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THE LEAPING TORPEDO - ITS RAMIFICATIONS

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ABSTRACT

Upon learning some time ago that high thrust torpedo motors were being developed, it was suggested that if the high speed torpedo were directed upward it would "leap" from the water and provide an air burst capability. This report lists some of the factors involved in the consideration of whether the leaping torpedo would be a useful weapon and some of the problems which would be encountered in the design of such a device.

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THE LEAPING TORPEDO - ITS RAMIFICATIONS

INTRODUCTION

Sometime ago, it was learned that torpedo motors capable of developing high thrust and of driving torpedos at high under-surface speeds were being developed.[1] One such motor was described in an Aerojet Engineering Corporation report where it was proposed that a 12-inch diameter torpedo could be propelled 4500 yards at a speed of 100 knots. The motor proposed was a hydroductor working, essentially, on the principles of the ram jet. It was noted in the Aerojet Engineering Corporation report, "The Hydroductor Propulsion System for Underwater Missiles,"[1] that if the torpedo were directed upward at 100 knots it would "leap" to an altitude of about 440 feet, while if the speed could be increased to 200 knots the torpedo would attain an altitude of about 1770 feet. In addition, the torpedo propellent which was proposed would leave no visible wake.

Thus, it appeared that the leaping torpedo idea, i.e. a deep running, wakeless torpedo capable of providing an airburst with the attendant feature of a probably secret and surprise attack, would be worth at least a short investigation.

The purpose of this paper is to make a preliminary investigation of the desirability for such a weapon and to note some of the factors which would have to be considered in its design.

It will be assumed that the carrying vehicle for the leapong torpedo would be a submarine, and that the torpedo would be launched from under the surface of the water. Obviously, some sort of guidance and fuzing system would be required to position and detonate the missile. As will be indicated later in this report, the guidance system would, of necessity, have to provide relatively good accuracy and be capable of guiding the missile through a programed maneuver.

TARGET SURVEY

As a first step in establishing the desirability for the weapon, a brief survey of the possible targets which might be attacked by the missile has been made. These targets include:

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[1] Originally proposed in an informal "Proposal for an Atomic Torpedo" by G. C. McDonald, 1210.

[1] "The Hydroductor Propulsion System for Underwater Missiles," RuA-RTM-60, Aerojet Engineering Corporation, Office of Naval Research, Washington, D. C., January 9, 1950.

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1. Surface vessels in mid-ocean (deep water).
2. Submarines and other underwater targets (deep water).
3. Harbours (ships, docks, channels, etc.).
4. Shore installations.

These target categories will be briefly examined from the standpoint of their vulnerability to air burst versus the damage resulting from underwater burst.

SURFACE VESSELS (DEEP WATER)

The Bureau of Ordnance report, "Relative Effectiveness of Air Burst and Underwater Burst Atomic Explosions Against Task Group Formations,"[2] which compares the estimated damage to surface vessels at sea resulting from underwater and air bursts, will be referred to extensively in this section. Three degrees of damage to ships were chosen in the Bureau of Ordnance report as follows:

"(1) Severe Damage: Complete destruction or sinking, no repair possible.

(2) Moderate Damage: Immobilized - failure of primary departments such as propulsion elevators - distortion of flight or other decks - no military use possible until extensive repairs are made at a base.

(3) Light Damage: Damage to electronic equipment and other light equipment - ship may still be able to operate effectively."

In order to evaluate and compare the relative effectiveness of the air burst versus the underwater burst, estimates of the horizontal range at which one of the above listed specific types of damage was expected were made in the Bureau of Ordnance report. For example, Table 1 shows the estimated horizontal distance for a 50 KT air burst at 50 KT underwater burst at which an aircraft carrier would suffer each type of damage.

From these and additional data, the Bureau of Ordnance report draws the following conclusions concerning the desirability of air burst atomic bombs delivered from high altitude and underwater burst bombs released from high or low altitude.

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[2] "Relative Effectiveness of Air Burst and Underwater Burst Atomic Explosions Against Task Group Formations," XAG Report No. 140, BuO-Q-41, Evaluation and Analysis Group, Department of the Navy, Bureau of Ordnance, 11 January, 1950.

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TABLE 1

	Severe Damage	Moderate Damage	Light Damage
AIR BURST	2800'	3500'	7100'
(Burst Height)	(1800')	(1800')	(1800')
UNDERWATER BURST	6600'	7900'	22,000'
(Burst Depth)	(4000')	(5000')	(2000')

"If the three types of bombs can be delivered properly, with estimated bombing accuracy for each type, and if the bombs are 100 percent operable, the underwater burst bombs are found to have a higher probability of damaging the task group than an airburst bomb of the same or somewhat higher yield. In particular, a 50 KT underwater burst will be at least as effective as a 120 KT air burst under comparable conditions. These conclusions arise, to a considerable extent, because of the greater damage radii for underwater bursts than for air bursts of bombs having the same yield."

No consideration was given in the foregoing conclusions to the special effects of atomic bombs such as contamination, but it is believed that if the data of the Bureau of Ordnance report are correct, it may be concluded that there would be little use for the leaping torpedo as a weapon against surface vessels at sea. That is, of course, assuming the delivery accuracy of the two weapons is approximately the same.

SUBMARINE AND OTHER UNDERWATER TARGETS IN DEEP WATER

The question of the possible usefulness of the leaping torpedo against subsurface targets in deep water seems to have been adequately answered in the preceding section. The larger radius of blast damage resulting from the underwater burst would preclude the use of an air burst weapon and eliminate the useful employment of the leaping torpedo.

HARBOR

It has been stated that the depth bomb exploded in deep water provides a more efficient weapon from the shock damage criteria than does the air burst. However, when the water depth is shallow there is evidence which shows that the underwater burst may not be as desirable as the air or surface contact burst for targets within the harbour.

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The U. S. Naval Ordnance Laboratory report, "Project Alex, A Study of Underwater Atomic Weapons," [3] concerning the targets within harbours states:

> "An analysis of harbours reveals that most harbours are less than 50' deep and that there are few, if any, more than 100' deep. It is apparent that there are one or more of the following target objectives in any harbour area:
>
> 1. Channel,
> 2. Underwater or underground installations,
> 3. Surface shipping,
> 4. Structures,
> 5. Personnel."

Figure I shows a graph taken from the U. S. Naval Ordnance Laboratory report comparing estimates of the ranges of effects on various harbour objectives for the surface burst and the sub-surface burst. If these estimates are correct, it is seen that the surface burst is more, or at least equally, as desirable as the sub-surface burst in shallow water.

The U. S. Naval Ordnance Laboratory report states as follows:

> "From the military application standpoint, the effects can be summarized by stating that against targets of military interest a surface burst atomic weapon is by and large just as damaging as an underwater burst weapon of the same yield if a water depth of no greater than 50 feet is involved. The sub-surface burst will have a slight advantage in range for damage by earth movement and underwater shock. In terms of total radiation dose in the first 10 minutes, the sub-surface burst will have no advantage though in radioactive contamination range it may have an advantage by a factor of two. On the other hand, in air blast, possibly more important than the other effects, the surface burst weapon will have an appreciable advantage."

Thus, it appears that from the blast damage standpoint a surfacing torpedo would be well-suited to harbour attack. As far as the leaping torpedo which provides an air burst is concerned, recent FDH curves obtained from the Nevada and Pacific tests indicate that the surface burst would be preferable to the air burst as far as hard and medium hard targets are concerned.

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[3] "Project Alex, A Study of Underwater Atomic Weapons," NOL Report No. 1172, U. S. Naval Ordnance Laboratory, White Oak, Maryland, 1 March, 1953."

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[illegible] the possible targets which might be attacked by the leaping torpedo, it is seen that on the basis of the reference noted, the harbour and its environs is the only target where an air or surface burst would be desirable. For the [illegible] in deep water, the depth bomb or deep running torpedo would be more efficient and hence more desirable assuming the delivery errors are comparable.

[illegible]

The following remarks concerning the delivery of the leaping torpedo will be restricted to the harbour attack. The problems involved in the delivery of this missile may alone determine its feasibility. In this regard, the Bureau of Ordnance report states as follows:

> "Each harbour has individual characteristics determined by its geographical location, geographical surroundings, man-made barriers, and actual or potential harbour defence against air or sea attack. These factors determine the accessibility of the target as well as the tactics of the attacking carrier, and may influence the weapon characteristics required for successful attack.
>
> "Economic and strategic considerations should play an important role in determining the feasibility of the weapon under study. A target of extreme economic importance to the enemy will certainly be strongly guarded against air attack. Harbour protection against underseas attack currently and in the foreseeable future is limited to comparatively short range. The expense of maintenance of long range underwater defence for harbours not protected by natural barriers would be quite large."

The expectation that the delivery submarine could approach and release the torpedo with greater accuracy than could an aircraft, provides much of the justification of the torpedo delivery. However, the difference in the [illegible] times involved should not be overlooked. The aircraft approaches [illegible] and delivers the weapon rapidly through a strong defence. On the other hand, the submarine may encounter a much weaker defence network but it will have to remain to complete the delivery, so that certainly some of the delivery reliability must be lost.

The Bureau of Ordnance report gives a list of the factors to be considered in torpedo delivery for a harbour attack.

1. "Depth of Water and Approaches to Harbour"

   This is an important consideration from the standpoint of safety for the delivery submarine. The submarine must be able to reach its release point, delivery the torpedo and escape without detection by

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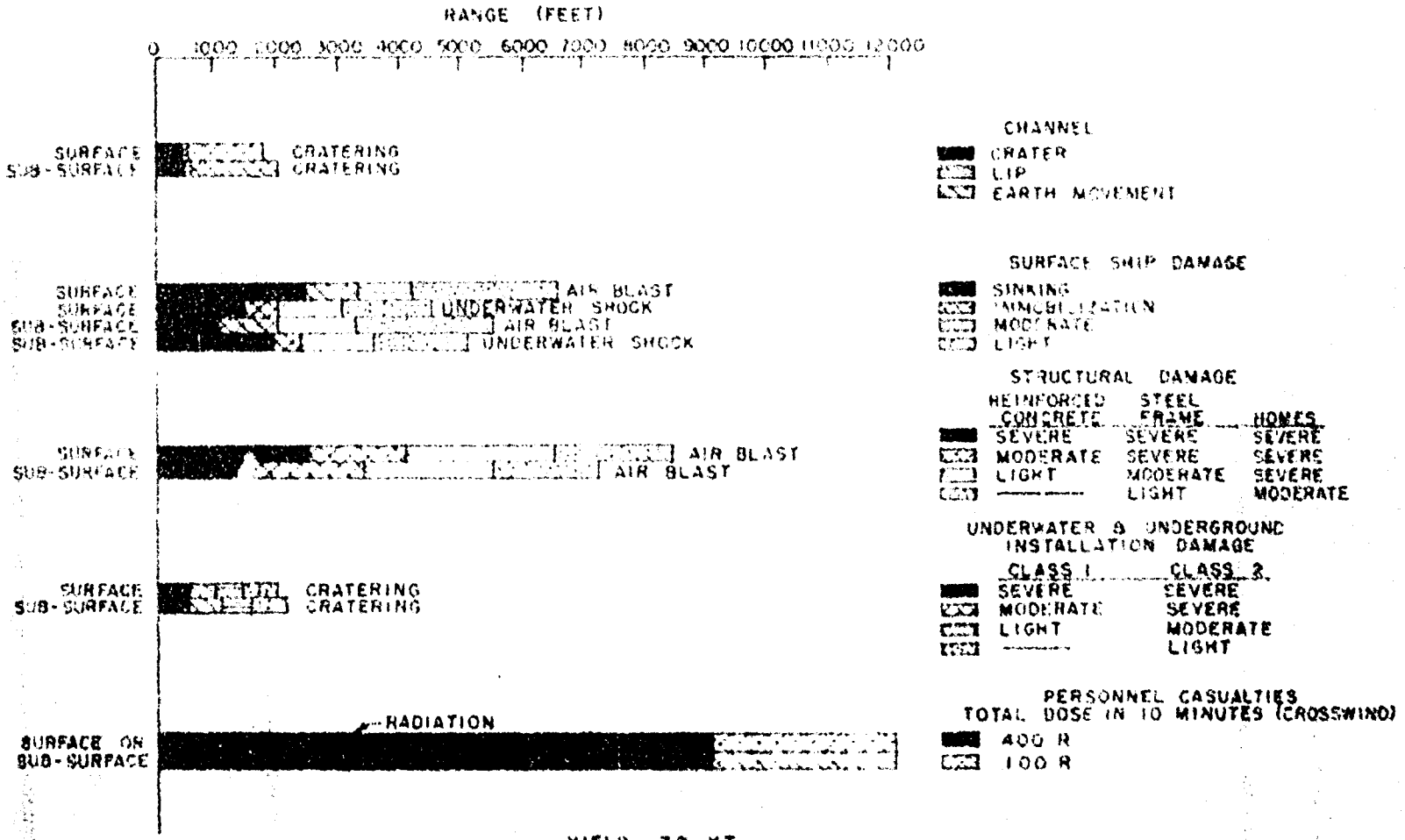

YIELD - 70 KT
WATER DEPTH - 50 FT.
SUB-SURFACE BURST IS ON THE BOTTOM

FIGURE 1

RANGES OF EFFECTS ON VARIOUS OBJECTIVES

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the enemy and this would be greatly implemented if deep water approaches were possible.

2. "Range of Harbour Entrance from Deep Water"

The closer the delivery submarine could approach the target the more the design of the torpedo would be facilitated. The size of the torpedo is clearly a function of the required trajectory range so that if range can be minimized the fuel carrying capacity and motor size could be reduced.

3. "Width and Depth of Harbour Entrance"

This factor would affect the guidance system design for if the harbour entrance is narrow and shallow the torpedo trajectory would have to be accurately controlled.

4. "Location of Harbour Installations in Relation to Harbour Entrance"

It seems that this factor might be one of the most important considerations in the torpedo delivery. If, for example, the target area is situated within the harbour, such that a straight shot from the submarine is not possible, a programmed trajectory would be a must, entailing accurate target reconnaissance and accurate positioning of the delivery submarine at the time of firing. It is not difficult to imagine a harbour entrance cut up with break waters and natural barriers such that the required torpedo trajectory could become very erratic.

5. "Location and Extent of Breakwaters"

6. "Climatic Conditions"

Climatic conditions would affect the sea conditions primarily from the standpoint of waves. Furthermore, visual observation of the coastline would be beneficial in accurately positioning the submarine for firing and this would be severely impaired in bad weather. From the point of view of surprise attack, so necessary in this manouver, it is suspected that bad weather would be desirable.

7. "Harbour Defenses"

The harbour defenses would affect the reliability of weapon delivery both in achieving the correct torpedo trajectory and in positioning the submarine. The main defense mechanisms to be considered here would be surface patrol craft, aircraft patrol, buoys, nets and mines.

Radar could be employed as a detection device if the submarine were required to surface. Enemy defenses also affect weapon design, since strong defense would require longer range delivery and more accurate guidance.

8. "Tidal Currents in Harbour Entrance"

Water currents would affect the torpedo trajectory and have to be accounted for in the guidance system.

9. "Harbour Depths and Bottom Geology"

The turn radius required for proper torpedo emergence would, for a given running speed, be determined by the maximum possible running depth. It has been predicted by Aerojet Corporation engineers that a 50 foot turning radius might not be sufficient for the high speed torpedo. The turn radius required may present a serious problem, since at 200 knots a 50 foot radius produces acceleration of about 70 g while at 100 knots about 18 g's would be experienced.

10. "Depth of Water and Sea Conditions Controlling Escape Tactics"

The submarine must be able to escape the explosions and the counter-attack, if any.

CURRENT STATUS OF HYDRODUCTOR PROGRAM[4]

The current hydroductor program sponsored by the Navy is still preliminary in nature. Water channel test work is being done and it is anticipated that sometime during the next fiscal year a 4 1/2" diameter free-running hydroduct will be tested to obtain range and trajectory information. The largest [illegible] under consideration at the present time is one of 2" diameter. The primary difficulty in the production of larger missiles results from the fact that no presses are available for the manufacture of large diameter [illegible] grains. It is believed that such a press is technically feasible but the costs involved would probably be large. Current plans for this weapon are to develop a straight line, high-speed, short range, unguided weapon. Thus, it would seem that if the leaping torpedo were to be developed, this development would entail a new basic weapon design or, at least, an extensive extrapolation of current efforts.

SUMMARY

1. For operation in deep water it would be much more desirable to employ an atomic depth bomb than to use an air or surface explosion.

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[4] Letter, Commander A. E. Lundgren, Office of Naval Research to Sandia Corporation, ONR:L63:RCG:jm, Ser. 6958, 18 June, 1953.

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- For shallow water, it would probably be preferable to detonate at the surface. Whether the differences in expected damage obtained from the surface burst as compared to a 50' sub-surface burst are sufficient to warrant the design of a new weapon is questionable.

- The problems involved in the delivery of a torpedo into a harbour from an off-shore submarine would be big ones probably entailing the development of an accurate guidance system.

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3. "Project Aliex, A Study of Underwater Atomic Weapons," NOL Report No. 1172, U. S. Naval Ordnance Laboratory, White Oak, Maryland, 1 March, 1953.

4. Letter, Commander A. E. Lundgren, Office of Naval Research to Sandia Corporation, ONR:463:RGG:jm, Ser. 0958, 18 June, 1953.