



A Look at Major HWTs & LWTs in NATO Countries & Ongoing Torpedo Programs in Turkey



by Ibrahim SÜNNETÇİ

Since their first use during the Russo-Turkish War of 1877-78, torpedoes have proven to be one of the most effective and lethal naval weapons. During the war, (also referred to as the 'War of 93,' named for the year 1293 in the Islamic calendar) the 381mm diameter Whitehead Torpedo, launched at a distance of about 65m from a torpedo boat under the command of Russian Vice Admiral Stepan Osipovich MAKAROV in January 1878, sank the armed cargo ship 'İntibah,' which was

The first true torpedo was invented in 1866 by British engineer Robert WHITEHEAD, based on the ideas of Austrian Navy officer Johann LUPIS. The word 'torpedo' (derived from the word 'torpere,' which means 'to stun' in Latin), was created in 1800 by the American inventor Robert FULTON, who also invented the first steam-powered ship.

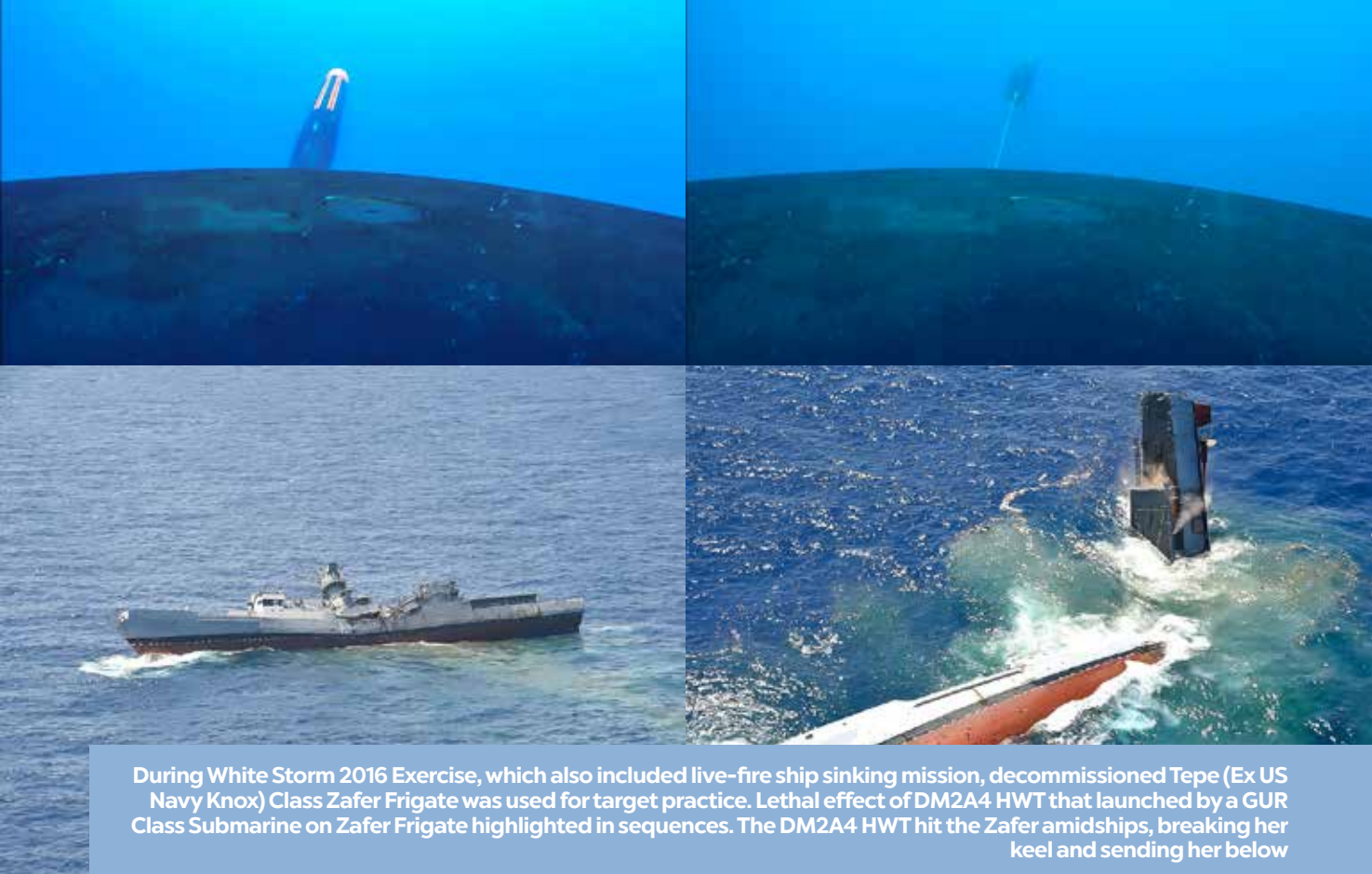
anchored in Batumi Port. Thus, İntibah went down in history as the first ship sunk by a self-propelled torpedo. Even the emergence of Anti-Ship Guided Missiles (ASMs) could not eliminate the role and importance of torpedoes.

Torpedoes can be used for both offensive and defensive purposes. Today, torpedoes are the primary weapon system of both nuclear and conventional (diesel/electric) and Air Independent Propulsion (AIP) type submarines and some fast attack crafts. Torpedoes are also carried

by numerous surface vessels, Maritime Patrol Aircraft (MPA), and Anti-Submarine Warfare (ASW) Helicopters to defend against enemy submarines. In the past, torpedoes were not highly accurate weapons, and their maneuverability was limited. Therefore, multiple torpedoes had to be launched to score a single hit on the target. However, with the advancement of technology, torpedoes have undergone a significant transformation in the last two decades. Today, a single wire/fiber optic guided, or fully autonomous torpedo launched by a skilled

operator can achieve at least a 95% hit probability.

The size of the global torpedo market in 2018 was US\$805.3 Million, and by 2026 this figure is expected to reach US\$1.114 Billion. On the other hand, the global Underwater Unmanned Systems market, which was US\$2.96 Billion in 2018, is expected to reach US\$7.53 Billion by 2026. The size of the Autonomous Underwater Vehicles (AUV) market, which is envisaged to be US\$638 million in 2020, is planned to reach US\$1.638 Billion in 2025. Torpedoes are expected to



During White Storm 2016 Exercise, which also included live-fire ship sinking mission, decommissioned Tepe (Ex US Navy Knox) Class Zafer Frigate was used for target practice. Lethal effect of DM2A4 HWT that launched by a GUR Class Submarine on Zafer Frigate highlighted in sequences. The DM2A4 HWT hit the Zafer amidships, breaking her keel and sending her below

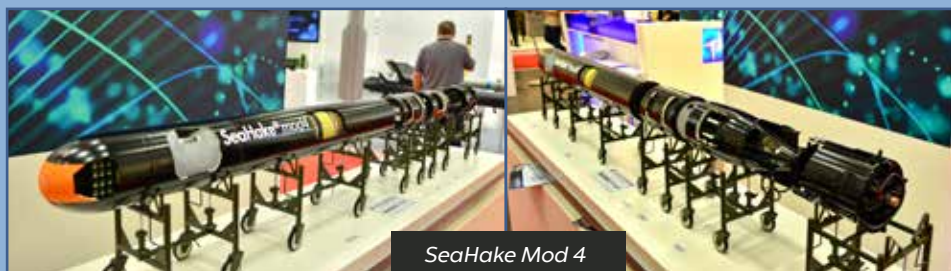
take the lion's share in the Underwater Unmanned Systems market in the next ten years.

Currently, two main types of torpedoes are used by the world's Navies: heavyweight (HWT) and lightweight torpedoes (LWTs). Heavyweight Torpedoes (HWTs) are carried by submarines for use against both enemy surface vessels and enemy submarines. Most HWTs have a diameter of 533mm (21 inches), while some Russian torpedoes have a diameter of 650mm (25.6 inches). Today's major HWTs are US Mk48 Mod 7 ATCAP and Mk48 Mod 7AT, British Spearfish Mod 1 (can reach 80 knots [148km/h] and 50km range), German DM2A4 SeeHecht (exported version SeaHake Mod 4), Italian Black Shark Advanced (BSA), French F21 Artemis and Swedish Type 62 Torpedoes. The main Russian heavyweight

torpedoes are Type 65 (650mm), Test-71M and Test 96, and gas turbine propelled DST-90, DST-92, and DST-96 models. As of October 2019, the major 533mm Heavyweight Torpedoes used in the Russian submarine fleet consisting of 58 submarines of different types and tonnages are electrically propelled Test-71 MKE and UET-1E (replacing USET-80), UGST (Universal Deepwater Homing Torpedo) powered by a liquid fuel thermal propulsion system (gas turbine engine) that operates a pump-jet, and its improved version, the UGST-M torpedoes. The 7.2m and 2,200kg UGST

also has a 6.05m and 1,880kg version that can be launched from NATO standard tubes. The first drawings of Russia's new long-range and nuclear-propelled torpedo were accidentally disclosed on the Russian NTV television channel on November 10, 2015. It is claimed that the new Status-6 heavyweight torpedo, also known as Poseidon (called Canyon in the USA), will be armed with a 100-megaton nuclear warhead. The Poseidon/Status-6 torpedo is also one of the 'super weapons' introduced to the public on March 1, 2018, by the President of the Russian Federation Vladimir PUTIN.

Light Torpedoes (LWTs) are carried by surface ships, Maritime Patrol Aircraft (MPA), and ASW/ASUW Helicopters to use against enemy submarines. The surface ships use LWT as offensive and/or defensive antisubmarine weapons. In western navies, the most common diameter/calibre for lightweight torpedoes is 324mm (12.75 inches). The US Mk46 NEARTIP (Mod 5) and Mk54 LHT (Light Hybrid Torpedo) are used by the United States Navy and many other Western navies, including the Turkish Navy. The British lightweight torpedo Stingray, the 3rd generation MU90/IMPACT, and Sweden's New



SeaHake Mod 4



A Mk46 Mod 5A Recoverable Exercise Torpedo (REXTORP) being air launched by a Turkish Navy P235 MPA (tail number TCB653) to hunt a submarine it detected during a naval exercise. The parachute that ensures the nose hits the water first is clearly visible

Lightweight Torpedo (NLT, also known as Torpedosystem 47 [TP 47]) are other notable lightweight torpedoes on the market. Most Russian ASW torpedoes are 406mm (16 inches). Most lightweight torpedoes (LWTs) use electric motors that are quieter while retaining enough reserve power to chase the target. One of the latest used in Eurotorp's MU90/Impact LWT is an Atlas Elektronik's stepless, variable speed, 120kW electric motor. In this weapon and the BAE Systems StingRay, which has a 63kW motor, a propulsor is used. Some weapons of slightly earlier design, such as the Whitehead Alenia Sistemi Subacquei (WASS, a Finmeccanica Company) A244/S (which uses a DC counter-rotating motor) and the Bofors Underwater Systems (şimdi SAAB) TP 43/TP 45, continue to use conventional propellers. American lightweight torpedoes not only use propellers but also have propulsion systems based upon high-energy chemical reactions, a hangover from the Cold War. In this context, Raytheon Technologies Mk46 and Mk54 LWTs use Otto II fuel and a five-cylinder motor.

As of June 2020, it is estimated that around 520 frigates and about 310

corvettes carrying LWTs are operating worldwide. In 2008, approximately 385 submarines, including 105 nuclear and 280 conventional diesel-electric attack submarines, were operating worldwide, this number reached 451 in 2016. Currently, it is estimated that around 510 submarines operate in different types and tonnages around the world. While the size of the submarine market was US\$22.4 Billion in 2019, this figure is expected to reach US\$31.3 Billion in 2029.

Although long-range modern HWTs used in submarines have an average range of 40–50km, a submarine that detects a surface target with its passive sonar usually approaches the target silently and launches a torpedo from a short distance. Because whatever the propulsion system (battery, piston engine, or gas turbine) of the torpedoes, the propeller creates a specific sound in the water, and this sound wave is either way detected by the sensors on the target ship. If the torpedo is fired at close range, there will not be enough time for the vessel to use countermeasures and perform avoidance maneuvers, as the time between the launch of the torpedo and its detection by the ship will be minimal

due to the speed of sound waves propagating in the water. Thus, the probability of torpedo hitting the target will increase.

A frigate can detect a submerged diesel/electric submarine at an average distance of 9.14km via a hull-mounted sonar at favorable sea conditions and tries to engage it with a lightweight torpedo at 4.57km (light torpedoes approach their target by turning side to side and following a snake-like path). During a naval exercise, one of the ADA Class corvettes was able to detect an AY Class Submarine at a distance of 11.4km with its hull-mounted mid-frequency YAKAMOS active/passive sonar. With its low/medium frequency passive sonar, a submarine can detect a frigate at favorable sea conditions from a distance of 45.7km and attack it from a much further distance (effective range of LWT) through its long-range modern heavyweight torpedoes such as the DM2A4 or Mk48 Mod 6AT (unlike lightweight torpedoes, heavyweight torpedoes approach their target on a straight path). The GÜR Class diesel/electric submarines of the Turkish Navy can detect very weak signals at approximately 50km under favorable sea conditions

with low-frequency passive sonar listening. Moreover, the Royal Navy (RN)'s Astute Class nuclear submarines' processing power is claimed to be equivalent to 2,000 laptops or 60,000 home PCs, and the Thales product Sonar 2076 System can detect the sounds of other ships 3,000 miles away.

Modern torpedoes have a much longer range and durability, much higher speed, more effective homing systems, and greater lethality than their predecessors from 20 or 10 years ago. Torpedoes, which now have built-in intelligence (guidance and control algorithms) and re-attack capabilities, pose the deadliest threat to submarines. Torpedoes, together with the Anti-Ship Cruise Missiles (ASCM), pose the most severe threat to the large naval warships, especially those operating in littoral waters. They are also highly effective weapon against merchant vessels. While the role of torpedoes in the surface versus surface ship engagement has been significantly reduced, they remain the most effective weapon in anti-submarine warfare (ASW). They also remain a potent weapon for submarines in attacking large enemy surface combatants and merchant shipping.

Torpedo Studies and Turkey

The number of countries that can design, develop, and manufacture torpedoes can be counted on the fingers of both hands: The United States (USA), Germany, China, France, South Korea, India, UK, Sweden, Italy, Japan, and Russia. Several countries, including Turkey, are trying to enter this 'elite' group with their indigenous projects that they have started to develop domestic heavy and lightweight torpedo systems.

Turkey took its first step in the heavyweight torpedo field with the AKYA National Heavyweight Torpedo Development Program, which was signed on May 8, 2009, with several domestic companies' participation under the coordination of the Presidency of Defense Industries (SSB) and the Main Contractor Roketsan. The first launch test of the 533mm AKYA HWT without the warhead and active/passive acoustic sonar sensor was carried out successfully in the Sea of Marmara on July 11, 2013, with the support of the Turkish Naval Research Center Command (TNRCC/ ARMERKOM). Under the AKYA National Heavyweight Torpedo Program, Roketsan will develop the warhead and guidance system, Meteksan Defence will develop the sonar transducer arrays (sonar wet end), and Koç Information and Defence Technologies (KBS) will develop the Wake Sensors, Torpedo Test Range Underwater Detection and Positioning System, Acoustic



AKYA National HWT

Signal Generators, and the Underwater Acoustic Models (to verify the systems and software to be developed under the program).

The AKYA Phase-2 Project was signed between the SSB and Roketsan in July 2016 to industrialize the AKYA National HWT prototype (controlled test torpedo) and make it ready for serial production by developing its critical sub-systems in line with the capabilities of the sector companies. The last publicized launch test with the AKYA HWT, qualification process of which is still ongoing, was carried out on December 20, 2019. During the trial, the

AKYA HWT was equipped with a live active/passive acoustic sonar for the first time and launched from a detailed 533mm torpedo tube replica installed to an underwater test platform at a depth of 40m with 'swim out' launch mode. During the International Store Certification Tests Symposium held on November 4, 2019, TÜBİTAK SAGE introduced a detailed replica of 533mm diameter torpedo tube, which is entirely similar to an authentic 533mm diameter torpedo tube and capable of firing both cruise missiles (ATMACAB1/B2 and GEZGİN), and heavyweight torpedoes (AKYA) from underwater.

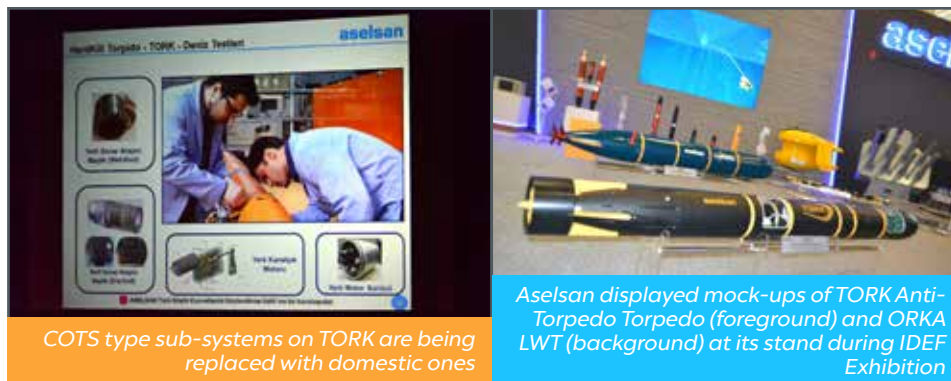
Aside from the AKYA National Heavyweight Torpedo Program, development studies are also carried out on Lightweight Torpedoes in Turkey. Thanks to its infrastructure and experience from the Anti-Torpedo Torpedo (TORK) Project, which was initiated in 2014 with the support of TÜBİTAK TEYDEB 1501, Aselsan also started to develop a prototype Lightweight Torpedo that can be used against submarines and other underwater targets. Aselsan introduced the first mock-up of the National Lightweight Torpedo ORKA, which the company developed with its own resources, during IDEF '17 Fair.



AKYA HWT being fired from a detailed 533mm torpedo tube replica at a depth of 40m on December 20, 2019

Aselsan TORK is an anti-torpedo torpedo developed to destroy acoustic homing, wire-guided, non-wire guided, and wake homing torpedoes launched against surface ships and submarines. TORK can precisely locate the incoming torpedo threat with its sonar seeker. TORK moves towards the threat torpedo by measuring the distance from it and explodes at an appropriate range using advanced interception algorithms. According to Aselsan TORK has a diameter of <30cm, a length of <3m, and weighs <200kg.

The first performance tests carried out in the maritime environment with the passive acoustic seeker equipped TORK system were completed in early September 2018. Within the tests' scope, TORK successfully identified the surface targets with its sonar seeker and moved towards the threats with its own guidance. Thus, the Development Process, which constitutes the first phase in the TORK Anti-Torpedo Torpedo Project with Hard Kill capability, was completed in the last quarter of 2018. In this context, the first guidance tests were carried out with TORK, and the Aselsan product passive seeker in the torpedo performed successfully. The second phase of the project aims to turn TORK into a Training Torpedo. In the meantime,



COTS type sub-systems on TORK are being replaced with domestic ones

Aselsan displayed mock-ups of TORK Anti-Torpedo Torpedo (foreground) and ORKA LWT (background) at its stand during IDEF Exhibition

localization studies on TORK continued and within this scope, for example, the Lithium-Ion (Li-Ion) Battery (a special battery with 100 amps current draw capacity is designed), Phased Array Sonar, Dry-End & Wet-Ends, Control Surface Motors, and the electric propeller were localized. The previous COTS (Commercial off-the-shelf) type Li-Ion Battery of the TORK was replaced with a domestic Li-Ion battery produced by Aspilsan. The Li-Ion Battery and Battery Management System developed in cooperation with Aselsan-Aspilsan will be tested on TORK in the second phase. An active seeker will also be developed in the second phase. In the third phase of the project, TORK will be finalized and produced with the warhead and war battery. According to the current calendar, a test torpedo prototype with an active seeker and training warhead will be produced and prepared in the next three years. In the second phase of the project, the TORK's diameter will be increased to the standard lightweight

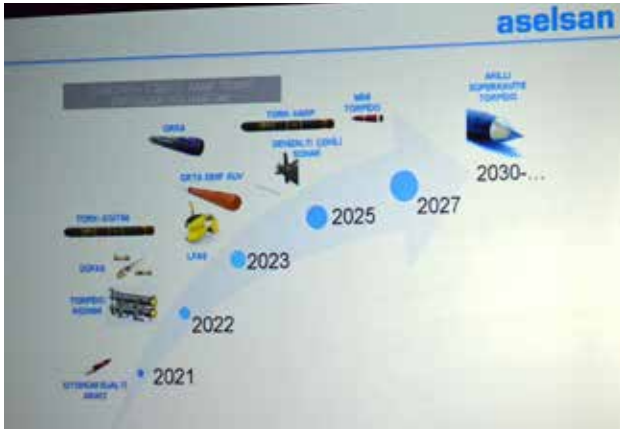
torpedo diameter of 32.4cm (324mm). Since the volume of TORK has grown, its body length will be shortened. Thus, TORK will be able to be launched from the Mk-32 lightweight torpedo launchers that are currently used onboard the warships. In the first phase, TORK is aimed to be used integrated with HIZIR Torpedo Countermeasure System (TCMS) to protect surface platforms against torpedo threats. In the future, the submarine-launched version of TORK will also be developed. Currently, the Seeker (Aselsan is also developing training Warhead), Battery (Aspilsan), Control Surface Motors of the Propulsion and Steering System at the tail section, and the propellers (Aselsan) used in the TORK are domestic products. TORK is electrically propelled. The propellers and the subsystems receive the power they need to operate from a Li-Ion Battery in the torpedo. The energy generated by the battery is distributed to the control surface motors and the main propellers via the Power

Distribution System. TORK was designed to detonate at proximity of incoming hostile torpedoes and neutralize the threats with the pressure effect it creates. Therefore, TORK does not need to hit the hostile torpedo threat physically.

The working principle, dimensions, and subcomponents of the TORK System have similar characteristics to Light Torpedoes. Some of the most critical subsystems of TORK (engine, steering, guidance, and control systems) is designed to be used in the Lightweight Torpedo without any modification. The National Lightweight Torpedo, which is aimed to have similar capabilities to the Mk46 and Mk54 Lightweight Torpedoes in the Turkish Navy inventory, is developed to be launched from existing torpedo tubes on the naval warships, ASW Helicopters and Maritime Patrol Aircraft (MPA). According to Aselsan Torpedo and Torpedo Countermeasure Systems Road Map, dual configuration lightweight



Shots from TORK's marine tests performed in 2018. The TORK succeeded in marine tests conducted with the first-ever domestically-produced sonar seeker



torpedo tube will be ready in 2022, TORK Training Version in 2023, Medium Class AUV & ORKA LWT in 2023-2025, TORK Live (Combat) Version in 2025, Miniature Torpedo in 2027, and the Smart Super-Cavity Torpedo will be available in 2030.

Head of Aselsan Naval Systems Group, Behçet KARATAŞ, who made a presentation titled 'ASELSAN Combat System Solutions for Naval Platforms and the Vision' at the 9th Naval Systems Seminar held on October 14-15, 2019 in Ankara, shared the following information about these projects: "We are planning to complete the Torpedo Tube development in 2022. The studies on low-frequency active sonar are already continuing with the SSB R&D Department, and we plan to complete it in 2023. We are planning to complete the development of TORK's Training Version by 2023. The Medium Class Autonomous Vehicle is also expected to be completed between 2023-2025. We also plan to introduce our own Lightweight Torpedo, which we call ORKA, before 2025. We continue our works on Submarine Towed-Array Sonar, combat version of TORK, Miniature Torpedo, and later Smart Super-Cavity Torpedoes..."

In the meantime, within the scope of the New Generation National Torpedo Technologies Development Studies, TÜBİTAK Defense and Security Technologies Research Grant Committee (SAVTAG) issued a wide-area call for Torpedo Batteries (T-BAT) in July 2019 under the 1007 Program. The scope of the call aims to develop torpedo batteries and charge/discharge units of these batteries by using long-lasting lithium-ion (Li-Ion) cells. Accordingly, multiple R&D intensive work packages will be realized and verified in a real-life environment. The studies aim to develop a form-fit lithium-ion (Li-Ion) torpedo battery system with national resources to replace (same size and weight) the Silver Oxide-Zinc (AgO-Zn) batteries used in training torpedoes without additional modifications. The project aims to eliminate foreign dependency, reduce the battery cost per launch, create a domestic and national design/production infrastructure for new generation national torpedo battery systems, and to eliminate different battery requirements for training and heavyweight torpedoes by providing a single common battery type.

Main Heavyweight and Lightweight Torpedoes in Turkish Navy and NATO Countries

The presence of different types of torpedoes produced by different companies/countries in a submarine is considered as a factor that increases its deterrence. Mk24 Mod 2 TigerFish and DM2A4 Torpedoes in PREVEZE and GÜR Class Submarines, Mk14, Mk23, Mk37 Mod 2 and Mod 3 and SST-4 Mod 0 Torpedoes in AY Class Submarines, and DM2A4 Heavyweight Torpedoes are used in addition to classic torpedoes in modernized AY Class Submarines of the Turkish Naval Forces Submarine Group Command. According to open sources, the Turkish Navy has 48 DM2A4, over 85 Mk24 Mod 2 TigerFish, around 50 SST-4 Mod 0, and about 50 Mk37 Mod 2 and Mod 3 HWTs. In 2014, 48 Mk48 Mod 6AT Heavyweight Torpedoes were ordered for the REİS Class Type 214TN Submarines, which will be commissioned from 2022, under a FMS approach that expected to reach about US\$170 Million, including spare parts, training, and

logistics support items. REİS Class Submarines will be equipped with both Mk48 Mod 6AT and DM2A4 HWTs.

A total of 50 DM2A4 SeeHecht HWTs, including training models, were ordered under an agreement signed in June 1999 for PREVEZE and GÜR Class Submarines (Type 209/1400 and Type 209/1400 Mod). Although the delivery date of DM2A4 SeeHecht Torpedoes, each of which was about €2,3 Million at the time (the cost of switching from the two-battery export configuration to the four-battery German Navy configuration and the modifications to the torpedo tubes are also included in this figure), was stated in the contract as of June 2003, deliveries were started only in 2005 and completed in February 2008. On the other hand, the German Navy received the first serial production model DM2A4 Torpedo it ordered for use in Type 212A Class Submarines from Atlas Elektronik Company on December 3, 2008. A maintenance & assembly line was set up in Başiskele, Gölcük, for DM2A4 SeeHecht Heavyweight Torpedoes.

The Turkish Navy performed its first live fire with the DM2A4 SeeHecht Heavyweight Torpedo



A Mk24 Mod2 TigerFish HWT being loaded into the Turkish Navy's PREVEZE Class Submarine



Atlas Elektronik's DM2A4 HWT

against the Tepe (Knox) Class Zafer Frigate, which was used as the target ship during the Beyaz Firtına (White Storm) 2016 Exercise held on May 16-28, 2016. The DM2A4 Heavy Torpedo launched from a GÜR Class submarine scored a direct hit on the target, and the Zafer Frigate, which was retired in 2012, sank within 15 minutes after its hull split into two parts.

The new generation DM2A4 SeeHecht Heavy Torpedo is faster and has a longer range than the veteran Mk24 Mod 2 TigerFish Torpedoes in the Turkish Navy service. The torpedo can perform target motion analysis with its own acoustic seeker and can transfer data at high capacity via the fiber-optic guidance wire.

The first live firing of with the Mk24 Mod 2 TigerFish Heavyweight Torpedo, which entered the Turkish Navy inventory in 1993 (90 of them were ordered) and is still used in PREVEZE and GÜR Class Submarines was performed during the Deniz Kurdu (Sea Wolf) 2001 Exercise. On June 15, 2001, the TigerFish Torpedo launched by Preveza Class TCG 18 Mart (S-355) Submarine to the target ship Tepe (Knox) Class USS Miller Frigate,

3,000 yards (approximately 2.7km) before the target impact and sank after 30 minutes due to running out of fuel. The ship was then sunk with the Mk23 classic Heavyweight Torpedo launched from the TCG 18 Mart Submarine. The second firing with the Mk24 Mod 2 TigerFish Heavyweight Torpedo was planned to be carried out between March 27 and April 7, 2017, during the Deniz Yıldızı (Sea Star) 2017 Exercise in the Marmara Sea and the Black Sea, but according to the information we obtained, the launch could not be executed due to a technical problem. The second (third planned) live fire with the Mk24 Mod 2 TigerFish Heavyweight Torpedo was carried out within the scope of the Lieutenant Erdem ÖZTÜRK Tactical Exercise 03/17, on October 4, 2017, against the USS Duncan Frigate which was previously hit by the Sub-Harpoon and Harpoon Block II ASMs during the Deniz Yıldızı (Sea Star) 2017 Exercise on March 31, 2017 but did not sink. After the USS Duncan Frigate was hit with a wire guided Mk24 Mod 2 TigerFish Heavyweight Torpedo, it sank in a short time since its hull broke into two parts. Within the scope of the Deniz Yıldızı

(Sea Star) 2017 Exercise, live firings of RGM-84L Harpoon Block II Anti-Ship Guided Missile (ASMs) that can be launched from warships to land targets and UGM-84 Sub-Harpoon Missile, which can be launched from submerged submarines to surface targets, were carried out on March 31, 2017. In this context, for the first time in the history of Turkish Naval Forces, 150km range RGM-84L Harpoon Block II missile from TCG Heybeliada (F-511) Corvette and UGM-84 Sub-Harpoon missile from the GÜR Class TCG Çanakkale (S-358) Submarine were fired against the target ship USS Duncan Frigate. However RGM-84L Harpoon Block II and UGM-84 Sub-Harpoon missiles hit were not enough to sink the US Duncan Frigate.

Additionally, on October 17, 2018, Mk37 Heavyweight Torpedo was launched from the AY Class TCG Batıray (S-349) Submarine to the target ship 'Münfesih Taşkızak' and on June 11, 2018, SST-4 Heavyweight Torpedo was launched from TCG Yıldırım (S-350) Submarine to the target ship 'Lieutenant Commander Sadettin Gürcan' logistic support ship, and the target ships were sunk.

On the other hand, a total of eight HWT firings, including a DM2A4, were performed in 2018 using the MÜREN Integrated Underwater Combat Management System installed in the AY Class TCG Doğanay (S-351) and TCG Dolunay (S-352) Submarines, which were modernized under the MÜREN CMS AY Project. The Turkish Naval Forces became the first Navy to fire DM2A4 Heavyweight Torpedo with the AY Class (Type 209/1200) submarine. As Mk48 Mod 6AT and AKYA Heavyweight Torpedoes are not defined within this project's scope, only DM2A4 SeeHecht Heavyweight Torpedo can be used with MÜREN CMS. Under the 'MÜREN CMS PREVEZE Project', contract signed in August 2017, MÜREN CMS will be integrated into a PREVEZE Class submarine by 2023. In this project, besides the DM2A4 SeeHecht Torpedo, Mk48 Mod 6AT and AKYA Heavyweight Torpedoes can also be launched with MÜREN CMS. Within the scope of the MÜREN CMS PREVEZE Project, which has been in progress since 2017, the tests are expected to start in late 2020 or early 2021.



A Mk48 HWT being loaded into a US Navy submarine

DM2A4 SeeHecht Heavyweight Torpedo

The 532mm diameter DM2A4 SeeHecht Heavyweight Torpedo, which is currently in service with the German, Turkish, Spanish, Pakistani, and Israeli Navy, was also recently selected by the Greek Navy. The DM2A4s selected by Pakistan in December 2008 use the Positive Water Discharge (enables the submarine to launch silent torpedoes) launch method instead of the Swim-Out method, and the DM2A4 Torpedo Training was given to the Pakistan Navy personnel at Gölcük Submarine Training Center. Live firing tests were carried out from Super Dolphin Class Submarine on June 18-19, 2018 with the DM2A4 Heavyweight Torpedoes named Kaved. It was announced that the deliveries of Kaved were completed in 2019, and it will be used in both Dolphin and Super Dolphin Class Submarines. In 1999, Israel ordered some 30 DM2A3s for its Dolphin Class submarines, which were built by Germany. In May 2020, the Greek Parliament approved the procurement of 36 DM2A4 Heavyweight Torpedoes and the modernization of 112 old-generation SUT Heavyweight Torpedoes in the inventory. The DM2A4 SeeHecht (exported version SeaHake Mod 4) Heavyweight Torpedo consists of eight parts, including:

- Conformal Array Sonar and wide-angle panoramic homing seeker up to a maximum of 220° (+/- 100° azimuth and +/- 24° elevation),
- Fully insulated battery (each Silver Zinc (Ag-Zn) battery contains 86 cells and generates over 150V power)



compartment (can hold four batteries) with an internal cooling system activated by the acid-water mixture,

- 260kg of plastic-bonded explosive (PBX) warhead (equivalent to 460kg TNT) with proximity (magnetic influence) and contact fuses and safety and arming devices,
- 300kW high-frequency permanent magnet motor with a low self-noise planetary gearbox,
- Two asymmetrical inclined contra-rotating propellers made of GRP material with nine blades in the front and seven in the rear,
- Electronic compartment with a central processor that manages the wake homing sensor and all torpedo functions,
- Guidance section with the fiber-optic cable (300 micrometers thick)
- Tail section,

Thanks to the fact that its batteries can be activated in a short time, the 6.9m, 1670kg (four-battery version, standard version has 6.22m length and 1.530kg weight) DM2A4 Torpedo can be launched from the torpedo tube within 10 seconds (with four batteries), and it has a completely digitized, jamming resistant signal processor. Although the torpedo is designed for dual-purpose (ASuW/ASW) use,

DM2A4's primary targets are believed to be naval warships because of the conformal array sonar, passive acoustic homing, and wake homing sensor preferences. It is stated that the four-battery version of the DM2A4 can reach a range of 50km with 40 knots, 38km with 55 knots, and approximately 100km with a low speed. It is stated that thanks to its advanced guidance and control algorithms, DM2A4 can distinguish the fake targets from the real ones.

Atlas Elektronik also markets the SeaHake Mod 4ER (Enhanced Range) Torpedo designed for network-centric warfare, coastal attack, and coastal defense. The maximum combat range of the torpedo is given as 150km. The 8.7m long DM2A4 SeaHake Mod 4ER Torpedo, which can be launched from naval warships and attack submarines, can also use satellites for communication and navigation (SatNav and SatCom) through its telescopic antenna in addition to its fiber-optic cable. The DM2A4 SeaHake Mod 4ER Torpedo, which can operate in shallow waters, ascends close to the water surface (7m) to receive target data or communicate with the main vessel or

shore via the retractable telescopic antenna and dives back to the planned depth after communication. The torpedo, which was delivered to an unnamed customer, can be launched from the coastal installations and surface combatants. The SeaHake mod4 ER, which was delivered to an unnamed customer, can be deployed from seagoing platforms and special land-based platforms. The sea trials took place in cooperation with the German Armed Forces Technical Centre for Ships and Naval Weapons in the Eckernförde Bay in March 2012.

During the sea trials carried out with Aselsan HIZIR Torpedo Countermeasure System (TCMS) in the first half of 2018, the DM2A4 Torpedo was detected, classified, and successfully deceived/jammed approximately 10-12km away. DÜLGER Acoustic Target Emulator and MEZGİT Acoustic Jammer, which are members of the ZOKA Acoustic Decoy Family developed under the DAKA Project, are used in the HIZIR system. In the tests conducted previously (in 2014), ZOKA Acoustic Decoys managed to deceive the DM2A4 Torpedo (training version) for a short time. However, thanks to its advanced guidance and control algorithms, the torpedo was able to distinguish the fake target from the real one and re-engage the actual target by analyzing the engine noise emitted by the target ship. This success is even more critical considering the fact that the DM2A4 Heavyweight Torpedo is still used by the Israeli Navy Dolphin and Super Dolphin Class Submarines and will enter service with the Greek Navy (Type 214HN and Type 209/1200 AIP) in the near future...

Mk48 Mod 6AT (Advanced Technology) Heavyweight Torpedo

The Brazilian Navy (Marinha do Brasil), which ordered 30 torpedoes in 2005 (bought for around US\$60 Million) as part of the modernization of 5 Tupi and Tikuna Class five submarines (US\$35.3 Million agreement was signed with Lockheed Martin for the modernization of 4 Tupi Class submarines), became the first international customer of the Raytheon Technologies product Mk48 Mod 6AT (Advanced Technology) Heavyweight Torpedo. Turkey was the second customer of the Mk48 Mod 6AT torpedoes.

In May 2014, 48 Mk48 Mod 6AT Torpedoes were ordered (estimated as US\$170 Million) via Foreign Military Sales (FMS) for 6 REIS Class (Type 214TN) Air Independent Propulsion (AIP) submarines built by Gölcük Naval Shipyard Command under HDW license. Initially, the class was to be called 'CERBE,' and the first vessel was planned to be commissioned in the first half of 2018. However, in the second half of 2014, the design of the submarines was updated, and their total length and weight were increased. The new design was renamed as 'REIS Class,' and they were intended to be delivered to the Turkish Navy in 2020-2025 with a 12-month phase difference. This delivery schedule was later updated to 2021-2026 and finally to 2022-2027.



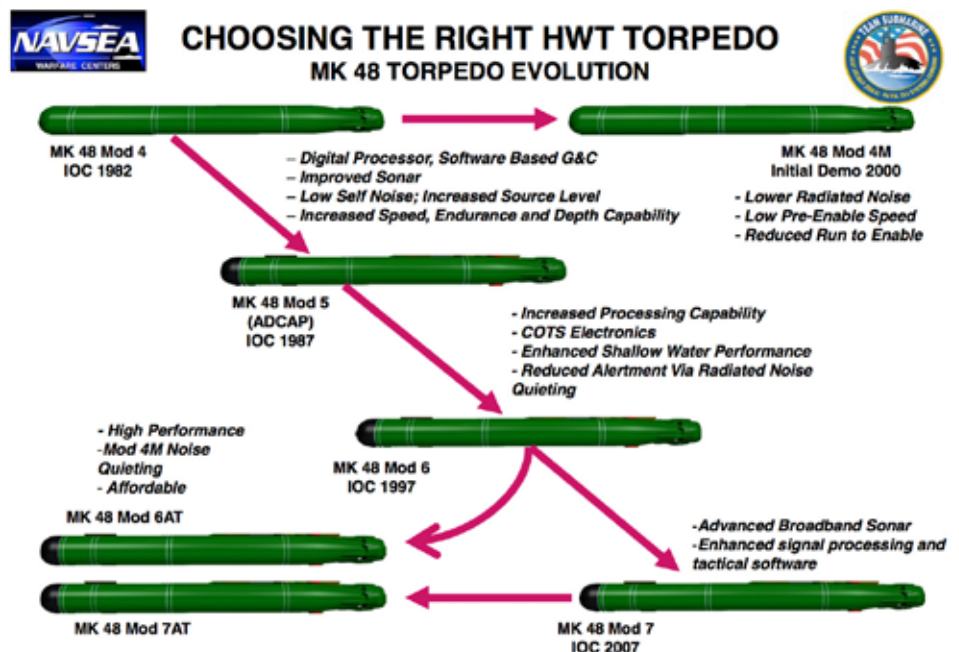
Sailors and Military Sealift Command civilian mariners transferring a M48 HWT to the Los Angeles Class Fast Attack Submarine USS Topeka (SSN-74)

In fact, Mk48 Mod 6AT HWT was created by combining the tail section of the Mk48 Mod 4M Torpedo, which is the export version of the Mk48 Mod 4 HWT (Initial Operation Capability (IOC) declared by the U.S. Navy in FY1982) with a silent propulsion system and the COTS (commercial off-the-shelf) hardware, sonar, guidance, and control electronics of the Mk48 ADCAP (Advanced Capability) Mod 6 Torpedo. Therefore, Mk48 Mod 6AT has the

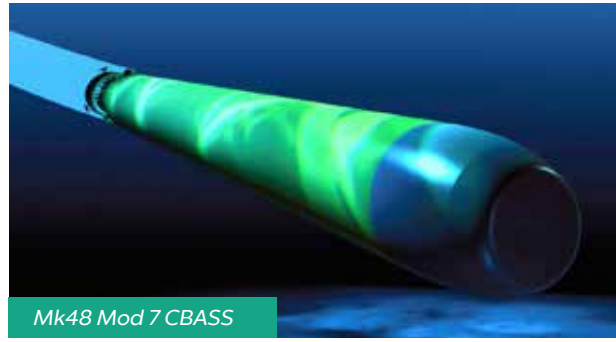
performance of ADCAP Mod 6 and the operating depth and speed of Mod 4M. The export version of Mk48 Mod 7 CBASS Heavyweight Torpedo, the newest version of Mk48 in the U.S. Navy service, is named Mk48 Mod 7AT. Mk48 Mod 7 CBASS, the development process of which was completed in November 2005, and the Initial Operation Capability was declared in 2007, is an improved version of the Mk48 ADCAP Mod 6 Advanced Common

Torpedo (ACOT) produced by Raytheon Technologies.

The first delivery of the Mk48 Mod 7AT CBASS Heavyweight Torpedoes, the production of which started in 2016, was carried out in 2019. Mk48 Mod 7AT CBASS, initially ordered by Australia, Canada, and the Netherlands, has the Guidance and Control Section (includes CBASS/ Common Broadband Advanced Sonar System) developed by Lockheed Martin's Sippican branch.



Mk48 Mod 7 CBASS Heavy Torpedo can work in both deep and shallow waters. Within the framework of the agreement signed with Lockheed Martin in 2011, the US Navy has been modernizing 1,263 Mk48 Torpedoes (20 CBASS kits per month) to the Mk48 Mod 7 CBASS level. The Netherlands signed a US\$85 Million contract with the U.S. Government in March 2020 to upgrade 16 Mk48 Mod 4M Heavyweight Torpedoes used by the Royal Netherlands Navy (Koninklijke Marine) in Walrus Class Submarines to the Mod 7 AT level. Each Mk48 Mod 7 CBASS Conversion Kit is claimed to cost US\$5.31 Million. On the other hand, another user of the Mk48 Mod 7AT paid an estimated US\$41 Million (US\$3.41 Million per kit) for 12 Mk48 Mod 7AT Torpedo Conversion Kits on September 24, 2014. Meanwhile, the U.S. Government gave the green light to Taiwan's request for 18 Mk48 Mod 6AT Heavyweight Torpedoes in mid-May with a price of US\$180 Million. In addition to torpedoes, the package also includes spare parts, support and test equipment, technical documents, user manuals, and engineering, technical and logistic support services. In case of purchase, Taiwan will be the third customer of the Mk48 Mod 6AT Heavy Torpedo. Taiwan, the third customer of the Mk48 Mod 6AT HWT, previously ordered 48 Mk48 Mod 6ATs in June 2017 via FMS channel for an estimated cost of US\$250 Million to replace with around 60 SUT HWTs in the Taiwanese



Navy service. Taiwan also ordered 168 Mk54 upgrade and conversion kits through FMS with an estimated cost of US\$175 Million in June 2017 to upgrade Mk46 Mod 5 LWTs in the inventory to Mk54 level.

The two-way wire-guided MK 48 Mod 6AT Heavyweight Torpedo is equipped with the MK 107 Mod 1 high-explosive (HE) Warhead loaded with 295kg (650lb) of PBXN-105, MK 22 Mod 1 Warhead Electronic Sensor, and MK 21 Mod 3 Exploder. Equipped with a pumpjet propulsor (six-cylinder piston engine) fueled by Otto Fuel II monopropellant, the Mk48 Mod 6AT Heavyweight Torpedo has a length of 5.86m, a diameter of 53.2cm, and weighs 1.691kg. According to the product brochure of the Mk48 Mod 6AT Torpedo equipped with an active electronically steered phased array sonar

on the nose cone, the active/passive acoustic homing seeker can scan an area of over 1.6 million m³ per second. Although the torpedo is designed for dual-purpose (ASuW/ASW) use, its primary targets are believed to be submarines because of the phased array sonar and active acoustic homing sensor preference.

Havelsan was selected for the integration of Mk48 Mod 6AT Torpedoes to the ISUS-90/72 CMS in REIS Class Submarines, and the company was deemed worthy of a 3-star supplier award by Raytheon in 2016 for its success in this work. The U.S. Navy and manufacturer Raytheon Technologies guaranteed supportability for the Mk48 Mod 6AT Torpedoes until 2025. However, due to the delays in the NTSP calendar, the first submarine, TCG Pirireis, is presumed to be delivered to the Turkish

Navy in 2022 and the 6th and the last submarine TCG Selmanreis in 2027 with the full operational capability. Therefore, the need to update the Mk48 Mod 6ATs has emerged in case of the problems that may occur in the maintenance due to the relative aging of the torpedoes when the last submarine is commissioned. In this context, we received information that the Turkish Navy would modernize the Mk48 Mod 6AT Torpedoes to the Mod 7AT level in mid-2017. To support this information, on September 23, 2017, Lockheed Martin signed a US\$53 Million contract for the production of the command and control units of the Mk48 Mod 7 Heavyweight Torpedo and the Mk48 Mod 7 CBASS Conversion Kits for Australia, Netherlands, Canada, Turkey, and the U.S. Navy. In the press release, Turkey's share in the order was stated as 1%, and the works under the contract would be completed by November 2020. Then on August 14, 2018, Lockheed Martin signed a new contract worth US\$59.1 Million for the production of the Mk48 Mod 7 CBASS Conversion Kits through the FMS channel only for the Netherlands, Canada, and Turkey. The completion date of the deliveries under this new agreement is given as March 2021. In light of this information, I believe that the 48 Mk48 Mod 6AT Heavyweight Torpedoes ordered by the Turkish Navy are being upgraded to Mk48 Mod 7 CBASS level using the Mk48 Mod 7 CBASS Conversion Kits supplied in batches.





AKYA National Heavyweight Torpedo

Technical Specifications of AKYA National Heavyweight Torpedo.

Length:	≤6.6m (Length of 533mm torpedo tubes is 6.6m according to NATO standards)
Diameter:	21 inches/53.3cm.
Weight:	1.4 - 1.6 ton.
Propulsion:	Electric.
Battery:	It is thought that Silver Oxide-Zinc (AgO-Zn) type batteries are used.
Range:	15km (with 40 knots).
Max. Speed:	40kt (40 nautical miles per hour).
Propeller:	Two contra-rotating propellers on a single axis.
Guidance:	Fire and Forget type, Active/Passive Acoustic Sonar + Fiber Optic Cable Guidance + Magnetic Proximity Sensor (Acoustic Sensor can be used in the future) and Wake Homing Sensor.
Body:	Metal body (prediction), fiber nose.
Sonar:	Conformal Array Sonar located inside the Parabolic nose cone of the torpedo made of fiber material (Parabolic nose structure both reduces the sound of the torpedo and cavitation).
Warhead:	AKYA is expected to use a warhead heavier (350-380kg) than that used in the DM2A4 Torpedo (260kg PBX).
Target:	Although the torpedo is designed for dual-purpose (ASuW/ASW) use, its primary targets are believed to be naval warships because of the conformal array sonar preference.
Unit Cost:	The unit cost of AKYA is expected to be lower compared to DM2A4 and Mk48 Mod 6AT Heavyweight Torpedoes.

The AKYA HWT is planned to be used as the first alternative to the veteran heavyweight torpedoes (Mk14, Mk23, Mk37 Mod 2, Mk37 Mod 3, SST-4 Mod 0, and Mk24 Mod 2 TigerFish) onboard the submarines in the Turkish Naval Forces inventory. The AKYA HWT is designed to be fired against both surface targets (ASuW) and submarines (ASW). It is a battery-powered (Otto Fuel II is not preferred), wire/fiber-optic cable guided heavyweight torpedo, equipped with an active/passive acoustic sonar, magnetic proximity sensor (can be replaced with an acoustic proximity sensor in the future), and wake sensor (wake-homing capability). Following the industrialization activities, the AKYA HWT is expected to be ready for the Serial Production Phase by the end of 2020.

The AKYA is planned to be tested for the first time in the PREVEZE Class Submarines that will be equipped with the MÜREN Combat Management System (CMS) and subsequently used as the first alternative torpedo in all submarines in the Turkish Naval Forces inventory. The first torpedo launch with the MÜREN CMS is expected to be carried out at the end of 2020 or the beginning of 2021.

AKYA National Heavyweight Torpedo will be equipped with a warhead designed to break the keel of a surface ship and destroy its structural integrity using the 'blast' effect. Thus, instead of hitting the target ship's hull, AKYA will detonate a few meters under the target vessel and will split its hull into two with the pressure effect it creates. AKYA's parabolic nose structure, wake homing sensor, and warhead configuration reinforce the claims that AKYA was primarily designed for surface targets. AKYA is expected to use a warhead that will weigh between 350-380kg.

Mk24 Mod 2 TigerFish Heavyweight Torpedo

The Mk24 Mod 2 TigerFish, which first entered service with the Royal Navy (RN) in 1987, is an electrically propelled, 533mm diameter, wire-guided heavyweight torpedo developed by Marconi Underwater Systems. The RN adopted its increased performance version in 1992. The maximum speed of the Mk24 TigerFish Torpedo, which is 6.46m

long and weighs 1,551kg, is given as 35 knots (65km/h). TigerFish has 39km (21nm) range at low speed, and 13km (7nm) range at high

speed. The torpedo has an active and passive sonar and is armed with a warhead containing 340kg (750lb) Torpex type explosive. The

RN replaced Mk24 Mod 2 TigerFish Heavyweight Torpedoes with SpearFish HWTs on February 27, 2004, after 37 years of service.



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F21 Artemis Heavyweight Torpedo

The first customers of the F21 Artemis Heavyweight Torpedo (HWT) developed by Naval Group were France and Brazil. The Brazilian Navy will use the torpedoes in four Scorpene-type diesel-electric attack submarines that were first ordered in 2009 and built by DCNS's Itaguaí Construções Navais and Odebrecht Defesa e Tecnologia in Brazil. The first of the submarines was launched on December 14, 2018 and is planned to be delivered in 2020. On the other hand, France ordered the F21 Artemis Heavyweight Torpedoes to use in 4 'Triumphant' Class and 6 'Suffren' Class (Barracuda) nuclear-powered attack submarines and to replace the F17 Mod 2 torpedoes used in 'Rubis' Class submarines. Although the F21 Artemis HWTs are expected to be commissioned by the end of 2015, the first batch of 6 torpedoes was delivered to the French Navy (Marine Nationale) only in November 2019.



The Brazilian Navy received the first batch of F21 Artemis Torpedoes in January 2020. France initially ordered 93 F21 Artemis HWTs. The F21 HWT has a diameter of 533mm, a length of 6m, and a weight of about 1.5 tons. The F21 has an endurance of around 1 hour and a combat range of over 50km (27nm) and can be operated in depths ranging from 33ft (10m) to 1,630ft (500m). F21 Artemis consists of an acoustic seeker, a fully insensitive warhead with 660lb. (300kg) PBX B2211D high-explosive and an all-electronic detonator, electric propulsion system based on the Silver

Oxide-Aluminum (AgO-Al) primary battery and the guidance and control parts. Wire guided F21 Artemis is launched via the MIGAL Fire Control System, which acts as an interface between the torpedo and the submarine's SYCOBS Combat Management System (CMS).

MU90/IMPACT Lightweight Torpedo

The MU90 torpedo was developed in cooperation with DCNS (now Naval Group), Thales Underwater Systems (TUS), and Whitehead Alenia System

Subacquei (WASS) within the scope of G.E.I.E EuroTorp Consortium, where Saft, Nexter, and Atlas Elektronik GmbH are the Main Subcontractors. It is a long-range, multi-role fire-and-forget LWT torpedo designed to counter all types of nuclear and conventional submarine threats. The torpedo consists of a digital acoustic seeker capable of simultaneously sending and receiving multiple beams, a propulsion system with an advanced closed-loop electrolyte recirculation system powered by silver oxide aluminum (Ag O-Al) battery that uses sodium dioxide dissolved with electrolyte, and a shaped charge warhead that contains 32kg high-pressure V350 explosive. The warhead has been proven to penetrate all types of double hull submarines. The 323.7mm diameter torpedo has a maximum engagement range of 46,3km (25nm). More than 1,000 MU90 torpedoes have been produced for Australia, Denmark, France, Germany, Italy, Poland, Egypt, and Morocco.



BAE Systems Spearfish Mod 0 and Mod 1

The Spearfish from BAE Systems is an advanced heavyweight torpedo designed to operate totally autonomously from all Royal Navy (RN) submarines and is effective against submarine and surface threats both in deep and shallow waters. It is equipped with an open-cycle variable speed 1,000hp turbine thermal engine using Otto Fuel II as a liquid monopropellant, and Hydroxyl Ammonium Perchlorate (HAP) as oxidant, both contained in separate tanks. The maximum speed of Spearfish is an astonishing 80kts with a maximum range of 12.5nms at 60kts. It can also operate down to 900m. The 1.850t Spearfish torpedo carries PBX explosive warhead of 300kg and is directed towards the target by high-capacity guide wire system and passive and active sonar. The torpedo's sonar and homing system enable it to operate primarily in a passive mode. However, when required to operate against a very quiet target, or in the final stages of attack, the active mode is used.

Spearfish Mod 0 is in service with the RN. The final weapon was handed over on 24 November 2003. It is believed that around 400 torpedoes are held in inventory. The weapon is projected to



A Spearfish Mod 0 HWT being loaded onto a Royal Navy submarine

remain in service until 2025.

The UK's Ministry of Defense (MOD) awarded BAE Systems a £270 Million contract in 2014 to upgrade the Spearfish Heavyweight Torpedo for the Royal Navy's Trafalgar, Vanguard, and Astute Class Submarines. Following the completion of the design phase, existing Mod 0 torpedoes will be upgraded by BAE Systems at its Broad Oak facility in Portsmouth to the new design, known as Spearfish Mod 1, with initial deliveries scheduled to take place in 2020. Deliveries are expected to be completed in 2024. The Mod 1 upgrade extends the life of the torpedo, improves safety through the introduction of an Insensitive Munitions warhead and by utilizing a single fuel system and provides more capable data links between the weapon system and the launching vessel. This results in capability improvements for the RN as well as significant reduction in through-life operating costs.

SAAB Defense Torpedo 62 & New Lightweight Torpedo (NLT)

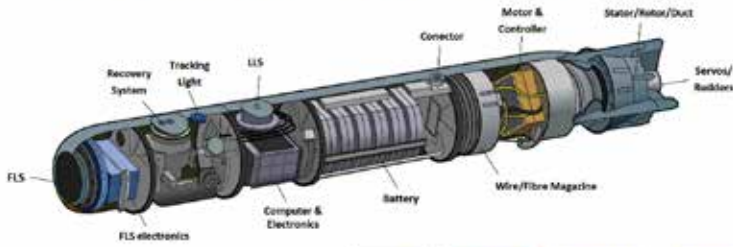
The dual-purpose, wire-guided Saab Underwater Systems Torpedo 62 (TP 62, designated Torpedo 2000 in export markets) began development in 1988. It uses a bi-propellant propulsion system (a combination of 85 per cent HTP and 15 per cent kerosene). Torpedo 62 uses a propulsor based upon the one used in the Spearfish and can trade off speed against range up to a maximum of about 50kt and

50,000m, respectively. The Torpedo 62 has a length of 5.9 meters and weighs 1,450 kg. It is in use with the submarine fleet of the Royal Swedish Navy. On July 9, 2020 SAAB announced that it has received a first order from the Swedish Defense Materiel Administration (FMV) for the life extension of the TP 62 heavyweight torpedo system. The order value is approximately 485 MSEK and deliveries will take place during 2020-2024. The order is part of a life extension program for the heavyweight torpedo and mainly comprises a review of the system, modifications, and enhancements. The order also includes preparations for upcoming stages of the life extension program. Thanks to this life extension

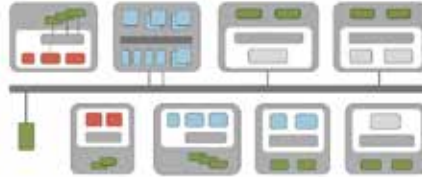


Torped 47 (TP 47) LWT being fired from a Visby Class Corvette

Torped 47 – design principles and performance



Dimensions	400 mm x 2850 mm
Weight	Ca 340 kg
Speed	10- to 2-35 kts Prepared for 245+ kts
Endurance	≥ 20 km (>1h) Prepared for ≥ 50 km
Battery	LiFePO4, >100 recharging
Propulsion	Electronic DC-motor / Pumpjet
Homing system	Active & Passive (Fully Digital) Prepared for HF
Warhead	IM compliant, omni-directional, PBX
Communication	Galvanic wire, Prepared for Optical fiber



effort the TP 62 HWT will be able to remain in operation with the Swedish Navy until the mid-2040.

Under a contract awarded by the Swedish Defense Materiel Administration (FMV) SAAB Defence has also developed a new generation lightweight torpedo under the Lightweight Torpedo (NLT) Program. Based on the proven Torpedo 45 (TP 45, entered service in 1995) with its outstanding shallow-water anti-submarine warfare capability, the 400mm New Lightweight Torpedo is designed to operate in the complex shallow water environment of the Swedish archipelago and the Baltic Sea and will deliver significant performance improvements to deal with evolving threats in international scenarios. Under the project, successful firing trials campaign of the NLT was successfully conducted from a Visby Class corvette and a Gotland Class submarine between February and March 2020. The NLT weapon system is also known as Torpedo 47 or Torpedo system 47 (TP 47) by the FMV and the Swedish Armed Forces.

The NLT/TP 47 can be indifferently used for surface and underwater platform applications, the difference being in the launching system. On ship, the torpedo is ejected from the launcher by a compressed air system while on submarines it is released by the launch tubes via a passive swim-out procedure, or active ejection launch system. The NLT/TP 47 is expected to be operational by late 2022 initially on surface vessels and later soon on the submarine class types.

Featuring a near-neutrally buoyant wire-guided torpedo design, the 2.85 meters long and 400 mm diameter NLT/TP 47 torpedo presents a fully acoustic homing head with active/passive, full digital sonar, high-performance

COTS-based processing in guidance and control, an insensitive munition (IM)-compliant warhead, a new two-way data communications protocol in the wire-guidance link based on galvanic wire – already used on current Swedish torpedoes, allowing seamless transition from the Torpedo 45 (TP 45) - to provide platform sensors information to the torpedo, a rechargeable lithium-iron phosphate (LiFePO4) battery technology for exercise and war-shot uses, and an electronically commutated DC propulsion motor coupled with a pump-jet (ducted rotor/stator) system design for silent and energy-efficient propulsion. The approximately 340 kg heavy weapon has a 10-40+ knots speed and 20+ km range

(over one-hour endurance) and can be launched in shallow water, while being capable to reach over 300 meters depth.

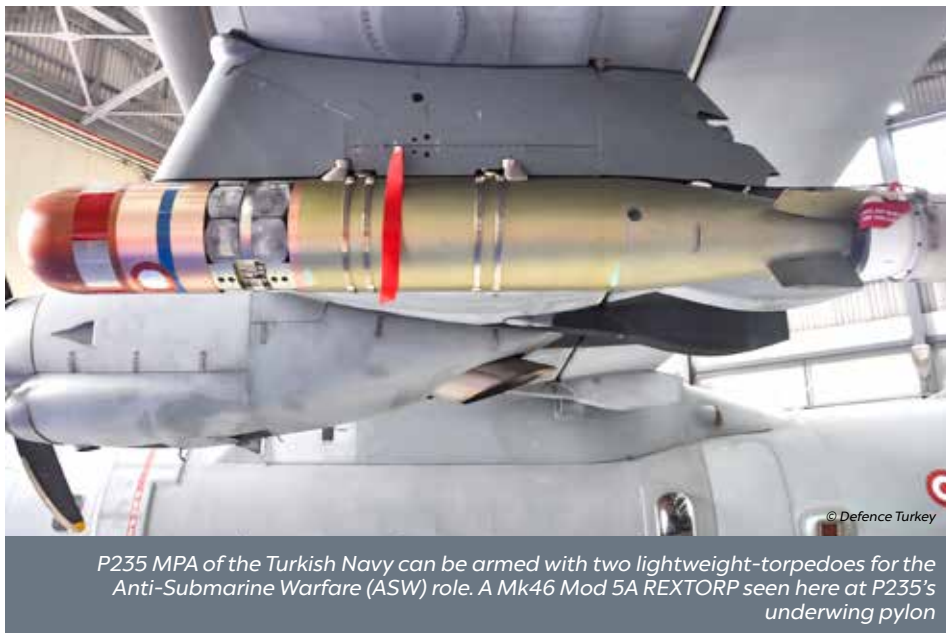
The NLT/TP 47 has already found an export customer. In January 2018, the Finnish Navy placed an order for the torpedo, as a part of the Squadron 2000 Mid-Life Upgrade Program. The Finnish Navy will operate the system on-board the upgraded Hamina Class vessels as well as the new Pohjanmaa Class corvettes of the Squadron 2020 Program.

Raytheon Technologies Mk46 & Mk54 LWTs

Featuring many improved capabilities, the Mk54 is the next generation of the Mk46 lightweight torpedo (LWT). Designed to attack high-performance submarines, the Mk46 LWT is the NATO standard and has been acquired by more than 25 countries including Turkey. The Mk46 has various configurations to enable use by surface combatants, fixed-wing, and rotary-wing platforms. Since its entry into service in 1965



A Mk54 LWT being launched from a surface vessel



P235 MPA of the Turkish Navy can be armed with two lightweight-torpedoes for the Anti-Submarine Warfare (ASW) role. A Mk46 Mod 5A REXTORP seen here at P235's underwing pylon

various modifications - including improved acoustics, guidance and control upgrades, and countermeasure detection capability - have been introduced into the weapon. In this context during the early 1990s, a major system upgrade - Mk46 Mod 5A(S) - was developed to improve weapon performance in shallow water. The Mk46 Mod 5A(S) is an active or passive/active, dual-speed torpedo, is the ASW weapon for surface ships and ASW fixed-wing and rotary-wing aircraft.

In September 1996, the Mk-46 Mod 5A (S) Service Life Extension Program (SLEP) LWT was introduced to the US Navy fleet in September 1996. It has improved counter-countermeasure performance, enhanced target acquisition, a bottom-avoidance preset, and improved maintainability and reliability.

The new generation Mk54 LWT was created

by combining the homing and warhead portions of the Mk50 LWT and the propulsion unit of the Mk46, improved for better performance in shallow water, and with the addition of commercial off-the-shelf (COTS) technology to further reduce costs. It shares much of the software and computer hardware of the Mk48 ADCAP HWT, based around a custom PowerPC 603e chip. The Mk46 LWTs are being replaced in the US torpedo inventory by the Mk54. The Mk54 is the first all-digital lightweight torpedo, significantly enhancing options for weapon employment. The use of COTS technology and open-systems architecture enables the Mk54 to be cost-effectively upgraded to incorporate the latest technology to counter evolving threats. The Mk54 can be deployed from a surface ship, helicopter, or fixed wing aircraft to track, classify and attack underwater targets. It uses sophisticated processing algorithms to

analyze the information, edit out false targets or countermeasures, and then pursue identified threats. The Mk54 Mod 0 reached IOC in 2004. Under an FMS contract that notified to US Congress on April 20, 2007 Turkey has procured a total of 100 Mk54 Mod 0 LWTs with an estimated cost of US\$105 Million. Deliveries took place in 2012 and 2013 in two batches each contains 50 torpedoes. Each Mk54 Mod 0 LWT is estimated to cost around US\$1 Million.

The Mk54 Mod 1 adds a new sonar array assembly that provides higher resolution than previous Mk54 Mod 0 and improved processing capability. The Mk54 Mod 1 uses Advanced Processor Build 5 (APB 5) software that shares many components with the APB 5 variant of the Mk48 HWT. The Mk54 MOD 1 LWT Conversion Kit includes a 112-element sonar array, transmitter, receiver, Processor Group Assembly (PGA), Modular

Recording and Exercise Control System Second generation (MRECS2), and associated cables. On July 9, 2020, the U.S. State Department approved the sale of Mk54 LWTs to Germany and Belgium. The German Foreign Military Sale (FMS) contract worth US\$130 Million and covers the procurement of 64 Mk54 All Up Round LWTs and 10 Mk54 Conversion Kits to be used with fleet exercise sections as Mk54 Exercise Torpedoes. The Belgian FMS contract valued US\$33.3 Million and includes supply of 29 All Up Round Mk54 Mod 0 LWTs. The Mk54 Mod 2 is expected to deliver in FY26. The Mk54 Mod 2 will have a new propulsion system and warhead.

Leonardo Next Generation Black Shark Advanced (BSA) & Black Shark HWTs

Under a Euro87.5 Million contract the NSP/BSA (Nuovo Siluro Pesante/ Black Shark Advanced) long-range, multi-purpose, Heavyweight Torpedo was developed by Whitehead Sistemi Subacquei S.p.A. (WASS), a subsidiary of Leonardo, as an evolution of the original Black Shark HWT that entered service in 2004 and can be launched in "Push Out" and "Swim Out" modes at any operational depth of a submarine. The 6.3m long, 533mm diameter

wire-guided torpedo is designed for a life of more than 20 years and can be deployed on attack submarines, midget submarines, surface vessels or stations ashore to defend it against any surface or underwater targets. Made in Italy at Leonardo's Livorno plant the BSA HWT integrates an innovative energy production section that can be optimized, according to the use of the system, for training or operational purposes. When the BSA is used for training activities, a newly developed rechargeable battery is used that allows a higher number of launches - up to one hundred - compared to that of previous versions, providing significant cost savings.

On January 28, 2014 the first test launch of BSA HWT was conducted from the Italian Navy's SSK Scire' (S 527), a Series 1 U212A Todaro Class attack submarine of Italian Navy, in the La Spezia Gulf. The torpedo launched in "Push Out" mode (water ram expulsion system, which ejects the torpedo by means high water-pressure), was equipped in a totally innovative way, thanks to the new Lithium-Polymer Battery. On June 19, 2014 second test launch of BSA HWT was conducted again from SSK Scire' (S 527) submarine. Following the completion of development and sea trials

in June 2018 Leonardo secured a contract to supply next generation Black Shark Advanced (BSA) Heavyweight



Leonardo's Black Shark Advanced HWT is loaded into the Italian Navy U212A Submarine

Torpedoes and associated logistic support services to equip the Italian Navy's Second Batch U212A Submarines. The BSA HWT will significantly increase the ASW and ASuW capability of the Italian Navy. Over the next few years, the BSA HWT is replacing the old A-184 HWTs in the Italian Navy inventory. Italian Navy is expected to procure around 80 BSA HWTs and first deliveries shall take place in 2020. The BSA HWT is also to be deployed on board new Italian Navy PPA vessels (Full version), with two launchers under the flight deck.

Designed to operate in deep and coastal waters the Black Shark HWT is already acquired by many

countries including Italy, Chile, Ecuador, Indonesia, Malaysia, Portugal, and Singapore for their U209, U214, U212 and Scorpene submarines. More than 100 Black Shark HWT have been manufactured and delivered. The acoustic head of the Black Shark, named ASTRA (Advanced Sonar Transmitting and Receiving Architecture), is a state of the art active and passive acoustic head for modern torpedoes, which represents the latest effort made by Leonardo. The Advanced ASTRA active and passive acoustic head features improved signal processing with real-time multiple digital processing and incorporates a new flat, steered, multibeam phased array which offers increased bandwidth in

two operating frequencies - 15kHz medium (MF) passive only and 30kHz active and passive high frequency (HF). The HF mode provides high resolution over a short range while the MF mode provides long-range acquisition. The seeker can operate simultaneously in both frequencies in passive mode, allowing the torpedo to discriminate between signals from the real target and signals from acoustic countermeasure decoys. The torpedo is fitted with STANAG 4439 and MURAT-2 insensitive munition explosive warhead and can track the targets in both acoustic and wake modes. The Black Shark HWT is powered by an electrical propulsion system, which is based on a Silver Oxide and Aluminum (AgO-Al) battery. Developed by Saft, the AgO-Al batteries are provided with high energy density and high electrolyte conductivity offering maximum safety and storage life of up to 12 years. The system delivers twice the power and energy of a standard Zinc/Silver Oxide (Ag-Zn) battery ■



A Black Shark Torpedo being loaded onto a Scorpene Class Submarine