UK UNDERWATER TRACKING RANGES

BY

G. S. J. BARTER, CENG, MIEE
(*Sea Systems Controllerate, Egdon Hall, Weymouth*)

ABSTRACT

Running torpedoes can be tracked acoustically at the deep water bottom-mounted range at BUTEC, by the shallow water Transportable Tracking Range and by the Submarine-Mounted Underwater Tracking System (SMUTS). These are described, with their background, functions, differences and possible future.

Underwater Tracking Ranges

Since the time of Leonardo da Vinci it has been recognized that sounds emitted by underwater objects can be tracked using suitable sensors. He noted in 1490 that 'If you cause your ship to stop, and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you'. Little use was made of this phenomenon until the Second World War when underwater acoustic energy was utilized to such great effect in the development of sonar. Underwater tracking ranges followed, and were used to monitor torpedo performance. At first they were elementary in their design because their primary purpose was to track the simple, straight-running Mk. 8 torpedo. With the advent of torpedoes able to run at various angles and of blind firing techniques it became apparent that there was a lack of facilities for assessing weapon system effectiveness, albeit there was always the ultimate check of firing a torpedo to hit a target. The introduction of complex homing and guided homing torpedoes exacerbated the difficulties and so it became necessary to provide fully instrumented underwater tracking ranges.

To start with, these ranges were ship-mounted, *Whimbrel* being the first in 1964, to be followed by *Kimberley* in 1968, and then *Whitehead* in 1971. The first two are long gone and *Whitehead* is on the disposal list. Such ranges had the advantage that they could go anywhere, but they also had disadvantages, a fundamental one being their short baseline, that is the distance between hydrophones, which made it essential to operate the range in the synchronous mode. Practical considerations limited the depth at which the hydrophones could be deployed to some 12 metres below the water surface, where thermal layering is much more unfavourable than in deep water, and own ship's noise contributed to the background level. Range and bearing data were relative to the vessel's hydrophone array and it was difficult to translate this into data relative to the sea bed unless the precise movements of the vessel were known.

Nevertheless, in the late 1960s a submarine-mounted target-centred tracker system was developed and was fitted to HMS *Porpoise* and *Otter*. Six hydrophones were fitted on booms projecting from the sides of the vessel; inboard a processing system connected to a printer presented long and short range plots of an approaching torpedo. The boom-mounted hydrophones were prone to high levels of flow and vibration noise, which severely restricted the submarine's operating speed, and the booms themselves were easily damaged. So in 1975 a requirement was raised to improve the system by mounting the hydrophones in apertures cut in the submarine's tanks and

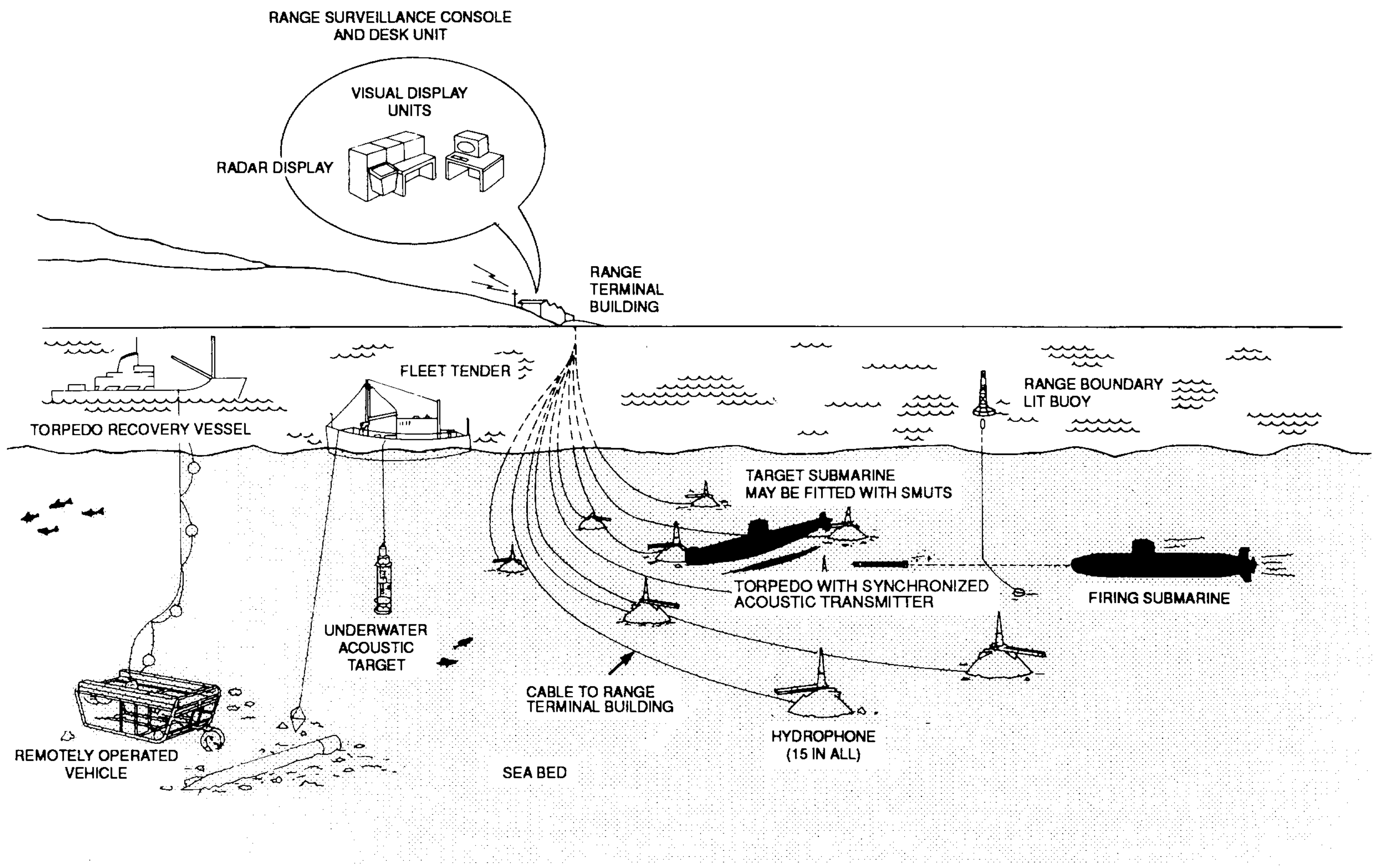

FIG. 1—BRITISH UNDERWATER TEST AND EVALUATION CENTRE (BUTEC)

SMUTS: Submarine-Mounted Underwater Target System covering them with small blister domes. Eight hydrophones were used to compensate for the reduced coverage obtained by their being flush mounted, and numerous changes were made to the electronics. Software was provided to interface with the computer analysis system at the Submarine Tactics and Weapons Group in Faslane, Scotland. This system was used with varying degrees of success until 1984 when a Minor Equipment Requirement was approved to develop and procure a Submarine-Mounted Underwater Tracking System (SMUTS), based on the target-centred tracker design, but with enhanced azimuth tracking range, and with on-board data processing and displays.

In parallel with the development of ship-mounted tracking ranges, and as a direct result of a report made in 1969 by the committee under Sir Rowland Baker, a submission was approved in principle in 1970 to create a permanent bottom-mounted range. The report criticized the Mk. 24 torpedo trials facilities as being dispersed, *ad hoc* and unreliable, and recommended that a properly instrumented and manned range be set up in UK waters to support future torpedo research and development, acceptance, production proofing and continuation firings. Initial investigations established that the British Underwater Test and Evaluation Centre (BUTEC), as it was to be called, should be sited in the Inner Sound of Raasay. Design investigations followed, which were completed in 1973, allowing the range to become functional in 1975. Bottom-mounted ranges generally incorporate long baseline arrays, where the sensors are distributed as uniformly as possible over the chosen range area. Errors due to range movement are eliminated and a high order of accuracy is obtainable over the instrumented area under all bathythermal conditions.

The need for such a bottom-mounted range in deep water, between 150 and 200 m, focused on the acceptance trials of the Mk. 24 Mod 0 torpedo. It was acknowledged that such a range would not provide the right conditions for every kind of torpedo firing and that a shallow water range, in about 60 metres of water, would be required to prove the performance of torpedoes in the presence of reflections from the surface and from the bottom. Development work started in 1976 on a short baseline array system that could be deployed in any desired location, providing the water currents were not too strong and the depth did not exceed 100 m. The first version was available for trials in 1979 and consisted of an array of sensors suspended from anchored buoys.

Experience gained from operating the system in this mode led to the conclusion that it would work more effectively if it were to be inverted, such that the sensors were laid on the seabed, thus allowing the range to be operated in higher sea states and at the same time getting rid of a potential obstruction for a participating submarine. This variant was accepted in 1983 and was and still is known as the Transportable Tracking Range (TTR).

It is now accepted policy to run torpedoes on fully instrumented ranges, during development and when in service, in order to test and evaluate sub-systems and the overall weapon system effectiveness. For these trials it is necessary to follow accurately, in three dimensions, the track of all vehicles taking part. Currently there are three operational ranges in the UK—BUTEC, TTR and SMUTS.

BUTEC

The British Underwater Test and Evaluation Centre is situated in the north west of Scotland, between the mainland and the Isle of Skye (FIG. 2). It comprises an underwater tracking range (FIG. 1) in the Inner Sound of

Surface vessels that arrive on range without an acoustic transmitter, can be positioned with an accuracy of 3 m, using a mobile Hyper-Fix surface navigation system receiver.

The RTB is equipped with radar, which is manned 24 hours a day, and is used to assist the Range Controller in positioning participants in a trial and for range surveillance; it is not used with aircraft. There are also comprehensive communication facilities available at both the RTB and the SSB.

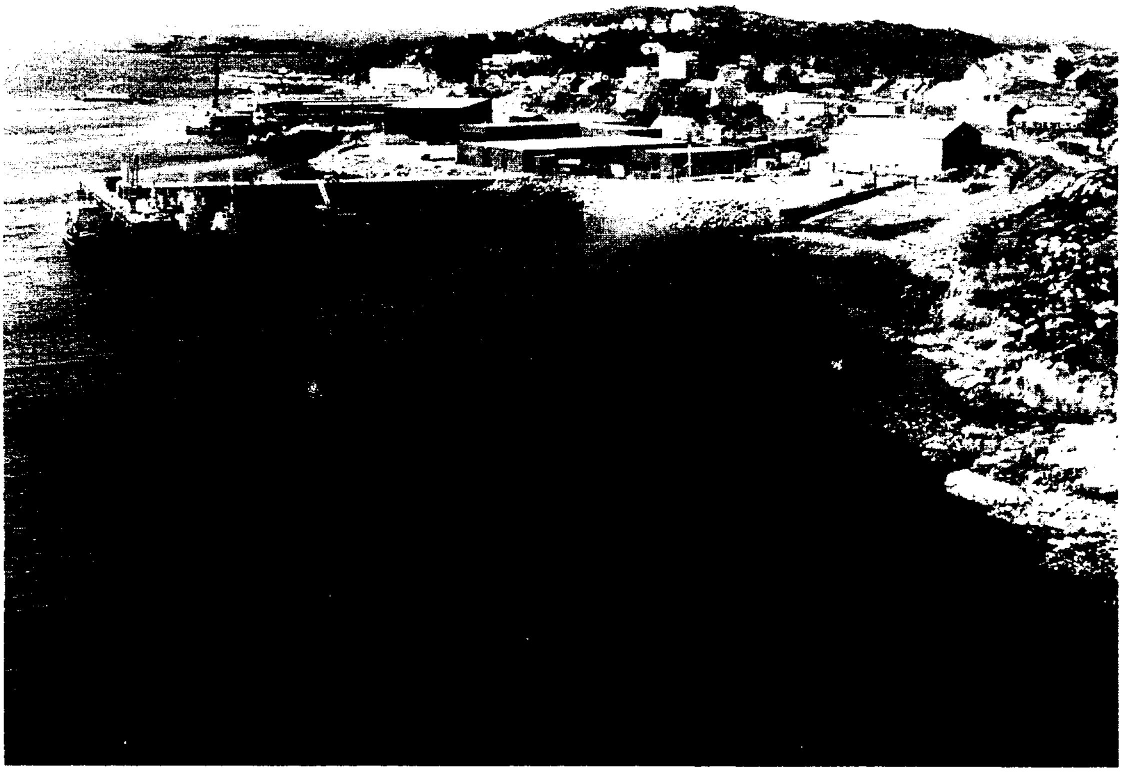

FIG. 4—THE SHORE SUPPORT BASE AT KYLE OF LOCHALSH

A variety of specially equipped vessels (FIG. 6) operate from the SSB in support of range activities. Their tasks include target deployment, weapon recovery, weapon firing using a side launch frame or a chute, and range safety. Generally, exercise torpedoes come to the surface after firing by ejecting ballast or by the use of a flotation collar, and are then recovered by one of the range vessels. However, some weapons end up on the bottom, either by design or by accident, and then have to be recovered by the BUTEC remotely operated vehicle, 'Skate' (FIG. 7). 'Skate' can be deployed in water up to 350 m deep and comprises a control caravan, a winch, a remotely operated vehicle and an umbilical cable. The caravan is fitted to a range vessel and houses the operator's control console together with a vehicle status display, a tracking system, an integrated navigation system and video equipment. The hydraulically operated winch can accommodate 900 m of cable, and is capable of lifting 2 tonnes. A helicopter, based at BUTEC, is used for lightweight recovery, movement of personnel and supplies, and aerial photography.

The depth of water and the proximity of the coast-line does not allow BUTEC to be used for free-play tactical trials. However, the range is extensively used for stage-managed trials involving a variety of platforms, weapons and targets that require precise measurement of underwater performance, such as underwater vehicle research and development, proof testing on in-service weapons, submarine tactical weapon system performance measurement, crew certification firings, and private venture work.

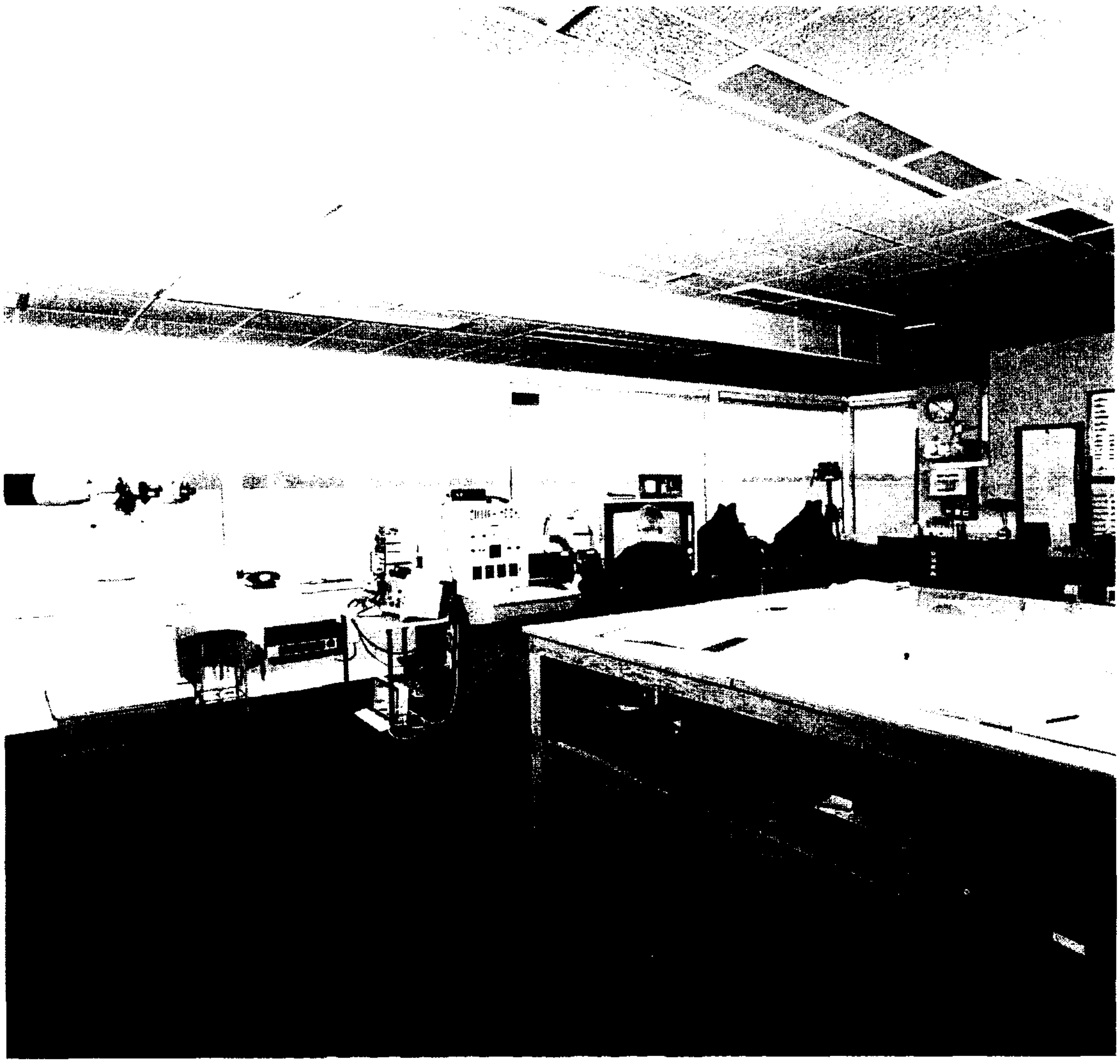

FIG. 5—INSIDE THE RANGE TERMINAL BUILDING

TTR

The Transportable Tracking Range, as illustrated in FIG. 8, is a shallow water range capable of being deployed in any chosen location providing the water depth is not greater than 100 m and the area is within 20 km and line of sight of a suitable site for the control caravan. The range consists of a bottom-mounted array of three hydrophones laid at the apexes of an equilateral triangle of side 200 m. Two of the hydrophones are joined to the third by cables, and thence by a 2.5 km cable to a moored Fleet Tender. The signals from the hydrophones are partially processed and digitized by equipment installed in the Fleet Tender and then transmitted by UHF radio link to the caravan, which is normally land-based but may be carried on the deck of a surface vessel. The caravan, which is self-contained, houses a computer and all the peripherals necessary to complete the data processing and present real-time tracks for the Trials Officer and full customer records in slower time. The raw tracking data received from the hydrophones is recorded on magnetic tape in the Fleet Tender, and the processed data are recorded in the control caravan.

TTR operates synchronously, using the UHF radio link, and can track up to three objects simultaneously. The tracking radius is 2.3 km at a pulse repetition interval of 1.6 seconds, which can be extended to 4.6 km by utilizing a 3.2 second interval. The transmitted acoustic pulses must be of the standard BUTEC type. Tracking accuracy is 3 m per 1000 m range but is dependent on hydrophone spacing and the velocity of sound in water.

FIG. 6—SUPPORT VESSEL AND RANGE HELICOPTER AT THE SHORE SUPPORT BASE

Each hydrophone floats clear of the bottom, attached by an acoustic link to an expendable concrete sinker. The hydrophone assembly incorporates an acoustic transmitter transducer as well as the acoustic receiver, and these are used in the periods between receiving tracking information to ping round providing data that is used to continually update the array spacing measurement. The speed of sound in water against depth in the range area is recorded and used in the tracking algorithm; it is also used to assess potential tracking performance.

The advantages of TTR is that it is mobile, and because the support vessel is moored some 2000 m away from the array, it is intrinsically safe and quiet. The disadvantage is that in laying and recovering the range, inflatable craft are used, and therefore operations are weather-limited to about sea state 3.

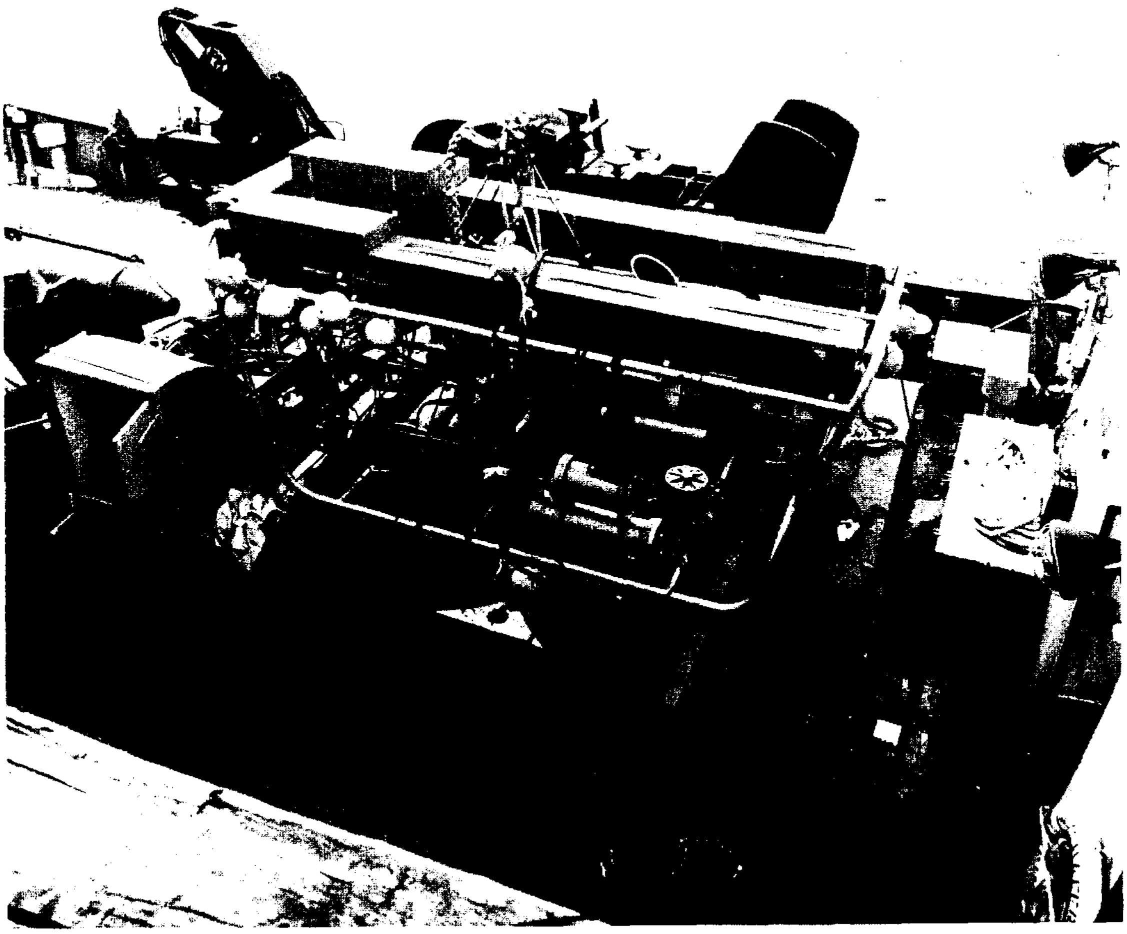

FIG. 7—ROV 'SKATE' EMBARKED ON THE SUPPORT VESSEL RMAS 'TORRENT'

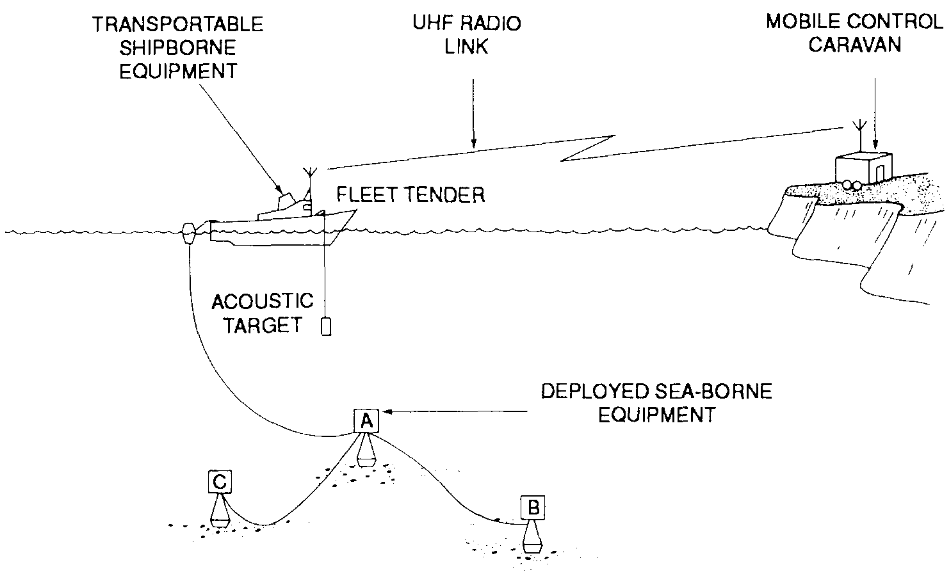

FIG. 8—TRANSPORTABLE TRACKING RANGE (TTR)

SMUTS

The Submarine-Mounted Underwater Tracking System is self-contained and can be installed in any submarine that is 'fitted to receive'. A nominated submarine is fitted with eight hydrophones arranged around the fore-ends to optimize tracking performance, two external junction boxes, an analogue unit, a logger unit and a computer and printer, as shown in FIG. 9. Earlier versions of these short baseline arrays were designed to assess the proximity fuze system of the Mk. 24 torpedo, and to measure the distance by which the weapon missed the target. A special torpedo synchronous acoustic transmitter was developed which produced high data rate transmissions at 125 kHz in addition to the normal tracking transmissions in the 17 to 23 kHz region. The 125 kHz transmission became known as the Miss Distance (MD) transmission, whilst the term SAT, after the name of the torpedo tracking section, came to be associated with the 17 to 23 kHz transmissions. The basic format of these transmissions, which are compatible with the BUTEC standard, as well as the names, have continued through to the present day.

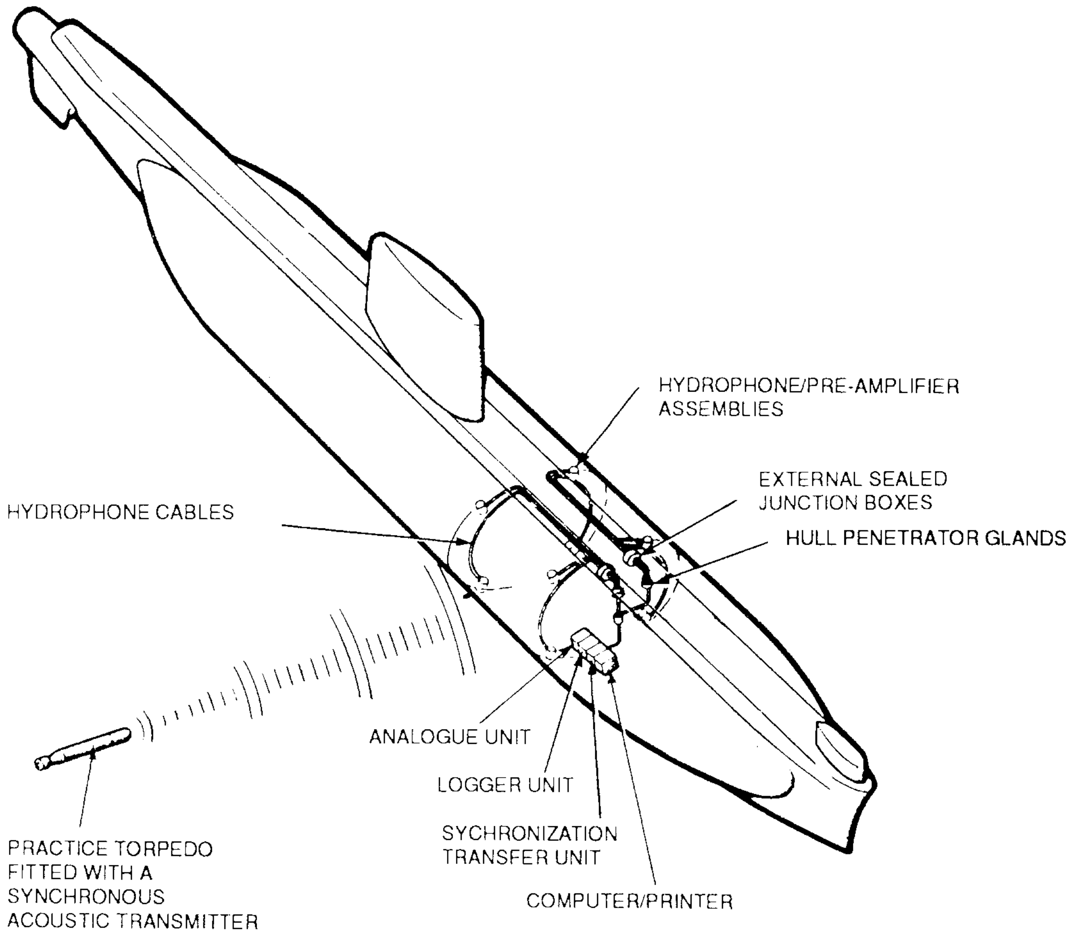

FIG. 9—SUBMARINE-MOUNTED UNDERWATER TRACKING SYSTEM (SMUTS)

The primary function of SMUTS is to measure and display the three-dimensional trajectory of an approaching torpedo, but it can also be used in the reverse role to measure discharge parameters. SMUTS operates synchronously, making use of a synchronizing transfer unit containing a rubidium frequency standard, thus negating the requirement for a radio link with its associated limitations. The received tracking signals, and the MD tracking information at a 0.1 second pulse repetition interval, are time-stamped in the analogue unit, digitized and then passed to the logger unit, together with submarine's roll, pitch, heading, depth and speed data. After processing, real-time tracking is displayed; the recorded data can be used ashore for detailed analysis. Long range SAT tracking is achievable at 4800 m, whereas short range MD tracking is limited to 300 m. Tracking accuracy depends on range and is typically 0.5 m at 20 m, 1 m at 300 m range and 3% of range out to 4800 m.

SMUTS has the advantage that it is truly mobile in that it can operate anywhere the submarine goes, but the system does suffer from relatively high background noise level and it can only track one weapon at a time.

The Future

BUTEC, TTR and SMUTS will go on evolving to meet the customers' requirements. In particular, BUTEC is investigating the possibility of doubling the length of the range by incorporating the tracking hydrophones of the Rona noise range, sited to the north of the existing range, to cope with longer range torpedo firing scenarios. Surface tracking, to give the Range Controller more flexibility and perhaps more importantly to help reduce the in-water acoustic energy transmitted at any one time, is being appraised.

TTR has been successfully used with the control caravan ship-mounted; the next step may be to use a moored raft to terminate the hydrophone cables and then radio the information ashore.

Developments are programmed for SMUTS to track two weapons simultaneously and to reduce the bow and stern shadow zones caused by the practical limitation of where the hydrophones can be mounted.

The requirement for all three ranges is heavily biased towards torpedo development and proofing. The usage rate is not constant, there are too many peaks and troughs; and in an effort to fill these gaps commercial exploitation of the large number of facilities available is being actively pursued.

Conclusion

This article is intended to give a brief overview of the three underwater tracking ranges and a glimpse of what is proposed for the future. Readers who require more detail on any aspect are encouraged to contact the author.