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Jane's INTERNATIONAL DEFENCE REVIEW

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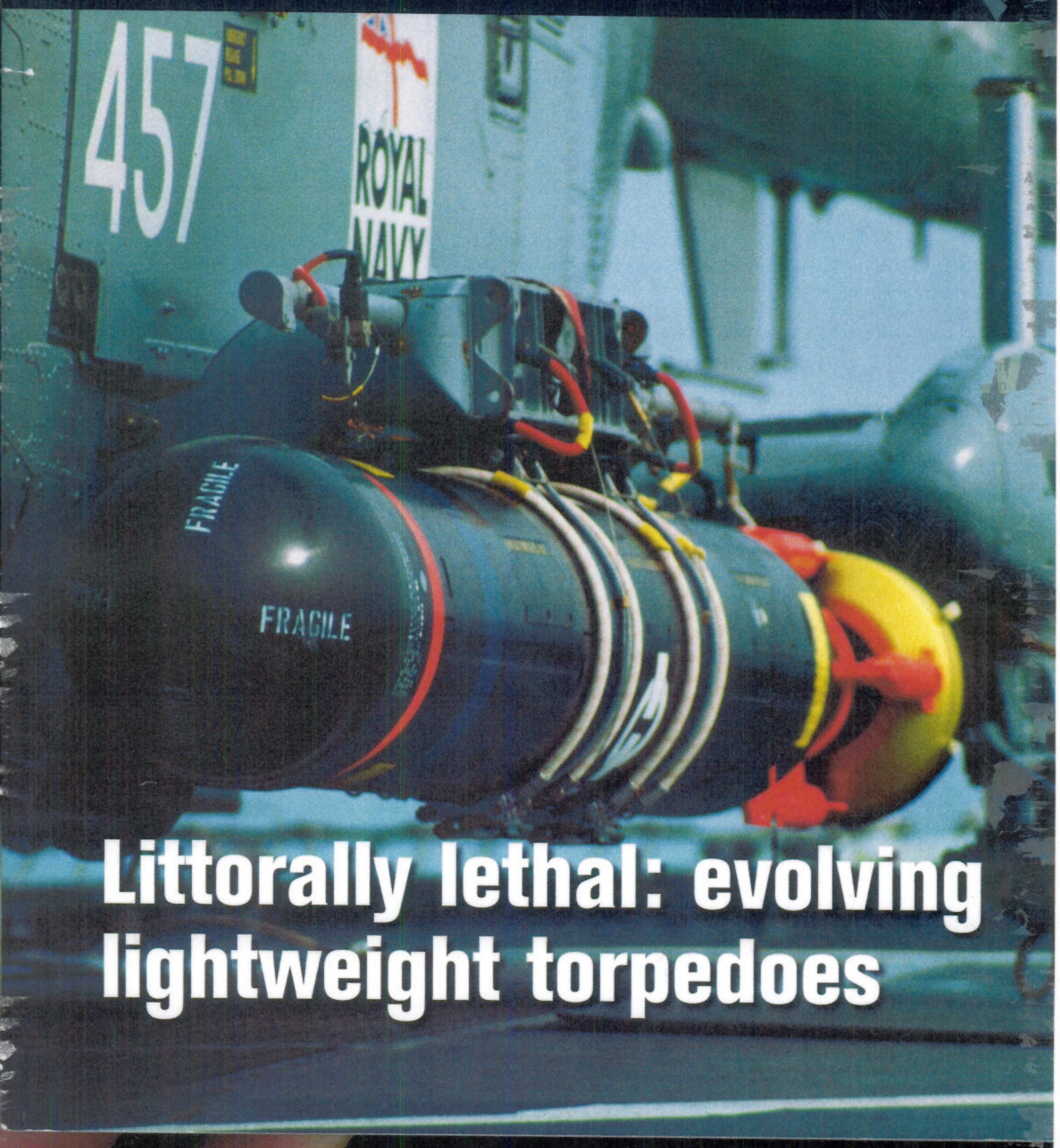


Littorally lethal: evolving lightweight torpedoes

Lightweight contenders: torpedoes dive in to meet littoral challenge

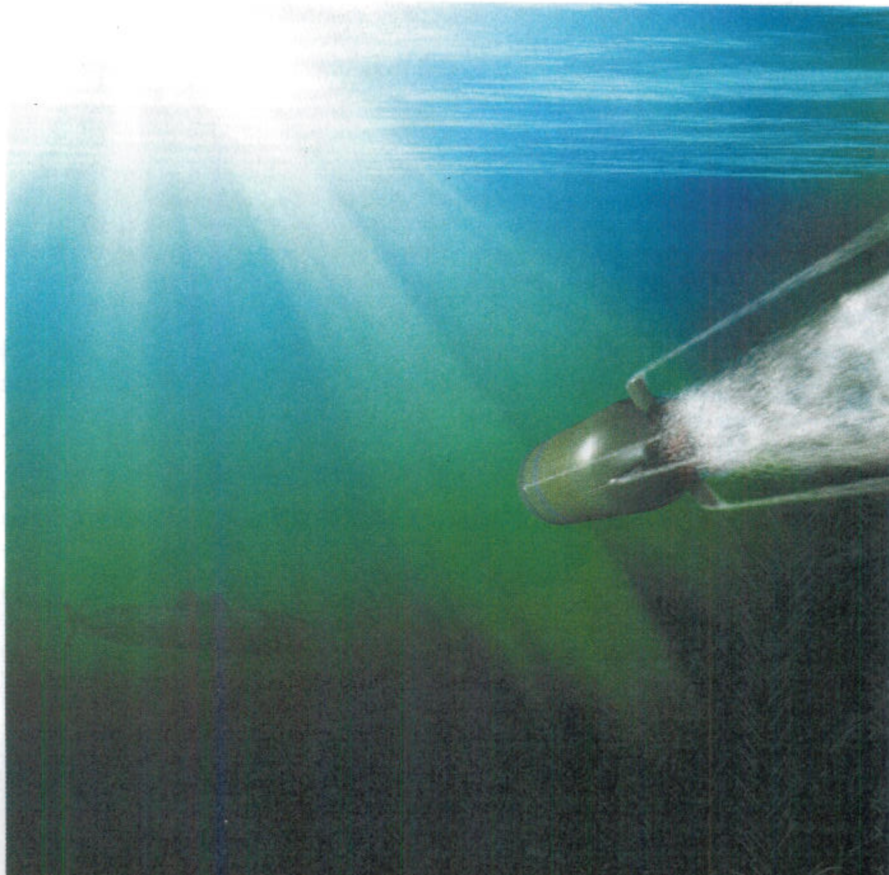
Contemporary torpedo development is being driven by the need to prosecute quiet diesel submarines in shallow waters. **Richard Scott** surveys lightweight torpedo programmes worldwide

Two decades is a long time in the world of underwater weapons. In the mid-1980s it was the Cold War requirement to acquire and prosecute fast, deep-diving nuclear-powered boats that was driving lightweight torpedo design and technology development.

Today, with that period of anti-submarine warfare (ASW) consigned to history, the lightweight torpedo is being honed to take on a quite different threat: the quiet, stopped or slow-moving conventional submarine operating in the shallow – and acoustically poor – waters of the littoral.

This sea change is spurring both upgrades and new developments to counter the challenge posed by reduced target echo strength submarines and sophisticated acoustic countermeasures, set amid the high clutter and reverberation encountered in shallow waters.

With a number of legacy weapons – notably the ubiquitous Mk 46 line – at the limit of their development spiral, the coming years will see a trio of new-generation NATO standard 324 mm lightweight torpedoes vying for orders in the international marketplace. Each has a Cold War heritage, and is claimed to afford superior performance against quiet targets and advanced countermeasures in the shallow-water ASW environments encountered in the littoral, as well as retaining the capability to prosecute blue-water threats.



Modern lightweight torpedoes are being optimised to meet the threat from quiet diesel-electric submarines running slow or stopped in shallow waters.

Raytheon: 1192434

The Franco-Italian Eurotorp GEIE – an economic interest grouping comprising Whitehead Alenia Sistemi Subacquei (WASS), DCNS and Thales – began production deliveries of the MU90 Impact lightweight torpedo in 2001, concluding a protracted engineering gestation dating back to 1991, when France and Italy merged their respective Murene and A290 torpedo development programmes. Eurotorp was established in 1993 by what was Whitehead (50 per cent), DCN (26 per cent) and Thomson Sintra Activites Sous-Marins (24 per cent).

Under work share arrangements, French industry – through Thales Underwater Systems and DCNS St Tropez – has taken responsibility for the homing head, warhead and battery, with WASS taking the lead on guidance and propulsion. Development of tactical software has been shared by WASS and DCNS. In addition, WASS has developed the exercise head section, while DCNS is responsible for the practice delivery torpedo.

The consortium, which claims MU90 as the world's only third-generation lightweight torpedo, has received orders for more than 1,000 weapons to date. France and Italy placed a multiyear joint production order through the French Délégation Générale pour l'Armement in December 1997.

Worth in excess of USD620 million, the combined procurement covers the delivery of about 300 warshot rounds to each country's navy. The German order was let in early 1998 to the UAW consortium – an industrial framework bringing together Atlas Elektronik and Eurotorp.

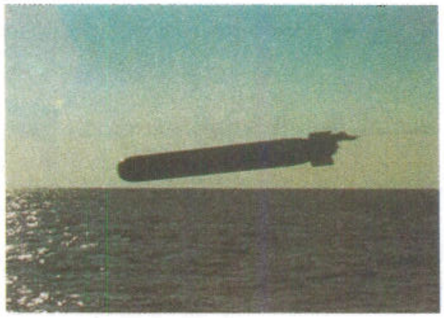
Denmark became the fourth customer for MU90 in 1999 when it signed a contract worth more than EUR23 million (USD31.8 million) covering the supply of torpedoes and four launcher shipsets for Standard Flex 300 multirole surface combatants. A EUR30 million contract for Poland – covering torpedoes, airborne and shipborne launching systems and integrated logistic support – was signed in December 2001 through local industry partner Metalexport.

Under Joint Project 2070 – Project Djimindi – the Australian Defence Force (ADF) plans to replace its current stock of Mk 46 Mod 1 and Mod 5A(SW) lightweight torpedoes with the MU90, which will be delivered under an alliance agreement between

Eurotorp and Thales Underwater Systems. Platforms due to receive MU90 are Royal Australian Air Force AP-3C Orion maritime patrol aircraft, and Royal Australian Navy Adelaide- and ANZAC-class frigates, and their embarked S-70B-2 Seahawk helicopters and SH-2G(A) Super Seasprite helicopters.

Optimum speed

MU90 uses a shrouded pumpjet propulsor driven by a 120 kW brushless variable-speed motor supplied by Atlas Elektronik. Power is delivered from a SAFT silver-oxide aluminium seawater battery (using a sodium dioxide electrolyte).



■ A surface ship launch of the MU90 Impact lightweight torpedo.

Tactical speed ranges from 29 kt to a maximum in excess of 50 kt, with the torpedo's tactical logic automatically selecting the optimum speed (in steps of 1 kt) according to the specific engagement scenario. Range is traded according to speed, from 12,000 m at maximum speed to more than 25,000 m at its minimum.

The MU90 acoustic homing head seeker features 47 pre-formed transmission and 33 pre-formed reception beams for a total acoustic coverage of 120° horizontal and 70° vertical. Operating across six different frequency bands – with a bandwidth significantly above 10 kHz – the acoustic head's parallel processing and simultaneous acoustic mode operations allow the mapping of up to 10 simultaneous targets, an active detection distance in excess of 2,500 m and high immunity to acoustic countermeasures.

According to Eurotorp, the synergy of homing system and propulsion allows MU90 to engage targets at ranges beyond 15,000 m and achieve an overall probability of kill in excess of 74 per cent. The group adds that Impact is effective against targets in waters as shallow as 25 m (periscope depth) down to beyond 1,000 m. The shaped charge Insensitive Munition (IM) warhead, using V350 explosive, is designed to penetrate double-hulled submarines.

About 20 pre-production rounds were produced during the programme's development phase. At-sea qualification trials, involving more than 100 in-water runs, began in mid-1994 and were successfully completed in July 1996. A further series of more than 50 in-water tests was conducted as part of an operational evaluation extending from 1997 to mid-2001. Production deliveries started in late 2001.

A Torpedo Reliability Demonstration Programme (TRDP) was subsequently launched to remedy a production engineering problem affecting the powder compound used to seed the electrolyte in the seawater battery. Improvements developed under the TRDP, and subject to two years of laboratory and at-sea testing, have been embodied in the Block 1 modification kit.

The TRDP was concluded in October 2006, when the French and Italian defence ministries gave approval for Eurotorp to re-start volume production. Weapons al-

NUWC LIGHT testbed demonstrates novel electric propulsion system

The US Naval Undersea Warfare Center (NUWC) Newport Division has since 2002 been developing a new electric propulsion system, based on a new-design Integrated Motor Propulsor (IMP) and rechargeable Lithium Ion (Li Ion) batteries, as part of the NUWC LIGHT lightweight torpedo testbed.

The new electric propulsion system has been integrated with the guidance and control functionality of a Mk 54 front end.

According to NUWC, rechargeable battery technology has progressed to the point that a viable fleet exercise lightweight torpedo propulsion system can be developed. However, this requires "new and novel approaches to technology in several areas," with the NUWC LIGHT vehicle serving to demonstrate these new technologies.

The IMP – developed in-house by NUWC – uses an outboard permanent magnet motor coupled to a rim-driven propulsor to deliver significant reductions in weight and volume for comparable performance versus conventional electric propulsion. It provides the NUWC LIGHT vehicle with a very power-dense propulsion system, allowing more volume to be allocated for energy – a critical performance feature with the achievable energy density in Li Ion technology currently available.

Two IMP systems have been built to date. The current design features a 150 hp rotor/stator set with a completely integrated power control suite. The motor controller utilises sensorless control to drive the IMP, thereby eliminating the need for a shaft position sensor and a through-hull drive shaft.

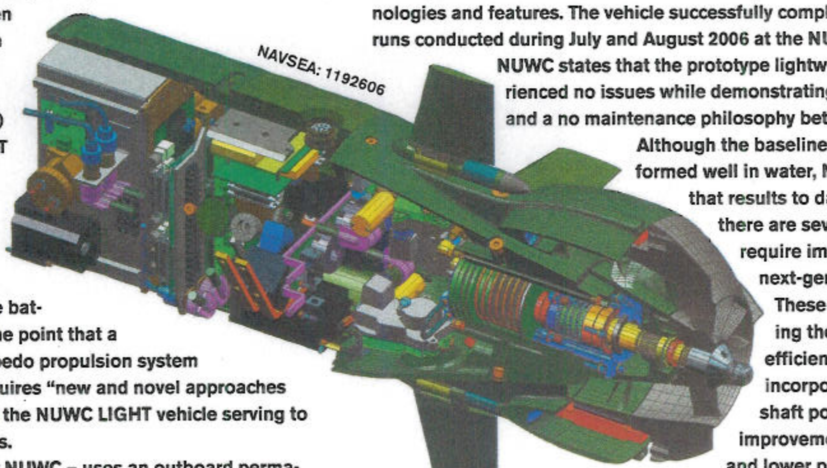
Yardney Technical Products has developed the high-density Li Ion rechargeable battery system, consisting of five discrete modules each containing 20 cells. These Li Ion modules can be configured to provide a battery of anywhere between 20 and 100 cells – in 20-cell, 60 V increments – corresponding to a nominal voltage range of 60 V to 300 V. Battery modules have been discharged in land-based testing up to 250 ADC and up to 200 ADC during in-water testing.

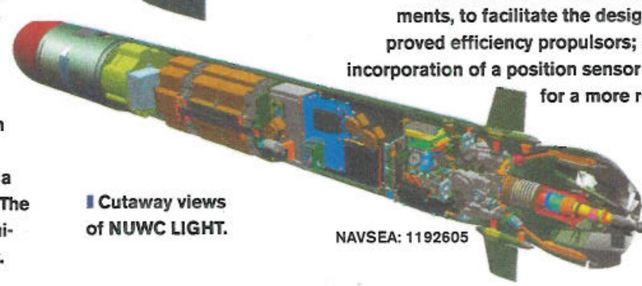
A prototype version of the testbed has been successfully integrated at NUWC Division Newport, where a buoyant vehicle configuration was developed to concentrate the in-water testing on validating critical technologies and features. The vehicle successfully completed all 39 in-water runs conducted during July and August 2006 at the NUWC Newport range.

NUWC states that the prototype lightweight testbed "experienced no issues while demonstrating ease of turnaround and a no maintenance philosophy between runs".

Although the baseline system has performed well in water, NUWC acknowledges that results to date indicate that there are several areas that require improvement in the next-generation design. These include improving the hydrodynamic efficiency of the propulsor; incorporating an absolute shaft position sensor; improvements in magnetics and lower power density requirements, to facilitate the design of improved efficiency propulsors; and the incorporation of a position sensor to allow for a more robust speed control algorithm and more stable high RPM operation. A second-generation propulsion battery for the NUWC LIGHT vehicle is currently being developed.

NUWC has previously identified a number of areas requiring improvement, notably extending the high rate discharge limits of the cells, reducing the overall voltage drop of the battery assembly, improving the cell to cell voltage drop characteristics and more robust electronics performance during discharge.



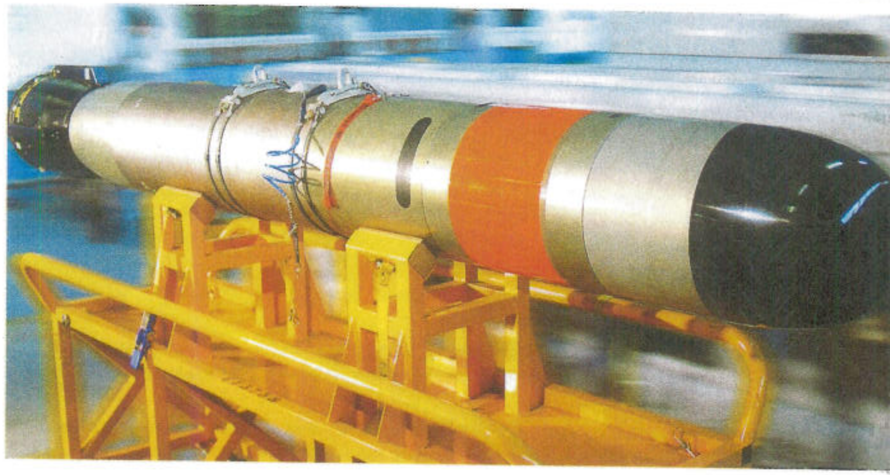


■ Cutaway views of NUWC LIGHT.

ready delivered will be recalled to have the Block 1 engineering change back fitted.

The MU90 Block 1 modification has been the subject of numerous in-water tests, including one trial where a target was struck at a depth of more than 800 m after the torpedo had travelled at an average speed of more than 45 kt. The most recent acceptance tests, which ran at the St Tropez-based Underwater Weapons facility of DCNS, concluded in May 2007. The French Navy was due to declare MU90 operational by late July.

Eurotorp is currently examining a high-altitude deployment option for MU90 from either maritime patrol aircraft or fast jets; the weapon is already cleared to a maximum deployment speed of 630 kt. The principal change is the inclusion of a more powerful, longer-endurance battery to power the torpedo during flight. The company has also studied the possibility of adding a wing kit to offer extended range and greater precision in weapon delivery.



Eurotorp: 1192613

A MU90 on its test stand. Developments may see high altitude and 'disabling' versions deployed.

Disable or kill

Another development being pursued is the use of MU90 as part of a coastal protection system, using either fixed or mobile launchers. Eurotorp suggests that requirements for such a capability are emerging in response to the threat posed by midget submarines and swimmer delivery vehicles.

The company has also engineered a 'non-lethal' modification to the MU90 tactical logic specifically designed to stop – rather than sink – surface targets. A demonstration of this functionality, which targets the propulsion and propulsor at the aft of the vessel, is planned for 2008.

An anti-torpedo MU90 hard-kill (HK) variant has been studied by Eurotorp. The company says that the MU90 HK would use a compact charge warhead, replacing the current shaped charge, and modified tactical software. Customer-funded trials of the variant are planned.

Eurotorp is also responsible for the continuing production and marketing of the A244/S Mod 1 and Mod 3 lightweight torpedoes originally developed by WASS. Variants of the A244/S are in service with more than 15 navies, including those of China, Greece, India, Indonesia, Italy, Malaysia, Peru, Singapore, Turkey and the United Arab Emirates. An upgrade kit is being offered to bring existing Mod 0 and Mod 1 variants up to the definitive Mod 3 standard, affording improved speed, endurance and shallow water target discrimination capability.

The US Navy (USN) achieved an initial operational capability with the Mk 54 Mod 0 lightweight ASW torpedo in 2004 and approved full-rate production in the same year. The USN plans to acquire about 1,500 Mk 54 torpedoes to achieve a full operational capability in Fiscal Year 2011 (FY11).

Combining proven hardware and software from existing USN lightweight and heavyweight weapons with selected com-

Eurotorp: 1192614

Variants of the A244/S torpedo have been sold to more than 15 navies. Here the weapon is being carried by an AB 212 helicopter.

mercial off-the-shelf (COTS) signal processing technology, the Mk 54 will eventually replace both the Mk 46 and Mk 50 to become the sole lightweight ASW weapon in the USN inventory. Its genesis dates back to a cost and feasibility study commissioned in 1993 to assess the practicality of merging the best aspects of the Mk 46 – its reliability and inexpensive propulsion system – with the sophisticated electronics of the Mk 50 to create a Lightweight Hybrid Torpedo (LHT).

A subsequent cost and operational effectiveness analysis concluded that a mixed lightweight torpedo inventory, comprising the Mk 50, Mk 46 Mod 5A(S), Mk 46 Mod 5A(SW) and LHT offered the most cost-effective way forward to meet the evolving littoral threat. As a result, the entire Mk 46 Mod 5 inventory and a substantial portion of the Mk 46 Mod 5A(S) inventory have been drawn down to provide assets for the Mk 46 Mod 5A(SW) upgrade and LHT remanufacture programmes.

The US Naval Sea Systems Command (NAVSEA) awarded what is now Raytheon Integrated Defense Systems a USD13.2 million Engineering and Manufacturing Development contract in June 1996 to develop the LHT. Subsequently designated as the Mk 54, the weapon mixes components from existing Mk 46, Mk 48 ADCAP and Mk 50 weapons with selected COTS electronics.

Under the management of NAVSEA's Undersea Weapons Program Office (PMS 404) the Mk 54 is being developed by a team comprising Raytheon (developing new torpedo components and the weapon hardware kit) and the Naval Undersea Warfare Center (NUWC) establishments at Newport (system software and hardware engineering development) and Keyport (supporting in-water testing).

Principal subsystems include the nose array and transmitter from the Mk 50, the Mk 103 warhead and Otto II-fuelled propulsion system from the Mk 46 (the latter modified to accept the Mk 50's thermal battery and dual-winding alternator), and the variable speed control valve from the Mk 48 ADCAP heavyweight. Major COTS components comprise a digital receiver, depth sensor, and signal and tactical processors running tactical software sharing significant commonality with the Mk 48 Mod 6. The Mk 54 Mod 0 also requires a new shell and power converter.

Derived from the unit previously demonstrated on the Mk 50 lightweight, the sonar system uses a 52-element array arranged in eight horizontal and eight vertical staves to provide for a superior narrow-beam capability. Up to 62 independent beams can be steered in both the horizontal and vertical planes. A fully digital programmable beam former provides the flexibility to select and steer narrow beams for optimum coverage according to the engagement scenario.

The transmitter, also proven in the Mk 50, can generate complex signals, including frequency-modulated and pure tone waveforms. A programmable dual-band receiver generates multiple receive beams to enable extensive volume coverage.

Guidance and control is based on a COTS-based open architecture Common Torpedo Processor (CTP) and a control group leveraging Mk 48 ADCAP technology. The CTP, also common to Mk 48 ADCAP, consists of a set of 6U VME64 boards for guidance functions (three Mizar Octal sonar signal

Region and Morteploteknika develop MTT for Paket system

Russia's Region State Research and Production Enterprise, which is part of the Tactical Missiles Corporation, is developing a new-generation lightweight torpedo known as MTT as part of the Paket anti-submarine/anti-torpedo system. Region is working in conjunction with the Morteploteknika Research and Design Institute. The same weapon may also be launched from submarines, aircraft or a long-range guided weapon.

Paket is described by Region as a compact, surface ship-mounted anti-submarine/anti-torpedo system comprising a control system, a torpedo detection and classification sonar subsystem – supplied by Aquamarin – rotating or fixed launchers, the MTT torpedo, a hard-kill anti-torpedo torpedo and associated transport/launch containers. Weighing about 385 kg, the MTT is 3.2 m in length and 324 mm in diameter.

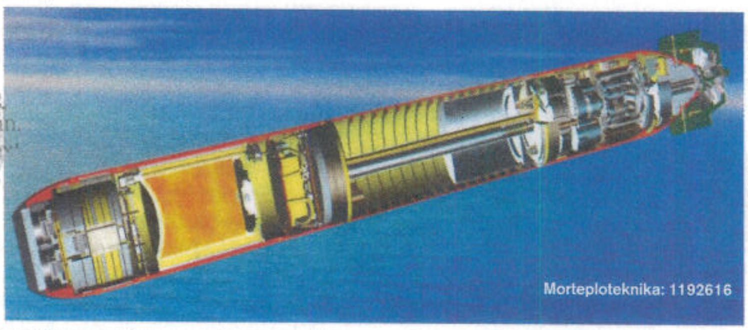
The Morteploteknika Research and Design Institute, which is part of Gidropribor, is responsible for the aft power and propulsion section of the MTT weapon. This utilises an Otto-fuelled piston engine driving a pumpjet propulsor.

MTT can operate at one of two speed settings – 30 kt or 50 kt – and is effective at ranges of up to 10,000 m and depths down to 600 m, according to Region. The company adds that the weapon can be fired in a minimum water depth of 40 m.

Region is responsible for the 'front end' of the weapon, comprising the warhead (equivalent to 70 kg of TNT), guidance and control section, tactical processor and active/passive acoustic homing head. The latter is credited with a maximum detection range of up to 2,500 m at depths below 200 m, reducing to a maximum of 1,200 m at shallower depths.

First in-water trials of MTT were conducted in 2006 according to Morteploteknika. Further development trials are continuing, with the Russian Federation Navy expected to begin state testing in 2008.

Morteploteknika: 1192615



Morteploteknika: 1192616

(Above) In-water firings of MTT undertaken in April 2007.

(Left) MTT cutaway view.

processing cards and a single tactical data processing card), a custom interface card and a solid-state recorder board. A seventh slot is left spare for expansion.

The control group assembly uses a digital autopilot leveraged from Mk 48 ADCAP technology using a custom PowerPC 603E data processing chip as its core processor, an improved Mk 50 attitude measurement unit and a COTS depth sensor.

KVH Industries is supplying its fibre-optic gyro-based TG-6000 inertial measurement unit for the Mk 54 programme. This followed extensive engineering and performance testing during 2004 and 2005.

In-water testing of the Mk 54 Mod 0 started in mid-1999. Early testing validated the dynamic performance of the weapon and demonstrated sonar functionality.

Capability has been progressively built up through a series of iterative software releases, with more than 200 in-water runs performed to date.

A technical evaluation began in early 2002 and ran through to February 2003 using early production articles from a first low-rate initial production (LRIP1) contract. In-water tests were conducted by the USN off the coast of the US and in the Caribbean to evaluate performance in a range of scenarios.

Appropriations in the FY03 defence budget saw additional in-water firings added to the Mk 54 integrated test plan to meet the requirements of Commander Operational Test and Evaluation Force, resulting in an extended operational evaluation (OPEVAL) and delaying initial operational capability (IOC) from FY03 to FY04.

In parallel, work was instituted to resolve testing problems linked to tactical and signal processing software, continue the development of ancillary hardware – including the fleet exercise section and Mk 695 automatic test equipment – and better align lightweight and heavyweight torpedo hardware and software baselines.

OPEVAL began in April 2003 and concluded in early May 2004. The extended nature of the OPEVAL period was in part due to the non-availability of live submarine target assets and also the requirement to effect repairs to the diesel test submarine USS *Dolphin* following an earlier fire.

Rapid improvements

FY06 funding supports a Pre-Planned Product Improvement Program (P3I) for the Mk 54 torpedo using a hardware spiral development acquisition approach and Advanced Processor Build (APB) software upgrades to enable rapid hardware and software improvements.

According to the US Department of Defense, the P3I programme will focus on common lightweight/heavyweight hardware and software architecture enhancements, Mk 54 integration in Vertical Launch ASROC, potential IM warhead capability improvement, a new broadband array and a fully open architecture design.

It is intended to incorporate Mk 48 ADCAP heavyweight torpedo algorithms and tactical software into the Mk 54 to create a Common Torpedo Development programme. As such, future APB software builds will utilise the common torpedo software to deliver software and tactics to both the Mk 48 ADCAP and Mk 54 weapons.

Another initiative that has relevance to Mk 54 development is the High Altitude ASW Weapons Concept (HAAWC), for which the USN awarded Lockheed Martin Missiles and Fire Control a 12-month, USD3 million deal in June 2006 to demonstrate delivery of the Mk 54 from a P-3C aircraft operating at an altitude of about 20,000 ft. Lockheed Martin's HAAWC concept employs the LongShot wing adapter kit to allow the launch of torpedoes from high altitudes and long standoff ranges.

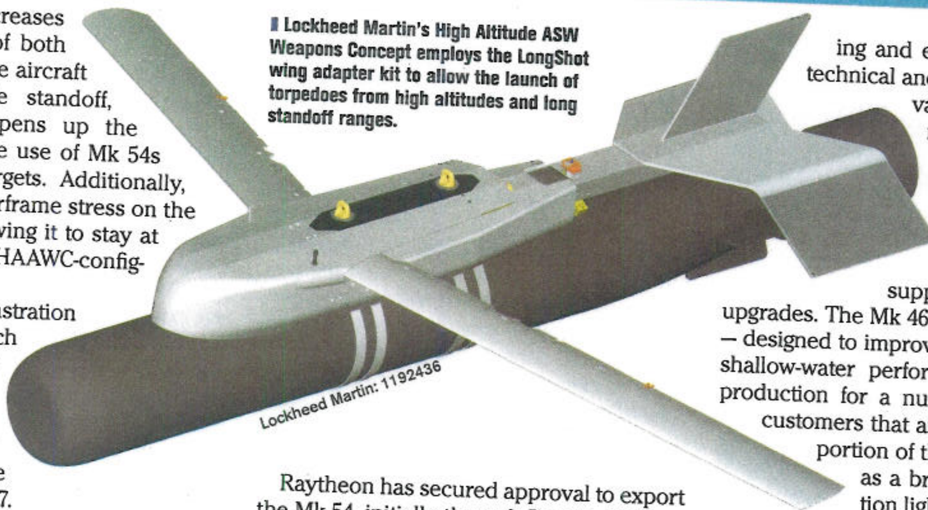
HAAWC is intended to improve the delivery accuracy and shorten the engagement time of the air-launched Mk 54 tor-

US Navy: 1192435

A Mk 54 lightweight torpedo being launched from a US Navy SH-60F helicopter.

pedo. It also increases the survivability of both the aircrew and the aircraft by providing safe standoff, and potentially opens up the possibility of future use of Mk 54s against surface targets. Additionally, HAAWC reduces airframe stress on the P-3 aircraft by allowing it to stay at altitude to launch HAAWC-configured torpedoes.

An initial demonstration high-altitude launch was conducted at the Atlantic Undersea Test and Evaluation Center (AUTEC) range in the Bahamas in May 2007.



Lockheed Martin's High Altitude ASW Weapons Concept employs the LongShot wing adapter kit to allow the launch of torpedoes from high altitudes and long standoff ranges.

In this single point concept demonstration, a Mk 54 exercise torpedo was launched from the internal weapon bay of a P-3C aircraft that was flying above 8,000 ft.

After executing a turn at a pre-determined waypoint, the HAAWC-configured torpedo navigated via GPS to its normal launch altitude close to the surface. Once at the desired release point, the LongShot wing kit self-jettisoned, allowing the Mk 54 to enter the water.

The HAAWC programme is due to transition into a system design and development phase, with full developmental testing scheduled to start in FY09.

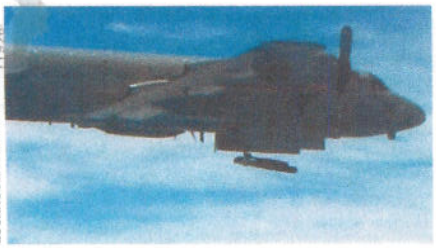
Raytheon has secured approval to export the Mk 54, initially through Foreign Military Sales (FMS), and, in conjunction with the USN, is primarily targeting existing Mk 46 customers on the grounds that launcher hardware compatibility and extant maintenance infrastructure simplifies the transition to the Mk 54. International customers will have the option of purchasing all-up rounds or refurbishment kits to upgrade existing Mk 46 stocks.

Turkey is set to become the first international customer for the Mk 54, with the US Defense Security Co-operation Agency notifying Congress in April 2007 of a potential FMS of 100 Mk 54 all-up-round warshot torpedoes, plus associated test, engineering and exercise hardware, and technical and logistic support. Total value is put at USD105 million.

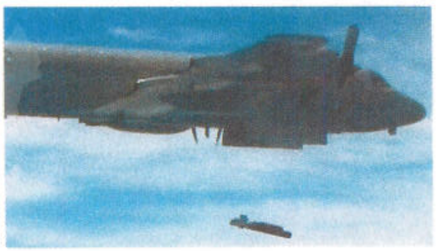
While Mk 54 represents the future for the USN, Raytheon and NUWC Keyport are continuing to support Mk 46 stocks and upgrades. The Mk 46 Mod 5A(SW) upgrade – designed to improve target detection and shallow-water performance – remains in production for a number of international customers that are upgrading a limited portion of their residual warstock as a bridge to a new generation lightweight.

BAE Systems Underwater Systems was awarded a GBP441 million (USD907.4 million) UK Ministry of Defence (MoD) contract in February 2003 for the Main Production Order and In-Service Support (MPO/ISS) of the Sting Ray Mod 1 lightweight torpedo. The upgrade programme, to meet the requirements of the Sting Ray Life Extension (SRLE) programme, is intended to improve the weapon's effectiveness against quiet submarine threats in shallow waters and prolong service life out to at least 2025.

Designed to meet the requirements of Staff Requirement (Sea/Air) 7589, Sting Ray Mod 1 is an extensive upgrade of the Sting Ray Mod 0 weapon – in service with the UK


Lockheed Martin: 1192600


Lockheed Martin: 1192601


Lockheed Martin: 1192602

Video stills showing the release of a demonstration high-altitude launch of Lockheed Martin's LongShot-equipped HAAWC. This was conducted from a P-3C at the AUTEC range in the Bahamas in May 2007.

Royal Navy (RN) and Royal Air Force (RAF) since 1983. About 2,500 Sting Ray Mod 0 weapons were originally produced for the RN and RAF, with quantities also sold to Egypt, Norway, Romania and Thailand.

The Mod 1 weapon marries the dynamic and electric propulsion features of the existing weapon with an upgraded homing system (addressing signal processing, navigation and guidance) based on modern high-level processing hardware that will enable future capability enhancements to be rapidly implemented through new software-based functionality. Other features include a modified front-end array, a new 'soft-start' motor controller, and repackaged nose electronics to increase warhead directional effect. An associated torpedo refurbishment programme is designed to improve through-life supportability to extend service life and minimise cost of ownership.

Sting Ray Mod 1 software is implemented in Ada95 throughout. BAE Systems has taken responsibility for the development of new tactical algorithms, including functionality pulled from applied research previously undertaken by QinetiQ.

As prime contractor for the Sting Ray Mod 1 MPO/ISS programme, BAE Systems takes overall responsibility for delivering the weapon's operational performance, and will also manage the complete supply chain with the majority of manufacture being drawn from domestic suppliers. DSDA Gosport has entered into a subcontract partnership with BAE Systems to convert, integrate and maintain existing Sting Ray torpedoes to Mod 1 standard.

Hardware changes

Key hardware changes incorporated in the Mod 1 weapon include a new control sensor unit and inertial measurement unit using the Northrop Grumman Navigation Systems Division LN-200 inertial measurement device, a digital signal processing unit, an enhanced pre-setter, a new safety and arming unit, a new digital nose unit and array (BAE Systems has re-started transducer production at its Waterlooville facility) and new motor controller electronics. The main items retained from the Mod 0 are the impact piston, motor, rotors, battery voltage regulator and the torpedo hull itself.

SAFT has been contracted to manufacture new magnesium silver chloride saltwater batteries. Other subcontractors include BAE Systems Integrated System Technologies (processor boards), Polaron Schaevitz (depth sensor), Volex Ionix (wiring harness and cables), Semelab (power hybrids), Ultra Electronics (fluxgate magnetometer), Goodrich (5000/6000 sections), Racal Instruments (automatic test equipment) and JJ Churchill (machined components).

A GBP109 million contract for the full development and pre-production phase of the Sting Ray Mod 1 modernisation was awarded to BAE Systems in July 1996. During this phase, a number of 'A' and 'B' standard pre-production torpedoes have been used to demonstrate Mod 1 performance through 18 separate trials events.

Alongside in-water trials, the performance of Sting Ray Mod 1 has been validated by an extensive programme of real-time hardware-in-the-loop simulations. Contract acceptance simulations – comprising 10,000 separate runs – began in late July 2003 and results were presented to the customer in October of that year.

Main production activities began in late 2004. A series of production qualification trials culminated with the testing of six torpedoes at the British Underwater Trials Evaluation Centre in November 2005.

A first batch of 100 torpedoes was delivered in June 2006 to meet the in-service date (ISD) requirement. The actual ISD was achieved three weeks later than planned, as a minor technical problem that came to light during production qualification trials resulted in a short delay to the production run of the weapon.

A second batch of 120 weapons was delivered earlier in 2007 and a third batch is currently being manufactured, with delivery due in early 2008. Deliveries will extend through to 2010 when production is expected to be completed.

The next key milestone is an annual in-water trial in the final quarter of 2007. This is a production acceptance trial that provides assurance the performance and reliability of the Mod 1 torpedo is maintained.

As a result of a study in February 2001 investigating a less sensitive warhead for the life-extended Sting Ray, a new shaped-charge IM warhead was included as part of the SRLE programme to comply with new departmental safety policy. However, this programme was subsequently separated from the Mod 1 upgrade programme and proceeds in parallel.

Assessment Phase 1, which was completed in July 2002, evaluated three different design solutions. TDW (now part of MBDA Missile Systems) was subsequently down selected as principal sub-contractor for Assessment Phase 2.

IM warhead development has proved challenging. The initial main charge materiel used by TDW demonstrated high insensitivity but did not deliver the required performance. However, by the end of 2003 the company had refined a design solution that offered the required insensitivity without compromising performance.

A design review was completed in January 2004 and extensive primary trials of the new IM warhead have now been completed. These have included land-based and underwater firings and a range of compliance tests including bullet attack, slow heating, fast heating, sympathetic reaction, fragment impact, a 12 m drop test and a fire test.

BAE Systems states: "The development of a new IM warhead for the Sting Ray Mod 1 torpedo has been successfully completed ... [the] development programme has included a full IM proving programme with the results endorsed by the UK IMAP [Insensitive Munition Assessment Panel], and we are currently concluding extensive performance, environmental and safety tests."

A qualification and production contract for the new IM warhead is expected in late 2007. This will cover the modification of the full Sting Ray Mod 1 warstock to IM standard.

Under a contract awarded to BAE Systems in mid-2006, a team of systems and software engineers is developing a range of tactical and signal processing software enhancements to improve shallow water capability against small targets. The award, worth almost GBP4 million and contracted as an amendment to the Sting Ray Mod 1 MPO, is intended to pursue selected technology insertions as part of a future capability road map agreed with the customer. It also seeks to sustain the sovereign intellectual base.

Enhancements have been trialled on a simulator prior to in-water testing. Insertion into the Mod 1 production programme is scheduled to take effect by mid-2008, with torpedoes already delivered receiving the update at their three-year 'A Routine' maintenance interval.

International sales

As regards international sales, BAE Systems has identified a number of export opportunities for the Mod 1 torpedo. If successful, the company expects to win export orders worth in excess of GBP150 million over the next few years.

Norway, which has provided trials support to the Mod 1 programme and is an existing Sting Ray customer, is regarded as a major prospect. The Norwegian Defence Logistics Organisation (NDLO) is currently evaluating options on whether to upgrade its own Mod 0 inventory to the Mod 1 standard (the Royal Norwegian Navy maintains its warstock at Defence Munitions Gosport in the UK). In the meantime, NDLO has contracted BAE Systems to supply a limited number of IM warheads for its existing Sting Ray Mod 0 inventory.

BAE Systems is also looking to expand its existing customer base by offering surplus Sting Ray Mod 0 torpedoes as they are withdrawn from UK service. Romania has already taken this route, buying a quantity of Mod 0 exercise and warshot torpedoes to equip two ex-RN Type 22 Batch 2 frigates. BAE Systems took responsibility for refurbishing and re-integrating the weapons under an agreement with the Disposal Services Agency.

South Korea's Agency for Defense Development (ADD) instigated the indigenous development of a lightweight torpedo – known as Cheongsangeo or Blue Shark – in 1995. This electrically-powered weapon, engineered for series production by NEX1 Future, completed development testing and qualification in September 2004 and is believed to have been introduced to service with the South Korean Navy aboard surface ships, helicopters and maritime patrol aircraft in 2006.

Few details of the Blue Shark have been released, save that it is capable of speeds in excess of 45 kt and a range of more than 9,000 m, is capable of prosecuting targets in shallow water and features a shaped charge warhead. It is surmised that the ADD has drawn on access to the Mk 46 torpedo in developing Blue Shark and has also benefited from limited technology transfer from Eurotorp in the area of power and propulsion. ■

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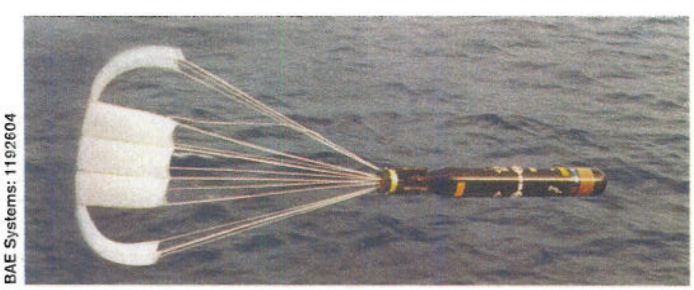
Sting Ray Mod 1 aboard a Merlin HM.1 helicopter.



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A Sting Ray torpedo firing from a surface ship.

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