to the NOLC effort, involves the launching rack. Studies of the various launching racks revealed several differences in the four types of launchers used in the present ASW aircraft. For example, the launch racks in the P2V and P3V aircraft require that the center of gravity of the SUS be located beneath the ejector for correct operation. Only a SUS designed specifically for a particular launch rack can be used without fear that the device will cock in the rack and jam the launcher.

Since several operational SUS units are available for training use, there seems to be a need for a universal dispenser that will accommodate all the SUS units. It is recommended that a dispenser compatible with all SUS units be designed to eliminate some of the present problems. This problem should be undertaken concurrently with the general overhaul of all SUS units so that the greatest degree of universal application can be achieved.

CONCLUSIONS

The NOLC-designed SUS incorporates several new features that would result in a safer, more reliable fleet item. The functional steps that have evolved with the development represent a substantial effort to upgrade this item to meet the standards of good ordnance design.

A brief review of the features of the NOLC-designed SUS shows the application of basic safety-arming design: The most sensitive elements of the interrupted explosive train are locked in a safe position by the firing pin, and are covered at both ends by the sterilizing blades for all shipping, handling, and stowage before use. This feature of improved safety permits normal stowage of the completely assembled unit. To emphasize this point, one might consider the steps that would have to occur before the device would be a hazard to the crew:

1. The rigid parachute container would have to be removed.
2. The cocking shaft would have to be pulled to energize the firing spring.

3. Water pressure sufficient to arm (14 feet) would have to be applied.

4. An axial impact of sufficient magnitude to move the g-weight and trip the firing pin and timer assembly would have to be experienced.

The task of providing a safe, reliable, and inexpensive sound signal, as noted previously, was terminated before development could be completed. It is regrettable that, because of lack of funds, the effort cannot be brought to a satisfactory conclusion. This Laboratory believes that a continuation of this effort would produce a fleet item that could make the ASW training exercises far more effective.

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2. Antisubmarine warfare—Training devices
I. Haight, H. W.
II. Giattino, L. R.

Tasks: TA 340-664/46037/07063 and WepTask RUDC-5B607/211-1/F001-13-005

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