TRIDENT

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(*Sea Systems Controllerate*)

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ABSTRACT

This article describes the Trident project and its progress to date. The background to the procurement of the D5 missile is reviewed and the components of the Strategic Weapon System detailed. The platform is then described, with the exception of the nuclear propulsion system. Finally the evolution and present form of the Tactical Weapon System is briefly explained.

INTRODUCTION

Commodore T. W. Craven

I am sure that at least some of you will doubt the wisdom of Trident, and for a variety of reasons. But if you want to argue against the need for an independent nuclear deterrent then I cannot help you very much, at least not here and now. If you question the cost to the Defence Budget of bringing Trident into service then I can go a little way in ensuring that you have a proper understanding of the situation. Our job as Engineers and Project Managers is to react to democratic and political will and maintain the current Deterrence force, as well as build the next, as economically as possible. The type and size of the force and its required capability is defined by the Defence Staff and endorsed by ministers. I am glad to say that as 'Project' we have a substantial input and as Engineers we now have a place on the Policy Staffs, but we are mostly involved in ensuring that Trident is realized to time and to cost.

But to deal with the subject sensibly, I must start by reminding you that for a deterrent system to be effective it must be:

of proven capability;
of proven reliability;
of proven availability;
of high invulnerability to first strike;

and there must be a political will to use it if necessary.

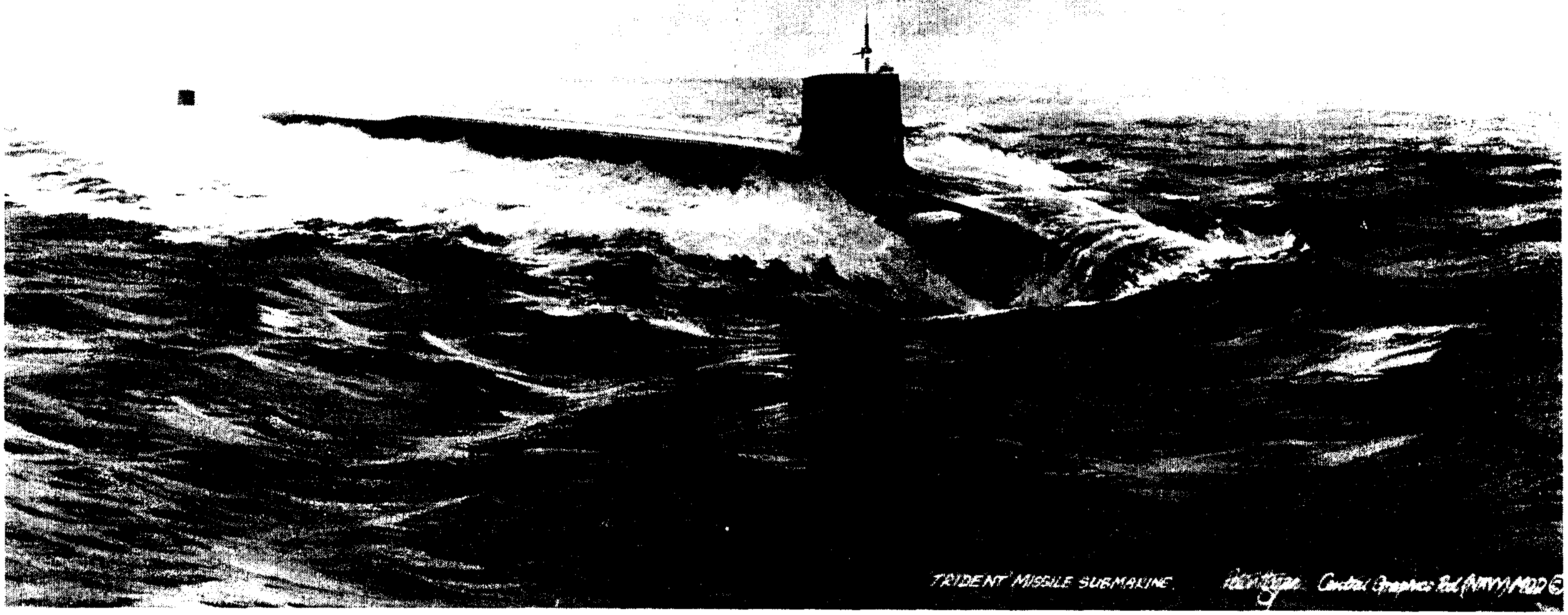

FIG. 1—A 'TRIDENT' MISSILE SUBMARINE   Drawn by Peter Hogan

You will be aware that the RESOLUTION Class entered service in the late 1960s and by the mid 1990s will need replacing. Whatever we do to the weapon systems themselves, Strategic or Tactical, we are certain (as with any other vessel) to run into platform problems, both in terms of age and of noise. Furthermore Polaris cannot go on forever despite costly updates such as the remotoring of the missiles to ensure reliability, the Chevaline programme to maintain effectiveness, or a navigation sub-system update to avoid the worst of obsolescence. These measures are mere palliatives and at some stage enough is enough. To have Trident in service by the middle of the next decade will hopefully not be to late. The Royal Navy has now completed 184 Polaris patrols and has a record of continuous deployment, since 1969, of a least one submarine on patrol. We have exceptionally high levels of availability to achieve and we do so. But a replacement is a requirement and it has to be delivered, maintained and operated by the likes of us.

The choice of a successor had to be made in the late 1970s; there were only two contenders, either a sea-based cruise missile or Trident (at that stage Trident I (C4)). There is no point looking at the situation as it is now and coming to a decision, or using the benefit of hindsight. I do not need to tell many of you how long it takes to get a total system, as complex as an SSBN, from Staff Target to sea, no matter what resources are deployed. The decision had to be made on the basis of the evidence then available and Cruise lost on the grounds that:

- it was unproven in terms of capability;
- it was unproven in terms of reliability;
- it could be opposed by non treaty limited air defences.

Equivalent capability to Trident required more submarines at sea, thus more to be built, more to be manned, and more missiles and warheads, exceeding production capacity, refit capacity, manpower capability—in short the resource implications would have been enormous. The weapon also lacked range, thus severely limiting operating sea room.

So the U.K. opted for Trident I (C4). Shortly afterwards, however the U.S. decided to push ahead with Trident II (D5) in order to:

- make full use of the diameter of their OHIO Class hull;
- increase range;
- maximize accuracy;
- use improved technology;
- allow alternative payload configurations.

Few of these advantages were of specific interest to the U.K., but what was important was that we did not wish to find ourselves unique. With C4 we would have been introducing a system into service just as the U.S. were about to withdraw it, an experience we have been through with Polaris and one that makes life very difficult. So D5 it is (FIG. 2), to be continuously deployed (which means two submarines operational) by the mid 1990s. That is our target and we are on track to achieve it.

What about the other factor which consumes us—cost? Trident submarines are not gold-plated, despite what you may have heard, nor are the support arrangements. Nonetheless Deterrence does not come cheap and the facilities required for its support are substantial, if we are going to ensure availability and reliability.

The Trident project either pays for such facilities in full, if they are used solely by the SSBNs, or there is a proper attribution if their use is shared. The Clyde Submarine Base development is currently the largest value construction site in Europe and will remain so until the Channel Tunnel gets going in earnest.

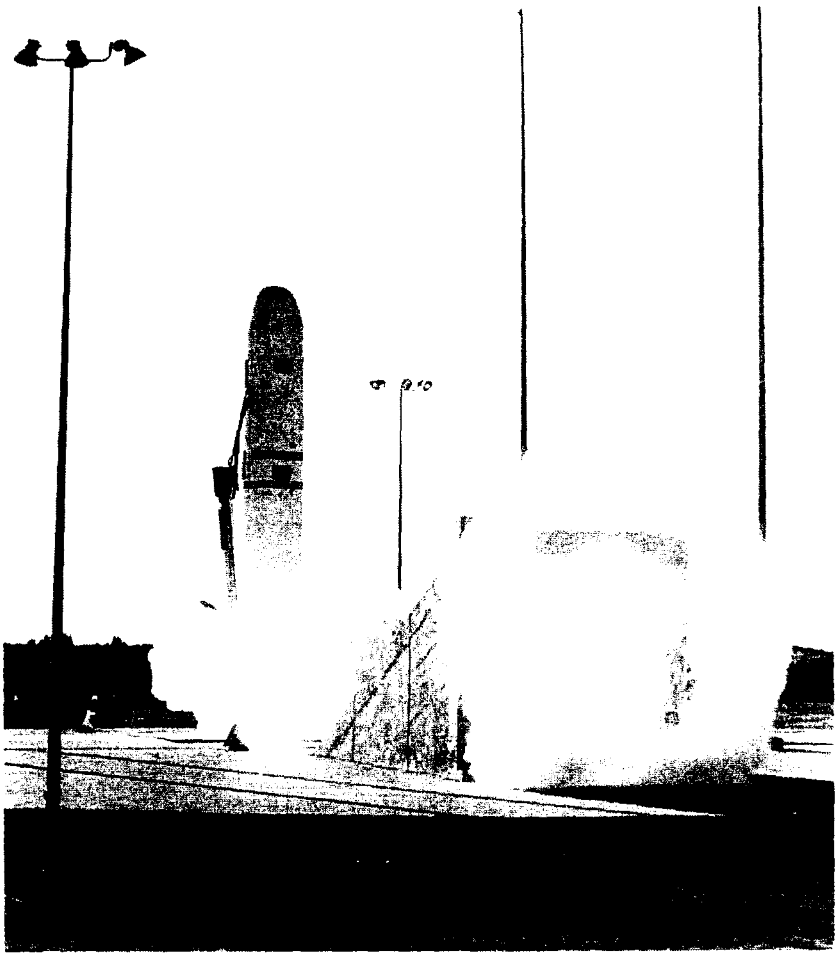

FIG. 2—TRIDENT II D 5

Addressing costs directly, bringing the original approval up to current price levels by increasing it for inflation and U.S. costs at $1.62 per £, it would stand at nearly 11 billion pounds. This figure is now reduced by the savings declared following the decision to process missiles at Kings Bay in the U.S. These savings amount to £7M when brought to 1987–88 prices, giving a revised Project baseline of just over 10 billion pounds. However the Trident estimate currently stands at just over 9 billion pounds. This represents a reduction of some 10% on real terms, resulting mainly from the refinement of cost estimates and the reduction of contingencies as the definition of project has improved.

THE TRIDENT STRATEGIC WEAPON SYSTEM

Captain R. C. Sharp

The entire concept of submarine-launched ballistic nuclear weapons has been developed by the U.S.A. over the last 30 years and therefore, to put Trident into perspective, I shall touch briefly upon the historical development of Strategic Weapon Systems.

From the outset of the Polaris Programme the U.S. Strategic System Project Office has had a policy of firm configuration and interface control. Having defined the interface parameters and sub-system performance criteria, the main contractors were effectively sent away to develop the equipment within their box.

Fig. 3—U.K. STRATEGIC WEAPON SYSTEMS

POLARIS A 3		TRIDENT II D 5
31	LENGTH (FT)	44
51	DIAMETER (INS.)	83
16	WEIGHT (TONS)	50
2500	RANGE (NAUT. MILES)	4000

The five main areas are:

- navigation;
- fire control;
- launcher;
- missile;
- guidance system.

This concept was a major contributor to the success of the original programme and has greatly facilitated the subsequent developments. Development has proceeded as required in different subsystem areas to meet updated requirements of performance, reliability or maintainability. The Trident D5 system is the sixth Strategic Weapon System to be deployed by the U.S. Navy but it is only the second such system to be procured by the U.K. For Trident, therefore, we are jumping over two significant generations of development: this, in itself, presents conceptual difficulties when discussing D5 with our U.S. counterparts.

This brings into sharper focus the very significant differences between the A3 and D5 Missiles (FIG. 3). The range of the D5 is 60% greater, for instance. The resulting increase in available operating areas, although a significant contributor to overall increase in deterrence, is not the greatest advance which we (and the U.S.) achieve from D5 as compared to all other systems. The greatest increase in overall effectiveness is brought about by increased accuracy.

Improved Accuracy Programme

This is, as its name implies, designed to provide a substantial improvement in accuracy and therefore in effectiveness. It utilizes 'state of the art' technology where available, but only where it has proven reliability.

Navigation

In a ballistic system overall accuracy is fundamentally dependant upon the initial parameters given to the 'projectile'. This is the main function of the navigation sub-system, which is where most of the accuracy improvements have been made.

Electrostatic Gyro Navigation (ESGN) provides a more accurate and more stable dead reckoning (DR) device than SINS and therefore one which requires fewer external fixes.

Navigation Sonar System (NSS). On patrol this provides the capability for accurate bottom contour fixing. At launch it provides extremely accurate platform velocity parameters to the missile.

Gravity Sub-System (GSS). This measures in real time the local gravity vector which, together with gravity maps stored in Navigation Memory Processors, provides this vital data as initial launch parameters to fire control (FC). These 'gravity maps' are being produced as part of the Ocean Survey Programme to which the U.K. has committed at least one survey ship/year for the next few years.

Global Positioning System (GPS) is a faster more accurate system, requiring less mast exposure time, than the equipments currently available.

Fire Control and Guidance

The additional capability of the D5 missile obviously complicates the potential targeting task and this in turn requires a considerable increase in the computing and storage power of the FC sub-system. Developments in microprocessor technology have enabled these requirements to be met; and indeed there is sufficient 'space' to enable FC to store its own 'gravity maps', necessary for the computation of 'in flight gravity corrections' for each missile.

In addition to the accuracies inherent in the guidance system because of the very high quantity components and manufacturing processes employed, it also contains a Stellar Navigator. This, in effect, enables the missile to take a 'star sight' once it is clear of launch and atmospheric perturbations, and then to apply mid-flight guidance corrections.

Launcher and Missile

Both these sub-systems have been subjected to fairly conservative development of the hardware traditionally used in the Strategic Weapon System—obviously scaled up in size to account for the range increase.

Support

On the support front there have also been significant changes in policy—not least of which is the decision to process and load missiles at King's Bay only. This, in turn, results in greatly reduced facilities (and therefore expenditure) at RNAD, Coulport. This policy has been made possible by the high design reliability of the D5 Missile which enables it to be kept in an SSBN launch tube for the entire commission

Although its involvement with Strategic Weapon System will diminish in respect of the missile handling function, RNAD Coulport will still be involved not only with traditional RBA (i.e. warhead) processing operations but also with mate/demate evolutions in the SSBN. So far equipment and supporting facilities are being designed and procured to schedule—with technical difficulties being overcome as they occur. However, none of this will be of any use without the provision of trained men.

Production of the Strategic Weapon Training Facility (the UKTTF) is well advanced, with building work almost complete. This structure, being built as an extension to the R.N. Polaris School in Faslane, is currently on track to support the start of training on 30th June 1990.

We have required strict control and detailed planning from the outset to ensure that there is adequate support for the Strategic Weapon System. The aim is to improve considerably the reliability of D5 over current systems which, themselves, have never resulted in the need to abort a deterrent patrol. Polaris availability to support 15 minutes notice to fire has been 99·96% over the life of the system. With Trident, we hope not only to better this, but to reduce support requirements and costs, and to improve the effectiveness of the deterrent.

THE PLATFORM AND GENERAL HULL ARRANGEMENT

N. Moores

Hull and Layout

The Trident submarine basically consists of a 16 missile tube centre section technically similar to the U.S. OHIO Class, a Pressurized Water Reactor propulsion system, and a new tactical weapons fit (FIG. 4). It is to have a hull life of not less than 25 years.

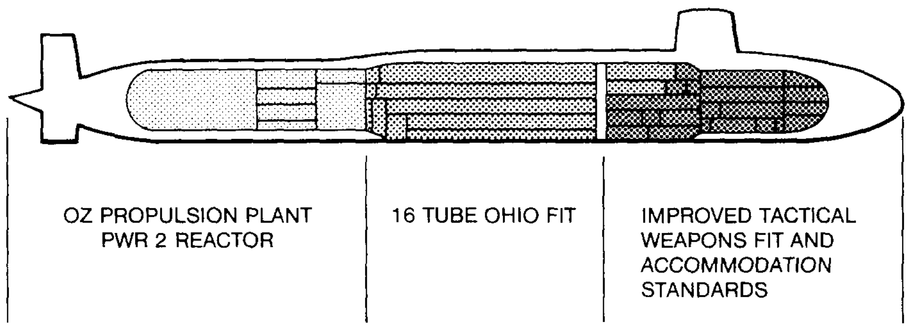

FIG. 4—'VANGUARD' CLASS SSBN: FINAL DESIGN

Vanguard is nearly twice as big as any previous Royal Navy submarine, with a submerged displacement of about 15 000 tonnes (FIG. 5). To put this in some perspective the upper rudder alone is the size of a badminton court and weighs as much as six double decker buses. At its widest, the pressure hull diameter is 12·8 m, nearly 3 m larger than that of Polaris boats and allowing a fourth deck.

Functional considerations dictate submarine layouts to a very large extent. The fore ends are given over mainly to the tactical weapons and command and control functions which are described in more detail in the next section. Further aft are the Strategic Weapon System navigation and missile control centres and the main accommodation area, concentrated on 3 Deck. Below this is the diesel generator compartment and a motor generator space. The missile compartment contains most of the Strategic Weapon Support Systems, with further bunk spaces on 3 Deck.

The general design concept for the overall boat and propulsion systems is that there should be evolutionary change from the TRAFALGAR Class, incorporating where appropriate essential improvements in nuclear and submarine safety, signature reduction, reliability, ease of operation and maintenance, and with reduced manning. In view of the importance of the submarine's role, availability is being given equal emphasis with performance for the first time. To achieve this, an extensive programme of Availability, Reliability and Maintainability (ARM) work is being undertaken, including Failure Mode Effects Analyses (FMEAs) on most systems, Upkeep Evaluations, and removal demonstrations.

An innovation for the Royal Navy is the use of Logistic and Escape Trunks (LETs). These are large pressure hull openings similar to those fitted in U.S. submarines. They are fitted with upper and lower access hatches which enable them to be used as escape towers. When alongside, the whole body of the LET can be removed, leaving a clear opening some 6 ft in diameter for shipping equipment.

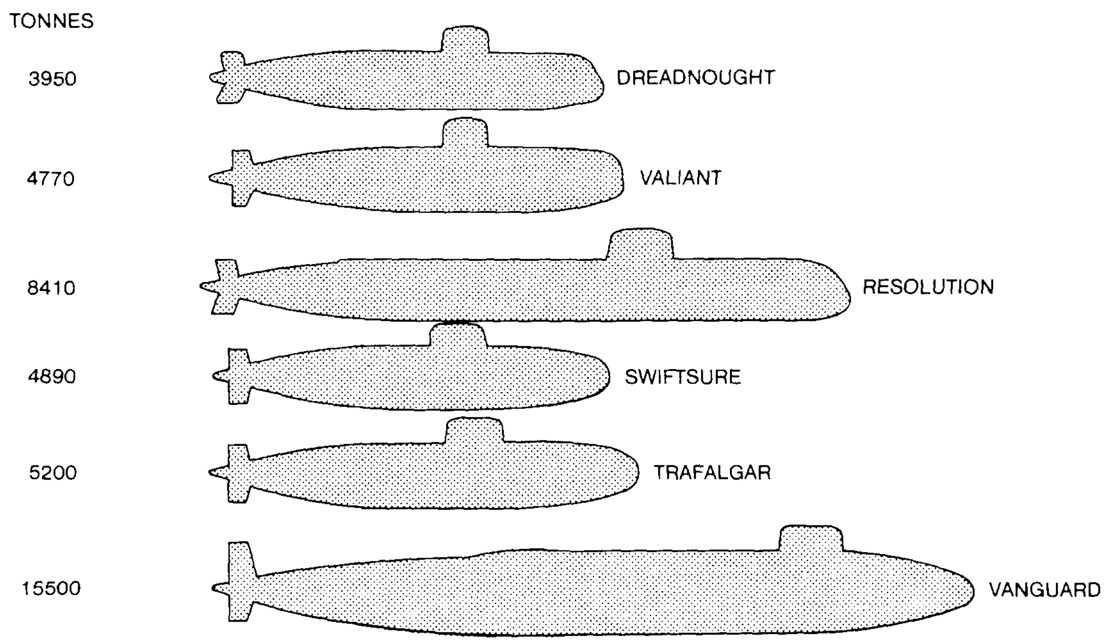

FIG. 5—BRITISH NUCLEAR SUBMARINES

Systems

Firefighting arrangements received attention early in the design. AFFF spray systems are fitted for the machinery spaces, and salt water sprays provided for the weapons stowage compartment. In addition, the vessel's nitrogen system is arranged so as to be capable of providing a zoned drench facility at $7\frac{1}{2}$ lb/in^2.

The ventilation system is zoned, the forward missile compartment bulkhead forming the boundary. Missile control and navigation system equipments have an additional closed loop system of U.S. design. Provision is made for purging all major compartments within the submarine whilst retaining a supply of conditioned air to compartments not affected by the purge.

Those of you who have experienced the biologically optimized mould propagating environment in certain areas of the RESOLUTION Class will be able to appreciate the improved detail design and margins in the VANGUARD system.

The hydraulic systems are developments of current practice. 150 litre/min Q type pumps are fitted throughout, there being five in the main port and starboard hydraulic system. Dedicated systems for the after hydroplanes and external equipments are also provided, with the usual facilities for cross-connection. Examples of equipment improvements include the adoption of helical unloader valves on the hydraulic pumps. These are quieter in operation and more compact, and they eliminate pressure transients which are believed to have been a major contributary factor in power plant seal failures in the past.

There are extensive air systems fitted in the submarine. In order to reduce HP air compressor running time, a separate 8 bar system has been fitted, with its own continuously running LP compressor. The systems are designed on the basis of achieving normal submarine surfacing entirely by LP blower. This is similar to U.S. practice and is a well-established practice in Royal Navy SSNs.

The many air and nitrogen bottles are installed for the life of the submarine. This will reduce refit workloads significantly. Acoustic emission NDE equipment is being developed for *in situ* revalidation of bottles.

Other advances embodied in the design are: electronic autopilot (first at sea in UPHOLDER); digitally based monitoring and control systems; improved communications standards; and reduced levels of airborne noise.

Design and Building

The detail design is being developed by Vickers Shipbuilding & Engineering Ltd. (VSEL), under Ministry guidance. The complexities of the design process are enormous and much use is made of the latest computer-aided design and manufacturing technology. A fifth-scale plastic model has been made.

The four submarines of the VANGUARD Class will be built in Barrow by VSEL, *Vanguard* and *Victorious* having been ordered already. The Ministry has negotiated tight contracts with VSEL, embodying target price and programme incentives. In order to meet the demands of the Trident programme and to improve productivity, some new construction facilities have been installed, and integrated planning techniques for procurement and production adopted.

The Devonshire Dock Hall is the centrepiece of the new facilities at Barrow. This provides a covered area for the assembly and outfitting of hull units, together with the necessary supporting facilities. An intensive programme of development and investment by the Ministry and VSEL has resulted in radically improved welding techniques, especially for pressure hull construction.

A major initiative being pursued with the VANGUARD Class is to undertake the outfitting as early in the build as possible, in order to reduce construction costs. Many structural, equipment and system packages are assembled off the submarine and the completed modules are end-loaded into the pressure hull units.

Outside the Devonshire Dock Hall is a transfer system, shiplift and wet berths where final outfitting and testing are carried out.

VANGUARD TACTICAL WEAPON SYSTEM

Captain N. C. Kirby

The main function of the Tactical Weapon System (TWS) is to assist the Command in ensuring that his submarine remains undetected on patrol from friend and foe alike whilst at the same time being ready to carry out the political directive of the moment. Thus the primary requirement is for comprehensive sonar and above water detection equipments which feed their information to a Command System, there to be combined with the intelligence and other data received via the external communications to give the commanding officer the best possible picture of the local and general situation. FIG. 6 shows the TWS.

The VANGUARD TWS is unique, comprising in-service as well as developing equipments. The risk to the overall programme has been minimized as far as possible by ensuring that the new items are logical developments from existing submarine equipments but this was not practical in all areas.

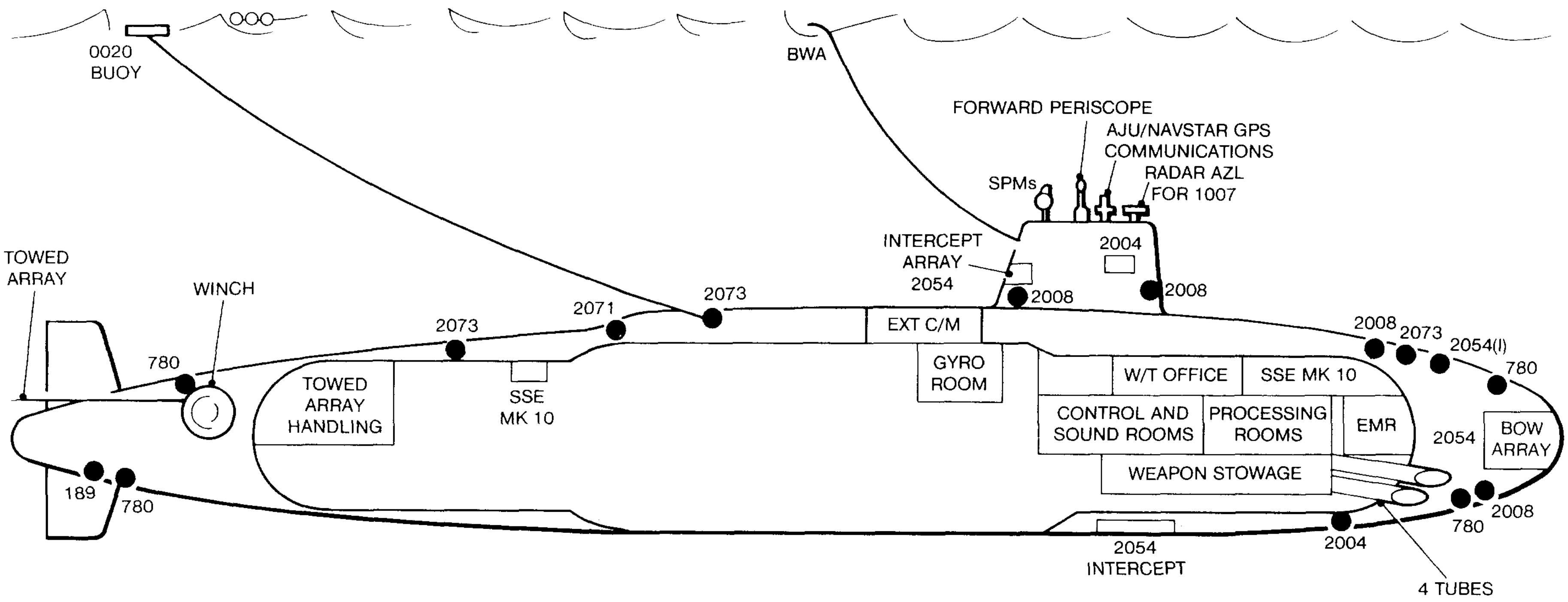

FIG. 6—'VANGUARD' TACTICAL WEAPON SYSTEM

AJU: radio mast
AZL: radar mast
BWA: Buoyant Wire Aerial
C/M: countermeasures
EMR: Electronic Maintenance Room
GPS: Global Positioning System
SPMs: Self Protection Masts
SSE: Submerged Signal Ejector

Sonar

FIG. 7 shows the arrays, of which those for Sonar 2054 are the most important. They include the large Chevron Bow array (optimized for passive operation but incorporating some active elements), the long fully reelable towed array and several Intercept arrays. These feed into five processing areas—intercept, passive ranging, narrowband, active and broadband which are integrated by the sonar data bus. Also on the bus are the sonar controller and maintainer equipments, the whole being contained in 18 cabinets and 7 operator consoles. The processed output goes to the Submarine Command System (SMCS), described later.

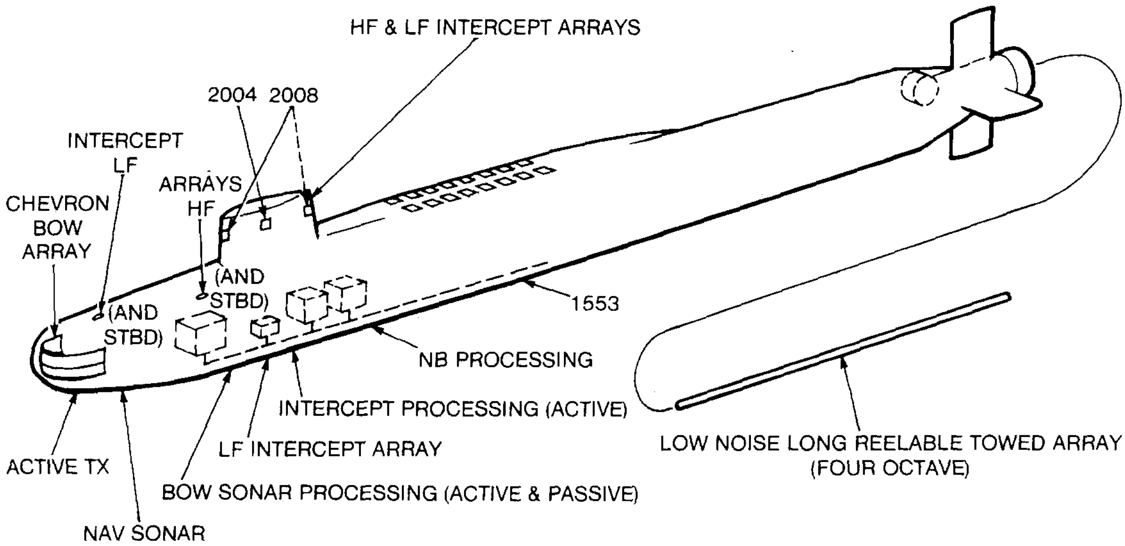

FIG. 7—'VANGUARD' SONAR

HF: high frequency LF: low frequency
NB: narow band TX: transmission

Self-Protection System

The above-water sensors are combined into two identical self-protection masts (SPMs) which include an optical path (viewed from 1 Deck, above the control room), thermal imaging, a TV camera, omni- and direction-finding ESM sensors, plus communications and navigation antennas. The masts are fully operable from the control room and, despite their apparent size, have a low radar cross-section. The inboard equipment includes the Tactical TV console and the latest ESM system—UAP. Also fitted is a simple low visual profile periscope

Navigation

The tactical navigation system may look complex but it is not. Inputs from NAVSTAR, HYPERFIX and so on are fed via a variety of aerials to the twin plotting tables which are fed also with ship's speed and heading. Outputs go to the TWS and, via the Ship Interface Buffer (SIB), to the Strategic Weapon System which can obtain a separate NAVSTAR input from its own aerial.

Communications

The communications system is very comprehensive but contains little new. Shore broadcasts range from VLF through HF to UHF SATCOM and are received via aerials which include the towed buoy and floating wire aerial, the non hull penetrating comms masts and the SPMs. On board, the signal traffic is passed through to the Semi Automatic Message Handling and Distribution System (SAMHADS) which has terminals in the W/T office and the Control Room.

Submarine Command System (SMCS)

The current SSN AIO systems are becoming overloaded and SMCS is being developed to replace them. Programmed in ADA, with massive processing and number-crunching power, SMCS should be capable of handling all that the sensors can throw at it and be flexible enough to cope with the threat in the next century. The Control Room, containing the SMCS displays and consoles, is illustrated in FIG. 8.

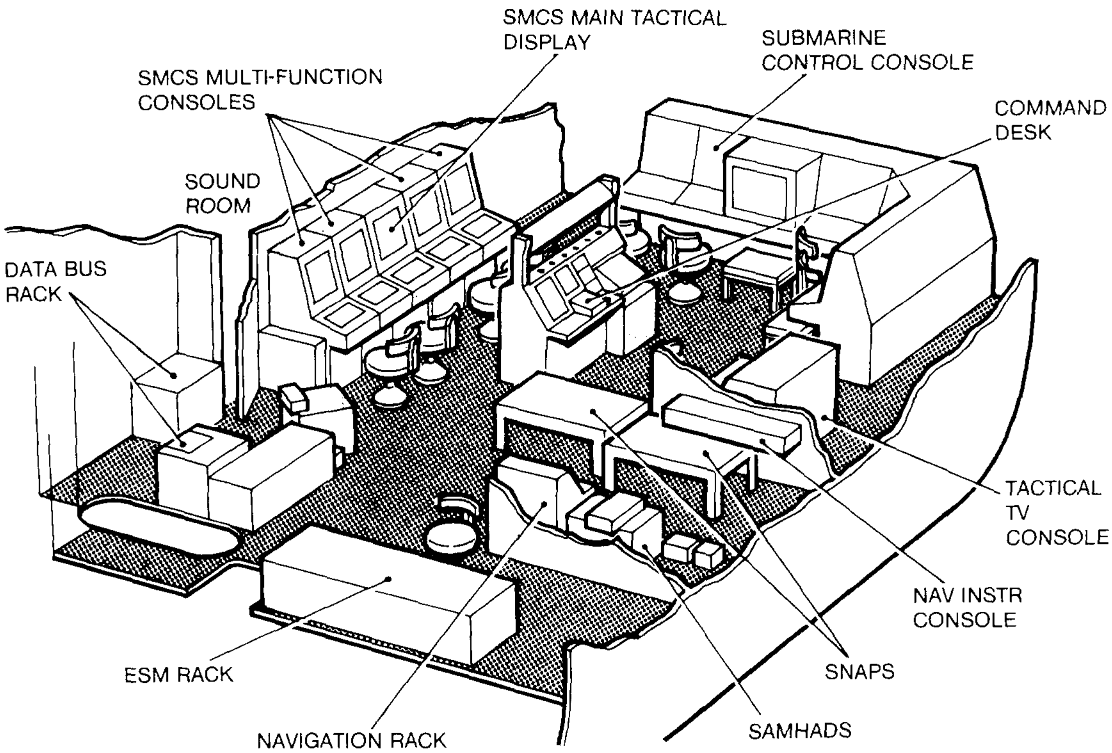

FIG. 8—'VANGUARD' CONTROL ROOM

Shore Development Facility

The submarine layout is being duplicated as far as is practical in the Shore Development Facility (SDF) at Vickers, Barrow, except for the communications equipment which will be in their own SDF at ARE, Portsdown. We are attempting to treat the SDFs as another platform in all aspects, from delivery of equipment, installation, setting to work and acceptance trials. The SDFs are the main tools in proving the TWS. All their activities will be in advance of those in *Vanguard* and by this means we aim to reduce still further the risk to the timely achievement of TWS Fleet Weapons Acceptance.