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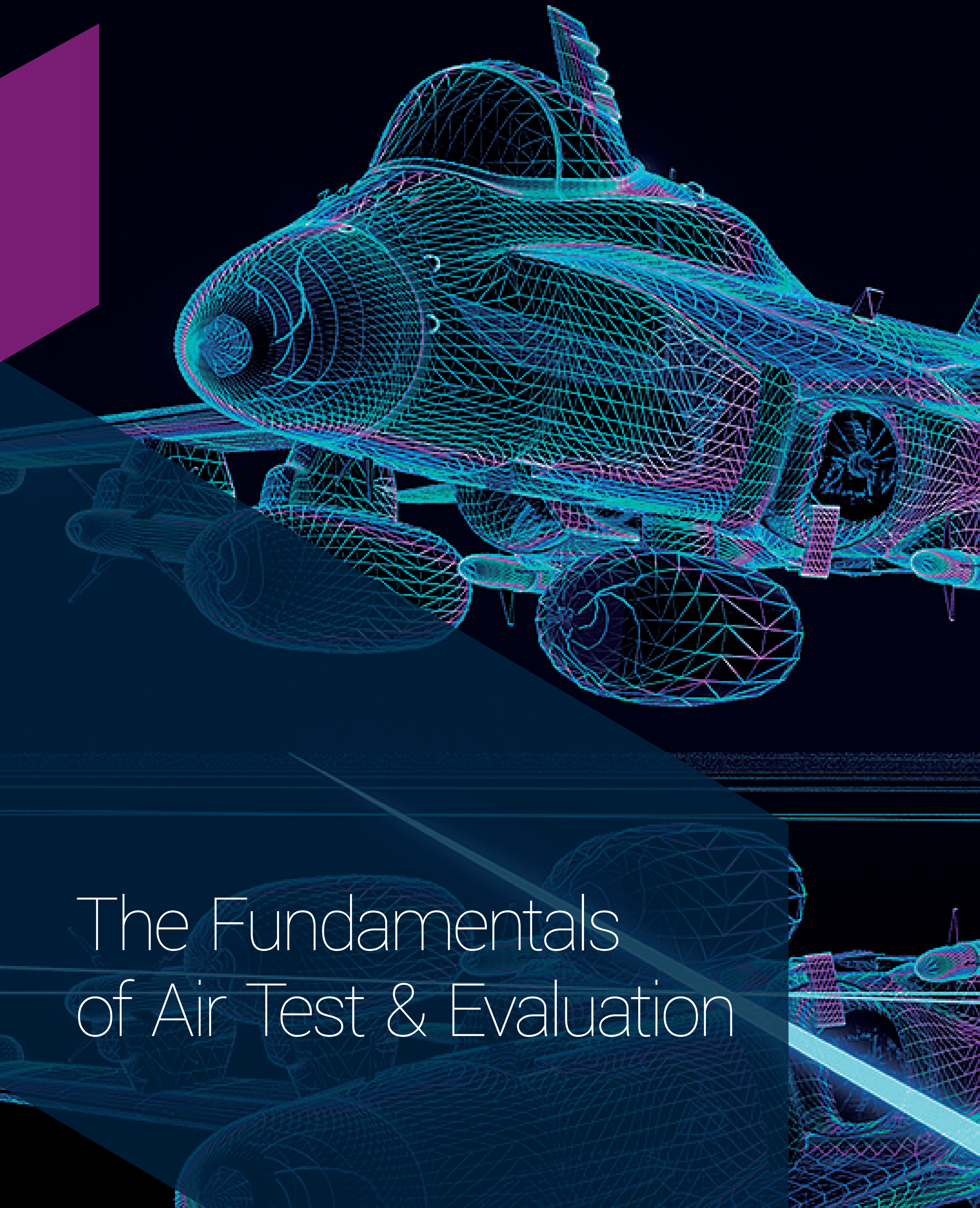

The Fundamentals of Air Test & Evaluation

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

The volume of airspace needed, the avoidance of foreign observation, significant running costs and the sheer speeds involved - all conspire to create challenges for testing in the air domain. But test we must; 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 air domain - and how must it evolve to meet the future requirements of our customers?

What is the aim of T&E in the air 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 air 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 its end user 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.

Air platforms have traditionally had some of the longest development timeframes of all platforms - for example, with some air superiority fighters taking decades to move from concept to fielding. Even with the desire to reduce timescales, managing the risk and costs through this development is a challenge to the manufacturer. T&E is essential for air platform manufacturers - in order to help them understand the risks through the development and lifecycle, including upgrades, 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, Typhoon, for which requirements were defined in the early 1970s, has now been in service for nearly twenty years with multiple tranches and continued proposed upgrades.

Third to benefit is the end-user: for example, the force commanders, pilot or aircrew in the case of the air 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 - this is particularly important, considering the range of theatres and operations today that forces are expected to perform in.

As such, T&E allows defence 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 air T&E?

Air platforms are highly complex and involve the deep integration of many elements - including propulsion, airframes, navigation and weapon systems - as well as life support in crewed systems. Modern strategic air power also relies on the integration of systems and data across a number of platforms, rather than each platform working in isolation. It is clearly imperative that these are all integrated to provide an effective capability.

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 craft or missile is seldom fitted with a completely new suite of systems. 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 air and land-based trials are undertaken; some in air ranges in which a platform is put 'through its paces' - and some on the ground, in instrumented facilities.

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. In the paragraphs below, we explore the use of calibrated and open-space environments to gather test evidence.

Modelling and Simulation

Modern defence programmes use increasingly sophisticated digital models and simulations. Where possible - and if suitably validated - these can be expected to increasingly provide elements of the required evidence. The essential role of live testing then becomes one of validation of the models, and, if needed, final acceptance testing - giving the customer ultimate confidence in the delivered product. Such environments also open up a more creative approach to gathering evidence - by providing more options. For example, you can test under conditions that would be impossible to replicate live - for practical, cost or security reasons. However, using modelling and simulation for T&E may require a mindset shift about what is accepted as evidence. Though the technology has existed for decades, many safety agencies still insist upon physical testing in order to sign off on a project. This is finally starting to change.

Use of calibrated environments

Air system T&E relies upon highly sensitive 'calibrated environments' in which air systems can be tested in meticulous detail and their performance measured under controlled conditions. In such environments, the hypothesis is that the craft and/or its subsystems are fit for purpose in a wide range of environments. Tests are conducted to see if this is true. Below are some examples.

Climatic chamber

This is usually a large aircraft hangar, configured to provide an environment in which an airframe can be exposed to anything from a -70C 'cold soak' to 70C temperatures. The chamber can modulate humidity, provide icing, as well as simulate UV and solar effects. QinetiQ operates the largest facility of this type in Europe.

Electromagnetic (EM) space

An outdoor area in which an aircraft of any size can fit. Airframes can be bombarded with high frequency (HF) and microwave radiation at various field strengths to test if there are any EM vulnerabilities in the system.

Calibrated light environment

An environment which can vary its light levels from pitch black to brighter than daylight, in order to test displays, IR systems, night vision systems, and so on.

Altitude chamber

This is a facility that is able to create various extremes of pressure. For example, it is able to simulate explosive decompression and can also be used for training personnel.

Anechoic EM space

Essentially a shielded hangar in which there is very little background radiation. This is the ideal place to test a platform's emissions - something very difficult to do without a quiet EM background. In the opposite direction, calibrated emitters can be used to test the suite of receivers on the platform. We can also test how a platform interacts with personal devices.

Open air testing

Of course, test and evaluation also must take place in the 'real world' - beyond calibrated environments. Some particular examples are:

Airborne testing of systems

Here, the hypothesis is that a specific component is suited to air use. A common way to test this is through an airborne test-bed. The test bed particularly comes into its own with future combat air and weapons systems - these often require significant miniaturisation and integration with other platform components. This allows the manufacturer to test and validate a component, before going through the expense and effort of miniaturising it.

QinetiQ operates an air fleet of multiple aircraft. It comprises a mix of rotary craft, as well as small and large fixed-wing platforms. This provides a range of options to test various payloads in varying conditions.

Communication system testing

A platform can be flown a few hundred miles away from the test facility in order to see how well its communication systems work - for example, its identification, friend or foe (IFF) capability, or secure communication systems. This allows the identification of any 'blanking' under operating conditions where an antenna loses line of sight due to the shape of the aircraft, or any other effects from the aircraft which may cause signal loss.

Use of unmanned air targets for weapons testing

The operational performance of air-to-air and surface-to-air missiles is confirmed using representative air targets. Today, only a few live firings may be undertaken for cost reasons, but such tests provide essential evidence that the weapon system functions correctly. Depending on the weapon system under evaluation, these targets must be able to replicate everything from supersonic missiles, to small UAVs, to helicopters and fixed-wing aircraft.

Targets are typically modular and, broadly speaking, fall into two classes. The first, a lower cost target platform that is likely to be shot down. The second is not destined for destruction, containing more expensive and more sophisticated payloads of varying configurations.

Such payloads include miss distance indicators - which show the point of closest approach that the missile passed by - and if that would have resulted in a successful kill. Targets can also be fitted with countermeasures - such as flares to throw off IR targeting, chaff to deceive radar systems, and seeker simulators that can be used to test that the client's radar warning receiver (RWR) is working properly. RCS (radar cross section) augmentation can also be fitted to the target (or a body towed behind it) - to make it appear as a bigger target to the weapon system being tested.

Use Case: Ship Air Integration (SAI)

To give a deeper understanding of air T&E, we will now explore one aspect in more detail, that of establishing the safe operation of aircraft from maritime platforms.

Referred to as 'Ship Air Integration' (SAI), this is the test and evaluation of aircraft that land and take-off from water-based platforms. QinetiQ has conducted SAI for more than 40 years. Here, we hypothesise that a certain aircraft and a certain ship class are interoperable for use at sea.

The majority of maritime vessels require an air capability. For example, even the smallest ships need to field a helicopter. But operation on ships brings its own challenges. Visual references, deck motion and turbulence are the three main factors causing pilot workload and impacting aircraft performance.

SAI: the process

Air flow air pattern trials must first be conducted before any aviation can be carried out on board a ship. An understanding of the ship's air patterns leads to preliminary ship interface trials, which are a vital step in obtaining approval for the safe use of a particular aircraft from the ship.

As part of the trials management process, QinetiQ will design a test programme for a new aircraft or ship - analysing and assessing various parameters in a suitable environment (eg. at sea, or on water-based ranges). For example, the hypothesis is to determine if a helicopter can perform suitably when flying off of a ship, and if any of the vessel's components (like emitters) interfere with the craft. This allows us to derive operational limits for any aircraft or ship combination.

Any time there's a new vessel with a flight deck, QinetiQ will take at least one type of aircraft and test its performance against the ship. This involves assessments in rough weather conditions, temperature extremes, low pressures, and rough seas - something that is sometimes known as 'storm chasing'.

In order to do this, we provide a team that includes safety managers, technical analysts, naval architects and flight test engineers - who work alongside test pilots. Engineers collect a substantial volume of data on aircraft performance under various conditions.

Saving resources with 'theory testing'

Theory testing is one such way to save time and resources, whilst reducing the operational impact of taking a ship off duty for testing. This can involve the use of simulation and computational methods, along with a massive database of prior ship performance data.

One example is the use of computational fluid dynamics (CFD) to represent the varying effects of wind on the ship and the craft operating on it. CFD is used for ship air wake calculations - assessing the affects of the turbulence created by wind flowing across the vessel's superstructure, and how it can interact with a craft attempting to land on the ship, or interface with the effects created by an aircraft's rotors.

Deck motion modelling (DMM) is used to better understand take-off and landing, and to gauge the effects of sliding and toppling of ship-parked craft, along with undercarriage and lashing (ship to craft attachment) failures.

Engineers build a variety of instruments to collect data from the ship and the platform. We can use this data to build ship and aircraft safety profiles. These profiles and the underpinning data can be integrated into the platform evaluation digital thread, where through-life data is captured into one single assured source of truth for exploitation and re-used by different users as needed for decades to come. With such tests, the aim is to reduce the time spent on ship trials - bringing ship downtime from weeks to as close to zero as possible - whilst also reducing the number of external personnel who need to access the vessel. An oft-quoted saying amongst QinetiQ's engineers is 'test once, use many times'.

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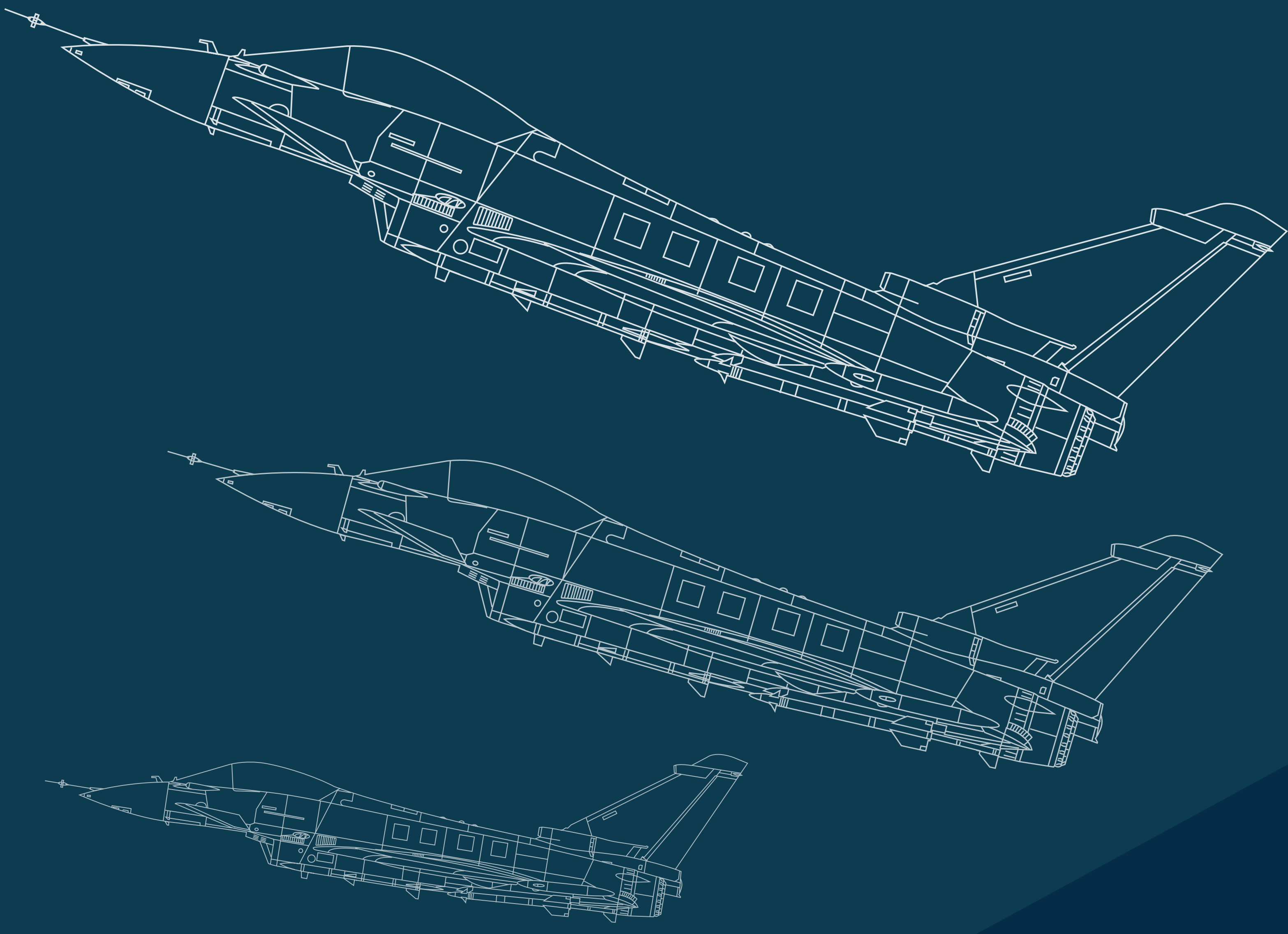
Pulling it all together: Independent Safety Advice

In order to form a coherent understanding of the safety and operational performance of the air platform, the evidence derived from modelling and simulation must be combined with data from tests using these facilities and capabilities.

Learning from experience, many nations - including the UK - require an independent analysis of this evidence to provide confidence that the new platform or system is safe to enter service. Having an organisation suitably skilled to provide this independent evaluation is a key part of a nation's air T&E enterprise, and is a role that QinetiQ is proud to offer.



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