THE TYPE 2400 'UPHOLDER' CLASS SUBMARINE

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Introduction

The Naval Staff Requirement for the Type 2400 UPHOLDER Class submarine was endorsed early in 1980. The First of Class, H.M.S. *Upholder,* was ordered in November 1983.

The Soviet Navy continues to grow in size. By the year 2000 it is estimated there will be over 100 submarines of all types and over 50 major surface ASW vessels in the Russian Northern Fleet. The quality and operational capability of their vessels continues to improve as new classes are introduced. One of the essential components in the mix of U.K. or NATO forces necessary to counter this increasing threat is the conventional submarine.

The Type 2400 is required to be primarily an ASW surveillance and attack unit both in deep and shallow water. While lacking the mobility of the SSN it will complement it and all other ASW forces, since it can, by exploiting its unique quality of quietness, operate covertly for long periods entirely without logistic support at sea. In performing the more static roles of area surveillance and barrier operations it can release SSNs to tasks where their mobility can be used to the greatest advantage. The Type 2400 will have the capacity for autonomous or cooperative prosecution of targets, having appropriate rapid communication facilities. It will have a capability in open ocean as well as in coastal and shallow waters. It should also be remembered that tasks such as that in the South Atlantic may arise in any part of the world.

The Requirements

The Staff Requirement calls for an ocean-going submarine capable of being deployed for a considerable period, dived throughout. During hostilities a typical operation would be the setting up of an ASW barrier in the U.K.—Iceland gap. This would entail a transit out to patrol and return, dived throughout.

The main features which the vessel is required to have are as follows:

- diving depth > 200 m
- flexible weapon discharge system

- towed array
- flank array
- main motor 1×4 MW
- diesel generators 2×1.4 MW
- communications as TRAFALGAR Class.

The Type 2400 is seen as an essential long-term component of the ASW submarine force mix. As will become apparent later, constraints were placed on the displacement of the UPHOLDER Class during the design, and a great deal of ingenuity has been used in meeting the demanding requirement within the available limits of weight and space. The result is a sophisticated and highly developed design which is ahead of any other in the world for this type of requirement.

Design and Development

To assist with the formulation of the Naval Staff outline targets, a very broad range of designs from 500 to 2500 tonnes was initially produced, with widely differing capabilities. The smallest at 740 tonnes (FIG. 1) was only suitable for basic surveillance and training, but cost less than half the 2000 tonnes design (FIG. 2). The latter fully met the staff targets and incorporated space for future sonar and AIO/FC developments. The design endorsed by the Naval Staff to meet the Outline Staff Target in 1978 was 10 per cent. cheaper than the 2000 tonne option. It utilized a mixture of largely off-the-shelf British, German, and American weapon equipments, at a displacement of 1960 tonnes. However as the Outline Staff Target was developed into the Naval Staff Target in 1979 the inclusion of improved weapon systems forced the displacement up to 2250 tonnes and added 15 per cent. to the cost.

Finally, to the Naval Staff Requirement (NSR), endorsed in 1980, which took the design to 2400 tonnes for another 5 per cent. in cost. This increase was made to reach agreement with British Shipbuilders on a common design for the R.N. and for export, and incorporated improved endurance, potential for R.N. Sub-Harpoon, and improved growth margins.

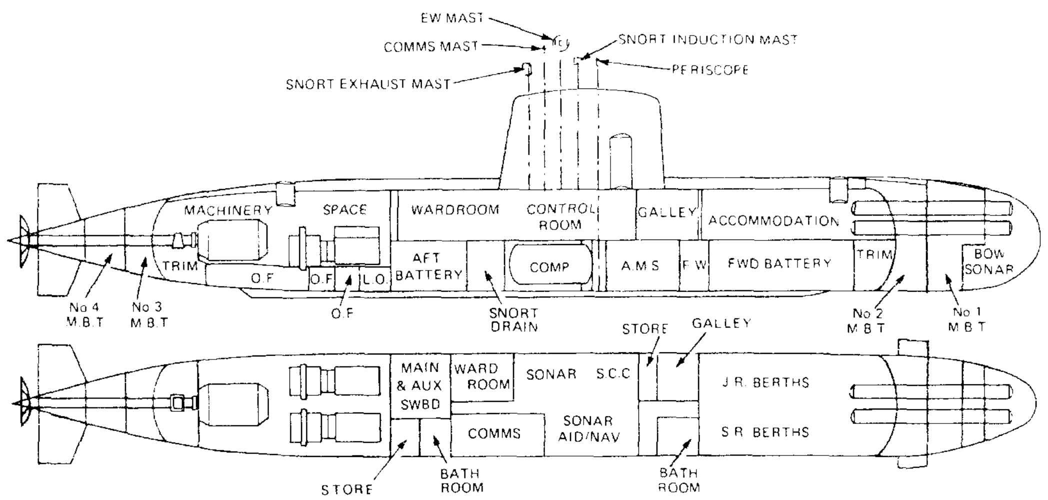

FIG. 1—740 TONNE DESIGN OPTION

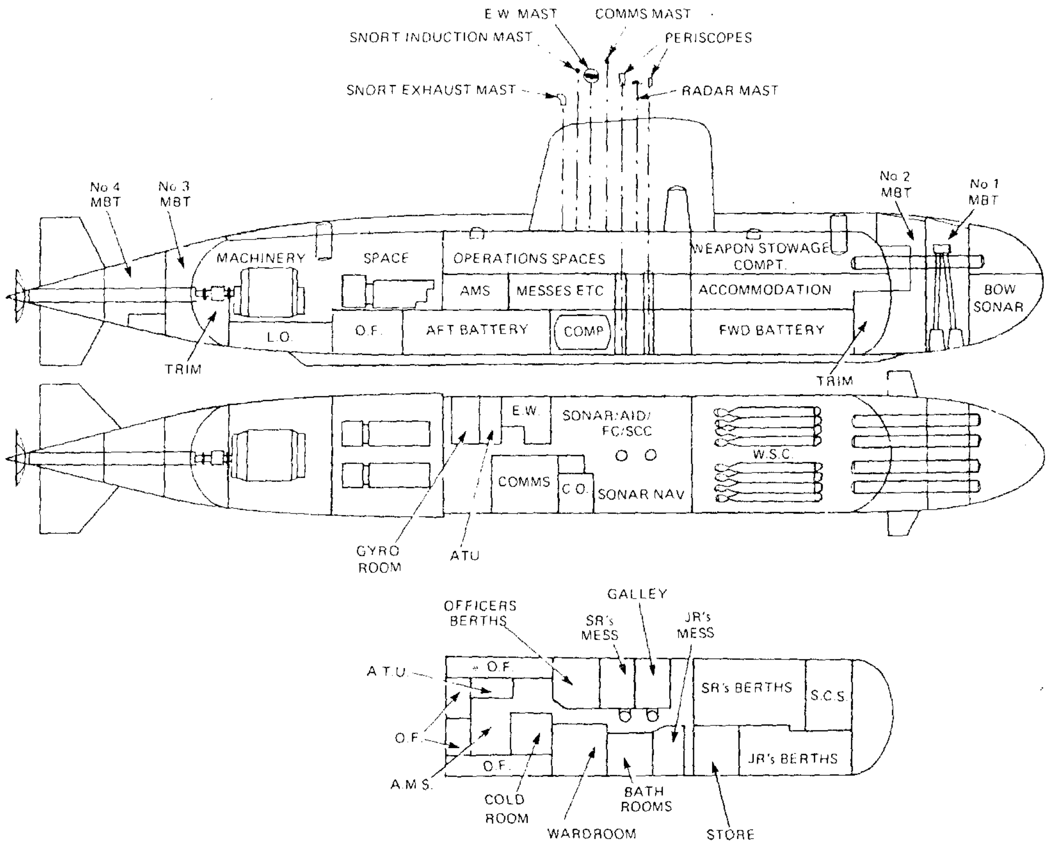

FIG. 2—2000 TONNE DESIGN OPTION

The sequence of the design phases of the First of Class is shown in TABLE I.

TABLE I—*Sequence of Design Phases and Build Programme for Type 2400*

Design	*Year*	*Build*
Outline Staff Target	1978	
Naval Staff Target	1979	
Naval Staff Requirement	1980	
Admiralty Board Approval	1981	
	1982	Long lead ordering commenced; invitation to tender
	1983	Order
Finalize design detail	1984	

The principal features of the final arrangement are shown in FIG. 3. The main sensors are:

- bow sonar
- towed array, sharing common processing and display with the flank array
- passive ranging
- 2 electrically controlled periscopes } in the fin
- a dedicated ESM mast } in the fin
- radar and communications masts. } in the fin

It is in the aspect of silence that the Type 2400 is special. Radiated and self noise reduction by incorporating the latest and best techniques and treatments will give a marked improvement over the OBERON Class for broad band and line levels. The low noise levels ensure that the Naval Staff's requirement for an excellent listening platform will be met.

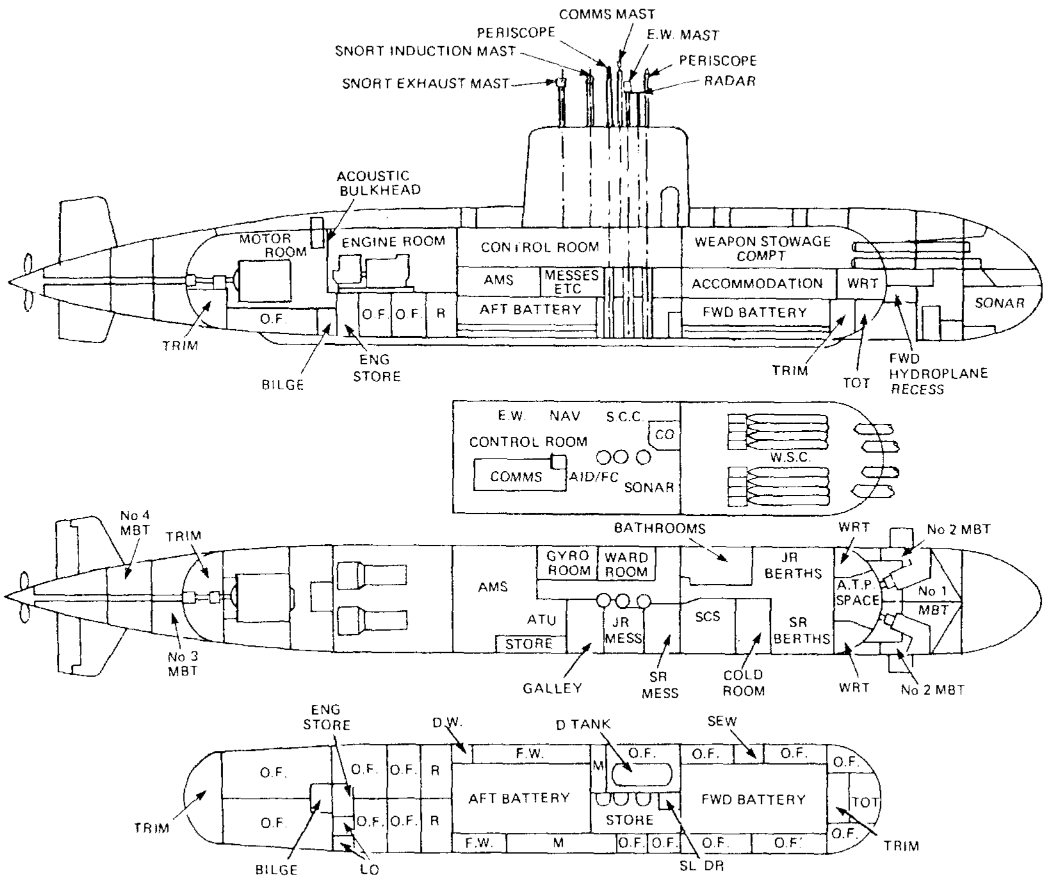

FIG. 3—TYPE 2400 ('UPHOLDER' CLASS)

Upkeep and Usage

The NSR stresses the importance of support aspects and meeting stringent availability figures. Great attention has been given to equipment removal routes, with demonstrations at either model or full scale. To allow the replacement of the diesel generator sets and other large items aft, a 'Dutch Breach' is fitted in the pressure hull giving a clear opening of 2.2 by 1.9 metres. This feature has been the subject of static and shock tests.

Comparison with 'Oberon' Class

The most obvious differences are in the hull form and propulsion. The Type 2400 has been optimized for silent submerged performance and is comparatively short and fat with a single propeller axial to the hull. These differences are illustrated by the power/speed curves, FIG. 4, and the consequent greater maximum speed of the 2400 is readily apparent.

The comparison of the weights and volumes illustrated in FIG. 5 highlights the greatly increased space in the Type 2400 for operational spaces, the similarity of weight and space allocations for machinery despite improved submerged endurance and generating capacity, the greater diversity and demand for auxiliary systems, and the improved standards of noise and shock resistance.

Platform Development Items

It has not been necessary to breach the frontiers of technology to meet the Naval Staff Requirement for this vessel.

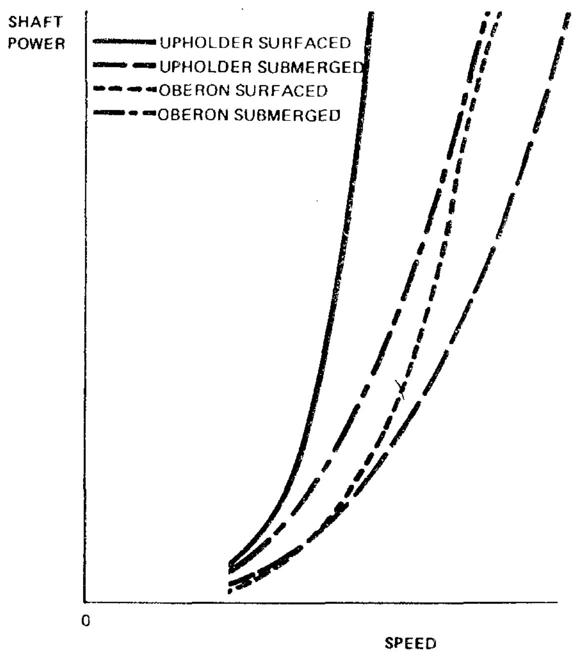

FIG. 4—COMPARISON OF POWER/SPEED CURVES FOR 'UPHOLDER' AND 'OBERON' CLASSES

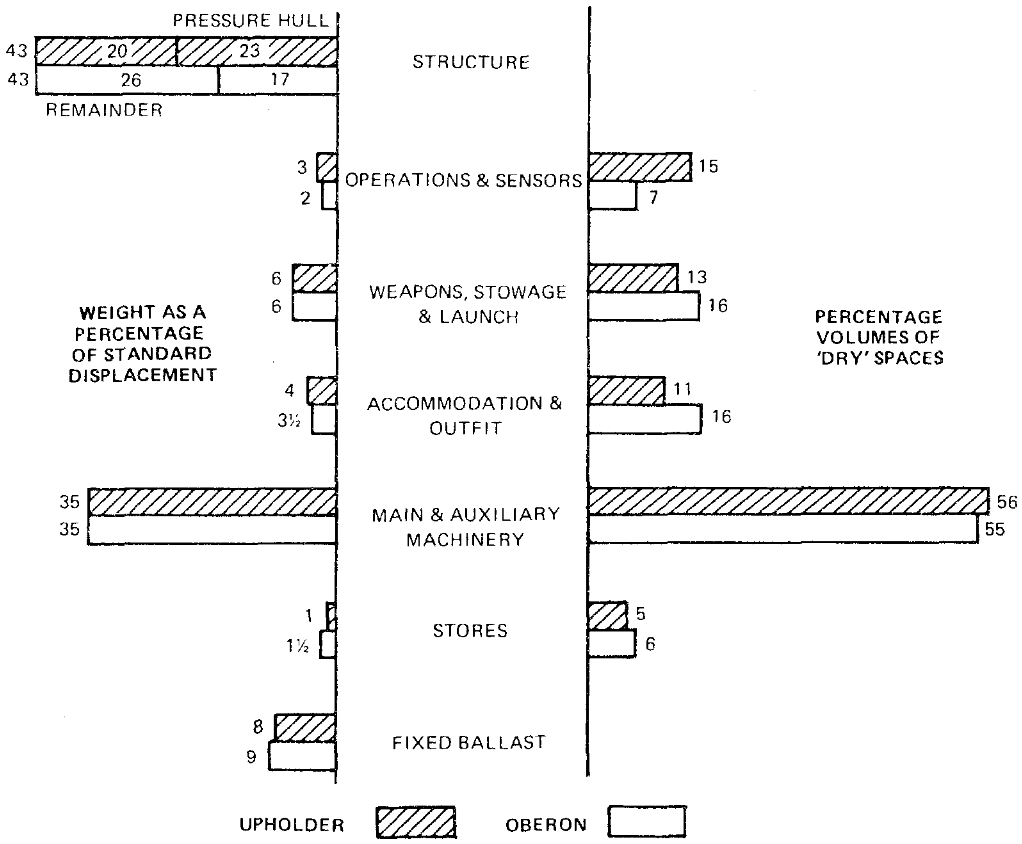

FIG. 5—COMPARISON OF WEIGHTS AND VOLUMES FOR 'UPHOLDER' AND 'OBERON' CLASSES

Nevertheless in the application of existing technology some interesting precedents have been created in the field of R.N. submarine machinery.

The following equipments have involved particular development effort worthy of mention:

(*a*) Paxman Valenta diesel engine.
(*b*) Main generator.
(*c*) Main motor.
(*d*) Propulsion control gear.
(*e*) Machinery surveillance system.
(*f*) Reverse osmosis desalination plant.

Paxman Valenta Diesel Engine

From the various engine types and configurations considered, two Paxman Valentas were favoured on the basis of compactness and proven reliability in the INVINCIBLE Class and in British Rail HS125 trains, albeit not at the same speed and not mechanically supercharged.

To provide the necessary confidence under these conditions, a new mechanical supercharger has been developed by Paxman and successfully evaluated on 2 prototype engines. One engine is now coupled to a prototype ship generator for extended performance testing under realistic submarine operating conditions.

Main generator

The prototype generator just mentioned has been designed, manufactured and electrically tested by GEC Rugby. Although outwardly similar to most closed air circuit water-cooled machines, it constitutes a significant design change from past submarine d.c. generator practice.

The new machine is basically an a.c. generator with integral solid state rectification. This arrangement is essential since a traditional commutator type machine cannot convert the engine power into electrical energy at the speed required.

Main Motor

To achieve the propulsion power in a single main motor at the required speed range requires the largest single rotating machinery item ever to be built for a Royal Navy submarine (FIG. 6).

Significant details are:

- Overall volume, including cooling equipment: 4.5 m cube
- Overall weight: 82 tonnes
- Armature diameter: 2.3 m
- Armature weight: 29 tonnes

To avoid removal route problems the armature has been designed for *in situ* rewinding.

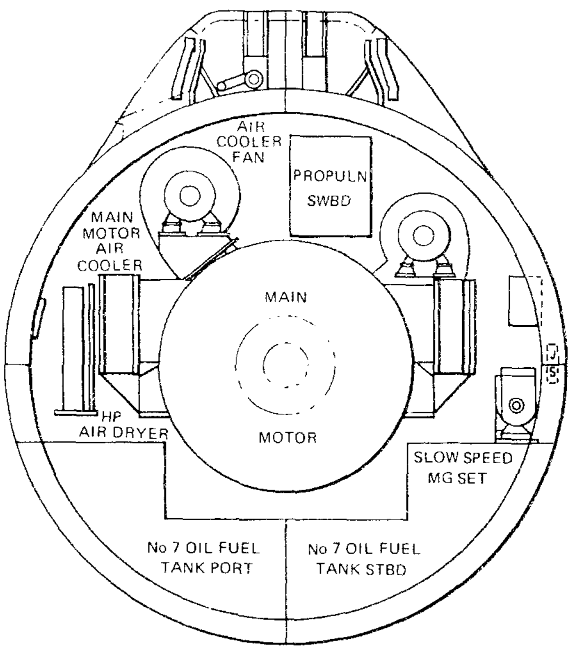

FIG. 6—PROTOTYPE MAIN MOTOR FOR 'UPHOLDER' CLASS

Propulsion Control Gear

Traditional battery and armature configuring has been adopted to obtain the primary speed ranges, but speed reduction to very low r.p.m. is achieved by a separate motor-generator set with variable voltage output. The propulsion switchboard housing these facilities is located on top of the main motor.

The major difference to traditional conventional submarine practice in this area is the ability to directly initiate all propulsion functions from the One Man Control section of the Ship Control Console. The 'black box' which processes the complex control algorithm is a sequential logic digital controller located on top of the switchboard. Fall-back control modes involving more muscle are provided at the Propulsion Switchboard.

Machinery Surveillance System

The remote propulsion control arrangement accords with the Naval Staff Requirement for greater automation and minimum crew, and remote control of diesel generators is also centralized at the Machinery Control Console for the same reason.

To assist both the Command and operators in comprehending the safe running status of all those systems under remote control, the significant parameters are continuously monitored on a processor-based surveillance system. Data can be presented on VDUs at the Ship and Machinery Control Consoles on demand or immediately presented as an alarm if a parameter goes out of tolerance.

This system is under development by Vosper Thornycroft and certain features are common with the similar system being developed by them for the Type 23 frigates.

Reverse Osmosis Plant

Traditional designs of steam and electric distilling plant have consistently presented problems over power demand and maintenance for many years. There is now confidence that the technique of reverse osmosis will ensure a more reliable plant with a reduced power requirement (see the article[1] elsewhere in this issue).

Prototype plants have been operating at Portland for a number of years and similar plants were called into service at short notice during the Falklands campaign.

Availability/Reliability

Upholder is a tightly spaced design. Unnecessary redundancy would aggravate this, so all systems and equipment significant to ship safety or performance have been subjected to Failure Mode and Effect Analyses to support realistic availability modelling of the overall vessel.

Weapon System Integration

The Naval Staff Target for the Type 2400 weapon system called for a low risk procurement plan using existing hardware. However the concept of establishing an integrated system defined by a single NSR was also endorsed—a somewhat conflicting situation. At the time of system definition it was recognized that the demands for MOD staff could not be met. This led to the formation of a large industrial design team, the Coordinating and System Design Authority (CSDA), managed by a small MOD Project Team. The Main Contractor is the Weapons Department of Vickers Shipbuilders of Barrow, who in turn is supported by Easams Ltd., a nominated sub-contractor.

The design requirements for the weapon systems, when matched against the off-the-shelf sub-systems, indicated the need for flexible data interchange between them. However the design authority for the input/output protocols of each sub-system rests with its manufacturer, the CSDA having little direct control over the individual manufacturers.

Work within MOD research establishments had established the viability of multiple source—multiple sink data communication systems, data buses, based on the U.S. aviation standard MIL-STD-1553(B)[2]. By use of data buses, data can flow automatically between sub-systems; the bus does not process the data, merely providing a data flow medium. FIG. 7 illustrates some of the principal components and their general disposition, and the diagrammatic arrangement of the *Upholder*'s data bus is shown in FIG. 8. The CSDA established a system design based on a data bus providing protocol conversion of data transmitters to a common 1553(B) transmission standard and data transfer protocol conversion for data reception.

The 1553(B) standard defines a time division multiplexed system, where a bus controller establishes a data link between two Remote Terminals (RT) for a finite time to enable the transfer of data. 100 per cent. hardware redundancy is specified for very high system availability. It can be seen that all the major elements of the weapon system have been integrated by way of the data bus. The link between the data bus and a sub-system is referred to as the user interface, the protocol of which is specified by the sub-system manufacturer. From this it can be seen that, for example, data flowing from the bow sonar to the AIO/FC equipment undergoes two data conversions. One of the main attributes of the design is in the ease of system change. Thus the recent addition of two more sub-systems required only the addition of two S-Cubed links.

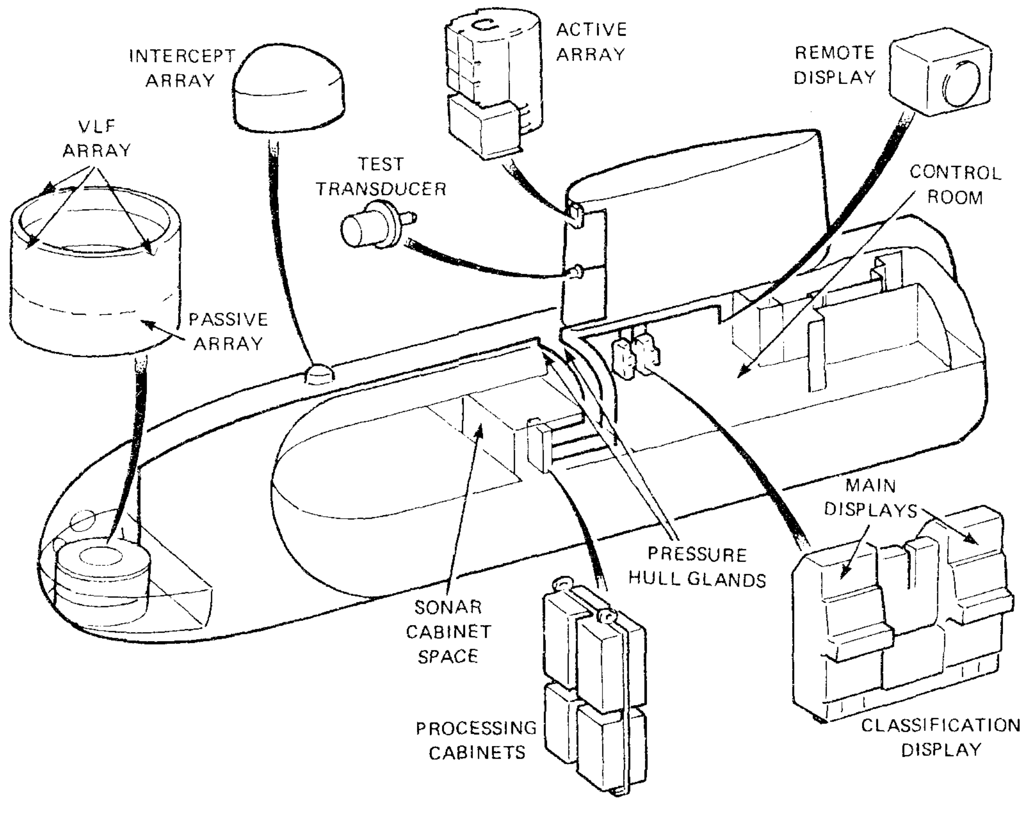

FIG. 7—SONAR: OVERALL SYSTEM DIAGRAM FOR 'UPHOLDER' CLASS

The weapon sub-systems linked by the data bus are located in the central and fore end sections, the length of each bus cable being 105 metres. The cable harness system is designed by Raychem Ltd. and meets the new requirements for low fire hazard cable. The remote terminals are co-located with the sub-systems connected to them. The design of the terminals is such as to put the minimum demands on ship services, only 115V a.c. being required, with wild heat 80 W and a size of 35 cm. cubed.

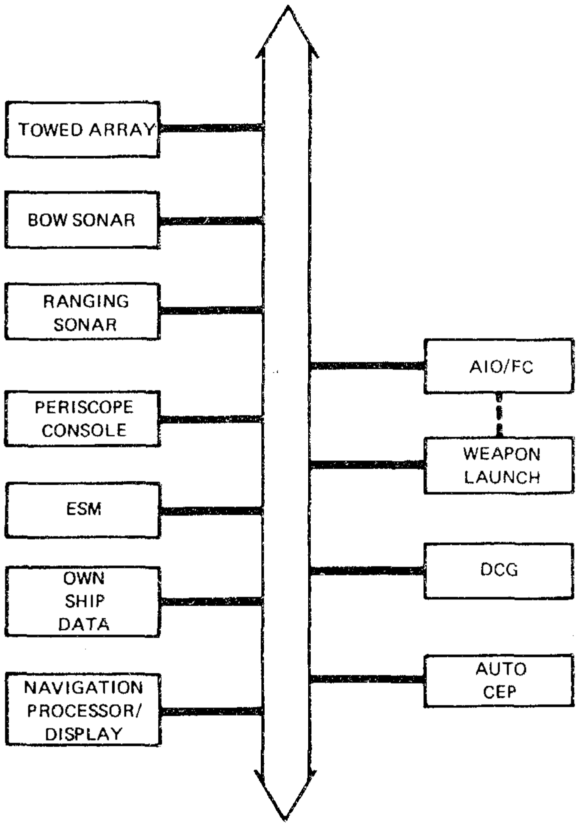

FIG. 8—'UHOLDER' CLASS: WEAPON SYSTEM DATA BUS

AIO/CF: ACTION INFORMATION ORGANIZATION/FIRE CONTROL
CEP: CONTACT EVALUATION PLOT
DCG: PERIPHERAL COMPUTER
ESM: ELECTRONIC SUPPORT MEASURES

Configuration control of the design has been recognized as a major task. All interfaces, including those with the platform services, have been identified and signed interface and test specifications are being produced. These documents, cross-referenced against the modification and build state of each sub-system, form the Weapon System Master Record Index. The risks to the boat building programme have been significantly reduced by the establishment at Barrow of the Shore Development Facility (SDF), a ship-like installation of sub-systems to test the electrical and software interfaces. Sub-systems have been installed within a metal tank and arranged in a similar fashion to the boat—except for separation. However in the majority of cases cable lengths have been maintained.

The Type 2400 Weapon System contains many interdependencies both in hardware and software. There is therefore a need to verify all changes that affect these interdependencies in a System Modification Reference Set. After acceptance of the first system in H.M.S. *Upholder,* the SDF will become such a reference system. New sub-systems, sub-system replacements, sub-system modifications and new software will all be proven in the SDF before modifications are allowed within a submarine. Considerable effort is being expended on the task of establishing a software model of the weapon system with platform parameters related to a software model of medium, weapons, and targets. These models are used to establish the performance envelope and identify cardinal measurable parameters for sea trials. The sub-systems integrated together in the SDF can be stimulated to provide input data to the AIO sub-system to enable the Target Movement Analysis algorithms to be evaluated. The operability of the system will also be measured. ARM Data are being collected in the SDF by logging running hours, faults, and restoration times. These data will be offered as evidence to support the ARM characteristics contained in the Agreed Characteristics.

Weapon Sea Trials will consist of verification of the cardinal performance characteristics including target detection, tracking, and weapon engagement.

Conclusions

Operational assessments have shown that the diesel electric powered submarine has many attributes and an important operational role alongside the Royal Navy's nuclear submarines. For the design of the Type 2400 it has been possible to use the successful experience from the OBERON Class and the wealth of research and development carried out for our nuclear submarines. The design process has ultimately led to a design having a very sophisticated sensor fit that is comparable to that in the TRAFALGAR Class, and capable of deploying the next generation of submarine-launched torpedoes and missiles. These aspects, integrated into a technically advanced overall submarine platform with high standards of signature reduction and shock protection, make the Type 2400 a major step forward in non-nuclear submarine technology. As such it is well ahead of all its potential contenders, and it is hoped that this design will have considerable export success.

References

1. Melly, R. G.: Reverse osmosis plants for the Type 2400 submarine and the Type 23 frigate; *Journal of Naval Engineering,* vol. 28, no. 3, Dec. 1984, pp. 441-447.
2. Military Standard MIL-STD-1553B: 'Aircraft internal time division command/responsible multiplex data bus' (Sept. 1978, amended Feb. 1980).

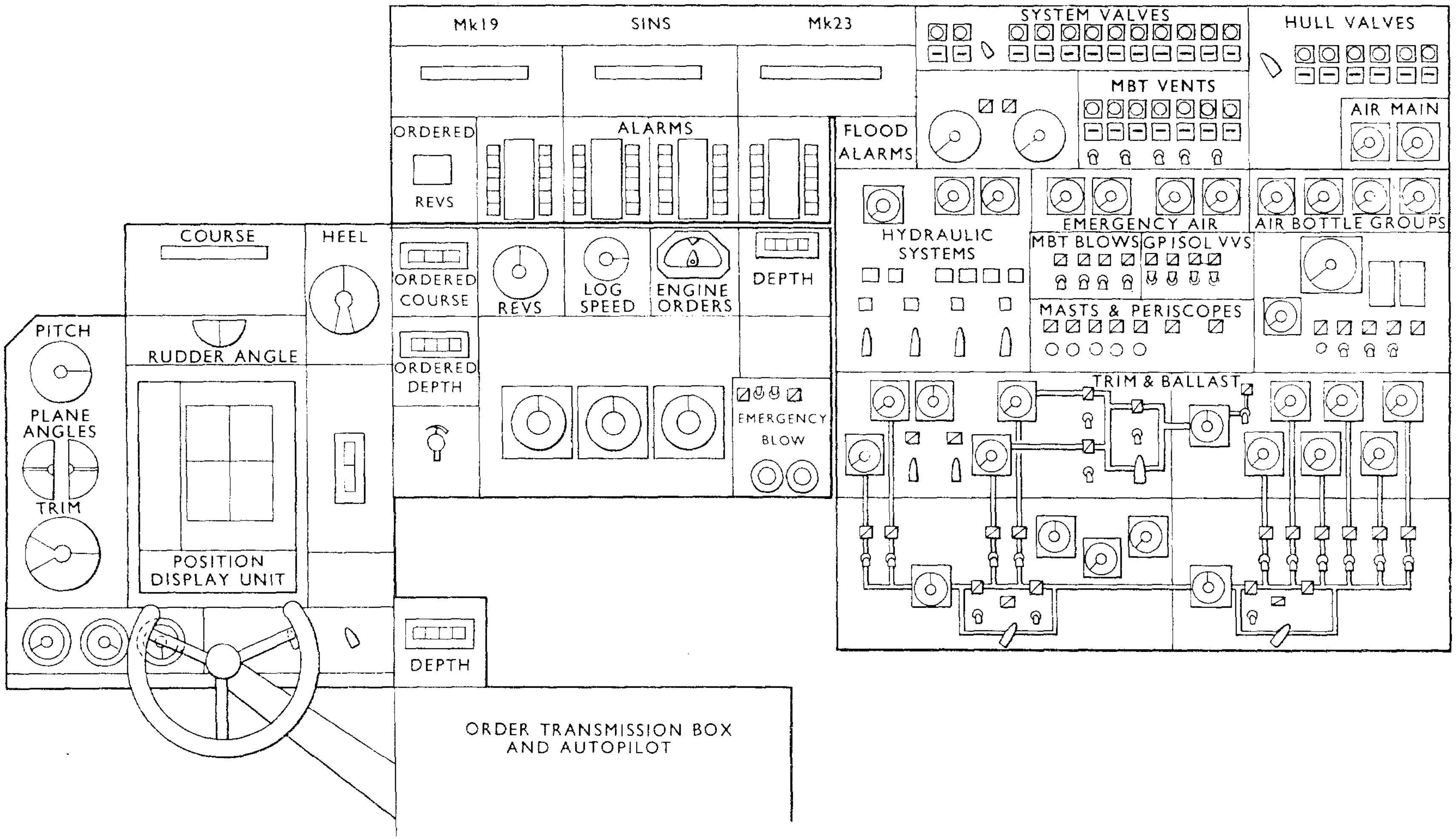

FIG. 1—MANOEUVRING AND SYSTEMS CONTROL CONSOLES