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Fundamentals of Maritime Test & Evaluation

The pace of change in defence is increasing. Rapidly advancing technology, unpredictable external political upheavals and an evolving pandemic continue to destabilise the world.

Maritime domain is particularly challenging. Maritime platforms are complex systems of systems with a large human component, they have long service lives with multiple system upgrades, inter-operate with other UK and partner platforms and provide a wide range of missions across a huge geographic footprint. Threats are evolving rapidly, driving the need for new tactics, new systems and system upgrades to be developed, tested and implemented at pace.

As such, we want to take the opportunity to remind ourselves of the fundamentals of our core business: Test & Evaluation (T&E). Why do we do T&E - in particular for the maritime domain - and how must it evolve to meet the future requirements of our customers?

What is the aim of T&E in the maritime 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 a maritime capability.

Broadly speaking, there are 3 reasons to do T&E in Defence:

- To assure a capability is safe
- To assure a capability is contractually compliant (i.e. the buyer gets what they want, and what they paid for)
- To assure that a capability delivers on what the end-user of that capability wants it to do

Who benefits from T&E?

In short: everyone involved with a capability.

First 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, that the capability remains relevant, and it reveals how it can be adapted to other uses.

A maritime platform can take many years to progress from requirements to fielding, and managing the risk and costs through this development is a challenge to the manufacturer. T&E is essential for maritime manufacturers, in order to help them understand the risks through the long development and lifecycle, and adapt plans where necessary.

Second to benefit is the procurement agency: 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.

For example, the contract for the Queen Elizabeth class of aircraft carriers was announced in July 2007 - and it was a decade later - in December 2017, that the first ship was commissioned.

Third to benefit is the end-user, the sailor or submariner in the case of the maritime 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, and how it will behave in different circumstances.

As such, T&E allows the end-user 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, as well as the rules of engagement.

How do we carry out maritime T&E?

Maritime platforms are highly complex and involve the deep integration of many elements - including propulsion, hull design and weapon systems, as well as a potentially large crew. It is clearly imperative that these are all integrated to provide an effective platform.

Correcting design mistakes late is extremely expensive. As such, T&E starts very early in the lifecycle - with extensive modelling for design and survivability. Importantly, a new ship or submarine is seldom fitted with a completely new suite of systems and weapons. Instead, key elements are often re-used from earlier platforms and then progressively upgraded through life. Testing the successful integration of these legacy systems is critical to the platform's effectiveness.

Once the platform is built, a progressive, structured series of harbour and sea-based trials are undertaken; some on the open sea and some on instrumented ranges in order to test weapons and confirm signature levels.

As covered in the first article in this series, T&E is, fundamentally, the application of the scientific process - testing the hypothesis that elements of the platform are safe and effective. Below we expand on how this plays out in four particular areas of design T&E.

Hydrodynamic design

The ever increasing need for faster, more manoeuvrable or quieter naval platforms present new and increasingly complex challenges to the ship or submarine designer, builder and operator. Predictive hydrodynamic T&E is key to providing operationally effective, efficient and safe designs for use in the world's oceans. In this case, for example, the hypothesis is that the design of a propeller or hull shape provides the performance or acoustic quietness that the platform needs.

Experience and knowledge based on many years of research into ship stability, propulsors and human factors coupled with extensive testing and experimentation allow an initial assessment and filtering of the design concepts. This is especially important when complex requirements render existing options unsuitable. As the design matures, a combination of computational testing and physical model testing is used to refine and predict the expected performance before the expensive commitment to a full-scale build. This is clearly a major step up in cost and to mitigate the chance of errors, bespoke facilities and modelling capabilities are used.

Such vessel testing is undertaken in some of the world's most sophisticated hydrodynamic facilities. One such example suite of capabilities comprises the world's largest ocean basin (at 120m x 60m), a 270m long towing tank and an associated high performance computing cluster for model-based analysis. Tests involve a combination of physical model experiments, a virtual towing tank and computational fluid dynamic (CFD) analysis - along with empirical and semi-empirical methods. The empirical approach is a calculation method that uses, as its basis, data measured from physical testing at the T&E facility. That data, combined with other similar data, helps the prediction of the performance of future designs.

Work done on the design and development of a vessel ensures that a thorough understanding of all the relevant performance factors is established and approved before the full-size vessel is manufactured. This helps ensure the vessel is safe, cost-effective and meets operational requirements.

System integration

As discussed earlier, new naval platforms tend to combine new and legacy components. Here then, the purpose of T&E is to confirm the hypothesis that the old and new systems have been integrated successfully.

Within a complex system, or system of systems, there is rarely a simple one-to-one link between a single component and the wider military capability. Bringing these components together to form a system that meets requirements is termed integration. Such integration has to be designed in from the outset and then progressively de-risked, integrated and accepted into service as the platform matures.

In addition, as threats evolve, the mission changes, or equipment becomes obsolete, the whole system must change, with components being replaced asynchronously. And throughout, consideration must be given to safety, security and cyber resilience. Making and coordinating these changes takes planning, monitoring and critical decision-making - all informed by a complex system risk profile.

So, a core consideration for maritime system integration T&E is the ability to:

- Gain confidence in an evolving system, one which is integrating maturing components that are being incrementally de-risked, tested and trialed. This works for both the system lead and the supplier, as they can gain confidence in their sub-system's ability to meet the host system's needs (ie. interface, functionality and standards)
- Assess and qualify the evolving impact that the changing component has on the rest of the system
- Conduct experimentation to evaluate candidate options (or potentially risky solutions with a possible high payoff) in order to understand the merits and drawbacks of progressing these options.

In the maritime domain, this is most cost-effectively done with a reference testbed, which could be used to represent various systems of a vessel - for example, its combat system or communications array. This testbed can be land-based, fitted into a floating platform, or entirely synthetic.

The testbed is flexible by design, allowing various standards of equipment to be brought together and their integration validated. This will become increasingly important in the future, as naval platforms are updated at an increasing pace and as vessels become increasingly software-driven. The ability of the testbed to replicate a particular ship at a particular time, with an associated history of validated upgrades, will be key to the successful deployment of new capabilities.

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Signature hygiene

A vessel's signature can be a life and death matter. The mine countermeasures vessel (MCMV) is a good example. Designed to possess a tiny acoustic and magnetic signature, even the smallest addition to an MCMV's footprint could compromise its ability to do its job - and risk the safety of the vessel and its crew.

Over the life of such a ship, modifications may be made which unknowingly increase its signature - for example, a pipe change during routine maintenance or a sensor system upgrade – so even the smallest change can have significant consequences.

The purpose of T&E in this instance is to confirm that key elements of the platform's signature are suitable prior to its operational deployment or after any major refits.

To do this, specialised and carefully designed maritime acoustic and magnetic ranges are used to assess a vessel's signature in various configurations and domains - for example, with all systems active and then with different configurations of systems turned on.

These measurements are complimented by a comprehensive assessment of a component's or sub-system's magnetic signature, undertaken at highly controlled land based magnetic ranges. Highly qualified personnel assess the platform's signature and the suitability of additions and modifications to that platform - providing advice on its suitability for the planned mission.

Maintaining a history of the measurements allows the creation of 'class data' - objective benchmarks that can be used both to identify issues with a particular vessel compared to previous measurements or how its signature compares to other in its class. This includes 'dashboards' that illustrate certain recurring problems in vessel classes. This is essential because, over time, each ship may begin to diverge from its class.

For example, three frigates in the same class may eventually receive different engine/propulsion components affecting their acoustic or magnetic signatures. The class data can tell us if one of the three frigates has a faulty component and, as a result, is dangerously noisier than other ships of that class. Having been first measured at build, or after the integration of new systems, a ship or submarine will typically be assessed prior to deployment or once fitted with additional components that it might not usually carry (eg. live munitions).

However, once a ship has left the T&E facility, unintentional changes over time may increase its signature. As such, ongoing T&E is required, working with ship personnel to identify and raise awareness regarding a vessel's ongoing noise and acoustic hygiene. This helps to establish best practices to keep the vessel as quiet as possible, once deployed.

Weapons testing

Maritime weapons testing involves two major hypotheses:
1. Is the weapon safe and effective through-life?
2. Is it properly integrated with the rest of the ship's combat systems, allowing for successful deployment?

Tests are usually undertaken as parallel activities and include specialist evaluation in the areas of:
- Accelerated ageing to test the safety of energetic materials when exposed to the maritime environment
- Weapon development and assessment trials to confirm weapon performance, prior to installation on the ship or submarine
- Weapon command and control system integration activities, as described previously in the system integration section

The culmination of these parallel strands is the first-of-class firing (the first time that a weapon is tested) or post-installation test firings. These bring together all of the elements of the weapon system to prove that integration has been successful. There are usually a number of scenarios, which are specified by the customer or user and may encompass a range of targets and environments.

These firings must be undertaken in highly controlled, safe ranges, allowing for the possibility of error. Airborne, surface or underwater targets are deployed in a controlled manner to provide a well-defined test profile for the weapon system.

For example, a weapon may be used against a target that represents a static vessel, and then against a rapidly moving subsonic target that possesses its own countermeasures. Careful deployment of instrumentation allows for post-firing analysis and comparison with model-based predictions. Such an approach can minimise the number of required firings (which are often expensive), saving significantly on costs.

Therefore, confidence in the modelled performance requires very careful test design. Aspects such as the use of the platform's radars and sensors to cue the weapon launch are also evaluated.

Today and tomorrow

If the inscriptions found upon Egyptian clay tablets are to be believed, humanity has been building ships for at least 6000 years. But, over the last century, the pace of change in the maritime domain has accelerated. Today, the demands placed upon the platforms that operate on, above and below the ocean are enormous. And these demands will only continue to grow as the technology races forward - and as political circumstances continue to evolve.

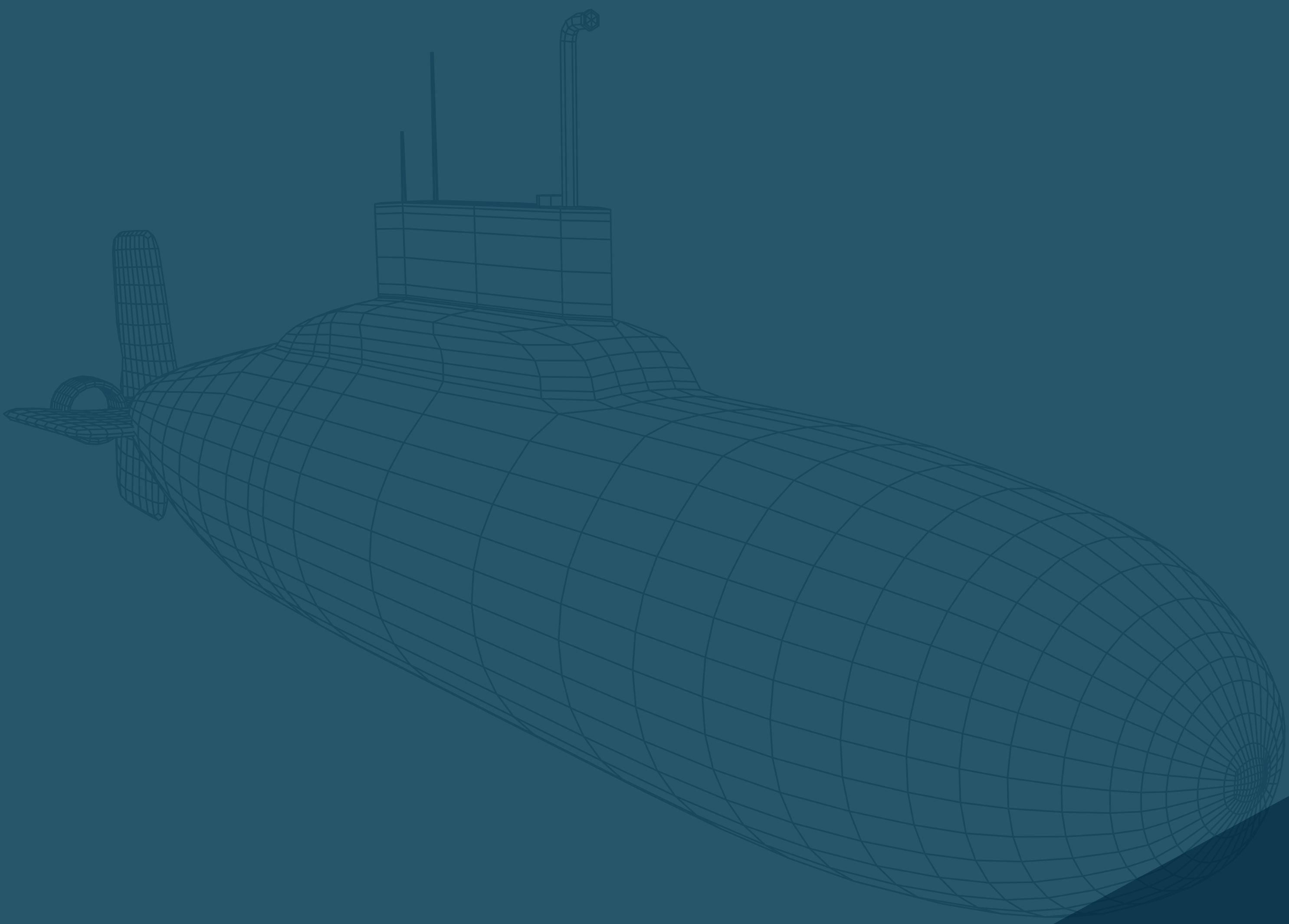
Those called upon to do the most difficult and most dangerous things rightly demand the highest level of confidence in the tools they use. Maritime T&E is there to ensure that water-based platforms (and all of their elements) are ready to face the missions of today and tomorrow.

The CAMM/Sea Ceptor missile was designated to replace Sea Wolf, an obsolete system, and would provide the Royal Navy's Type 23 Frigates with a vastly superior short-range air defence (SHORAD) capability.

The challenge: to drive down costs, there was a very limited number of live firings available. QinetiQ collaborated with a group of stakeholders to maximise the amount of data that could be gathered under these conditions.

The trials included a number of pre-defined scenarios in which extremely precise results had to be achieved, first time. The team went above and beyond - for example, installing Go Pro cameras on the wings of targets, in order to corroborate test data in a complex, cluttered environment.

Sea Ceptor would go on to be installed on the follow-on 23 ship and is also set be installed on the new T26 Frigate and on the T31 and T45 as part of SV-CAMM.



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