Virtual Training using Real Application

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ABSTRACT

Modern systems, particularly in the maritime domain, are increasingly reliant upon software applications and services that are provided by different equipment or delivered via a shared open architecture using virtual machines. This creates a challenge for training equipment operators and maintainers, as access to the real systems hardware and applications for training is often expensive and only accessible for a limited amount of time at a single site.

The use of real software applications within a virtual training environment provides a highly cost effective, realistic and accessible training solution, which can be delivered via standard PC hardware at the point of need. When combined with virtual interactive 3D models of physical equipment units and the potential use of Virtual or Mixed Reality displays, many of the training objectives for operators and maintainers can now be delivered via these rapidly evolving technologies.

This paper presents the new approaches that have been adopted to deliver a training system for a complex maritime communication system, including accessing real systems software running on virtual machines within a simulated 3D environment. This approach may be exploited to deliver far more flexible and cost-effective training solutions across different domains, when compared with traditional hardware-based training solutions.

1.0 BACKGROUND

1.1 Current Approaches to Maritime Operator and Maintainer Training

Within the maritime domain, operational systems are increasingly comprised of complex software applications provided by different suppliers, potentially hosted on a Virtual Machine (VM) within an 'open architecture' mission or combat system. These systems may also require bespoke hardware to provide the operator user interface and server infrastructure for hosting the applications.

For example, a typical ship mission system may include multiple different equipment types from different suppliers providing the following functions:

- Platform management
- External and internal communications
- Sensors (e.g. radar, sonar)
- Effectors (e.g. weapons, decoy launchers)
- Mission planning and situational awareness

- Navigation

Traditional approaches to the provision of operator and maintainer training for maritime systems have often relied upon procuring from the Original Equipment Manufacturer (OEM) additional sets of operational hardware and software, or a system-specific part-task trainer, as the primary training media used within a designated training course. Whilst this may be a straightforward solution, this approach has its limitations as described below in delivering operator and maintainer training for modern maritime systems.

1.2 Challenges using Hardware-focussed Training Solutions

Where equipment operator and/or maintainer training solutions are primarily based upon the provision of hardware devices, the following issues can arise:

- **Accessibility**: Trainees may only be able to access the training hardware once as part of a designated training course at a single site. This does not lend itself to supporting training 'on demand' or refresher training whenever the trainee requires.
- **Affordability**: The initial purchase price of an equipment set may be significant, especially if it is identical to an operational piece of equipment. Savings could be achieved by lowering the fidelity of the hardware whilst still meeting the training need. Ongoing support costs for complex hardware also need to be considered. In addition, if the hardware is only available on one site, then there may be a significant recurring cost for the trainees to travel to attend equipment training courses.
- **Configuration Control**: Changes to the equipment fit across the lifetime of a system are almost inevitable and differences often occur between equipment fitted across the same class of ship and/or across a fleet. Any training system hardware will require further hardware and/or software upgrades to remain representative of the 'as fitted' equipment.
- **Adaptability**: Dedicated equipment specific training hardware can only provide training for one equipment type.
- **Flexibility**: Training may be limited by what can be achieved using the hardware, e.g. some faults may not be able to be replicated or modes of operation covered using the hardware, due to a risk of damage or lack of external data provided by other systems. This may negatively impact upon what individual or collective training objectives can be met.
- **Space Constraints**: Many training establishments/schools are required to train multiple operators and maintainers on a significant number of equipment types and simply do not have the space to host dedicated training hardware for multiple systems.

With the above issues in mind, the use of new simulation and training technologies and software methodologies offers the opportunity to address many of these issues, whilst still providing a highly realistic training solution. This is particularly relevant for maritime systems as they become increasingly software driven.

The UK Ministry of Defence (MOD) has also recognised the importance of training within two out of its five Defence Innovation Priorities [1], specifically: Defence People – Skills, Knowledge and Experience; and Simulating Future Battlespace Complexity. The following challenges were identified within the paper:

- *The application of procedures and solutions that provide effective training evaluation of both the operator and the systems being operated*;
- *Integrating and fusing data from, and collaborating between, diverse and geographically distributed*

training and experimentation systems;

- *Training operators to perform in complex or high stress, sometimes remote, environments;*
- *Adoption of Virtual Reality (VR), Augmented Reality (AR) or other novel technology into our approaches to training field operators; and*
- *Effective capture and exploitation of performance information collected during training, to understand the impact and effectiveness of training regimes.*

The UK MOD has also issued a Defence Policy for Modelling and Simulation [2], which sets out an approach to Defence Modelling and Simulation Coherence (DMaSC), including delivering increased value for money and consistent, enduring, accessible, agile and adaptable modelling and simulation solutions.

All these factors must be considered when developing a new simulation-based approach to training.

2.0 ENHANCED TRAINING SOLUTIONS

To meet the challenges of the above we have created single solution that combines the training solutions for software systems and OEM equipment, which can simulate signals between multiple different equipment types and software, and can also allow a trainee to interact with the software inside a virtual environment. There are three major components to this approach;

- An **emulation engine** capable of emulating equipment, the signals between them and their 3D representation;
- A **VM infrastructure** and custom remote desktop interfaces;
- An emulation engine **signal interface** capable of converting emulated signals to real signals and vice versa.

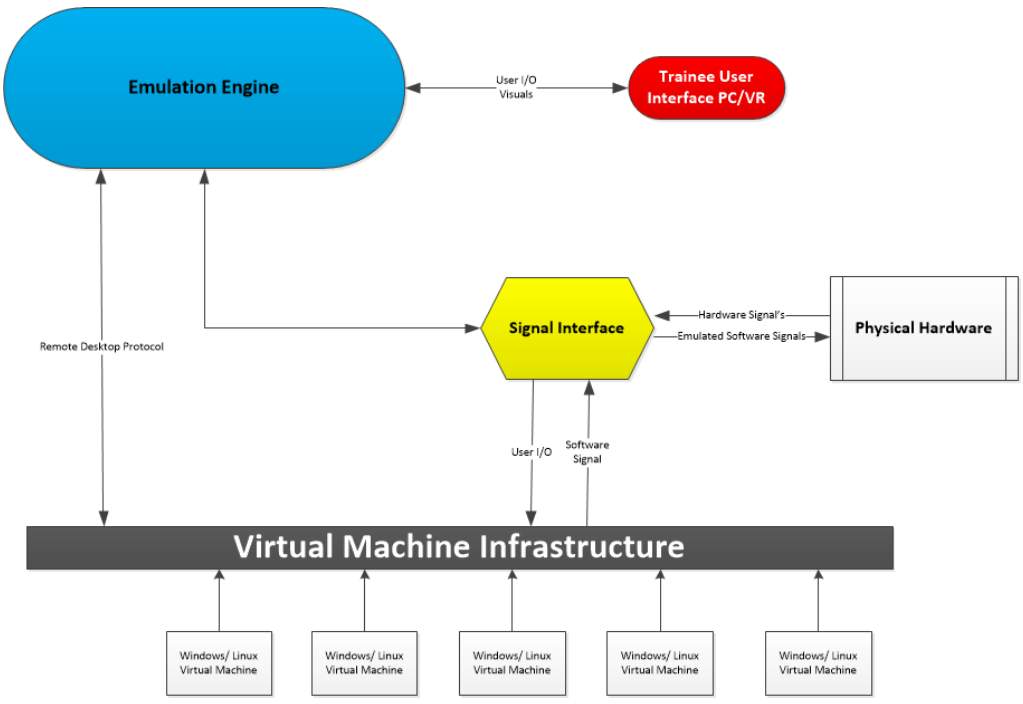

Figure 2-1: The use of an emulation engine allows trainees to interact with several Virtual Machines hosting real systems software and emulated or physical hardware via a signal interface.

2.1 Emulation Engine

Many systems are built up of individual equipment components from multiple suppliers, each piece of equipment is often referred to as a Line Replaceable Unit (LRU). This could be a simple switch or a bespoke piece of signal processing equipment. The emulation engine emulates equipment at the LRU level and displays it in a 3D environment which allows a trainee to interact with it; this is not something new and has been done effectively in many different industries. The emulation engine simulates the signals between emulated LRUs at a very high fidelity and in most cases, it matches the interface specification of the real equipment. This is important, as replicating the interfaces accurately improves the realism of the training.

Figure 2-2: Interactive Line Replaceable Units can be viewed within a 3D virtual environment, as they would be seen within the compartment on the operational platform.

2.2 Virtualisation

Although a lot of bespoke equipment is still used to process and manipulate data within a system, an operator often interacts with the system via a standard X86, Windows or Linux, processor. To train this element, normally a separate trainer would be created or the software running on those processors would be emulated which is both time-consuming and limiting.

Our solution uses the real processors images as they are delivered to the customer and virtualises them using Microsoft Hyper-V. We have then created a custom Remote Desktop Protocol (RDP) interface based upon the Microsoft open specification; this allows us to embed the VM into our 3D graphics and so the trainee can interact with the real software in a virtual environment. This gives the trainee the ability to navigate a virtual operational environment to the operator's terminal and interact with the real system software within the context of the rest of the system around them.

The RDP technology we have developed goes a step further and works with the Microsoft Hyper-V instead of connecting directly to a virtual machine. This means the VM does not need to support RDP and a trainee can also interact with the VM as it is booting and perform failover tasks like disk re-imaging.

2.3 Emulator to Real World Signal Interface

Up to this point the trainee can perform procedures on emulated equipment and interact with the real-world software within the virtual environment. This last piece of the solution joins them together. We have developed a system which allows any piece of emulated equipment to work with a real-world interface, for example an IP network or RS232 serial port. This works especially well with the VMs, where the emulation engine can impersonate hundreds of different pieces of equipment and allow the software on the virtual machines to believe it is talking to real hardware.

It is common to see stimulators attached to real software for training purposes. However, this approach is different, in that it is not another instructor-controlled utility 'injecting' specific signals into the software but impersonating entire sets of equipment. This allows a trainee to press buttons on emulated equipment in the virtual environment and see how it affects the real software, also in the virtual environment.

This same technology can also be used for Hardware In the Loop (HIL) testing or training applications. where a virtual piece of equipment can be replaced with a real piece of equipment, and still work seamlessly within the virtual environment of the whole system.

2.4 Virtual Reality and Mixed Reality

As now both emulated equipment and real software can be interacted with from within a virtual environment, this solution lends itself to more modern approaches to training and the use of Virtual Reality (VR). As both VR technologies and the way users can interact with objects within VR improve, coupled with this solution, we can walk around and interact with an entire system running real software using a single PC, even for systems which can have multiple pieces of equipment, spanning different racks or even compartments. This is extremely beneficial as it promotes muscle memory and enhances familiarity with a platform. When a trainee steps into a compartment on board the real platform, they feel like they have already been there.

Inversely you can have a training system that is made up of actual physical equipment, that has some missing components due to cost or availability. By using Mixed Reality (MR) and our solution, you can overlay an emulated version of the required equipment into the system and have it co-operate with the real equipment.

2.5 Benefits Offered by New Technologies

By adopting the approach outlined above in combination with the new software and training technologies, significant benefits can be delivered to trainees, instructors and training system providers.

A complete operator and maintainer training solution for one or more complex systems is now achievable using a single set of reusable, adaptable and reconfigurable hardware and software. Traditionally, this level of training would require multiple separate training systems with potentially significantly higher procurement and support costs.

Further savings can be achieved by replacing real hardware with emulated equipment, which may have a much lower (or zero) recurring cost, if you need multiple instances of the emulated equipment. Virtual or emulated content can also run on a standard Commercial Off the Shelf (COTS) PC, without the need for specialist hardware.

If the training system is also using the identical software as the real system, then configuration control of software versions becomes easier, lowering the risk of negative training due to using out-of-date training software.

Finally, the footprint of the training system may be significantly reduced, as several systems can be trained using a reconfigurable blend of an emulation engine and VMs, freeing up space within a training school which may already be at a premium.

3.0 USE CASE – MARITIME COMMUNICATIONS TRAINING SYSTEM

3.1 System Description

Maritime communication systems are complex, consisting of hundreds of different pieces of specialised equipment making it very difficult to create a complete training set, due to affordability and availability of some equipment. To reduce the cost of a training system in this scenario, emulation is an obvious path and the emulation can help trainees both learn procedures as well as gain familiarity with the system. However, a core part of maritime communication system training is the control software and auxiliary tools which are hosted on several standard windows processors; to emulate the full functionality of these control systems would be very expensive.

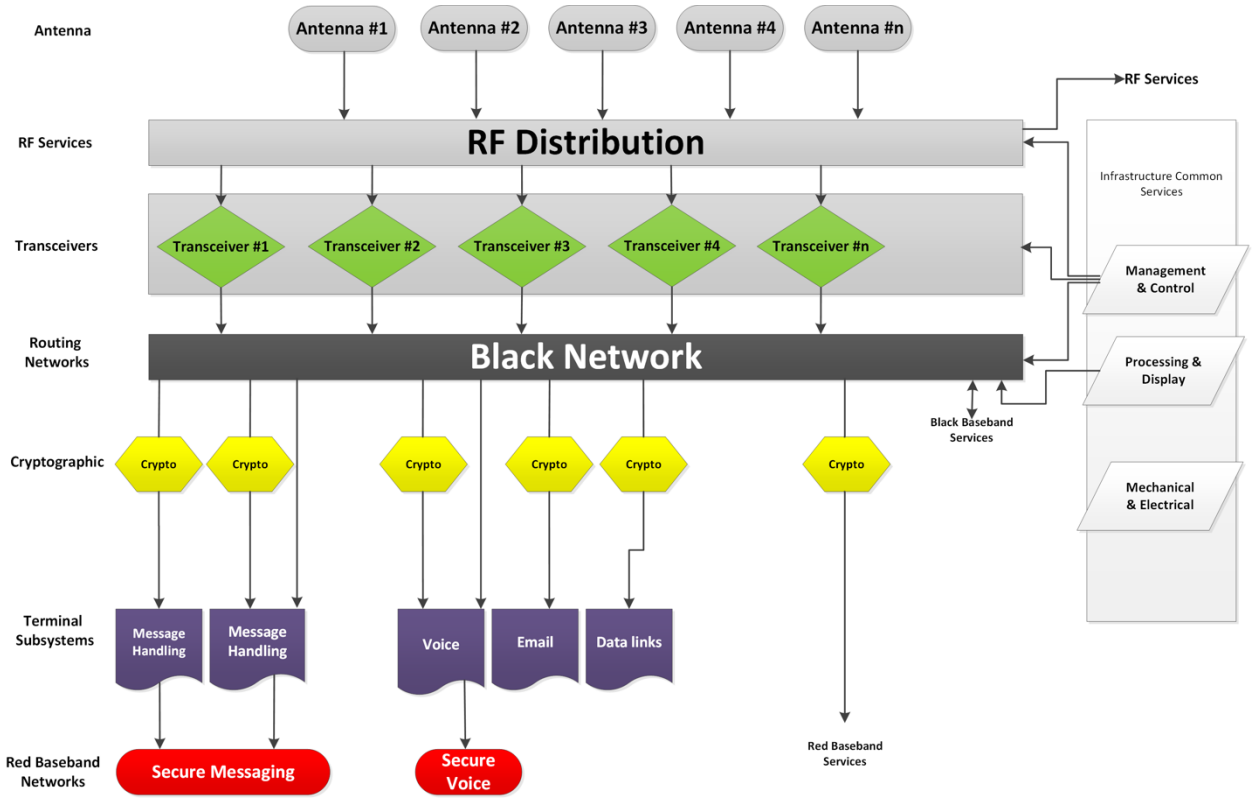

Figure 3-1: A typical maritime communications system contains many layers of interconnected equipment, presenting a significant challenge to provide a comprehensive operator and maintainer training system at low cost, but with a level of fidelity and realism.

A solution to this is to have part emulation and part real equipment hosting the control software. This would give the trainees familiarity with the software and recognise key elements of it, but they would not get a real world feel of the software, especially as this software controls and reports the status of 100+ pieces of

equipment. Without the real equipment connecting to the software many training requirements must be left out and can only be taught on a real system.

However, using the new solution outlined above we can have the best of both worlds; for the equipment that connects to the control software we can emulate at a high fidelity and use the real software hosted on VMs. As well as performing strictly defined procedures the student can use the system in free play which opens up the opportunities for more complete fault-finding exercises, as the software acts exactly as it would act in the real system. By allowing the trainees to interact with the real software via the virtual environment we can also train them how to use the operators terminals which use Keyboard Video Mouse (KVM) switches, and so the trainee begins to build muscle memory on what keys they need to press to access specific control software.

This maritime communications training system was not built for a single platform and is designed to instruct trainees on multiple platforms. Although the equipment may be similar between platforms, the way they are setup can have large impact on their functionality. By having the whole system, include the operating software, in a virtual environment means a completely different platform can be loaded within a couple of mouse clicks. It also means if a trainee makes a mistake, for example when loading a backup on the operating software, they can reset back to a known working state within seconds.

3.2 Benefits of a Virtual Communications Training System

In addition to the generic benefits highlighted earlier in the paper, by adopting a blend of emulation and real software, further specific benefits for the training of a complex communications system are also achievable.

Since the trainee is using real software but in a secure virtual environment, faults can be injected into the training system that would otherwise be expensive or impossible to replicate without damaging a real piece of equipment. For example, signals between LRUs can be interrupted or degraded without the need to remove a physical cable connector. This provides the trainee with a much more realistic environment to train fault finding or troubleshooting procedures.

For training procedures that involve a large number of procedural steps using different equipment and interfaces, the trainee's progress through the procedure can be tracked within the virtual environment and measured against an 'ideal' procedure generated by an instructor. This may provide a powerful set of metrics to assess the trainee's performance.

The use of a virtual training environment also enables the possibility of some, or all of the training being made accessible on-line, provided that a secure network can be made available to access the training content. This provides a much more accessible set of training media to support pre-course or refresher training when no instructor is present and reduces the reliance upon a dedicated training classroom just for one system.

4.0 CONCLUSIONS

As more maritime systems are comprised of separate software driven applications, the adoption of a flexible, reconfigurable and accessible approach to training, using equipment emulation and real systems software within a virtual environment, offers significant potential benefits. These include lower cost of ownership, improved training accessibility, flexibility and trainee progress monitoring, when compared with traditional hardware-based approaches to operator and maintainer training.

5.0 REFERENCES

[1] Ministry of Defence, Defence Innovation Directorate (2019). *Defence Innovation Priorities - Accelerating commercial opportunities to solve Defence's most pressing challenges*.

[2] Ministry of Defence (V2.0, April 2020), *JSP 939 Defence Policy for Modelling and Simulation (M&S), Part 1 – Directive and Part 2- Guidance.*