Use of Synthetic Environments to Support HFI Position Paper

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Contents

1 Executive Summary

The Human Factors Integration Defence Technology Centre (HFI DTC) has, over its first three years, conducted a number of research studies relating to the use of Synthetic Environments to support the HFI process. These include a review of current and future use of SEs and the development of a SE 'test-bed' to support HFI, which incorporated embedded human performance measures.

As the HFI DTC enters its second 3-year phase, research proposals are being put forward for agreement with the customer for follow-on work which includes the generation of guidelines for the development and use of SEs to support HFI, and the study of the potential use of modifiable games technologies. In order to assist in the prioritisation of HFI DTC research proposals, a review of stakeholder issues and requirements related to the development and use of SEs was conducted.

This position paper contains the results of this stakeholder engagement, together with a review of the HFI DTC research programme for years 4 to 6, and makes a number of recommendations relating to the focus of proposed topics, closer liaison with customer and stakeholder organisations and the consideration of alternative (or additional) areas of study.

A key recommendation is that the HFI DTC should establish, and agree with key stakeholders and output owners, a clearly defined focus for its research into modifiable games technologies which complements, but does not duplicate, the work being performed by the QinetiQ COTS EU. In addition, the HFI DTC should work to establish clear industry and/or MoD stakeholder support for the development of guidance on the use of SEs to support HFI.

2 Introduction

2.1 Background

The HFI DTC is currently in the process of compiling, and agreeing with the customer and stakeholders, its research programme for the next 3 years. The programme currently proposed includes a number of research topics which relate to the development and use of Synthetic Environments. Proposed research topics feature predominantly in Theme 2 - "Managing HFI SMART Acquisition and Procurement", where the focus is on developing guidance for the use of SEs to improve the HFI Process, and in Theme 8 – "Emerging Technologies" where the focus is on researching the potential application of modifiable Games Engines for defence applications.

During years 1 to 3, a number of research activities have been conducted which have included a review of how SEs are currently being used across MoD and the UK Defence Industry and the development of an SE 'test bed' to support HFI activities across the system lifecycle. This work produced a thorough review of existing SEs and software tools and involved a wide range of stakeholders within MoD and Industry. However, an external audit of the HFI-DTC performed in April 2005 [1] included the following two comments:

'There appears to be undue emphasis on the role of Synthetic Environments within the HFI Process [and] their use seems to be a given without adequate justification.'

'…the impression that better or more adoption of low-cost SEs (and gaming technology in particular) will offer significant support to the HFI process is unjustified thus far."

The question is now being asked within the DTC consortium as to which direction future research relating to SEs should take. The 'accelerated programme' has provided an opportunity to review current research plans, to engage with stakeholders and to examine research priorities for the next 3 years.

2.2 Objectives

The purpose of this position paper is to offer a view on the priorities for research in the field of HF/HFI relating to the use and development of Synthetic Environments, as an input to the shaping of the HFI DTC research plans for the next three years. This view has been formed on the basis of discussions held with key stakeholders within MoD and industry. It is also informed by the author's own experience, as a Human Factors Engineer in the Defence Industry with experience of working on a variety of MoD programmes which have developed and used SEs to support system concept development, system design and the assessment of proposed solutions.

Specific objectives of this study were therefore:

1. To identify key stakeholders for HF/HFI research relating to the use and development of SEs.

2. To identify HF/HFI research requirements relating to the future development and use of SEs.

3. To comment on how the proposed HFI DTC Phase II research programme addresses these research requirements.

2.3 Definitions

The term 'Synthetic Environment' is used to describe a range of technologies and facilities including platform simulators, battle space simulations, immersive and non-immersive virtual reality (VR), teleoperation and modelling. Although it is semantically true that each of these involve the development and use of synthetic environments, this breadth of coverage leads to confusion when considering research requirements and a more focussed definition is required.

The UK MoD definition of an SE is:

"A computer-based representation of the real world, usually a current or future battle space, within which any combination of 'players' may interact. The 'players' may be computer models, simulations, people or instrumented real equipments. In essence it's a complex virtual simulation" [2].

For the purposes of this position paper, the above definition is assumed, and the term *SE* is used to refer to both multi-player networks of models, simulations, people and equipment or non-networked simulation facilities.

3 Potential Use of SEs in Capability Acquisition

3.1 General

As a tool to support capability acquisition, Synthetic Environments have a number of *potential* applications throughout the CADMID lifecycle in support of HFI activities. Figure 1 shows some of the key HFI activities performed throughout the system lifecycle and lists the potential SE application areas appropriate to CADMID phases. These potential applications are discussed in the following sections.

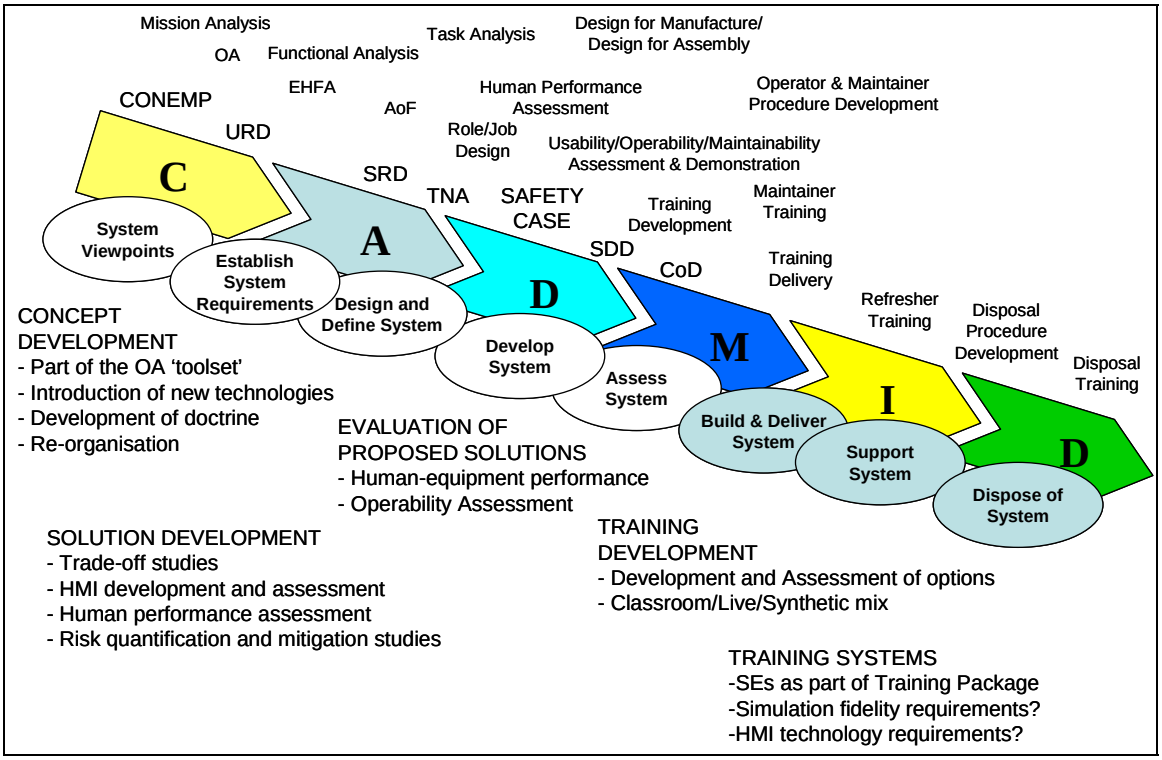

Figure 1 - Potential SE Use in Capability Acquisition

3.2 Concept Development

During the concept phase, Synthetic Environments have a role to play as part of a wider Operational Analysis (OA) toolset when investigating the potential impact of introducing new technologies, developing new doctrine and/or implementing organisational changes, such as those which may be associated with the introduction of new command and control technologies. Although other OA modelling activities will provide answers to many questions during concept development, where human performance impacts upon assessment criteria, human in the loop simulation can provide quantitative evidence to support assessment of concept options. In addition, SEs can provide a 'visualisation' of concepts which provide an important focus for stakeholder engagement.

In terms of HFI activities, the focus during the concept phase will be on the identification of key HFI issues and risks, captured through the Early Human Factors Analysis (EHFA) process. In addition to other analysis activities, the development and use of an SE during the concept phase can provide a tool with which to conduct early visualisation of concepts aimed at identifying HFI issues and understanding user requirements. Potential issues to be addressed can include: impact on manning and personnel requirements, likely impact on future training requirements, human factors engineering issues such as information, control and communication requirements, and potential safety and health hazard issues. Where concepts impact upon organisational change, for example where information flows change or where new decision 'nodes' are required, an SE provides a powerful tool to investigate the impact these changes may have on aspects such as sensor to effect times and situational awareness levels at various nodes in the organisation.

As well as HFI issues or risks arising as a direct consequence of using an SE, they may also result from lessons learnt during the development of the SE itself and during the discussions which arise following demonstrations.

3.3 Solution Development

In the assessment phase, following successful pass through Initial Gate, the focus will be on the development of potential solutions. This will normally involve a competition to choose the system provider or Prime Contractor Organisation (PCO) which will be based upon, amongst other factors, the maturity of the proposed solution and assessed inherent risk. During this phase potential solutions will be developed by candidate system providers, through the translation of user requirements, as contained in the URD, into solution-based system requirements captured in the SRD. HFI activities during this phase involve the development of human roles and tasks within the system and the progressively detailed design of operator and maintainer interfaces.

SEs provide a tool to iteratively evaluate proposed solutions in terms of human-equipment performance, assessing factors such as workload, task time and accuracy, potential human error, and situational awareness levels. Comparative experiments can be conducted to generate data to assist in the selection of alternative solutions. HFI trade-offs can also be investigated through SE-based studies, including for example: automation levels vs. manning levels, role/task design vs. training provision, interface design vs. training provision etc.

Risk mitigation activities can be performed to assist in the quantification of likelihood and/or impact, and to provide evaluation of risk mitigating design options. An example would be the assessment of risk associated with reducing a flight deck crew by removing the navigator and/or flight engineer and the assessment of the reduced crew's ability to cope with stressing missions or emergency procedures. The potential cost associated with such risks will often form the basis of the justification for the SE development.

3.4 Evaluation of Proposed Solutions

In the demonstration phase of capability acquisition, candidate system providers or PCOs are required to demonstrate the degree to which proposed solutions satisfy customer

requirements. An important part of the demonstration activity is the provision of evidence that the proposed solution can be operated and maintained effectively and safely. In many cases a system prototype or technology demonstrator, comprising 'real' equipment will provide the basis for design demonstrations, for others it may be necessary to demonstrate aspects of the design using an SE. This may be due to the risks or practicalities associated with creating a representation of the intended operational environment (including the threats), or due to the costs associated with use of the real equipment. For example, Synthetic Environments have been used in the demonstration of integrated missile defence systems in order to minimise the requirement for live firings, substantially reducing the cost associated with demonstration. Compared to previous systems, a relatively small number of live firings were required for validation and verification purposes.

Synthetic Environments can also be used to provide a simulated context in which to demonstrate system prototypes or technology demonstrators. The SE provides the simulated operational environment, cooperating platforms/units and threats with which the real equipment interacts.

3.5 Manufacture & Assembly Process Development

In the manufacturing phase, there is potential to use SEs to support the design of manufacturing/assembly processes and the visualisation and rehearsal of manufacturing tasks. To date there is very little evidence to suggest that the Manufacture phase is supported by SE technology [3], although there is some evidence that visualisation techniques have been used during the manufacture and assembly of ships and submarines to provide a 3-dimensional reference for assembly workers [4].

3.6 Training Development and Delivery

Although training considerations should be addressed as early as possible, it is often not until the manufacture phase of capability acquisition that significant attention is given to the development of training packages and associated systems. SEs can provide a significant component of a package comprising a mix of live, classroom and synthetic training and provide the ability to deliver training capability before the actual equipment is available.

During the in-service phase, SEs can continue to provide part of the training package, and can be used to investigate individual and team performance issues associated with proposed changes to operating procedures and doctrine and the introduction of technology updates. Properly instrumented, SEs have the potential to provide an environment in which individual and team performance can be measured and fed back as part of the training process.

3.7 System Disposal

Although no examples of the use of SEs during the disposal phase could be found, there is clearly scope for their potential use to support the analysis of disposal activities, the

development of disposal procedures and the training of personnel required to perform disposal tasks. This is particularly the case where the disposal process involved potential health hazard or safety issues, such as with the disposal of hazardous materials such as chemical, nuclear or biological waste.

4 Stakeholder Views

4.1 General

The stakeholder community for research into the development and use of SEs to support HFI is large and diverse, and a short study can only hope to engage with a representative cross-section. Stakeholders include the different MoD agencies responsible for sponsoring the HFI DTC, IPTs (as customers for the development and use of SEs), and UK Industry as developers and providers of SEs. Within each of these there is a range of engineering disciplines that have a stake in research conducted to further the understanding of how SEs are developed and used in support of HFI. These include systems engineers, system architects, OA specialists, software engineers, training specialists and human factors engineers.

Representatives of the following stakeholders have been consulted during the preparation of this position paper:

- Directorate of Analysis, Experimentation and Simulation (DAES)
- Defence Science and Technology Laboratories (Dstl)
- Joint & Battlefield Trainers, Simulation and SE (JBTSE) IPT
- NITEworks
- Industry:
    - MBDA SE Group
    - BAE Systems, InSyte, Battlespace Management Evaluation Centre (BMEC)
    - QinetiQ COTS Evaluation Unit
- Synthetic Environment National Advisory Committee (SENAC) and Synthetic Environment Based Acquisition Forum (SeBA)
- Human Factors National Advisory Committee (HF NAC)
- Human Factors Integration Defence Technology Centre (HFI DTC)

The following two sections summarise the key points raised by MoD and Industry stakeholders consulted.

4.2 MoD Stakeholder Views

4.2.1 "The HFI DTC must establish clear parameters to discriminate its research role from that of the [QinetiQ] COTS EU"

With respect to the HFI DTC plans for research into the application of modifiable games engines, concern was expressed that there should be clearly defined objectives for the DTC research which can be discriminated from those of the QinetiQ COTS EU. It was stated that the DTC focus must be on the HF/HFI issues and benefits associated with this emerging capability rather than the technology itself.

The COTS EU is the focus for research, and the coordinating authority into games technologies for DAES. It is concerned with supporting operational analysis, exercises, training and mission rehearsal and, in general, is focussed on paving the way for introducing games technologies into service by understanding the issues and barriers associated with exploitation. This includes the development of a process for the introduction of games technologies, which will help other commercial and non-commercial organisations to do the same. Their focus is on the operational issues and they do not currently put any significant effort into researching detailed HF issues such as understanding how to optimise the interface between the user and the SE.

The COTS EU view themselves as subject matter experts – they have no products and are happy to work in conjunction with the HFI DTC in the development of applications for modifiable games engines. The DTC has established good communications with the COTS EU, participating in liaison group meetings. It is important that this relationship is maintained in order that research objectives can be developed which avoid any potential duplication of effort.

Concern was expressed that there are potentially significant barriers to the exploitation of games technologies which need to be explored and understood. These barriers include IPR restrictions on the use of games technologies for commercial application, questions over the long term (or even medium term) support for games engines and questions regarding the quality of models contained in games engines. There is also some concern that the potential for use of games engines may be 'over-rated' and 'over-hyped'.

4.2.2 "There is no financial impetus for SE re-use. IPTs are focussed on developing or acquiring the equipment. Re-use (e.g. to support training or for future projects) is seen as an additional cost."

The view was expressed that IPTs (in general, although this may not be true for all) have difficulty justifying the development of SEs with re-use in mind. Organisational, financial and possibly cultural barriers appear to exist which prevent an IPT from adopting a long-term, through lifecycle approach to the development and use of a SE. In the early phases of the lifecycle, the IPT focus is on developing or acquiring the equipment and investment in SE development is aimed at investigating issues associated with equipment development or assessment of options. Development for future re-use of the SE, to support activities during later stages of the lifecycle, such as training or future system upgrades, is viewed as involving (avoidable) additional cost. Whether or not this is true, requires further investigation. Although it is true that the identification of requirements

for future use may involve additional cost, it is likely that the development of an SE with a modular architecture, using standard interfaces, could provide a high degree of flexibility to support future re-use at minimal additional cost.

Industry was viewed as being further advanced in its approach to re-use. The reason for this is likely to be a combination of organisational and financial factors. Certainly in the case of BAE Systems and MBDA, investment has been made in the development of SE facilities as 'core' facilities available to support a wide range of projects. The ability to re-use these facilities across projects and across the lifecycle was seen as a de-risking factor when deciding to invest. In addition, through re-use, these facilities have been able to accumulate, through incremental development and acquisition, extensive libraries of simulations and models which further increase their scope of application.

4.2.3 "Technical Enabling Service (TES) HF Group is seen as the focus for process development and process guidance"

"The HFI DTC is viewed as a source of knowledge and tools to support processes"

With respect to HFI DTC research to develop guidelines for the use of SEs to support HFI, the view was expressed that the TES HF Group (in conjunction with the Sea Systems Group) is seen as the focus for the development of HFI process. As such, any research conducted to further develop the HFI process, including guidance on the development and use of SEs to support HFI, should be done in consultation with the TES HF Group who will be responsible for exploitation. Where the TES HF Group are not addressing a topic related to HFI process development, then there may be a case for the DTC to perform this work. However, it is important that the TES HF Group are made aware and are in agreement with the research proposals and objectives.

The view was expressed that the DTC is seen as a provider of fundamental knowledge and developer of tools which support HFI activities across the lifecycle, rather than the developer of HFI process.

4.2.4 "There is a requirement to develop training metrics, particularly for collective training, to provide the ability to evaluate training benefit and quantify training cost."

When discussing the development and use of SEs to support training, the requirement for the development of training metrics was raised. In order to understand the value of SE-based training when compared to alternatives such as classroom instruction or live training, or to understand the optimum mix of training methods, it is first necessary to be able to quantify the relative costs and benefits. The view was expressed that there are currently no established metrics for evaluating training benefit or indeed agreed methods for establishing training cost. These are research topics which the HFI DTC might consider addressing.

4.2.5 "Network Enabled Training is the next big challenge and there is currently no vision of what this will look like".

With respect to the use of SEs for collective training, the point was made that Network Enabled Training (NET) represents an enormous challenge for training agencies and there is currently no vision of what this will look like, or how to make it happen. There will be a dependency on all IPTs to coordinate their training needs analysis (TNA) in order to capture the requirements for NET.

Currently there is a severe lack of financial resources and appropriately skilled people to conduct TNA at the individual IPT level. As a result, it is common for the TNA to be subcontracted to one of a few specialist consultancies, when the view is that ideally it should be performed by Customer 2. The provision of easy to access, practical guidance with associated tool support, is required to enable IPTs to conduct equipment level and collective training needs analysis.

4.3 Industry Stakeholder Views

4.3.1 "There is significant interest in the potential use for COTS games technologies to enhance our existing SE capability"

Although there currently appears to be minimal use of modifiable games technologies within the UK Defence Industry's SE capability development, discussion with industry stakeholders indicates that there is a clear interest in the potential that these technologies may offer. The SE National Advisory Committee (SENAC) and Synthetic Environment Based Acquisition (SeBA) Forum are following developments closely and the QinetiQ COTS EU is focussed on developing exploitation routes for games engine technologies. Within the industrial stakeholders consulted (other than the COTS EU) there is already some evidence of the use of modifiable games engines to develop small-scale simulation elements of larger SE capabilities. SE facilities such as the BAE Systems BMEC, and those at MBDA, QinetiQ, Thales and the recently launched EADS UK SE facility offer good exploitation routes for DTC research into the UK Defence Industry.

The HFI DTC, primarily through both Prof. Robert Stone and David Morris, is well represented at both the SENAC and SeBA Forum and it is important that this representation continues.

4.3.2 "The interfaces between the engineering disciplines involved in the development and use of SEs, in particular OA, HF and software engineering need to be understood and defined"

There are a number of key engineering disciplines that need to be involved in the design of SE architectures and the experimental environment. In some cases the role of these different disciplines and the interfaces between them are well understood and mature processes have been developed to support the development of a required SE and the design of visualisation, experimental or demonstration activities. A prime example is the process developed by the NITEworks organisation [5] to address the design of warfighting experiments to assess the benefits of Network Enabled Capability (NEC). NITEworks, a partnership between MoD and Industry with DAES as Customer 1,

employs a range of engineering disciplines and facilities to answer questions set by the MoD. Often, this will involve the development of visualisation or experimental activities using federated SE facilities operated by one or other partners.

Since its inception 3 years ago, NITEworks has developed processes for rapidly analysing NEC issues and developing warfighting experiments to address the key questions. In parallel, SE facilities such as those at the BAE Systems BMEC have developed processes for quickly developing required SEs, using both existing libraries of models and simulations, plus techniques for rapid application development. They have also developed mature processes for detailed experimental design to ensure that the turnaround time from tasking by NITEworks to completion of experiment is minimised.

Lessons learnt from NITEworks and from leading industrial players in the development of these processes offer potential benefits for the development and use of SEs to address a wider range of applications.

The HFI DTC should make efforts to establish links with NITEworks and with the federated SE facilities such as those operated by BAE Systems, MBDA and QinetiQ to explore the capability gaps and to identify potential research exploitation opportunities.

4.3.3 "New measures and tools are required to support the assessment of Command and Control issues. For example, measures of team SA and metrics of 'decision quality'."

"There is a requirement to integrate HF tools with existing SE data-logging facilities"

Discussion with industrial stakeholders involved with the development and use of SEs to address NEC questions, revealed a requirement for new measures and tools to support the assessment of human performance associated with command and control. Whilst it was felt that the measurement of performance aspects such as workload and SA levels for individuals are reasonably well understood and supported by adequate tools, there is a paucity of measures to address team performance. In addition, new measurement techniques and tools are required to assess features of command and control networks. In the development and introduction of new command information systems, it is important to be able to measure the impact that these systems have on overall military performance. Specifically raised was a requirement to be able to measure the quality of decisions made within a network and to be able to assess the impact of decision quality on overall operational performance.

Another requirement raised was the need to integrate HF tools within existing SE data-logging facilities. Currently, it is common practice for HF measures of human performance (e.g. workload and SA) to be taken during the conduct of trials or experiments using data gathering tools which are independent from the SE facility. At the same time, event data can be captured automatically by the SE facility using a DIS/HLA logging facility which can be viewed post exercise. There is a requirement to be able to simply and quickly synchronise these data to ascertain how event X impacted upon human performance (or loading) and vice versa.

4.3.4 "SE re-use is challenging, but clearly desirable. Some 'ad-hoc' re-use is happening, but there is no 'grand strategy'."

The benefits of being able to re-use SEs across projects and across the system lifecycle are well understood within industry. Major SE facilities such as those developed by MBDA and BAE Systems are founded on the ability to re-use models and simulations for different projects and to continually extend these libraries. In general, it would appear that most re-use occurs across projects rather than within, with most SE applications being concentrated around the early stages of the lifecycle (i.e. concept development and assessment). To date there has been very little re-use of SEs through the lifecycle of a project, such that, for example, a SE has been used to develop concepts and solutions, assess those solutions and then used as part of a training system later in the lifecycle. That said, the commercial benefits of, and opportunities, for doing this are appreciated by industry and discussion with stakeholders revealed that there are efforts being made to re-package SE elements as training products.

5 Scope for SE-Related HF/HFI Research

5.1 General

There is a diverse range of potentially beneficial research activities that could contribute to the development and use of SEs to support the application of HFE and HFI to capability acquisition. This section of the report discusses some of these research 'opportunities' and their relative merits under the following headings:

- Awareness and Promotion
- Process Development
- SE Technology Development
- SE Instrumentation (Tools and Metrics)

It is recognised that many of the research areas discussed herein are already being considered by MoD, industry and academia.

5.2 Awareness and Promotion

Synthetic Environments, in their various forms, have an important role to play in the development of system concepts, the maturation of system requirements, the iterative design and assessment of complex systems and as part of integrated training systems. To the Human Factors community, the ability to put operators and maintainers into an environment within which they can perform representative tasks using actual or prototyped equipment, has obvious benefits in terms of de-risking the development and introduction of new technologies, doctrine and procedures. However, these benefits are not always as evident to those responsible for deciding whether or not to invest in the development of a SE, particularly in light of the significant costs which may be involved.

Organisations such as the Modelling, Simulation and Synthetic Environments (MS & SE) Forum [6], the SENAC [7] and the SeBA Forum [8] all have objectives to promote awareness and the use of SEs. In collaboration with technical specialists in these fora, the HF Community has a key role to play in the promotion of appropriate use of SEs throughout the system lifecycle. This includes the conduct and reporting of cost-benefit analyses of SE-based concept development and risk reduction activities, and the provision of appropriate training facilities.

IPT investment in the development and use of SEs to support capability acquisition is dependent upon a business justification based upon clear cost-benefit evidence. Whilst there is a growing pool of data associated with the cost-benefits of SE development and use, further efforts are required to promote an awareness of the benefits in order to justify broader IPT investment.

The HFI DTC has made a start in this process through the survey of the use of existing SE facilities to support HFI and the cost of their development and use, and in the development a SE test-bed with which to demonstrate the potential for re-use and the integration of human performance measurement and recording techniques.

5.3 HFI & SE Process Development

As discussed in Section 3 of this report, there is a wide range of potential uses for SEs to support HFI across the acquisition lifecycle. Currently, however, it is apparent that SE development and use is not aligned with achieving HFI objectives. In the survey conducted by the HFI DTC [3] it was found that SE application is concentrated on the early stages of concept development and assessment and then later as a potential component of training.

It may be argued that the concept of SE-based acquisition (SeBA) and HFI are both linked by a common reference, that being a Systems Engineering approach to capability development and introduction. The objective of HFI is to ensure that, as part of the wider Systems Engineering process, human capabilities and limitations are sufficiently and properly addressed. As with HFI, Systems Engineering is dependent upon the successful integration of various specialist engineering disciplines and achieving balanced trade-offs between requirements. Synthetic Environments are tools which can support the System Engineering process from the capture and analysis of requirements, through the development and assessment of concepts, the design integration of solutions, verification and validation testing and onto in-service support and eventual disposal.

The development of appropriate process guidance, which addresses the development and use of SEs to support HFI activities across the lifecycle, will help to align the objectives of SeBA and HFI. Guidance is required to address the use of SEs to support:

- User and System Requirement Capture and Maturation
- Early Human Factors Assessment/HFI Issues Identification
- HFI Risk Identification and Mitigation
- Usability/Operability Assessment
- Analysis of Manning Levels, Personnel Requirements and Organisational Design
- Design Acceptance
- Training Design and Assessment
- Safety and Health Hazard Assessment

5.4 SE Technology Development

In terms of the development of technologies that form part of a SE, there are a number of areas to which Human Factors research can contribute. An example is in the development of behavioural aspects of automated or semi-automated Computer Generated Forces (CGF). Whereas the modeling of physical aspects of CGF are fairly well addressed in SEs, the behavioural aspects which determine where, when and how synthetic forces perform physical actions are less developed. Numerous models of human behaviour exist for use in SEs which serve a multitude of purposes. But it is perhaps worthwhile considering where these models can be improved to provide more realistic human behaviour.

Modular Semi-Automated Forces (ModSAF) is a system for simulating entities (platforms) on a simulated battlefield [9]. It is perhaps the most widely used behavioural simulator in military synthetic environments. The goal of ModSAF is to replicate the behaviour of simulated platforms in sufficient detail to provide useful training and a simulation of tactics. Although some semi-intelligent behaviours are included in ModSAF, users report problems in learning and using the system [10]. An opportunity therefore exists for the development of alternative, and better, methods for simulating intelligent entity behaviour within SEs, although it should be acknowledged that this is a specialist field requiring considerable expertise.

A further example of SE technology development to which HF can contribute is in the understanding and specification of required simulation fidelity levels. When developing a SE for a particular application, be it for concept or system development, or as a training facility, it is important to understand how the fidelity of various simulated components impact upon the goals and objectives for the SE. Often the temptation of SE development teams is to 'over-engineer' models and interfaces in the belief that the highest fidelity provides the best environment for training or system assessment. In most cases, an analysis of the user tasks being investigated, or trained for, will highlight where high fidelity simulation is important and where low fidelity simulation will suffice. A structured approach to the analysis of simulation requirements would help to ensure that an appropriate level of fidelity is afforded to the various components of a SE.

Human Factors also has a role to play in the development of novel interface technologies which can potentially enhance the capabilities of a SE. Immersive interface technologies such as helmet mounted displays and virtual reality caves can form useful components of a SE, particularly within training applications. Other interface technologies, such as head and eye-tracking systems may also have useful application in the instrumentation of SEs, for example as a method for understanding how information is used to acquire situational awareness.

5.5 SE Instrumentation

There is considerable scope for the development of new tools and techniques for the measurement of human performance, both of individuals and teams, which can be integrated with SE technologies to improve current data gathering capabilities. Although progress has been made in the instrumentation of SEs to measure human performance,

examples being the *HALO*™ (Human Assessment Linked to Operator) system used by BAE Systems BMEC [11] and the *HFI Federate* developed as part of the HFI DTC SE Test Bed [12], further development is required. Existing instrumentation involves the use of established human factors tools such as the NASA-TLX or ISA (Instantaneous Self-Assessment) for operator workload measurement and probing techniques for the assessment of SA. The DTC's HFI Federate enables a user to synchronise data obtained from these tools with event data logged by the SE. Set-up and data manipulation is performed using the Administrator Interface which has been recently developed as part of the HFI DTC Phase 2 acceleration programme. Furthermore, there are currently few tools and techniques which address the measurement of team performance, which is essential for example in the development and assessment of collective training facilities and in the development of command information systems technologies.

Improvements are also required in the ability to measure individual and team performance through non-intrusive methods which capitalise on the data-logging capabilities which exist within SEs. This may involve the development of new analytical techniques for identifying measures of effectiveness (MoE) and measures of performance (MoP), the development of new human performance assessment techniques, and the development of technologies for human performance data capture which can be integrated within SE architectures.

6 Review of the HFI DTC Research Programme

A brief review of the HFI DTC research plan for years 4 to 6 shows that there are a number of proposed topics which relate, either directly or indirectly, to the development or use of Synthetic Environments. Figure 2 shows how these topics relate to the four areas of 'research scope' discussed in the previous section.

Promotion & Awareness	**SE – HFI Process Development**
COTS EU Liaison *SENAC Involvement* *SeBA Forum Involvement* *General Promotion/Exploitation Opportunities*	Embedding HFI in the Sys Eng Process Future Procurement Process and HFI Specification Use of SEs to Improve HFI Process (Guidelines) RATaC Evaluation
SE Technology Development	**Instrumentation & Metrics**
Re-Configurable Experimental Test-Bed for C4I	
Training to Make Better Tactical Decisions	
Develop & Evaluate Games Engine Demonstrator Emerging Technologies for Defence Medicine Emerging Technologies to Support Distributed Team Working	Future WESTT

Figure 2 - HFI DTC Research Topics with Relevance to Synthetic Environments

In terms of promotion and awareness, continued liaison with the SENAC, SeBA Forum and COTS EU, together with opportunities which arise to promote and exploit DTC research findings should provide a means to ensure that the use of SEs to support HFI, and the input which HF can make to SE development, are sufficiently addressed.

The main research activity addressing HFI - SE Process Development is the development of guidelines for the use of SEs to support and improve the HFI Process (task 2.16). This work has started during the 'Acceleration Phase' and has involved a survey of existing documentation and the generation of initial guidelines for the use of SEs to support HF activities across the CADMID lifecycle. Further work is planned, including a workshop with SE and HFI stakeholders to review and improve these guidelines. Other work includes an evaluation of the RATaC (Rapid Assessment of Task and Context) technique (task 5.2.3) which offers potential as a first iteration training needs analysis, and is particular relevant to the specification of simulation/SE based training solutions.

With respect to SE technology development, there are a number of proposed DTC research topics which, although not focussed on SEs, will require the development of simulation-based experimental or demonstration environments. An example is the

development of a re-configurable test-bed for C4I studies (task 3.2.3). Lessons learnt in the development and use of this facility, both in terms of development process and the specification and use of SE technology, may offer a useful input to the guidelines being developed within Theme 2. Of more direct relevance is the proposed research aimed at developing and evaluating a modifiable games engine demonstrator of relevance to the HFI process (task 8.3.4). This research should aim to generate findings which have 'broad' value to the development of HFI Process, rather than to create a solution to a specific simulation/SE requirement. Generic value will come from the lessons learnt in developing the demonstrator, from understanding potential barriers, and from the generation of guidelines for the use of this emerging technology. Consideration should be given to the use of modifiable games technology to rapidly develop an experimental environment in which HFI issues (e.g. human performance, organisation, interface design options, training etc.) can be investigated. This will provide the potential to demonstrate a direct relevance of this emerging technology to HFI.

The proposed research programme contains few topics which aim to address the instrumentation of SEs and the development of new metrics. The notable exception is the planned further development of the WESTT (Workload, Error Situation awareness, Teamwork and Time) tool (task 1.2.1.2). This has the potential to provide a powerful suite of functions which can be applied to the observation and analysis of command and control studies/experiments performed both in the field and within a Synthetic Environment. Planned developments, which include facilities to create Operational Sequence Diagrams (OSDs) have the potential to support the early identification of network and organisational issues which may then be addressed through experimentation using SEs. WESTT may therefore have application as a tool to help define SE experimentation objectives and also as a tool to gather human performance data during SE-based studies during concept and system development and later in the measurement of training effectiveness.

7 Conclusions

1. From the stakeholders consulted it is clear that there is no strong consensus on the SE-related research priorities for the HFI DTC. There is a diverse range of interests and requirements from MoD and Industry stakeholders and it has not been possible to identify distinct research topics which satisfy the requirements of all stakeholders consulted.

2. It is evident that whilst there is interest in both MoD and Industry in the potential benefits offered by the use of modifiable games technologies, there is also concern that potential benefits are possibly being 'over-rated' and 'over-hyped', and that the potentially significant barriers to exploitation have yet to be fully explored.

3. There is a concern amongst MoD stakeholders that the DTC may duplicate research being performed by the QinetiQ COTS EU.

4. Within the MoD stakeholders consulted there appears to be little support for proposed research into the development of guidelines for the use of SEs to improve HFI Process. Furthermore, promotion and exploitation within MoD is, to a large extent, dependent upon support from the TES HF Group. Whilst this group recognises its importance as an exploitation route, it does not currently have the resource or expertise required to promote these guidelines.

5. Industry stakeholders consulted have a requirement to better understand the role of, and interfaces between, the various skills and disciplines required to develop SE architectures and experimental processes. The development of guidelines for the use of SEs to support HFI could go some way to address this requirement, by highlighting the HF/HFI factors needed to be considered during the development of facilities and experiment/study procedures.

6. Within IPTs there are financial, organisational and possibly cultural barriers which act to restrict the potential for SE re-use. In the early stages of an acquisition programme, inevitable financial constraints mean that the IPT focus is on ensuring that the equipment is developed or acquired and any investment made in SE will be aimed at supporting this goal. Any additional investment which may be required, or *perceived* to be required, to ensure that an SE will support future re-use in later stages of the lifecycle (e.g. to support training) will be difficult to justify. Consideration of 'downstream' activities such as delivery of operator/maintainer training or future system upgrades can sometimes be viewed as the responsibility of other organisations (e.g. training development teams).

7. Industry is keen to exploit SE re-use across projects and across the lifecycle, recognising the commercial benefits that this offers. Those companies that have invested in significant SE capabilities have done so with a view to supporting a wide range of projects with the same 'core' facility using ever-expanding libraries of models and simulations. As such re-use is central to the success of such facilities. To date, however, there is little evidence of industry making re-use of SEs within a project and across the lifecycle, with most applications concentrated on the early concept, assessment and demonstration phases.

8. A brief review of the current high-level DTC research plan for years 4 to 6 indicates that, with the notable exception of Future WESTT, there is relatively little research aimed at the development of new tools and metrics to assess individual or team performance; tools which might be embedded into SEs to support system development and training assessment.

8 Recommendations

1. The HFI DTC should establish, and agree with key stakeholders and output owners, a clearly defined focus for its research into modifiable games technologies which complements, but does not duplicate, the work being performed by the QinetiQ COTS EU.

2. The HFI DTC should work to establish clear Industry and/or MoD stakeholder support for the development of Guidance on the Use of SEs to Support HFI. Support from the TES HF Group/STG for this research is considered important in order to promote exploitation of guidance through to IPTs.

3. The goal for the research into modifiable games technologies should be on achieving a broad exploitation base through the development of generic processes, tools and data, rather than the development of specific applications (though it is recognised that this may be required as *proof of concept*). Future research into this emerging technology should focus on demonstrating how it can be used to support HFI across the lifecycle (e.g. through the rapid development of an experimental environment to investigate user requirements, human performance associated with design options, HFI trade offs, etc.)

4. The potential significant barriers to the exploitation of COTS gaming technologies should be explored and understood in parallel with the potential benefits. In particular, evidence should be sought to alleviate concerns regarding commercial/IPR restrictions that may render such technologies far less 'affordable' than currently assumed.

5. The HFI DTC should continue to liaise with the SENAC and SeBA Forum to promote an HFI 'viewpoint' on priorities for SE technology, process and guideline development.

6. The HFI DTC should consider allocating research resource to the development of (additional) new tools & techniques which can be applied to the measurement of individual and team performance to support system development and assessment, and/or the measurement of training effectiveness. The integration of such tools within SE technology, such that human performance measures can be synchronised with data/event logging facilities should be considered. This would build on the work already conducted by the DTC in the development of a SE test-bed.

7. Closer liaison with the NITEworks partnership and federated SE facilities such as the BAE Systems BMEC should be sought. This will provide an insight into existing processes for defining SE requirements and the development of warfighting experiments, and may potentially provide a valuable exploitation route for research into the use of SEs to support HFI and the application of modifiable games engines.

8. This short study has only been able to engage with a small cross-section of the stakeholder community. It is therefore recommended that the HFI DTC should liaise

with the MOD research output owners and the RAO to define and agree the requirements for SE-related research and to prioritise research topics accordingly.

9 Abbreviations

AoF	Allocation of Function
BMEC	Battlespace Management Evaluation Centre
CADMID	Concept, Assessment, Demonstration, Manufacture, In-Service, Disposal
CGF	Computer Generated Forces
CoD	Certificate of Design
CONEMP	Concept of Employment
COTS EU	Commercial Off The Shelf Evaluation Unit
DAES	Directorate of Analysis, Experimentation and Simulation
Dstl	Defence Science and Technology Laboratories
DTC	Defence Technology Centre
EHFA	Early Human Factors Analysis
HALO	Human Assessment - Linked to Operator
HFI	Human Factors Integration
HF NAC	Human Factors National Advisory Committee
IPR	Intellectual Property Rights
IPT	Integrated Project Team
ISA	Instantaneous Self Assessment
JBTSE	Joint & Battlefield Trainers Simulations and Synthetic Environments
ModSAF	Modular Semi-Automated Forces
MoE	Measure of Effectiveness
MoP	Measure of Performance
NEC	Network Enabled Capability
NET	Network Enabled Training

NITEworks	Network Integration Test and Experimentation works
OA	Operational Analysis
OSD	Operational Sequence Diagram
PCO	Prime Contractor Organisation
RATaC	Rapid Assessment of Task and Context
SA	Situational Awareness
SDD	System Design Definition (or Document)
SE	Synthetic Environment
SeBA	Synthetic Environment Based Acquisition
SENAC	Synthetic Environments National Advisory Council
SRD	System Requirements Document
TES	Technical Enabling Service
TLX	Task Load Index
TNA	Training Needs Analysis
URD	User Requirements Document
VR	Virtual Reality
WESTT	Workload, Error, Situation awareness, Teamwork and Time

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