Fleet Boat Reference, Torpedo Solution Methods

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Contents

1 Introduction

The GitHub SubSkipper repository contains the core logic of the app, such that it can be verified or used for other projects. The documentation contains the principles and equations on which the logic is based, and some method documentation.

The main purpose of the repository and documentation is to record techniques and methods of early submarine attack techniques in a way which are simple to employ in computer programs (i.e. showing mathematical equations where possible), as well as acting as a reference for Submarine Simulators.

The Android App will be developed from this repository as a separate, polished product.
This document is a reference for Torpedo types and common conversion factors, as well as types of US Fleet Boats and Types of US Torpedoes. A brief recognition manual will be provided in a separate document. This document also aims to provide a brief overview of common torpedo solution methods.

2 Unit Conversions

2.1 Speed

1.0 knots	1.0 NM per hour
1.0 m/s	1.94384449 knots
1.0 m/s	3.6 km/h

2.2 Length

1.0 NM	1852.0 m
1.0 km	0.539956803 NM
1.0 NM	2025.37 yards
1.0 NM	6076.12 feet
1.0 m	3.2808399 feet
1.0 m	1.0936133 yards

3 Torpedo Data

The following is torpedo for American torpedo types as used predominantly in the Pacific theatre.

Torpedo data adapted from *SH4 V1.2 Ultimate Torpedo Guide* by Mechan, found at the ubisoft forums (http://forums.ubi.com/showthread.php/475595-SH4-V1-2-Ultimate-Torpedo-Guide-Forums). Dated: 06-22-2007, Accessed: 18.08.2015

Slow and Fast speeds and ranges removed as appropriate.

3.0.1 Mark 10

Available from:	Always
Range(m):	3200
Speed(kt):	36
Warhead:	80-160 radius 3-6m
Depth keeping:	70% chance of deviating $\pm 0.8m - \pm 1.2m$
Dud Chance (at AOB):	1% (0°-70°) 25% (70°-90°)
Renown cost:	0

Notes: Default torpedo for the S-Class. Slower and with a shorter range than the Mk. 14, but extremely reliable.

3.0.2 Mark 14

Available from:	Always
Range(Slow)(m):	8200
Range(Fast)(m):	4100
Speed(Slow)(kt):	31
Speed(Fast)(kt):	46
Warhead:	100-170 radius 3-7m
Depth keeping:	70% chance of deviating $\pm 1.5m - \pm 3.3m$
Dud Chance (at AOB):	1% (0°-35°); 34% (35°-70°); 99% (70°-90°)
Renown cost:	0

Notes: Default torpedo for all modern fleet boats. Faster and with a longer range than the Mk. 10, it packs a roughly 20% stronger punch but is much less reliable.

3.0.3 Mark 16

Available from:	1945-01-01
Range(m):	12500
Speed(kt):	46
Warhead:	180-250 radius 3.5-8m
Depth keeping:	70% chance of deviating $\pm 1.5m - \pm 3.3m$
Dud Chance (at AOB):	4% (0°-35°); 45% (35°-70°); 100% (70°-90°)
Renown cost:	400

Notes: Fast torpedo with an exceptionally long range, but also terribly unreliable.

3.0.4 Mark 18

Available from:	1943-07-12
Range(m):	3650
Speed(kt):	29
Warhead:	120-180 radius 3-7
Depth keeping fault chance:	55% chance of deviating $\pm 1.2m - \pm 2.8m$
Dud Chance (at AOB):	1% (0°-35°); 34% (35°-70°); 99% (70°-90°)
Renown cost:	500 (200 from 1944-01-16; 0 from 1944-09-01)

Notes: Slower, 10% more powerful, with a shorter range and much more reliable than the Mk. 14.

3.0.5 Mark 23

Available from:	1943-01-01
Range(m):	4100
Speed(kt):	46
Warhead:	120-180 radius 3-7m
Depth keeping fault chance:	70% chance of deviating $\pm 1.5m - \pm 3.3m$
Dud Chance (at AOB):	1% (0°- 35°); 34% (35°- 70°); 99% (70°- 90°)
Renown cost:	100 (0 from 16-01-1944)

Notes: Same range, speed and reliability than the Mk. 14 but roughly 10% more powerful. Definitely replaces the Mk. 10 as the "standard" torpedo from 16-01-1944.

3.0.6 Mark 27 "Cutie"

Available From:	1944-01-01
Range(m):	4570
Speed(kt):	12
Warhead:	50-100 radius 1.5-5
Depth keeping fault chance:	NA
Dud Chance (at AOB):	1% (0°-25°)
Renown cost:	500

Notes: Slow acoustic homing torpedo with a small warhead primarily used for defence against destroyers.

3.0.7 Torpedo minimum arming distance

arming_distance is set across all torpedoes to 220m except the Mk. 27, which is 150 meters.

3.0.8 Torpedo max dive angle

max_dive_angle is set to 20 degrees for all torpedo types.

3.0.9 Torpedo maximum turn angle

max_turn_angle is 135°for all torpedoes except the Mk. 27, which is 180°.

3.0.10 Magnetic detonation range

mag_detonation_range is 2m for all torpedoes except for the Mk. 27, which is 1m.

3.0.11 Circular runner torpedos

circle_runner_chance is 0.5% for all torpedoes except for the Mk. 27, which is 0%.

3.0.12 Gyro problems

The chance of having gyro problems is 0.3% at the introduction time of all torpedoes and drops to 0.2% in later periods for all torpedoes except for the Mk. 16. The *max_deviation* when having gyro problems is always 50°. This does not apply to the Mk. 27.

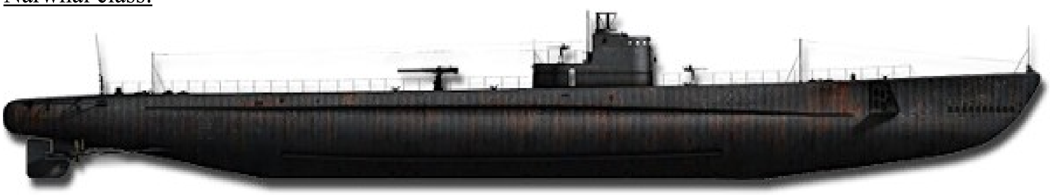
3.0.13 Homing torpedos

The Mk. 27 will run straight for 200m before homing.

4 Trigger Maru Overhaul - Fleet Boat Types

This section consists of pages 25-28 of the Trigger Maru Overhaul Manual which detail fleet boat types:

Narwhal class:



(pseudo design added by mod)

Max speed:	17 knots surfaced 6.5 knots submerge	Test depth:	300 ft
Armament:	Four 21” bow torpedo tubes Two 21” aft Torpedo Tubes Two 6”/53 caliber deck guns One 20mm Oerlikon AA gun	Range:	9,000 nm @ 12.75 kts

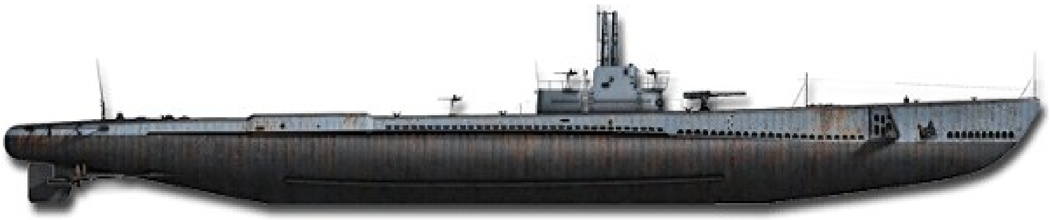
The *Narwhals* were completed in 1930 and were the culmination of the cruiser sub concept in the U.S. They were big and roomy, which made them natural candidates for transport missions such as the raid on Makin. However, they could rarely mantain the design speed of 17 knots. Subsequent submarine designs would be considerably smaller than the *Narwhals.*

Porpoise Class:

Max speed:	17 knots surfaced 8 knots submerged	Test Depth:	250 feet
Armament:	Four 21” bow torpedo tubes Two 21” aft torpedo tubes One 4”/50 caliber deck gun Three 20mm Oerlikon AA guns	Range:	8,700 nm @ 13.5 kts

The *Porpoises* were completed in 1935-1937 and represented a trend away from the cruiser sub concept towards smaller, handier boats. However, they still had slow dive times, though they were capable of diving deep and were quite habitable (for submarines.)

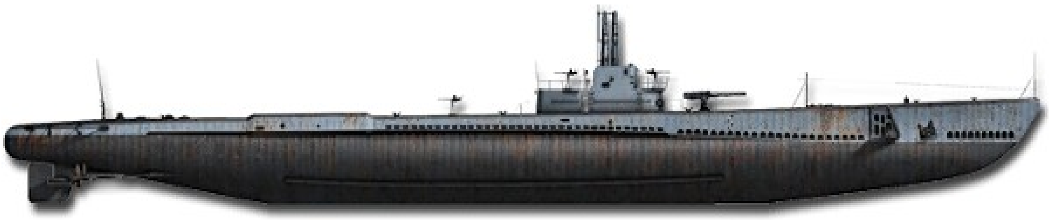
Salmon Class:



Max speed:	21 knots surfaced 9 knots submerged	Test Depth:	250 feet
Armament:	Four 21" bow torpedo tubes Four 21" aft Torpedo tubes One 4"/50 caliber deck gun Three 20mm Oerlikon AA guns	Range:	8,700nm @ 15 kts

The Salmons were completed in 1937-1939 and introduced important innovations. They boasted lightweight high-performance diesel engines designed by private firms, could dive in less than sixty seconds, and used diesel-elecric drive, which increased the flexibility of the powerplant. Any combination of engines could be used to either drive the boat or recharge its batteries. They continued the trend towards better habitability, heavier torpedo armament, and improved fire control. The improved batteries allowed a boat to move at two knots submerged for 48 hours. They were still fairly modern boats when war broke out. None were lost in combat.

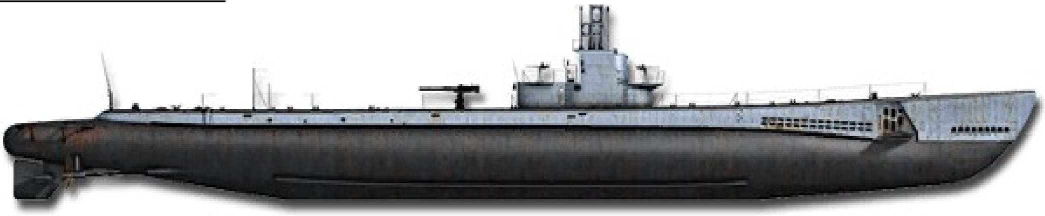
Sargo Class:



Max speed:	21 knots surfaced 8.75 knots submerged	Test Depth:	250 feet
Armament:	Four 21" bow torpedo tubes Four 21" aft Torpedo tubes One 4"/50 caliber deck gun Three 20mm Oerlikon AA guns	Range:	8,700nm @ 15 kts

The Sargos were completed in 1939 and were quite modern boats for the time. They were essentially slightly modified Salmons. They were required to be able to maintain 17 knots on three of their four diesel engines and to have 25 percent reserve buoyancy. They used a new Navy battery design (Sargo batteries) in place of the commercial batteries previously used. . Extra fuel could be carried in some of the ballast tanks at the cost of reducing dive capability. The class introduced the "down express" ballast tank, which was fitted under the forward torpedo room to reduce the dive time; this was flooded at the start of the dive, to pull the ship down, then blown as soon as the ship was underwater.

Tambor and Gar Class:

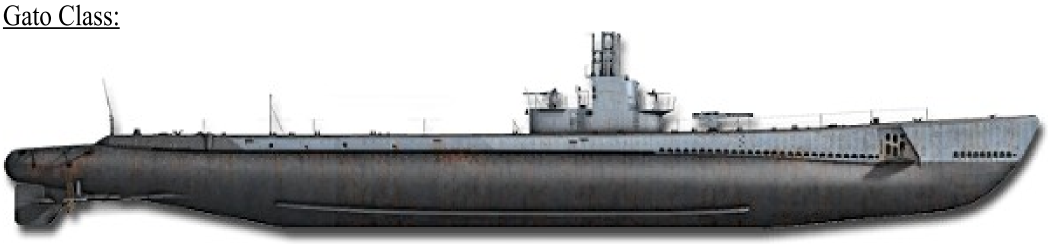


Max speed:	20.4 knots surfaced 8.75 knots submerged	Test Depth:	250 feet
Armament:	Six 21” bow torpedo tubes Four 21” stern torpedo tubes One 5”/51 Caliber deck gun Two 40mm Bofors cannons One 20mm Oerlikon AA gun	Range:	8,700nm @ 15 kts

The Tambor's and Gars were completed in 1940-1941 and were essentially improved Sargos. They established the configuration (six forward torpedo tubes, four rear torpedo tubes, and a total of 24 torpedoes) that characterized all American submarines built during the war, and were designed with gun foundations strong enough to carry a 5” deck gun at Lockwoods insistence. This would later prove to be a boon the succeeding classes.

No other American submarine class suffered as high losses in proportion to its numbers in the Pacific. Seven of the twelve boats of these types were lost, all but two with all hands.

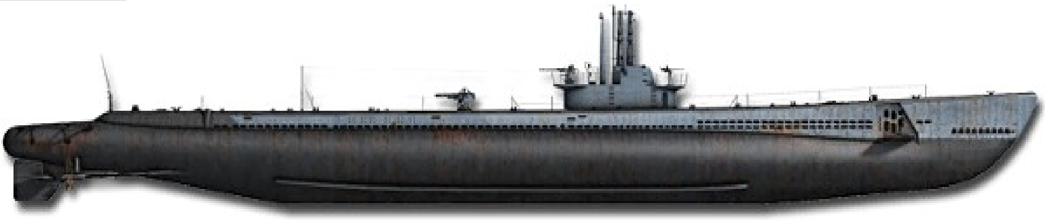
Gato Class:



Max speed:	21 knots surfaced 9 knots submerged	Test depth:	300 feet
Armament	Six 21” bow torpedo tubes Four 21” stern torpedo tubes One 5”/25 caliber deck gun Two 40mm Bofors cannons One 20mm Oerlikon AA gun	Range:	8,700nm @ 15.18 kts

The *Gato's* were just beginning to join the fleet at the start of the war. The last peacetime design, they were somewhat larger than their predecessors, improving stability and subdivision and allowing more powerful machinery. Their large engine rooms were subdivided by a pressure-proof bulkhead. They were a good design that was suitable for mass production, and they became the definitive US submarine model of the Pacific War. They set new standards of habitability and endurance, had sophisticated fire control computers (by the standards of the day), and were heavily armed. A couple of these boats continued to serve in the US navy as late as the 1950's and 1960's.

Balao Class:



Max Speed: 20 knots surfaced
8.75 knots submerged

Test depth: 400 feet

Armament: Six 21” bow torpedo tubes
Four 21” bow torpedo tubes
One 5”/25 caliber deck gun
Two 40mm Bofors cannons
One 20mm Oerlikon AA gun

Range: 8,700nm @ 15.18 kts

The Balaos were completed in 1943-45 and were essentially Gatos with strengthened hulls. This allowed them to dive deeper, which was tactically important when evading Japanese depth charge attacks. The hull plate was increased in thickness from 0.5625" (14.3mm) to 0.875" (22.2mm) and the plate material was upgraded to high-tensile steel. It was calculated that this would increase the crush depth to 900 feet (270m) but other components, such as propeller shaft glands and the trim pump, could not be redesigned quickly to take the higher pressure and the maximum design operating depth was set to 400 feet (120m). A Gould centrifugal pump was adopted in 1944 that could operate at 600 feet (180m) depth or more, and the refitted Balaos were thereafter able to more fully exploit their thick skins. Many of these boats continued to serve in the US navy as late as the 1960's and 1970's.

Tench Class:

(Tench added by mod)

Max Speed: 20 knots surfaced
8.75 knots submerged

Test depth: 400 feet

Armament: Six 21” bow torpedo tubes
Four 21” bow torpedo tubes
Two 5”/25 caliber deck gun
Two 40mm Bofors cannons
One 20mm Oerlikon AA gun

Range: 8,700nm @ 15.18 kts

The design dated to 1943, the *Tenches* were completed in 1945, with just two units ready in time to conduct war patrols. They were evolutionary improvement over the Gato and Balao classes, only about 35 to 40 tons larger, but more strongly built and with a slightly improved internal layout. Many of these boats continued to serve in the US navy as late as the 1960's and 1970's.

5 O'Kane Torpedo Solution

The Dick O'Kane method was devised by members of the Subsim.com[4] forums. It is a constant bearing method which relies on calculating a lead angle – an angle on which torpedoes, if launched will intercept the course of the target– to which the periscope is pointed. As parts of the target ship cross the bearing, torpedoes are fired along it. The O'Kane method relies on being ahead of the target, and the final AOB – at which the torpedo strikes the target– to be 90°.

Calculates *lead angle* based on target and torpedo speed.
The solution requires submarine to be ahead of target.
Captain inserts target speed into TDC, puts the scope on the lead bearing, fires as the target crosses the bearing.

The Equation for lead angle is as follows:

$$LeadAngle = 90 - \arctan\left(\frac{TorpedoSpeed}{TargetSpeed}\right)$$

6 Calculating Distance To Target

No methods for calculating Distance To Target will be provided as solutions such as a periscope stadimeter and *sonar* are readily available.

7 Calculating AOB Based on Aspect Ratio

Method adapted from Angriffscheibe Handbuch by Karl Hahn, 2008.

AOB can be determined given the following data:

- Observed Mast Height
- Observed Ship Length
- Reference Aspect Ratio (i.e. $\frac{ReferenceLength}{ReferenceMastHeight}$)

7.0.14 Determine an observed *aspect ratio.*

$$AR\_observed = \frac{ObservedLength}{ObservedMastHeight}$$

As the required figure is a ratio, it does not matter in what units the figures are given. For example, this could be the number of degrees Length and Mast Heigh subtend, the number of periscope graduations subtended or angular length in metres. It only matters that units for Observed Mast Height and Observed Length are the same.

7.0.15 Determine the Reference Apsect Ratio

Identify the target and find the Length and Mast Height as given in the recognition manual (if possible) or calculate these figures using the SubSkipper ship parser. Proceed as for the observed aspect ratio to get the Reference Aspect Ratio ($ARreference$).

7.0.16 AOB calculation

$$AOB = arcSin\frac{AR\_observed}{AR\_reference}$$

- Note: This method is less accurate as AOB approaches 0. Indeed, using this method with a sample size of 16 at various AOBs, the average error was 9.1°and the median error 6.88°. The optimum range for collecting data seems to be around 2000m.
- Note: This method does not compute whether the AOB is on the port or starboard side.
- Note: "The AOB can only go up to 90, and gives no indication of starboard or port side showing. You have to determine that visually. If the target is moving away from you, you have to subtract the given angle from 180."[1, 2, p 15] In Other words, the arcSin function has a domain of +90°to -90°. When the AOB is between 90°and 270°, subtract the result from 180°. [5]
- AOB (Relative to Target) for each Quadrant:

- 0°- 90°: Use AOB result as is.
- 90°- 180°: Subtract AOB result from 180.
- 180°- 270°: Subtract AOB result from 180, subtract result from 360.
- 270°- 360°: Subtract AOB result from 360.

8 Find the speed of a target with constant relative bearing

This technique takes advantage of the fact that if you are on a convergent course (moving towards each other), and the targets bearing is not changing over time, then you are actually on a collision course. Since you know your Uboats speed and two angles of the triangle (AOB and target bearing), you can calculate the targets speed.

$$Targetspeed = Ownspeed\left(\frac{sin(TB)}{sin(AOB)}\right)$$

You are maintaining 2 knots on an intercept course with a potential target. At the original observation, it was on a bearing of 280°with an observed angle on the bow of 20 °starboard. After several minutes, the bearing was still 280°.

Note: Although you may not be able to achieve an attack position, this technique will also work to calculate the targets speed if you are on divergent courses. !If an angle is greater than 90°, then simply subtract it from 180°(since the sine function is symmetrical around 90°).

$$Targetspeed = Ownspeed\left(\frac{sin(180 - TB)}{sin(180 - AOB)}\right)$$

9 Determine the distance to the track of a target

As you manoeuver into a firing position, it is useful to know your distance to the track of your target. Knowing the range and AOB of the target:

Track: intersection point between Submarine course and the current target course.

$$DistancetoTrack = Range\,(sin(AOB))$$

10 Determine the lead angle for a perpendicular attack with 0°gyro angle

Once you are turned onto a perpendicular intercept course, this method calculates when to fire. The lead angle is simply the target bearing at the moment you fire. The range is irrelevant to the calculation although it is best to plan the attack within 500-1000m.

This is O'Kane, except more simple.

$$leadangle = tan - 1([targetspeed/torpedospeed])$$

11 Determine the torpedo gyro angle

This example will show how to calculate the required gyro angle for a firing solution. This method is somewhat simplified and is best for smaller gyro angles (<30°) and shorter ranges (<1000 metres).

$$sin(leadangle)/sin(AOB) = (targetspeed)/(torpedospeed)$$

$$gyroAngle = targetBearing - leadAngle$$

12 Knot to Km Travelled Conversion Chart

Kt / Hr	1	2	3	4	5	6	7	8	9	10
1	1.85	3.70	5.56	7.41	9.26	11.11	12.96	14.82	16.67	18.52
2	3.70	7.41	11.11	14.82	18.52	22.22	25.93	29.63	33.34	37.04
3	5.56	11.11	16.67	22.22	27.78	33.34	38.89	44.45	50.00	55.56
4	7.41	14.82	22.22	29.63	37.04	44.45	51.86	59.26	66.67	74.08
5	9.26	18.52	27.78	37.04	46.30	55.56	64.82	74.08	83.34	92.60
6	11.11	22.22	33.34	44.45	55.56	66.67	77.78	88.90	100.01	111.12
7	12.96	25.93	38.89	51.86	64.82	77.78	90.75	103.71	116.68	129.64
8	14.82	29.63	44.45	59.26	74.08	88.90	103.71	118.53	133.34	148.16
9	16.67	33.34	50.00	66.67	83.34	100.01	116.68	133.34	150.01	166.68
10	18.52	37.04	55.56	74.08	92.60	111.12	129.64	148.16	166.68	185.20
11	20.37	40.74	61.12	81.49	101.86	122.23	142.60	162.98	183.35	203.72
12	22.22	44.45	66.67	88.90	111.12	133.34	155.57	177.79	200.02	222.24
13	24.08	48.15	72.23	96.30	120.38	144.46	168.53	192.61	216.68	240.76
14	25.93	51.86	77.78	103.71	129.64	155.57	181.50	207.42	233.35	259.28
15	27.78	55.56	83.34	111.12	138.90	166.68	194.46	222.24	250.02	277.80
16	29.63	59.26	88.90	118.53	148.16	177.79	207.42	237.06	266.69	296.32
17	31.48	62.97	94.45	125.94	157.42	188.90	220.39	251.87	283.36	314.84
18	33.34	66.67	100.01	133.34	166.68	200.02	233.35	266.69	300.02	333.36
19	35.19	70.38	105.56	140.75	175.94	211.13	246.32	281.50	316.69	351.88
20	37.04	74.08	111.12	148.16	185.20	222.24	259.28	296.32	333.36	370.40
21	38.89	77.78	116.68	155.57	194.46	233.35	272.24	311.14	350.03	388.92
22	40.74	81.49	122.23	162.98	203.72	244.46	285.21	325.95	366.70	407.44
23	42.60	85.19	127.79	170.38	212.98	255.58	298.17	340.77	383.36	425.96
24	44.45	88.90	133.34	177.79	222.24	266.69	311.14	355.58	400.03	444.48
25	46.30	92.60	138.90	185.20	231.50	277.80	324.10	370.40	416.70	463.00
26	48.15	96.30	144.46	192.61	240.76	288.91	337.06	385.22	433.37	481.52
27	50.00	100.01	150.01	200.02	250.02	300.02	350.03	400.03	450.04	500.04
28	51.86	103.71	155.57	207.42	259.28	311.14	362.99	414.85	466.70	518.56
29	53.71	107.42	161.12	214.83	268.54	322.25	375.96	429.66	483.37	537.08
30	55.56	111.12	166.68	222.24	277.80	333.36	388.92	444.48	500.04	555.60

13 Recognition Manual

References

[1] Karl Hahl, Kriegsmarine Angriffscheibe Handbuch, p. 15, 2008.

[2] http://www.tvre.org/en/acquiring-torpedo-firing-data, Acquiring torpedo firing data, 2015.

[3] Corey "Gutted" Hardwell, Silent Hunter IV 90°- AOB Firing Angles, circ. 2008(?).

[4] http://www.subsim.com

[5] MathOnWeb, The arcsin function, Accessed 17.08.2015,