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The Fundamentals of Underwater Test & Evaluation

Submarines operate in an unforgiving, complex and highly pressurised environment where the need for absolute stealth is paramount. Threats and technology are rapidly evolving, driving the need for new tactics, new systems and system upgrades to be developed, tested and implemented at pace.

Test & Evaluation (T&E) is at the heart of QinetiQ's offering to our defence customers and, as such, we want to take the opportunity to remind ourselves of the fundamentals of why do we do T&E - and how must it evolve to meet the future requirements of our customers?

What is the aim of T&E in the underwater domain?

At the highest level, T&E aims to provide customers with an evidence base that allows them to make well-informed, objective decisions in relation to an underwater capability.

Broadly speaking, there are three reasons to do underwater T&E in Defence:

- To assure a capability is safe – during design, manufacture, acceptance and through-life
- To assure a capability is contractually compliant (i.e. the buyer gets what they want, and what they paid for)
- To measure elements of a capability, in order to quantify operational risk

Who benefits from T&E?

In short: everyone involved with an existing - or future - capability.

First to benefit is the customer: who can be sure that they are getting an asset that is safe, and that meets specific requirements - relative to costs and investment. In other words, that the capability provides value for money.

Due to the extensive costs and timeframes involved, procurement agencies need to know that a programme is on schedule to deliver the capability contracted and that the capability will remain relevant through life. For example, HMS ASTUTE, for which requirements were defined in the 1990s, will still be operational into the 2040s.

Second to benefit is the manufacturer: who can use T&E to understand the options available to them early in the development process, gather the evidence to support their technical submission for contractual acceptance, and understand the upgrade options once a capability has been fielded. This ensures that costs can be better managed and that the capability remains relevant.

Submarine platforms have some of the longest development timeframes of all platforms with the concept through to adoption in service taking up to 30 years. Even with the desire to reduce timescales and costs, managing the risk and costs through this development is a challenge to the manufacturer and customer. T&E is essential for maritime manufacturers - in order to help them understand the risks (including cost drivers) through the development and lifecycle, including upgrades, and adapt plans where necessary.

Third to benefit is the end-user: for example, submariners and operational duty holders in the underwater domain. With appropriate T&E, the end-user can be sure that the capability will meet operational requirements and that it is safe to use. They also have an idea of what it is capable of in relation to the threat, and how it will behave in the varying environments presented by changing temperatures and salinities.

As such, T&E allows defence customers to manage risk earlier, which can reduce programme costs and development times. Additionally, it provides assurance that the capability will be compliant with legal requirements.

How do we carry out underwater T&E?

In the underwater space, an enormous range of factors are tested and evaluated - from weapons systems to acoustic signatures and the integrity of the pressure hull. Some key areas are outlined below.

Safe operating envelope (SOE)

Establishing an SOE is a vital part of the development process. It defines what depths, pitch angles and speeds are safe in a given set of circumstances, allowing the submarine operator to remain safe whilst maximising operating parameters. Early SOEs are established via physical scale models of the submarine, and evidence from previous full-scale submarine trials. This is used to confirm computational predictions before the final SOE is determined. Engineers carry out a mix of tests: from proving specific components like the propulsor, to testing the whole submarine model.

Acceptance trials

Once the SOE has been established to be accurate via the scale model, the prime contractor will then construct the vessel to the suggested design. That submarine will then typically proceed on sea-trials – one example of which would be a manoeuvring trial. This involves the full scale testing of its manoeuvring and control systems. Feedback from this trial is then used to update the computer and scale models, and modify the vessel's design, if required.

Structures and survivability

Survivability looks at the submarine design using sophisticated digital models in order to understand what would happen were the submarine to collide or be impacted by an explosion. Design tools allow the assessment of ship design vulnerabilities. However, as is always the case with modelling, it is critical that the limits of what these tools can provide is understood and physical testing undertaken, if needed. The results of this modelling inform the types of material used in the structure, which are later tested to be sure. Other physical tests involve the non-destructive examination of welds to ensure integrity.

Environmental and shock testing

Shock testing assures the durability of a submarine's individual components by evaluating them to ensure that they meet the durability standards required of a military vessel. Parts are tested to ensure that equipment and onboard weapons can withstand the types of shock caused by explosions, running aground at speed, or a collision. In a similar fashion - accelerated 'ageing' using vibration-inducing equipment is used to test the safety and longevity of energetic materials.

Weapons range testing

In addition to being tested for shock, submarine weapons and combat systems are evaluated on various ranges. A range is a controlled, highly instrumented water space where objective measurements of a submarine's sensors and weapons can be made. In the modern world - where such test events are becoming increasingly expensive - range data is crucial to validate simulations that are then used for a more broad evaluation of weapon systems. This data also informs how these weapons are represented in training simulators. T&E is also undertaken on underwater sensors and sonobuoys, which are employed by maritime patrol aircraft and helicopters. A similar process (one which also incorporates mission rehearsal) takes place in mine warfare threat representation. Here, a variety of mine shapes are simulated on a range using inert materials. This tests the ability of vessels (and their crew) to detect mines using sensors, and then to safely clear such mines with the use of divers or other specialised hardware.

Signatures

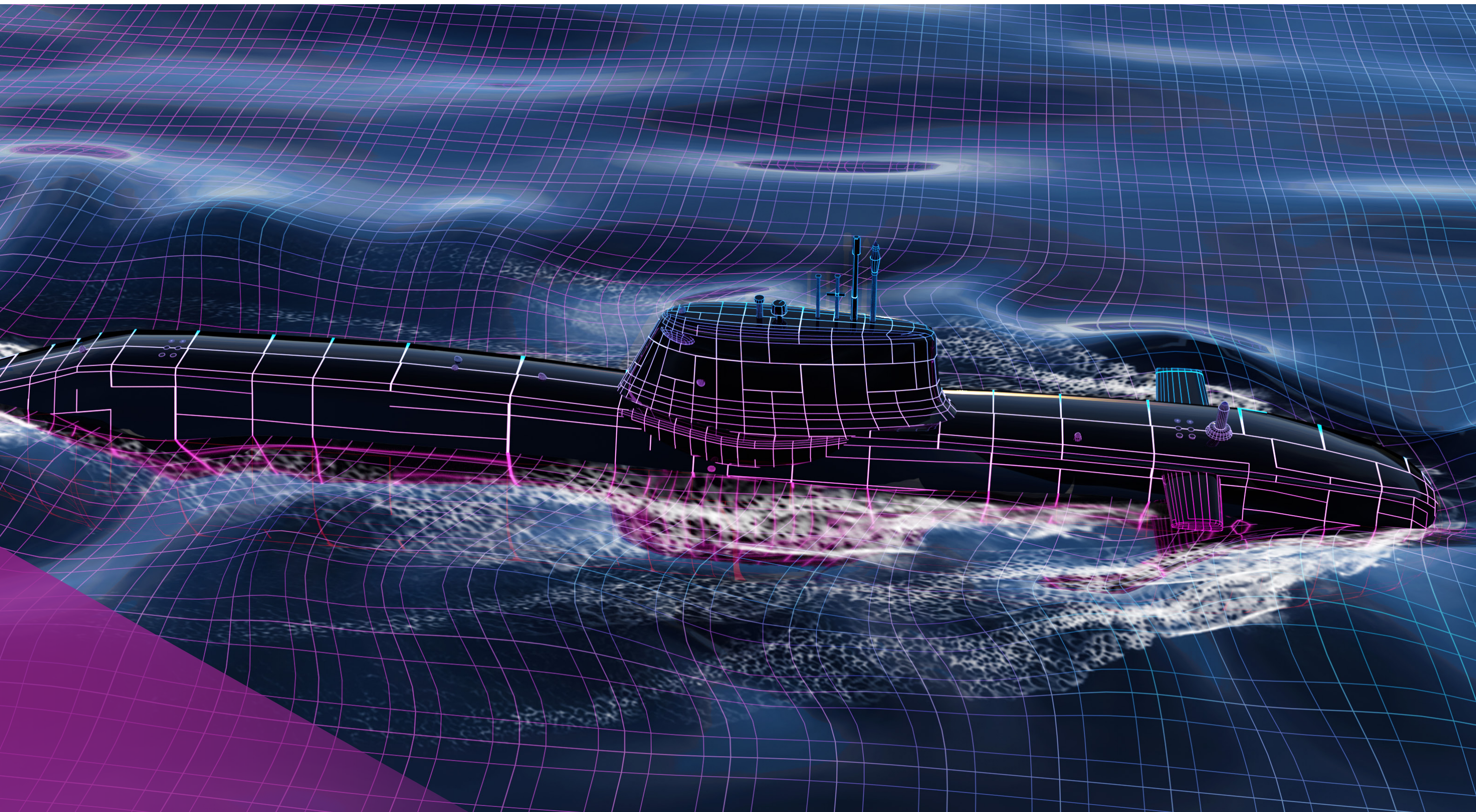
In order to mitigate vulnerabilities, you must first know what they are. Signatures are considered in the design of a submarine, and signature T&E conducted on in-service submarines on a routine basis ensures that they remain as stealthy as possible. This involves testing a range of the submarine's signatures, with electromagnetic and acoustic signatures being the most important (since they are commonly used to detect submarines). Radar, infrared, and Target Echo Strength signatures are also evaluated, with 'dashboards' provided for each vessel that contain all of this data.

One of signature measurement's goals is to identify emerging faults in a vessel's machinery. Maintenance can then be scheduled to address such faults, so as to maintain the submarine's effectiveness. Because submarines are often deployed for such extensive periods, there are less opportunities for routine maintenance than conventional vessels. As such, the process has to be done thoroughly and efficiently when it is required, in order to completely assure the submarine and reduce interference with its operational schedule. The measurement of key signatures and the associated activity to link to the physical causes on the platform is a key enabler for this.

Escape and safety systems

Reducing the risk to life of the ship's company in the event of a serious incident is critical, and is the focus of Submarine Escape, Rescue, Abandonment and Survival (SMERAS). Life saving equipment is tested in various temperatures, pressures and flood rate. This includes escape suits for individual crew members, rescue mini-subs that can dock with a distressed submarine and life rafts for surfaced ships. Tests are undertaken against a stringent set of regulations and processes, incorporating human factors and the participation of submariners.

In the next piece in this series, we will look at the many challenges of carrying out Underwater T&E, and how they are overcome.
For further information, email: **TandE@qinetiq.com** or visit: **Test & Evaluation (qinetiq.com).**



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Synthetic environments in design and T&E

Synthetic environments save greatly on time and costs by allowing errors to be detected safely and cost effectively in a digital environment. Digital design and T&E allows a significant percentage of the submarine design to be trialed and verified, before the steel of the vessel is cut.

For example, if the hull is too large on a design, a vessel may struggle to dive. To compensate, additional tanks can be added to the design - however, these additional tanks could take up space required by other submarine components. This, as a result, requires the rearrangement of other components within the hull. This is a much easier proposition in the digital world.

Taking the deterrent submarine as an example, its design driver will be its ballistic missile tubes - around which everything else will be built. Physics and weights of the components will first be modelled and then validated in a synthetic environment, before progressing further with the design. Not only does this process allow the design to be planned and optimised in a cost-effective way, it also allows for greater and faster integration of different original equipment manufacturer (OEM) components.

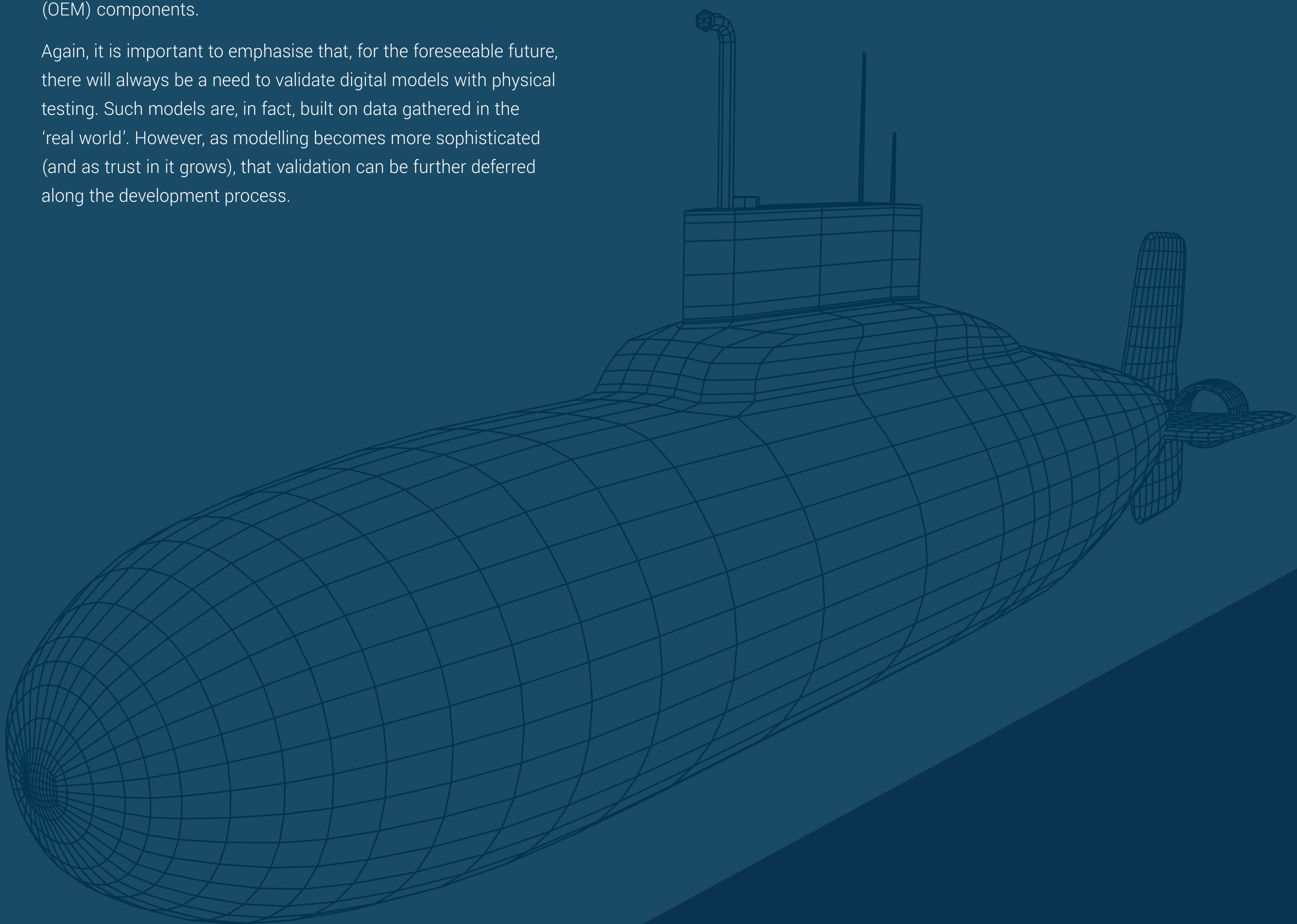
Again, it is important to emphasise that, for the foreseeable future, there will always be a need to validate digital models with physical testing. Such models are, in fact, built on data gathered in the 'real world'. However, as modelling becomes more sophisticated (and as trust in it grows), that validation can be further deferred along the development process.

Case study: Operation Relentless

In 2019, the Royal Navy marked a significant milestone in its long, illustrious history – fifty years of deploying ballistic missile submarines to deliver a continuous at sea deterrent (or 'CASD'). In that time, QinetiQ and its predecessors have played a central role in supporting both the development and safe operation of the Royal Navy's submarines.

Delivered through the Long Term Partnering Agreement (LTPA) and Maritime Strategic Capability Agreement (MSCA), QinetiQ has used its experience and the specialist skills of more than 700 maritime personnel - from physics to physiology, acoustics to atmospheres and structures to survivability – to meet the CASD's challenges.

The key outcomes for the Royal Navy throughout have been to maximise fleet availability, capability, safety, and survivability, while ensuring operational efficiencies and performance in all areas. This has helped the Royal Navy to maintain its operational advantage - and to capitalise on the latest material and technology innovations.



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