

A 'mixed reality' simulator concept for future Medical Emergency Response Team training

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**A "Mixed Reality" Simulator Concept for Future Medical
Emergency Response Team Training**

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A “Mixed Reality” Simulator Concept for Future Medical Emergency Response Team Training

ABSTRACT

The UK Defence Medical Service’s Pre-Hospital Emergency Care capability includes rapid-deployment Medical Emergency Response Teams (MERTs) comprising tri-service trauma consultants, paramedics and specialised nurses, all of whom are qualified to administer emergency care under extreme conditions to improve the survival prospects of combat casualties. The pre-deployment training of MERT personnel is designed not only to foster individual knowledge, skills and abilities in Pre-Hospital Emergency Care (PHEC), but also in small team performance and cohesion in “mission-specific” contexts. Until now, the provision of airborne pre-deployment MERT training had been dependent upon either the availability of an operational aircraft (e.g. the CH-47 *Chinook* helicopter), or access to one of only two ground-based facsimiles of the *Chinook*’s rear cargo/passenger cabin. Although MERT training has high priority, there will always be competition with other military taskings for access to helicopter assets (and for other platforms in other branches of the Armed Forces). This paper describes the development of an inexpensive, reconfigurable and transportable MERT training concept based on “Mixed Reality” technologies – in effect the “blending” of real-world objects of training relevance with Virtual Reality reconstructions of operational contexts.

Keywords: MERT, Technology-Based Training, Human Factors, Fidelity, Simulation, Virtual Reality, Mixed Reality.

INTRODUCTION

The UK Defence Medical Service’s (DMS) Pre-Hospital Emergency Care (PHEC) capability includes forward Aeromedical Evacuation assets that can be called upon for deployment in conflict situations. Referred to as the Medical Emergency Response Team (MERT), this particular asset is made up of personnel possessing a wide range of complementary skill sets and has, in the past, included an emergency medicine-qualified nursing officer, two qualified paramedics and a consultant clinician [1]. DMS is mandated by the Ministry of Defence (MoD) to maintain MERT capabilities at a high level of readiness for operational deployment and, consequentially, the need for regular, in-depth and high-quality mainstream and refresher training is of paramount importance.

In 2003, the Army Medical Services Training Centre (AMSTC) within 2nd Medical Brigade at Strensall, near York, became the centre of training assurance for Deployed Hospital Care (DHC) for forces preparing for operational deployment and for those being held at readiness. This included elements of Royal Air Force capability, including MERT but also the

1
2
3 Critical Care Air Support Team (CCAST). The training of MERT personnel is wide-ranging,
4 covering not only the fostering of individual knowledge, skills and attitudes/abilities (KSAs),
5 but also performance and cohesion in both small team and collective “mission-specific” –
6 contexts [2]. Training is conducted within a progressive educational environment with peer-
7 to-peer review, which includes after-action review and daily summary performance
8 feedback [3]. Of relevance to this paper are the first two of the three training categories,
9 individual and small team, with collective training issues described elsewhere [4, 5, 6].
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11

- 12 • **Individual Training** – is based on clinical competence and suitability to the rigour of
13 delivering PHEC in the most austere and dynamic of environments. Future PHEC
14 practitioners must be able to function effectively in the pre-hospital environment and
15 adapt their clinical decision-making to the evolving situation around them. This also
16 builds on the teaching provided in Battlefield Advanced Trauma Life Support (BATLS)
17 and related military courses. Training is typically delivered via practical sessions, such
18 as those offered by the Tactical Medical Wing (TMW) based at RAF Brize Norton, and
19 further consolidated during moulage exercises using role-playing personnel, or
20 amputee actors.
21
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- 23 • **Team Training** – familiarises the MERT paramedics, nurses and doctors with their
24 operational team, environment and equipment. Laerdal SimMan® and SimMan 3G®
25 “patient simulators” are used to rehearse clinical skills and drills. Clinical scenarios are
26 exercised in a pre-hospital setting, initially in a CH-47 *Chinook* ground-based trainer and
27 subsequently in an operational airframe, including the *Chinook* and the C-130 *Hercules*
28 [7].
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33 **Training Delivery Limitations**

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36 Historically, as AMSTC had only delivered the DHC component of assurance, new forms of
37 training media had to be considered. For example, the dedicated MERT platform during Op
38 HERRICK was the *Chinook*. As such, the initial solution for pre-deployment training for
39 MERTs was to utilise an operational aircraft to familiarise personnel with the noise and
40 space constraints of undertaking deployments onboard such a platform. Although authentic
41 in nature, this form of training was unpredictable, due to higher priority tasking of aircraft
42 and their limited on-site availability, making it almost impossible to synchronise their
43 participation with the schedules and timelines formulated for DHC training exercises. A
44 further confounding issue from the perspective of training assurance was the inability to
45 conduct comprehensive after-action reviews following training scenarios.
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49 Given the problematic nature of utilising operational aircraft for training purposes, it was
50 decided to create a facsimile of the rear cargo/passenger cabin of a *Chinook*. In the design
51 stage of the *Chinook* facsimile, considerable effort went into providing appropriate detail,
52 including lighting, noise, heat and smell. Construction of the facsimile was undertaken by
53 38 Royal Engineer Regiment and the unit was delivered to AMSTC in the autumn of 2007. A
54 second, similar ground-based training facility was delivered later to the TMW by a
55 commercial contractor (Figure 1).
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FIGURE 1 HERE

Ground-based trainers have a number of limitations in terms of training fidelity, and their construction and ongoing running costs can be high. They are also designed in such a way that they may only be representative of one MERT-relevant platform and cannot be reconfigured easily and cost-effectively to provide a potential training solution for other branches of the Armed Forces. It is important, therefore, that alternative forms of training, including those based on digital simulation or Virtual Reality (VR) techniques, are evaluated [8, 9, 10].

Digital Simulation Techniques – Virtual, Augmented and Mixed Reality

Over the past five years or so, there has been a flurry of activity across the globe – at defence, aerospace, automotive and creative media conferences and exhibitions, and on technology-focused Internet sites – relating to the “re-birth” of so-called Virtual Reality (VR). VR refers to a form of simulation in which the end user interacts in real-time with multisensory, computer-generated databases (comprising predominantly, but not exclusively, visual imagery). VR scenes can be presented to the human using a variety of two-dimensional and three-dimensional (stereoscopic) display technologies, including head-mounted displays (HMDs), conventional flat screens, smartphones and tablets, whole-wall displays and even room-sized “immersive” enclosures. Non-visual aspects of Virtual Environments (“VEs”) include sound, haptics (the delivery of rudimentary sensations of touch and force), motion and olfaction (smell). In the UK, projects undertaken during the Human Factors Integration Defence Technology Centre (HFI DTC) programme between 2003 and 2012 [11] delivered many important concept capability demonstrators based on commercial off-the-shelf (COTS) VR hardware and software technologies, from submarine spatial awareness training [8] and pre-deployment counter-improvised explosive device awareness, to subsea mine countermeasures detection [12] and a remote driving and manipulation skills trainer for the UK’s *CUTLASS* unexploded ordnance disposal system [13; Case Study 19].

A related technology, Augmented Reality (AR), typically displays virtual objects and behaviours (and, indeed, other forms of media, including video) to the end user in an attempt to *augment* the real-world with additional, task-relevant information. AR can share some of the display and interaction hardware products available for VR, but in addition relies on dedicated software tools and location recognition techniques in order to register virtual objects accurately with the real-world views. A more recent member of the simulation sector is known as *Mixed Reality* (MxR), a form of AR, but one that attempts to exploit the existence of *real-world* objects in order to enhance the believability and usability of the simulated elements. Such objects can be as basic as tables (Figure 2) and wall- or ceiling-mounted frames, or as advanced as deactivated items of equipment, machinery or weapons [9], even complete rooms or temporarily-erected enclosures.

FIGURE 2 HERE

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4 The present paper describes the design and development of an early concept capability
5 MERT training demonstrator. By virtue of its MxR construct, the physical enclosure
6 developed for the MERT simulator has been designed to be reconfigurable through the
7 addition of low-cost physical interior embellishments, enhanced by the generation of high-
8 fidelity VR and AR representations. This demonstrates the potential to simulate a variety of
9 mobility platforms in a range of deployment scenarios. The MxR solution can also be
10 transported to training sites, thus avoiding the need for costly fixed-site, ground-based
11 training facilities.
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14 15 16 **MERT DIGITAL SIMULATION: STUDY METHODOLOGY & HUMAN FACTORS**

17
18 The success of projects involving the exploitation of novel interactive technologies,
19 especially in the rapidly evolving domains of VR, AR and MxR, depends upon a wide range of
20 factors. One of the most important is the need for close involvement on the part of
21 stakeholders and end users, and a strong underpinning human-centred design (HCD) theme
22 [13, 14], ensuring that the hardware and software technologies selected deliver usable and
23 meaningful training experiences. An important starting point in the development of any
24 technology-based training project relates to how, by observing real-world training scenarios,
25 one can identify those features of the tasks that are central to the final design of the
26 training simulator, and, in particular, to defining the accuracy of the simulation, or its *fidelity*
27 [13].
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31 Early Human Factors observations were undertaken during training sessions at the TMW.
32 The sessions were conducted using TMW's ground-based *Chinook* trainer (Figure 1), with
33 each training trial concluding with the transfer of simulated casualties to military vehicles.
34 Two sub-teams of trainee paramedics were involved in each session and limited-function
35 adult and child SimMan® mannequins provided the focus for manual handling and medical
36 intervention procedures. The training sessions took place over an approximate duration of
37 15 to 20 minutes and consisted of three basic phases – casualty recovery from the field to
38 the helicopter, in-flight care, and casualty transfer to ground medical teams with hand-over
39 briefings. From a simulation fidelity perspective, the following comments summarise just
40 some of the outcomes of the observations:
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- 43
44 • Trainees work in very constrained conditions, surrounded (in addition to the
45 stretchered casualties) by multiple items of equipment, weapons and structural
46 elements, plus specific items of medical equipment and instrumentation, storage
47 containers, cables and other hanging items, such as intravenous fluid bags and
48 drips.
49
- 50
51 • As well as the PHEC personnel, the typical MERT complement also includes Quick
52 Reaction Force (or “Force Protection”) personnel – four RAF Regiment gunners
53 deployed on landing to provide small arms cover during casualty recovery.
54 Appropriate representations of the presence and role of these personnel need to
55 be included in the final simulation.
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- Ambient noise and communications (a combination of the TruLink hands-free, short-range radio system, shouting and hand signals) were also an important part of the observational findings. The sound system provided to deliver the *Chinook* audio effects was deemed to be inadequate, not only due to the volume, but also to the short duration of the sound file provided (which cycled through the start-up, shut-down and in-transit sequences at least twice per session).
- Realistic external views are also limited with the ground-based trainer, particularly in terms of terrain type and in-flight effects. In the case of terrain types, environmental effects such as brown-out and the dust entering the cabin during landing is also absent, but is achievable using present-day simulation technology [13, Case Study 22].
- The limited functionality and fidelity of the SimMan® mannequins was also noted during the MERT training sequences. It will be essential to ensure that the level of fidelity delivered in any VR/AR/MxR solution – including that of the casualties – reproduces only those key elements of the task that are relevant to the desired training outcomes, as specified by the instructors and subject matter experts.

Following the observational sessions, it was rapidly concluded that, for the same Human Factors reasons highlighted in previous projects [9, 10, 13], a system based solely on VR technologies would be incapable of replicating the levels of fidelity required for any simulation-based solution. It was, therefore, decided that an MxR solution, based on a transportable and reconfigurable enclosure that would physically constrain the motions of trainees within any virtual environment developed for training, would need to be investigated. A physical enclosure would also provide a meaningful sense of haptic feedback (touch/contact and force) to the simulation users. Present-day haptic feedback technologies for VR, including glove-integrated piezoelectric, pneumatic and other transducers, or hand- and full-arm exoskeletal devices, are still at an immature level of development and are not yet able to simulate the wide range of real-world haptic experiences observed during the observational sessions.

EARLY MxR MERT PROTOTYPE DEVELOPMENT

The concept designs for a physical enclosure supporting early MxR investigations were based on a representative area within the *Chinook* cabin, using internal dimensions sourced from the Internet and images of an actual aircraft facilitated by RAF Odiham (Figure 3). Due to the size of the area required to incorporate up to three trainees at a time (this number was chosen arbitrarily), with all three surrounding a human body representation, it was decided that an inflatable (hence transportable) enclosure, with access at either ends, side windows, various internal attachment points for medical equipment and features capable of supporting cables and other computing-related equipment, would provide the best option for an MxR demonstration prototype.

FIGURE 3 HERE

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5 Working with a Leicestershire-based inflatables company, a “tunnel”-like structure (Figures
6 3 and 4) was designed, measuring (externally) 3m long by 2.35m high by 3.05m wide. The
7 material used for the construction of the enclosure is 0.5mm PVC tarpaulin. Approximate
8 internal dimensions are 3m long by 2m high (floor to internal roof), with a 2.3m internal
9 wall-to-wall span. Front and rear “wall” sheets are attached using Velcro and can be
10 removed if required. A fixed tarpaulin base is part of the structure and includes a zone
11 marked out in black with a yellow/black hatched hazard line, representing a fluid spill
12 region, as found on the actual aircraft. Three windows are provided on each side of the
13 enclosure, and these can be left open, or, using Velcro-applied transparent and opaque
14 circular “patches”, covered as necessary. Hanging points (e.g. for intravenous drips) exist
15 within the structure, running along the roof and side walls. The enclosure is inflated using a
16 single hand-held air blower (a constant air supply is not necessary once inflated) and can be
17 erected and deflated in around 20 minutes.
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21
22 **FIGURE 4 HERE**
23

24 25 **Human Body Representation** 26

27
28 Turning to the requirements for representing the casualty in the MxR setup, earlier VR-
29 based surgical and trauma training projects [15, 16] demonstrated conclusively the
30 problems of trying to simulate accurate – and believable – anatomical and physiological
31 characteristics of a virtual casualty, not to mention the complex physics involved in
32 simulating and visualising such features as flexible tubing and cables and invasive clinical
33 procedures. Whilst developments in human body simulation have improved dramatically
34 over the past decade, the credible recreation of these processes for real-time interaction
35 and display still remains a challenge to the simulation community. However, for the
36 purposes of the present concept capability demonstrator, it was decided that the provision
37 of a physical body, capable of representing certain forms of trauma, such as unilateral or
38 bilateral lower limb amputation caused by an improvised explosive device, or smaller
39 wounds caused by bullet entry or lacerations, would be appropriate. Such a body model
40 would, it was argued, provide focus for a demonstration of the potential (and technical
41 challenges) of a later, more advanced MxR solution and, at the most basic level, would
42 deliver a reasonable form of haptic feedback for the end users.
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47 Consequently, a realistic male mannequin known commercially as a SIMBODIE, developed
48 by the UK company TraumaFX, was commissioned to fulfil these requirements. The
49 SIMBODIE (Figures 5 and 7) is constructed using soft silicone with movable joints.
50 Additional features include an endotracheal intubation capability, modifications to allow the
51 placement of intraosseous needles in the humeral heads, proximal tibia and sternum, sites
52 for intravenous access and detachable lower limbs to simulate traumatic amputations.
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Other Enclosure Elements

Standing alone with the synthetic mannequin in place, the inflatable enclosure initially gave the impression of being quite spacious, with substantial room for trainees to move around, even when equipped with VR headsets and related interactive devices. To overcome this, a variety of low-cost items were procured, including foldable stadium seats, webbing, replica weapons, sourced mostly from online or other COTS sources, with additional military items, such as Bergens being provided by the RCDM collaborators. Many of these items can be seen in Figure 5 and were selected to act as “space-fillers”, the aim being to provide some degree of additional constraint to the trainees, over and above that provided by the enclosure.

FIGURE 5 HERE

Virtual and Augmented Reality Software & Hardware Elements

The virtual scenario developed for early demonstrations consisted of a range of 3D assets, some developed from scratch, but many others being sourced from online 3D model repositories. The 3D model of the CH-47 *Chinook* was obtained from such a repository, but required remedial effort to remove US markings and to produce an interior scene of acceptable quality and fidelity (Figure 6). The virtual humans required to populate the VE were kept low in number for the purposes of this early demonstration and included two members of the QRF (based on a modified 3D model of a Royal Anglian Soldier in a temperate multi-terrain pattern (MTP) uniform with SA80 – seated at the rear of the helicopter, the M60 gunner and a simple 3D representation of a “casualty”, placed onto a virtual stretcher. Other 3D models, such as Bergens, Minigun and M60, ammunition containers, and so on, were also sourced online. Once modified to a level suitable for real-time rendering as fully-textured and animated VR scenarios, all 3D assets were integrated within the real-time software rendering package (the *Unity* game engine), ready for display and interaction using a variety of hardware devices.

To provide a realistic view of the world external to the virtual *Chinook*, rather than generating a large terrain database in 3D (which would have been both computationally and financially expensive) it was decided to make use of the development team’s small unmanned air systems or “drones”. The aim was to capture a flight sequence of a reasonable duration using airborne video over a relatively barren area, which could then be replayed as a looped sequence without a perceptible “join” or “stutter” between segments. For this, an area of Dartmoor, in the south-west of the UK, was chosen (specifically Foxtor Mire near Princetown). The video was captured using a DJI *Inspire 1* drone equipped with a Zenmuse X3 Ultra High-Definition camera mounted on a 3-axis gimbal. The drone was flown in an elliptical flight path over the Foxtor Mire area for approximately 4km under manual control, with the Zenmuse camera system facing rearwards.

To create a realistic presentation of the video captured, as if looking towards the ramp area from within the virtual *Chinook* cabin, a flat plane (or “billboard”) was created as part of the *Unity* game engine, located at an apparent distance of 25m from the rear ramp of the

1
2
3 helicopter in virtual space (Figure 6). The video plays as a projection onto this billboard at
4 run-time and additional effects, including helicopter exhaust clouds, external lighting and
5 the “flicker” generated by the rotor blades, are generated to create the illusion inside the
6 virtual cabin that the helicopter is in flight. To add to the in-flight illusion, high-quality
7 *Chinook* engine sound effects were integrated with the visual flight sequence, provided to
8 the development team by Boeing Defence UK Limited.
9

10
11 **FIGURE 6 HERE**
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15 Turning to the hardware side of the current MERT training demonstrator, four COTS head-
16 mounted display systems were evaluated during the period in which the enclosure concept
17 was being developed. In brief, the Oculus Rift DK2 (the pre-commercial “development kit”
18 release of the HMD with an image resolution of 960 x 1080 pixels per eye and a total
19 horizontal field of view of around 100°) and the Razer OSVR (“Open Source Virtual Reality”,
20 with a similar display resolution and horizontal field of view) were initially used, mainly to
21 quality-test the VR *Chinook* in-cabin scenario and to experiment with the registration
22 between the physical SIMBODIE and its virtual counterpart. The head and hand movements
23 of the users of these HMDs were recorded in real time using an optical motion capture
24 (MOCAP) system, the OptiTrack V120 Trio. This system tracks small, high-contrast plastic
25 spheres mounted on the faceplate of the HMD and on fingerless gloves, enabling the end
26 user to control two “disembodied” virtual hands within the simulated *Chinook* environment.
27
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29
30 Unfortunately, the early experiences with these technology combinations were far from
31 satisfactory, due to a variety of technical and Human Factors issues. For example, the visual
32 quality of the VR images displayed within the two HMDs did little to preserve the otherwise
33 acceptable fidelity of the virtual *Chinook* cabin when displayed on, for example, a high- or
34 ultra-high definition LED screen. The V120 MOCAP system was also found to be inadequate,
35 due to the fact that the movement of users often led to the HMD and glove markers
36 becoming obscured from the camera sensors, leading to unstable virtual images, or other
37 distracting incidents, such as the disappearance of one or both of the virtual hand
38 representations.
39
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41
42 During the course of the early demonstrator development programme, two new COTS HMD
43 systems were launched, the Oculus Rift CV1 (the “Consumer Version” with a resolution of
44 1080 x 1200 pixels per eye, and a total field of view of 100°) and the HTC Vive (with an
45 identical resolution to the Rift CV1, but a slightly larger field of view at 110°). Whilst neither
46 of these HMDs are, from a Human Factors perspective, totally satisfactory [13], they
47 represent (at the time of writing) the current state-of-the-art in affordable COTS VR
48 headsets. Having evaluated both of these headsets with the virtual *Chinook* cabin scenario,
49 the decision was taken to adopt the HTC-Vive for near-term development activities (Figure
50 7). A key factor in this decision was the existence of an impressive integrated position and
51 orientation tracking system as part of the Vive product, which uses two small scanning laser
52 units, mounted at diagonally opposing locations within the MERT enclosure, scanning the
53 space to create reference points courtesy of photosensors mounted onto HMDs or hand
54 controllers.
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FIGURE 7 HERE

It is worth noting that the HTC Vive HMD, tracking and hand controller system cost less than *one-third* that of the previous V120-OSVR hardware combination. Unfortunately, however, the solution is not without its problems. For example, it was immediately obvious to the current MERT trainer development team that the current design of the HTC-Vive hand controllers (see Figure 7) made interaction with the SIMBODIE mannequin clumsy and non-intuitive (when compared to that offered by, for example, a typical interactive glove device). Fortunately, and again at the time of writing, new glove-based input devices are under development based on the HTC Vive tracking technology, and full advantage will be taken of these products as they appear on the market.

CONCLUSIONS AND NEXT STEPS

The research and development activities leading to the installation of the prototype MERT training facility described herein took a total of 5 months to complete. The main goal of the exercise was to demonstrate that it was possible to develop a credible simulation-based concept based on the integration of a range of interactive media and real-world objects. A second aim was to demonstrate the feasibility of developing a portable and highly cost-effective training solution using COTS products and suppliers in specialised domains such as synthetic mannequins and inflatable enclosures.

At the time of writing, the current MERT training prototype has been experienced by a wide range of potential adopters – civilian emergency services as well as potential future defence medical users. The feedback received has been consistently positive, although it is clear that the current stakeholder base would benefit from being expanded for future developments, particularly in helping to define the key training outcomes expected of such a simulation facility and the types of scenarios that would best help to deliver those outcomes.

In addition, further stakeholder input and MxR implementation support will be invaluable when considering extending the existing test bed to account for the different platforms currently in use (and projected for use) in the evacuation and PHEC of casualties by other branches of the Armed Forces. For example, a short study is underway, again at the time of writing, to investigate what would be necessary – and how difficult or straightforward it might be – to modify the existing enclosure to be representative of the cabin onboard the UK's LCVP Mk5 (Landing Craft Vehicle Personnel), manned and operated from HMS *Bulwark*, *Albion* and *Ocean* by 1 Assault Group Royal Marines (1AGRM). Other possibilities worthy of investigation along these lines include the Landing Craft Air Cushion (Light) (LCAC(L)) Hovercraft, also used by 1AGRM, the RAF *Puma* HC Mk2 and *Merlin* HC3 Helicopters, and the C-130 *Hercules* C1/C3 Transport Aircraft.

A number of other interesting challenges face the development team during the next phase of the research. For example, the integration of the current synthetic SIMBODIE with the computer-generated environments, thus providing a credible sense of haptics and casualty

1
2
3 realism, will require extensive research into how current MxR technologies can – if at all –
4 be modified to allow real-world physical objects to appear as blended and stable
5 components of a virtual image, such that, as features and activities within the virtual cabin
6 change, they do so in a way that is realistic and are not occluded or distorted by the
7 presence of a large static object, such as the SIMBODIE. The alternative will be to
8 investigate ways in which the SIMBODIE can be generated in VR, using off-the-shelf 3D
9 scanning technologies to produce – from a training delivery perspective – reasonable and
10 acceptable 3D representations of the body, together with an associated dataset of wounds
11 and amputations that correspond to the physical changes that can be made to the current
12 SIMBODIE configuration.
13
14

15
16 Another challenge demanding further research is how to accommodate more than one end
17 user within a virtual MERT deployment. The HTC Vive display and tracking hardware
18 currently used in the MxR concept demonstrator is (according to various online posts by
19 gaming users of the HMD) capable of supporting up to three, possibly four HMD-equipped
20 users within a single 3D space. Given that one of the key aims of this project is to develop
21 an affordable and transportable solution for the future of MERT training, attempting to
22 expand the current inflatable enclosure to accommodate, say, two groups of three trainees,
23 would impact significantly on overall costs, system reliability and portability (including set-
24 up and calibration times). One solution to this may be to retain the current size of
25 enclosure, but to introduce virtual team members, or *avatars*, some of whom could be
26 represented as attending to a second virtual casualty, thus providing a more dynamic
27 context to the MERT training mission. However, other avatars may be provided with the
28 aim of completing the size of the team in which the real trainees are working. The role of
29 these avatars, and the extent to which they need to interact with the real trainees, will
30 require careful Human Factors evaluation and planning, and will also require significant
31 input from the project's military stakeholders.
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37 **Funding & Competing Interests**

38
39 This study was undertaken as part of a subcontract placed upon the University of
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11 **Figure Captions**

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14 Figure 1: *Chinook* facsimile trainer at the Tactical Medical Wing of RAF Brize Norton.
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17 Figure 2: Mixed Reality Command and Control Concept Demonstrator – the MxR user (right
18 image) is able to see the 3D cityscape scenario (left image) via the HMD and can interact
19 with the displayed features and information panels using gestural commands, including
20 sweeping motions on and around the otherwise empty table shown.
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23 Figure 3: Design layouts for the MERT trainer inflatable enclosure.
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26 Figure 4: The basic MERT inflatable enclosure, external and internal views.
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28 Figure 5: Inflatable enclosure with various additional elements, including a SIMBODIE
29 mannequin.
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32 Figure 6: Interior view of the virtual *Chinook* cabin.
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35 Figure 7: The HTC Vive HMD in use within the MERT trainer.
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Editor in Chief Comments:

There is much support for publication of this paper but the feeling is that it is too long. As such I would ask that you look to remove between 500-1000 words from the main body of the manuscript.

Corresponding Author Response – this has been done, and the paper word count has been reduced by well over 1000 words.

Associate Editor Comments to the Author:

This is a comprehensive paper, well written and undoubtedly of use and interest to the military medicine community. It describes its concepts well and challenges the readers about simulation and creating environments with a higher physiological and psychological fidelity. It should be published in the JRAMC and will be of value.

However I am concerned that in its current form it is just a little too long. It is difficult to hold attention through the whole article just due to the length. A minor revision would permit the length of the piece to be addressed and to allow the paper to be more concise which would increase the degree to which it is read by the readership. And many people of the readership will find value by reading the whole thing through.

One of the reviewers recommended acceptance and the other minor revision and I agree with the second that a minor revision would allow this relevant paper to have a larger impact on the readership.

Corresponding Author Response – as above – the paper word count has been reduced significantly.

FORMATTING AMENDMENTS

Required amendments will be listed here (if any); please include these changes in your revised version:

Reviewer(s) Reports:**Reviewer: 1**

Comments to Author

Spelling - Page 5 of 22, Line 20, should read 'task' not 'ask'.

Corresponding Author Response – this word has been removed as a result of the shortening of the paper.

This is an excellent article that looks at the importance of training in a high-stress, low-risk

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3 environment and identifies the need to ensure that team and individuals are constantly practicing
4 their skills. The concept involves using innovative VR/MxR to replicate and reproduce an
5 environment in order for the practitioner/s to learn and train safely.
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8 The article discusses the pros & cons of using different types of mannequins to meet the needs of
9 the learner in order to immerse them in the simulation. It does mention the use of 'role-
10 play'/amputee actors on page 2, but focuses on the technological element of the simulation with
11 VR/AR & MxR. Standardised Patients (role-play) has been used significantly in Military simulations
12 from very basic to more complex scenarios, it would be useful to understand to what level of
13 consideration these have been used here. There is equipment available to allow tasks to be carried
14 out on the standardised patient where needed.
15
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18 **Corresponding Author Response – I am hoping to include role play and standardised patients in a**
19 **subsequent paper – possibly as part of an experimental comparison with the Mixed**
20 **Reality/SIMBODIE solution, once developed fully.**
21

22
23 Often when developing scenarios faculty are keen to utilise all tech available, and often requires
24 someone with an understanding of what needs to be achieved to discuss the suitability of using
25 different equipment to achieve the same aim. I am not saying that is the case here, but we do often
26 see this occurring in simulation.
27
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29 **Corresponding Author Response – agreed. This is why we have adopted a human-centred design**
30 **approach (a la ISO 9241 Part 210), to ensure that the end user requirements are incorporated**
31 **(with iterative revisits to the evolving design in subsequent phases, but also being sure that**
32 **expectations re. the technology are managed carefully.**
33
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35 It is vital to protect the candidates when immersed in simulation that has increase environmental
36 and psychological fidelity, and further examination of the candidates post simulation may present as
37 a further paper, or indeed a further examination of the Human Factors around team training using
38 this tool.
39
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41 **Corresponding Author Response – absolutely. Indeed we take our “duty of care” regarding the use**
42 **of so-called immersive VR technologies very carefully and have guidelines (themselves sponsored**
43 **by the MoD) we apply for all experimental trials and subsequent operational usage. These will**
44 **form part of a future paper (or papers) reporting on the next phase of development and the**
45 **transfer of training/usability evaluations.**
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49 A novel, although not new concept for simulation training, which does have its limitations such as
50 increased cost, power requirements, fidelity and psychological immersion, most of which the paper
51 discusses.
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53

54 **Corresponding Author Response – from a hardware perspective, and in contrast to the £100k**
55 **ground trainers at TMW and Strensall, the current MERT enclosure cost around £10-12k. The**
56 **entire concept demonstrator contract to reach this stage was £40k!**
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4 This kind of training is the future of healthcare and military healthcare and deserves a more in-depth
5 look at what opportunities can be exploited across all Arms and services. The DMS held a simulation
6 conference last year but unfortunately does not look like it will be replicated this year, which I
7 believe is a mistake given the usability of this type of training.
8
9

10 **Corresponding Author Response – thank you for this encouraging comment. Agreed that it was a**
11 **shame that the DMS conference was not repeated. We hope to have the enclosure and contents**
12 **at Dsei next year (at least).**
13

14
15 It may have been interesting to the reader to understand where and how these type of 'pop-up'
16 environments are in use already, specifically within the NHS both acute and pre-hospital.
17
18

19 **Corresponding Author Response – they aren't. There are examples of so-called “immersive**
20 **classrooms”, based on 1:1 cardboard scenarios or SIMBODIEs surrounded by large display screen**
21 **in a tent, but these are inadequate (in the author's opinion) from a Human Factors and training**
22 **perspective. I could have included a critique of these and why a Mixed Reality solution provides**
23 **better task, context and interactive fidelity, but that really would have resulted in a long – and**
24 **possibly “overly academic” paper!**
25
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29 Reviewer: 2

30 Comments to Author
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32
33 I enjoyed reading the paper, and I believe the work is original and of genuine value in terms of
34 operational preparation. The MERT trainer is a really interesting concept, and I look forward to
35 seeing it develop.
36
37

38 My overall comment on the paper is that it is quite long given the state the project. As far as I can
39 see, it's still in the test phase, and the authors have not yet fielded the simulator for live training.
40 There is still some work to be done in terms of the hardware, but it's clearly made impressive
41 progress.
42
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44 Whilst I think the readership would benefit from the article, in its current form it's quite long, and
45 perhaps overly detailed. I think there would be great interest in this work, and I have followed its
46 recent progress in the media with interest. Nonetheless, I think it could be revised to reduce the
47 amount of detail which might increase its interest to the non specialist.
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50 **Corresponding Author Response – as above – the paper word count has been reduced**
51 **significantly.**
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**HEADQUARTERS
JOINT FORCES COMMAND**

JMC FORM CC1: PERMISSION TO WRITE/SPEAK TO THE MEDIA/ PUBLIC

PERSONAL DETAILS		
<p>I acknowledge my responsibilities under JMC Corporate Communications Policy, MOD Defence Instructions and the Queen's Regulations for my Service to safeguard the good name of JMC, the Department and my Service and to obtain formal clearance for my presentation.</p>		
Proposers' names:	Peter Mahoney Christopher Gibson Di Lamb	Rank/Grade: Col Lt Col Gp Capt
Unit: Medical Directorate / RCDM		
E-mail:	profpfm62@me.com	Telephone: 07411 945861
Signed:	PF Mahoney	Date: 23/11/2016
We understand that we may only proceed with Chain of Command approval.		
DETAILS OF PROPOSAL		
<p>We propose to contribute in writing to, or otherwise present the following information to an audience which may include the public and or the media, and we attach relevant papers and/or CD-ROM.</p>		
A "Mixed Reality" Simulator Concept for Future Medical Emergency Response Team Training		
Proposed audience(s): Journal of the Royal Army Medical Corps		
Event to be managed by: N/A		
Proposed Date(s):	N/A	Proposed location: N/A
Proposed cost (funding to be arranged separately): N/A		



**HEADQUARTERS
JOINT FORCES COMMAND**

CLEARANCES AND APPROVALS			
I confirm I have read this proposal and approve/do not approve as indicated.			
CO / PDO	Signature:	Date:	Approve*
Name:			Not Approve*
Comd JMC	Signature:	Date:	Approve*
A K Samra	Electronically submitted	24/11/16	
(as appropriate) HQ SG Secretariat:			
CC1 Administrator Action Completed (all stakeholder actions completed and decisions/ information disseminated)			
Signature:		Date:	

*Delete as appropriate
Jun 11 JMC 01/06/01/01



Figure 1: Chinook facsimile trainer at the Tactical Medical Wing of RAF Brize Norton.

169x112mm (300 x 300 DPI)



Figure 2: Mixed Reality Command and Control Concept Demonstrator – the MxR user (right image) is able to see the 3D cityscape scenario (left image) via the HMD and can interact with the displayed features and information panels using gestural commands, including sweeping motions on and around the otherwise empty table shown.

169x70mm (300 x 300 DPI)

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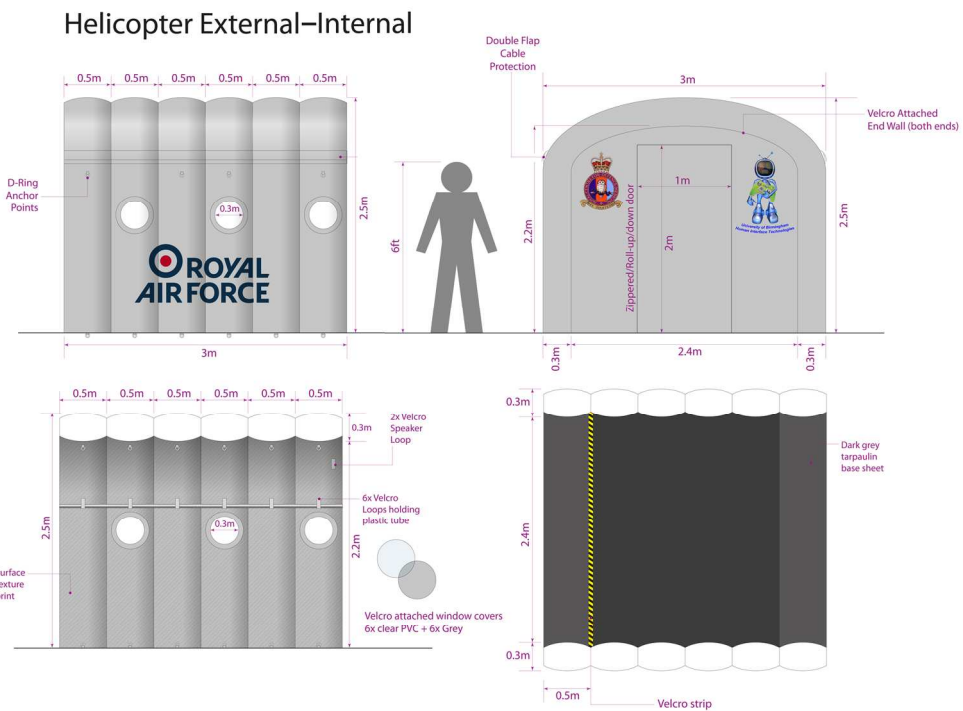


Figure 3: Design layouts for the MERT trainer inflatable enclosure.

169x125mm (300 x 300 DPI)

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The basic MERT inflatable enclosure, external and internal views.

169x56mm (300 x 300 DPI)

peer review only



Figure 5: Inflatable enclosure with various additional elements, including a SIMBODIE mannequin.

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Figure 6: Interior view of the virtual Chinook cabin.

169x96mm (300 x 300 DPI)

review only



Figure 7: The HTC Vive HMD in use within the MERT trainer.

705x396mm (72 x 72 DPI)

review only