

Single Synthetic Environment Software Platform for the MoD

Summary Impact Assessment
June 2021

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Summary of benefits

Potential total quantitative benefits over 10 year timeframe in excess of

£3bn

A SSE platform

has the potential to provide the MoD with:

A step change in capability, transforming the way the military operates across its full breadth including: training, planning/decision support, C2, procurement, testing & evaluation, logistics, infrastructure, and others.

A critical enabler of multi domain integration, delivering the digital ambition set out in the UK's Integrated Review 2021, Integrated Operating Concept 2025 and the MoD's Digital Strategy for Defence April 2021.

A key pillar of the defence digital backbone capable of delivering wide reaching and exponential quantitative benefits significantly beyond the 10 year timeframe reviewed.

Wider economic benefits
£300mn-£750mn

Direct cost benefits
£1.3bn

Indirect cost benefits
£1bn-£1.5bn

Capability qualitative benefits

Versatility

A SSE software platform has the ability to develop and support a wide range of interconnected and coherent third party applications which can be used to transform the way the military operates across its full breadth including: training, planning, C2, procurement, T&E, logistics, infrastructure, and others.

Consumed at the point of need

The potential to leverage cloud as well as traditional physical hosting enables the SSE to be drawn down globally, wherever and whenever it is needed.

Greater interoperability

Greater ability to undertake joint and multi-domain training and planning with multiple forces, agencies and allies.

Evergreen service

PaaS ensures all synthetic solutions are perpetually up-to-date, performant, leveraging the latest technology and security standards.

Rich synthetic representations

Powerful advances in distributed computing enable synthetics to offer greater richness and complexity, in greater volumes.

Rapid access to context and Insight

Enables MoD to leverage existing content across the defence estate and remove barriers to bringing in new content. This in turn reduces barriers to content suppliers into MoD promoting greater supply chain diversity, competition and innovation.

Reduced technical delivery risk

With an established and common technological base, industry players can deliver SSE-enabled solutions with lower risk and leverage the breadth of installed capabilities and content.

Reduced environmental impact

It reduces the need to travel, use carbon heavy equipment in live testing and expend resources (e.g., fuel, ammunition, equipment) in training.

existing net working infrastructure

A specialised synthetics platform, such as a SSE PaaS, should be able to drive scale (user numbers, complexity) without requiring the significant upgrades to working infrastructure that alternative (DIS/HLA) approaches are likely to need.

Robust feedback loop

Provide more data/analytics for more effective After-Action Review/feedback leading to better training, planning, decisions and operational outcomes.

Direct Cost Benefits

c. £1,280mn

£810mn from reduced content development costs driven by the reusability of models/applications on a standardised SSE PaaS system vs. standalone, non-platform based synthetic solutions.

£470mn from reduced back end support costs to host and ensure availability of the platform vs. similar costs on a non-platform solution.

Indirect Cost Benefits

c. £1,000mn-£1,470mn

£100mn-£225mn from the wider adoption of synthetic training due to the benefits brought by a PaaS SSE.

£500mn from better decision-making across the MoD enterprise.

£350-700mn reduction in spend on R&D and equipment programmes T&E.

£20mn from more effective use of resources and use of a common commercial model.

£10-25mn environment value driven.

Wider Economic Benefits

c. £300mn-£750mn

£200mn-£300mn

UK Export opportunities

£100mn-£450mn

Innovation spill overs across the UK





Executive Summary

02

The UK Government's Integrated Review of March 2021 and the Ministry of Defence's (MoD) Integrated Operating Concept and newly released (April 2021) Digital Strategy for Defence have re-stated the need for a radical digital transformation and for the UK to secure its status as a science and technology superpower by 2030.¹

Critically it is recognised that "the economics of warfare are changing the balance between platforms and weapons, and between crewed and uncrewed systems. In short, we face an inflection point between the Industrial Age and the Information Age – it is one that Defence will need to respond to if it is to retain a competitive edge."²

The UK Government has made it clear it will respond by investing " ... in synthetics and simulation, providing a step change ... "³ and pathfinders are underway to assess a potentially transformative capability supporting the military 'digital backbone'; a Single Synthetic Environment (SSE). A SSE forms one of the three critical pillars needed to "build and exploit the Digital Backbone for Defence".⁴ Whilst there are alternative approaches to simulation interoperability (e.g., DIS/HLA), a SSE delivered as a PaaS has the potential to provide a more cost effective, powerful, cohesive, and evergreen foundation for a multitude of military use-cases across training, planning and decision support, integrating and enhancing best-of-breed content, GFX, hosting and applications to deliver a more realistic, continuously adapting and distributable synthetic environment.

However, whilst similar platform technology has been successfully used in other industries for years, it is still being tested in a military context and quantitative data around the benefits it could deliver is still emerging. Step-change towards any platform such as the SSE requires material investment and operational change and whilst the qualitative benefits of transformative synthetics are potentially wide and broadly acknowledged at policy level, the financial benefits must also justify the investment required to procure and implement such a platform.

This report finds that a MoD SSE delivered as a 'Platform as a Service' (PaaS) has the potential to provide significant and tangible quantitative and qualitative capability benefits that could deliver a step change in the effectiveness of joint-force military training, planning, procurement and decision-making at all levels and across all Commands. These include:

Potential Qualitative Benefits

Versatility

By providing a common simulation layer of PMESII/DIMEFIL⁶ models and data, a SSE platform has the ability to develop and support a wide range of interconnected and coherent third party applications, which can be used to transform the way the military operates across its full breadth, including:

- ▶ **Decision support** – decision-makers will potentially be able to continuously test and rehearse different courses of action within a simulated operating environment, assessing the consequences of decisions, and adapting, in a more data-driven, scientifically rigorous way.⁷
- ▶ **Collective training** – a SSE platform would drive consistency in user experience, **content** re-use across the defence estate, and more detailed training feedback loops, driving continuous improvement in training and operations through trial, error, learning and retesting.
- ▶ **Planning** – the whole lifecycle of a plan, including Command and Control (C2), could be facilitated and optimised by a SSE platform. Constructive simulation modules (e.g., population sentiment, logistics, weather) would ensure that all analysts, planners, operatives and commanders had access to all of the relevant information enabling them to evaluate and improve potential interventions by continuously 'playing them out' synthetically.⁷ This would include the use of a SSE platform to assist in the more cohesive and realistic planning of emergency situations, such as COVID19, both for the MoD and across wider government agencies.
- ▶ **Other Key Use Cases** – the potential value of a SSE platform could span into numerous other areas of both the MoD and broader government. These include:
 1. Testing and evaluation – synthetic testing (e.g., digital twins) of, for example, aircraft engine failures, would allow for an increased number of scenarios to be evaluated, at a higher level of repetitions, in a shorter timescale and for a lower cost.

2. Network planning – new infrastructure or communications networks can be synthetically tested first to highlight potential weaknesses/issues, and subsequently monitored for planned and unplanned outages.
3. Logistics – supply/support chain activities can be continuously tested and optimised (e.g., distribution activities and routes) in a SSE PaaS.
4. Procurement – it may be possible to utilise a SSE PaaS to test MoD equipment/infrastructure/services virtually during the procurement phase, reducing the timescales and/or allowing more testing to be performed in a similar or reduced timescale, leading to more robust procurement decisions/outcomes.
5. Cyber planning – cyber resilience can be assessed synthetically assessing the cascading implications and potential mitigations of cyber attacks on the resiliency of critical assets or national infrastructure.

Consumed at the point of need

The potential to leverage cloud as well as traditional physical hosting would enable a SSE to be drawn down globally, wherever and whenever it is needed. This should increase the use and convenience of synthetics, reduce existing latent redundancy, the need to house all users in a single 'fixed' training facility and the environmental impact of training (see below).

Greater interoperability

The ability to undertake joint and multi-domain training and planning with multiple forces, agencies and allies is expected to be significantly enhanced by a PaaS based SSE.

Evergreen service

PaaS ensures all synthetic solutions are perpetually up-to-date, performant, leveraging the latest technology and security standards, and reducing upkeep expenditure.

Realistic synthetic representations

Powerful advances in distributed computing enable synthetics to offer greater realism and complexity, in greater volumes (e.g., 5+1 domains, millions of entities, entire countries or regions), which will ultimately drive military personnel to be more effective in live training and operations, drive improvements in the testing and evaluation of equipment and allow MoD personnel to make better decisions/plans.

Rapid access to the best content, applications and insight

A PaaS architecture enables defence to leverage existing content across the defence estate and remove barriers to bringing in new content (both within defence industry and in broader commercial or academic sectors). This in turn reduces barriers to content suppliers into MoD promoting greater diversity, competition and innovation within the supply chain and enables faster adaptation, collaboration and ability to keep pace with fast-evolving threats by providing MoD with access to the best tools to efficiently deliver successful outcomes.

Reduced technical and delivery risk

With an established and common technological base, industry players can deliver SSE-enabled solutions with lower risk and leverage the breadth of installed capabilities and content.

Reduced environmental impact

It reduces the need to travel, contaminate green spaces and use carbon heavy equipment and other resources (fuel, ammunition) in testing and training exercises.

Ability to leverage existing networking infrastructure

A specialised synthetics platform, such as a SSE PaaS, should be able to drive scale without requiring the significant upgrades to working infrastructure that alternative approaches require.

Robust feedback loop and continuous improvement

It will provide more data/analytics for more effective After-Action Review/feedback, driving continuous improvement in training, planning, decisions and operational outcomes through trial, error, learning and retesting.

Potential Quantitative Benefits

Further to the many qualitative benefits, this report finds that over a 10 year period a PaaS based SSE has the potential to deliver **quantitative benefits in excess of £3bn** across:

Direct Quantitative Benefits of c£1,280mn in the form of cost benefits (or reinvestment potential), for example from reduced software/hardware, maintenance and development costs that result from the reusability of applications/models on a single, central, flexible, scalable and managed PaaS.

Indirect Quantitative Benefits of c£1,000mn – £1,470mn from, for example, increased usage and efficiency of synthetic training, testing and evaluation and enhanced planning and decision making across domains/Defence Lines of Development (DLOD's) enabled by a more realistic and efficient SSE.

Economic benefits to UK Plc of up to £750mn from, for example, greater opportunities for innovation and the exportability of the technology, productivity and innovation-focused jobs, more SME opportunities, all of which enhance the UK's competitive edge.

As part of this report, we have not sought to estimate the upfront costs required to implement a SSE PaaS system into the MoD. However, if the cost of an SSE and associated configuration and integrations is estimated to cost in the region of £200-400m, the size of the potential qualitative and quantitative benefits this technology could bring appear to make the case for a PaaS based SSE compelling. There are inevitably some risks/issues to overcome, for example around data policy/management, security standards, the potential for cognitive overload, the implementation needed and the cultural shift required for the Armed Forces to embrace higher usage of synthetic environments for training and planning. However, these are considered by many to pose surmountable challenges⁸ and the current pathfinders are providing mitigations to these and other potential challenges, whilst also demonstrating the robustness and maturity of the underpinning technology.

Whilst more analysis is clearly required utilising more mature data and definitive MoD cost estimates, overall it would appear that "the use of a SSE as an underpinning enabler to all the other aspects of defence transformation for the digital age will be a pivotal capability in how forces are conceived, designed, commanded and operated"⁹ allowing the UK to maintain its edge in this 'competitive age' and acting as a key enabler to delivering the critical defence modernisation aims set out in recent defence narrative.¹⁰





Introduction

03

The UK Government’s Integrated Review of March 2021, the Ministry of Defence’s (MoD) Integrated Operating Concept 2025 and the MoD’s Digital Strategy for Defence April 2021 have re-stated the need for a radical digital transformation and for the UK to secure its status as a “science and technology superpower by 2030”.¹¹

Critically it is recognised that “the economics of warfare are changing the balance between platforms and weapons, and between crewed and uncrewed systems. In short, we face an inflection point between the Industrial Age and the Information Age – it is one that Defence will need to respond to if it is to retain a competitive edge.”¹²

However, trying to predict the optimal balance of these different warfighting elements will not be easy. The MoD’s Integrated Operating Concept 2025 sets out the following approach:

“ ... we will have to take risk, accept some failure and place emphasis on experimentation by allocating resources, force structure, training and exercise activity to stimulate innovation in all lines of development”¹³

'Live' activities will continue to have a critical role but attempting to identify, test, plan and train the optimal mix of personnel, assets and effects through live experimentation alone is likely to prove too slow and too costly. Using synthetics across training, planning and decision support can mitigate this but the current crop of synthetic solutions are limited in the technical capability and flexibility required to bring together multiple components/domains and effects in a fully immersive, realistic interoperable and integrated way.

However there is a potential solution currently being trialled in pathfinder projects; a Single Synthetic Environment (SSE). A SSE forms one of the three critical pillars needed to "build and exploit the Digital Backbone for Defence".⁴ Whilst there are alternative approaches to simulation interoperability (e.g., DIS/HLA), a SSE delivered as a PaaS has the potential to provide a more cost effective, powerful, cohesive, and evergreen foundation for a multitude of military



use-cases across training, planning and decision support, integrating and enhancing best-of-breed content, GFX (such as exists within DMAcS (Defence Modelling and Simulation Coherency) or within the commands themselves), hosting and applications to deliver a more realistic and distributable synthetic environment. Such a system has the potential to provide a continuously adapting loop of military rehearsal and experimentation that could dramatically improve the ability of UK military chiefs to solve complex problems in real time, take better decisions and conduct more decisive and efficient operations.¹⁴

What is a Single Synthetic Environment (SSE)?

A Synthetic Environment (SE) is a digital version of a chosen environment – the environment may be physical e.g., land based (such as a digital twin of a country or particular terrain), airspace, a command centre, hospital or the inside of a vehicle, or it may be non-physical e.g., a social network or a 'will to fight' model.¹⁵ The possibilities are broad and SE's have been used across industry for many years to develop and test cars, engines and buildings, in the gaming sector for large scale interactive multiplayer games such as Fortnite, and in the military to train pilots, tank commanders, artillery, logisticians and infantry.

The explosion of technology in recent years (VR, AR, AI, machine learning), along with significant advances in distributed computation and development platforms through the cloud has led to the exploration of more foundational *single* synthetic environments (SSE). Whilst SE's, in a military context, tend to be standalone, often housed in a particular location, built with monolithic technology stacks, generally used for one specific application and historically lacking in rich interactions or the ability to integrate multi-domains, people and effects together, a SSE would potentially have the capability to significantly break this mould. The vision is to develop a single digital environment that contains within it multiple terrains (e.g., full digital twins of the UK/other countries, maritime and air domains), avatars, opposing forces which adapt each time they are used via AI, multiple effects and equipment platforms, cyber/information feeds (e.g., social media), weather, infrastructure networks and, importantly, the ability to allow all branches of the Armed Forces, and their allies to train, plan, and operate together. In doing so, a PaaS based SSE could provide the UK with a unique training, planning and decision support tool which delivers the modernisation and competitive edge set out in recent Defence

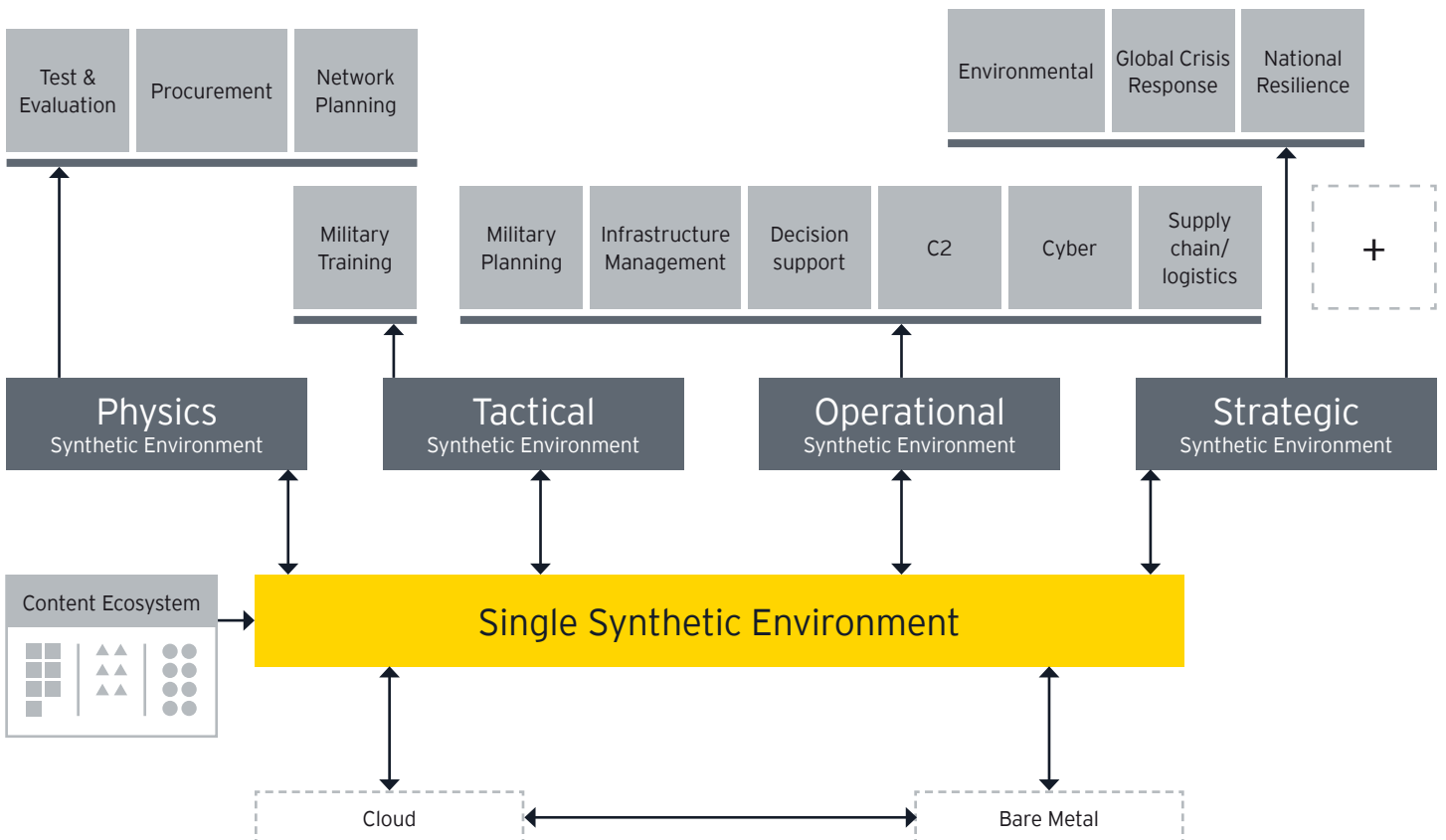
strategic narrative.¹⁶

The graphic below is a visualisation of a SSE platform. It shows the multiple terrains, behavioural models, and other significant content housed in an ever growing ecosystem library which is then used to drive interoperable synthetic solutions across the physical, tactical, operational and strategic domains, which in turn are able to harness the synthetic solutions across multiple military use cases ranging from testing and evaluation to supply chain and logistics.

The concept of a SSE is being embraced by modern defence forces across the globe including the US¹⁷, NATO and the UK's Strategic Command and Army, where pathfinders with Industry partners are already underway.¹⁸ In addition, the UK has clearly stated its intent "to ensure our workforce are able to exploit new domains and enhance productivity by investing in synthetics and simulation, providing a step change ..."¹⁹ and through the provision of a "digital backbone to enable

multi-domain operations and interoperability with allies and partners".²⁰

This document seeks to answer some of the critical outstanding questions in relation to this potentially transformative platform by looking at some of the likely quantitative and qualitative impacts of the UK's Ministry of Defence procuring and implementing a SSE, delivered as a Platform as a Service (PaaS). Step-change towards any platform such as the SSE requires material investment and operational change. Whilst the qualitative benefits of transformative synthetics are wide and broadly acknowledged at policy level, the MoD, and defence departments across the globe, will need to have the confidence that the financial benefits also justify the investment required to procure and implement such a platform.





Capability Benefits of a PaaS SSE

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A MoD SSE delivered as a PaaS has the potential to provide significant qualitative benefits, above and beyond the identified quantitative benefits, that could deliver a step change in the effectiveness of joint-force military training, planning, procurement and decision-making at all levels and across all Commands.

Some of the qualitative benefits this could bring include:

Versatility

By providing a common simulation layer of PMESII/DIMEFIL²⁰ models and data, a SSE platform has the ability to develop and support a wide range of interconnected and coherent third party applications. This can be used to transform the way the military operates across its full breadth, enhancing a wide range of other critical activities, including collective training, planning, C2, procurement, T&E, logistics, infrastructure, and others. For example:

- ▶ **Decision support** – it has the potential to enable decision-makers at every level – from political to tactical – to continuously test and rehearse different courses of action within a simulated operating environment, assessing the consequences of decisions, and adapting, in a more data-driven, scientifically rigorous way.²¹
- ▶ **Collective training** – a common synthetic environment to drive consistency in user experience, **content** re-use across the defence estate, and more detailed AAR/analytics to support training feedback loops, driving continuous improvement through trial, error, learning and retesting.

- ▶ **Planning** – the whole lifecycle of a plan, including Command and Control (C2), could be facilitated and optimised by a SSE. Constructive simulation modules including, for example, population sentiment, logistics, weather, civilian infrastructure and computer generated forces (CGF) would ensure that all analysts, planners, operatives and commanders involved in the plan from inception to execution had access to all the relevant information enabling them to evaluate and improve potential interventions by continuously ‘playing them out’ synthetically.²² This includes the use of a SSE platform to assist in the planning of emergency situations, such as COVID19, both for the MoD and wider government, with the simulation modules and interoperability providing a more realistic and cohesive environment for cross agency planning.
- ▶ **Other Key Use Cases** – the potential value of a SSE platform could span into numerous other areas of both the MoD and broader government agencies. These include:
 1. **Testing and evaluation** – improving the effectiveness and efficiency of T&E across MoD equipment, where synthetic testing (e.g., digital twins) of, for example, aircraft engine failures, allows for an increased number of scenarios to be evaluated, at a higher level of repetitions, in a shorter timescale and for a lower cost.
 2. **Network planning** – new infrastructure or communications networks can be synthetically tested first to highlight potential weaknesses/ issues, and subsequently monitored for planned and unplanned outages.
 3. **Logistics** – supply/support chain activities can be optimised by continuously testing warehousing and distribution activities and routes in a SSE PaaS.
 4. **Procurement** – it may be possible to utilise a SSE PaaS to support the MoD Assessment Phase of the CADMID cycle for new equipment, infrastructure and even services, with the potential for such equipment/ infrastructure/services to be virtually tested during the procurement phase. This could reduce the timescales for testing new equipment and/or allow more testing to be performed in a similar or reduced timescale, leading to more robust procurement decisions/outcomes.
 5. **Cyber planning** – cyber resilience can be assessed synthetically assessing the cascading implications and potential mitigations of cyber attacks on the resiliency of critical assets or national infrastructure. The importance of such activities has been highlighted by the cascading consequences of the recent cyber ransom attack on the colonial pipeline in the United States.

In these and other areas the MoD, and other government agencies, could use a SSE platform to experience, rehearse, adapt and plan different activities and scenarios, driving better decisions and significantly de-risking the delivery of their outcomes.

Consumed at the point of need

Gathering military personnel together and/or travelling to training facilities is time consuming and costly. The aim for the military moving forward will be for personnel to train” ... wherever they may be located – home station, armouries, institutions or deployed locations and enter into a Synthetic Training Environment ... that replicates where they will fight; whom they will fight with; on the terrain they will fight on.”²³

The potential to leverage cloud as well as traditional physical hosting enables the SSE to be drawn down globally, wherever and whenever it is needed. In addition, setting up a live, virtual, constructive exercise can currently take months.²⁴ It is hoped that a SSE platform could dramatically reduce these timescales, reduce latent redundancy and speed up consumption where it is needed.

Interoperability

The lack of interoperability across UK agencies and allies has always been a significant issue. Allies are now actively reviewing and progressing with ‘plug and play’ SSE’s which have cloud based, open architectures at their heart to enable interoperability, with the US DoD’s Synthetic Training Environment (STE) “allowing joint, interagency and multi-national interoperability.”²⁵ Industry see a UK MoD SSE platform as a system which “ ... hundreds or even thousands of users can work in and experience ... at the same time”²⁶ allowing the UK to significantly increase its ability to undertake joint and multi-domain training with multiple forces, agencies and allies which is expected to be significantly enhanced by a common PaaS based SSE.

Evergreen service

PaaS ensures all synthetic solutions are perpetually up-to-date, performant, leveraging the latest technology and security standards, and reducing upkeep expenditure (e.g., as maintenance costs are effectively split across all PaaS users). This helps to provide a stable, extensible platform that’s less susceptible to outages and more responsive to changes, avoiding the traditional “boom to bust” upgrades and refresh cycles that have historically been disruptive and expensive in MoD and wider Government IT.

Realistic synthetic representations

Powerful advances in distributed computing enable synthetics to offer greater realism and complexity, in greater volumes (e.g., 5+1 domains, millions of entities, entire countries or regions). A state of the art PaaS SSE solution is likely to bring together all of the complexities of warfighting (different platforms, effects, terrain, social media feeds, etc) into a single, more representative environment which would provide continuous virtual rehearsal and experimentation of 'what-if' scenarios, allowing the military to train, plan, learn and repeat. AI will inject complexity which will force soldiers to adapt in real time, instead of learning how to defeat pre-programmed scenarios. It is this enhanced realism and complexity, meshed together in a PaaS SSE, that should better prepare the UK's Armed Forces for the realities of war in the Information Age and allow it to drive the radical digital transformation set out in the Integrated Operating Concept 2025.

Rapid access to the best content, applications and insight

As we move further into the information age, the speed of change will continue to increase. Those with the ability to adapt training and systems quicker, enabling their synthetic solutions to keep up with the changing battlefield, will have an operational advantage.²⁶ In particular, a PaaS SSE ecosystem approach enables defence to leverage existing content across the defence estate and "reduces the barrier to developing and trialling new technologies, facilitating the development of a truly evolving capability that draws on the very best governmental, academic and industrial institutions."²⁷ This in turn reduces barriers to content suppliers into MoD promoting greater diversity, competition and innovation within the supply chain and enables faster adaptation, collaboration and ability to keep pace with fast-evolving threats by providing MoD with access to the best tools to efficiently deliver successful outcomes.

There are also division of labour benefits from having a dedicated specialist at the simulation layer, leveraging expertise at the content, the application, and the services layers to drive efficiency and greater performance in the supply chain.

Reduced technical & delivery risk

With an established and common technological base, industry players can deliver SSE-enabled solutions with lower risk and leverage the breadth of installed capabilities and content. This means MoD would have access to a greater variety of choices up and down the application development stack and the potential to test new operating systems, languages, and tools with less risk (i.e., on a proven, evergreen IT infrastructure that does not require continuous further investment).

Environment

The Integrated Review (March 21) and the recent MoD Climate Change and Sustainability Strategic Approach (Mar 21) recognise the significant impact the MoD has on the environment and sets out an approach for tackling some of these issues in the future. However, whilst the MoD has undertaken a number of estates based measures (solar panels, meters, etc) which have had an impact, it is estimated that the 'headline' emissions declared in the MoD's annual report (0.94 million tonnes of carbon dioxide equivalent (tCO₂e) are only one third of its actual emissions (those relating to its estate and business travel), with a significantly higher proportion of carbon emissions actually being produced by the MoD's equipment and arms and not the estate. The total emissions produced by 'MoD spending' (including on its arms suppliers) has been calculated as being 11 million tonnes of carbon dioxide equivalent, the same as roughly 6 million cars a year.²⁸

A distributed, PaaS hosted SSE, has the potential to achieve a positive net environmental impact – whilst it does require power, hosting, bandwidth, etc "virtual training does not use fuel or physically damage the environment."²⁹ There are no fired rounds or shells or fuel spills contaminating the ground and no need to transport troops, armour, helicopters, etc to training locations and then use them for many days on end, with the ensuing impact on carbon footprint. A SSE platform would allow the MoD to train and plan multiple scenarios, over and over, at a significantly reduced rate of emissions. In addition, the SSE can be used to synthetically model logistical operations and/or host and develop digital twins of aircraft engines and other equipment where different failure scenarios are played out digitally rather than needing to perform them 'live', thus avoiding significant potential emissions being produced.

Synthetic Environments are being used more and more in all walks of life to deliver better societal (e.g., pandemic response testing) and environmental (e.g., the "Destination Earth" initiative ³⁰) outcomes, and a PaaS SSE, alongside

other technological trends such as smaller robotic drones and electric vehicles, has the potential to make a real difference to the significant, negative impact the MoD currently has on the environment, helping the Government to meet its 'net zero' agenda.

Ability to leverage existing networking infrastructure

A specialised synthetics platform, such as a SSE PaaS, should be able to drive scale without requiring significant upgrades to working infrastructure. Alternatives in the creation of large scale, complex, interoperable synthetics do exist, however it is believed that these alternatives would require a significant time and cost investment in bandwidth to drive the user numbers and complexity required by the MoD.

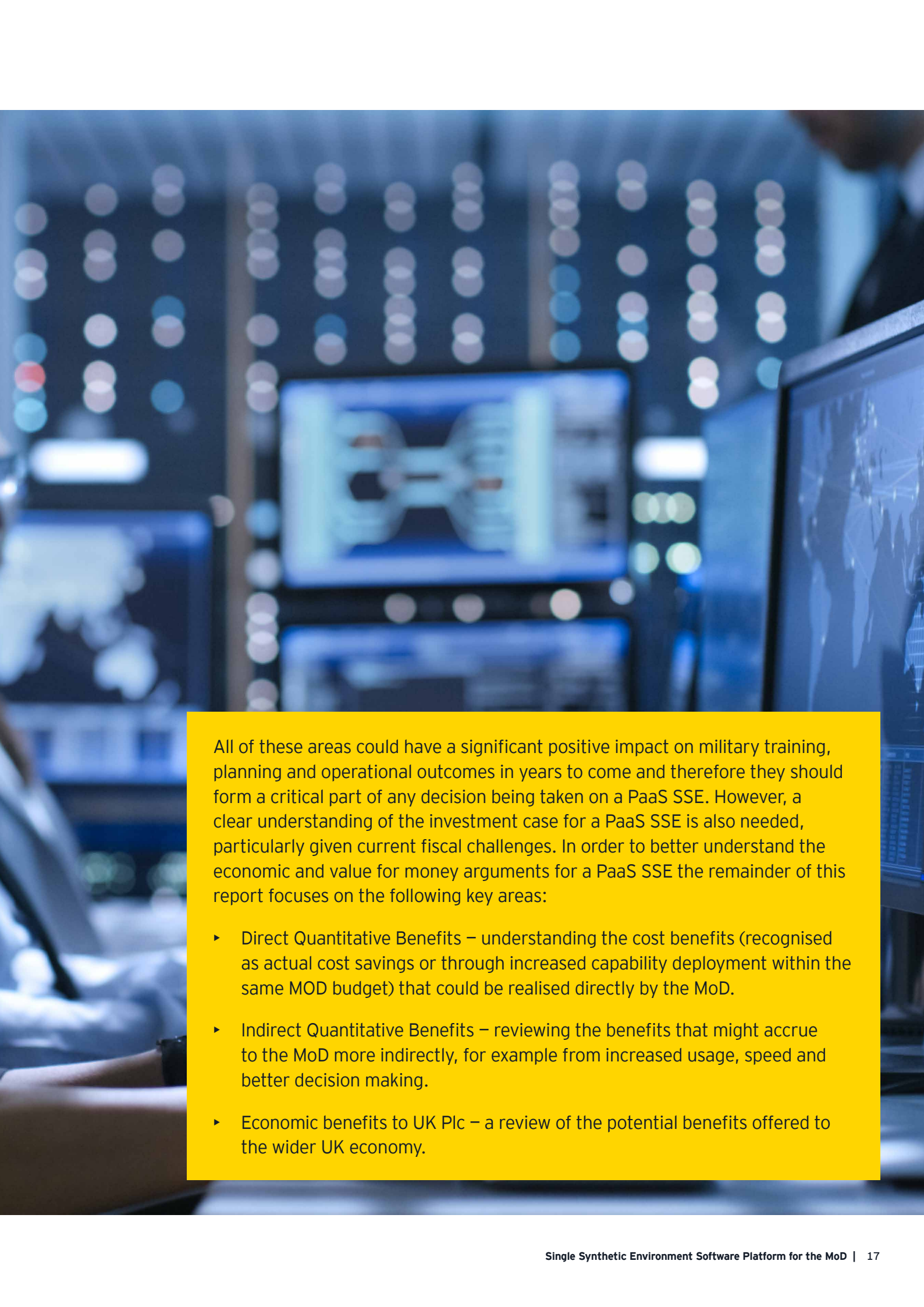
For example, a 'Shared Bus' approach following DIS is the most common approach in the industry today, but typically these solutions are limited to <150 connected users in relatively simple simulations. By contrast, 'Interest-Based' approaches, such as HLA and its use of Declaration and Data Distribution Management, aim to 'prune' the information being transmitted, reducing the bandwidth and computation requirements and these may be able to support up to 500 users within simple to moderate simulations. However, even a small increase in users for these approaches requires a dramatic increase in requisite bandwidth and, whilst increasing the bandwidth cap is possible (e.g., upgrading the network infrastructure such as JMNIAN), it is inherently costly, time-consuming, impractical, and may require continuous investment to meet the exponential bandwidth requirements of non-specialised approaches such as DIS and HLA.

Specialised low-latency interest-based solutions, such as a PaaS approach, combined with data compression and other optimisations that are now emerging (which can offer upwards of 10x the number of users in a standard interest-based solution (c.30x vs. shared-bus) while maintaining or increasing the complexity with the simulation comparably) would appear to offer a more cost-effective way to deliver complex synthetic architectures such as the SSE and a future-proofed approach to synthetics.

Feedback and continuous improvement

A number of studies have highlighted the benefit of repeated training and planning exercises with swift, accurate feedback cycles. A PaaS based SSE should enable the collection of a huge number of centralised data feeds, which are digitally stored and continuously analysed using AI/machine learning, allowing for significant improvements in After Action Reviews (AAR's) and an environment where users can 'fail fast', learn and adapt.





All of these areas could have a significant positive impact on military training, planning and operational outcomes in years to come and therefore they should form a critical part of any decision being taken on a PaaS SSE. However, a clear understanding of the investment case for a PaaS SSE is also needed, particularly given current fiscal challenges. In order to better understand the economic and value for money arguments for a PaaS SSE the remainder of this report focuses on the following key areas:

- ▶ Direct Quantitative Benefits – understanding the cost benefits (recognised as actual cost savings or through increased capability deployment within the same MOD budget) that could be realised directly by the MoD.
- ▶ Indirect Quantitative Benefits – reviewing the benefits that might accrue to the MoD more indirectly, for example from increased usage, speed and better decision making.
- ▶ Economic benefits to UK Plc – a review of the potential benefits offered to the wider UK economy.





Direct Quantitative Benefits

05

Our analysis suggests that transforming from the current approach of multiple, stove-piped synthetic solutions (e.g., MCAST, TES, etc.) to a centralised SSE, delivered through a PaaS, could potentially provide the MoD with direct quantitative benefits (or reinvestment potential) of up to and potentially in excess of c£1,280mn over a 10 year period.

£1,280mn – Direct Cost Benefits

£810mn from reduced content development costs driven by the reusability of models/applications on a standardised PaaS system.

£470mn from reduced Back End service costs to host and ensure availability of the platform.

Platform As A Service – framing the opportunity

A recent study by IDG found that large enterprises were reducing their IT spend by almost 30% on average through efficient use of cloud services such as PaaS.³¹ When looking at PaaS specific studies, it has been identified that cost benefits of 50% – 80% are possible, for example, across IT administration and resource costs.³² A key factor in the realisation of benefits is the ability to reuse applications and content multiple times, across multiple scenarios supported by a single platform. This ‘build once, use many’ concept is cited by many commentators as being a potentially significant cost driver.³³

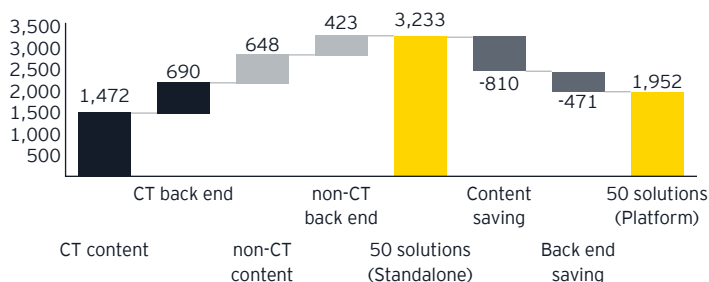
It is important to recognise that the specifics of each organisation's sector, size, affected programmes and existing systems will play a significant role in any benefits from adopting PaaS. However, the MoD could still potentially achieve significant benefits given the possible economies of scale, development agility and reduction in overprovisioning/duplicative procurement offered by a single, centralised, scalable distributable PaaS based synthetic environment.³⁴

Platform As A Service – MoD SSE Specific

To triangulate the above PaaS benchmarks and their applicability in a MoD SSE context, it is necessary to analyse the addressable spend and cost categories of some of the MoD solutions that would be likely to utilise a SSE PaaS if it was implemented.

Through research and a series of discussions with industry experts in this area, the following high level cost estimates were arrived at to help calculate the potential benefits that could be achieved by moving to a SSE PaaS approach:

Cost Impacts of Platform delivery of solutions



The calculations assume that 50 synthetic solutions³⁵ are implemented over a 10 year timescale.³⁶ The synthetic solutions are split into collective training (CT) and non-CT solutions to recognise the differing costs associated with the different use cases. The content costs (e.g., synthetic models/applications (e.g., terrain models, 3D assets, military behaviour models) and back end support costs (e.g., compute costs, security, testing) for an 'average' CT and non-CT solution were then calculated, for both a SSE PaaS and a non-SSE (current) approach.

The diagram above details the estimated content and back end support costs for 50 potential synthetic solutions across CT and non CT areas. The total estimated cost if the 50 solutions were developed on a relatively standalone basis as they are today, is c£3,233mn. The total estimated cost if a SSE PaaS approach were utilised is c£1,952mn. At a headline level this created estimated potential benefits across content costs and back end support costs of c£1,281mn over 10 years. Splitting the benefits down further:

Content Benefits (c£810mn)

The key driver for the potentially significant content saving is the concept of 'reuse' which sits at the heart of a SSE platform approach. This is common practice in typical content commercial agreements (e.g., in the gaming industry) where using a PaaS hosted environment enables faster application development and the ability for significant reuse of the relevant synthetic applications/models and services across multiple solutions. The benefits of open systems architectures and potential reuse have also been recognised for multiple Defence applications.

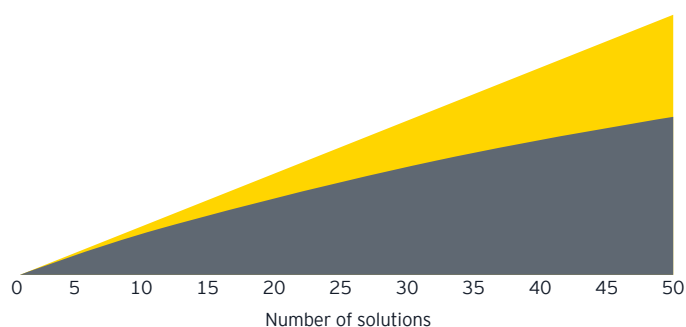
Applying this approach to training and simulation has been a goal of the ongoing NATO Modelling and Simulation as a Service (MSaaS) approach and DMaSC (Defence Modelling and Simulation Coherency)/JSP939. Currently each of the synthetic solutions used by the UK military (e.g., the CATT and CAST trainers) have their own models/applications for terrain, behaviour, etc. In a single, central, flexible, scalable PaaS synthetic approach, solutions would be part of the SSE (not standalone) and would draw down and utilise the same models/applications rather than developing and maintaining their own bespoke models/applications. This would lead to the potential for re-use of common assets across industry and the defence estate, such as:

- ▶ Input data (terrain, environment, threat systems etc.).
- ▶ Models of interactions between similar entities (e.g., a model of missiles fired against a moving land target could be tailored to model missiles fired against a moving sea target).
- ▶ Models of human behaviour (both representing military decision making and agents representing the population).
- ▶ User interfaces for common purposes (e.g., a replay facility for a training simulation could be useful in an analytical simulation).

It is estimated that this reusability factor has the potential to significantly reduce (by up to 90%) the marginal development, maintenance and service costs each time a model/service is reused. The benefits are also exponential – the first solution integrated to the SSE PaaS would need a number of new models and other content to be developed, but by the 15th solution, a much higher level of existing content can be reused (reducing per solution content costs by c30%) such that when the MoD reaches the 50th solution, the amount of new content that needs to be developed is likely to be minimal, driving significant, exponential benefits, as shown by the yellow shaded section of the below graph.³⁷

Cumulative content cost SSE platform vs. non SSE platform

(area in yellow is cumulative cost saving of platform delivery)



Back End Support Benefits (c£471mn)

Discussions with industry estimated back end support costs (e.g., deployment, hosting integration, security, testing infrastructure, maintenance and support costs) to be c20-35% of the cost of delivery of a standalone non-platform solution. Under a PaaS solution this is expected to drop to 13-22% of the total solution cost. In cash terms that reduction in back end support costs is estimated to be c£9mn per solution. This reduction in cost is achieved through the economies of scale of consistent design and requirements for all solutions developed on the PaaS (i.e., platform sharing/build once, use many times). Using a platform over a 10 year period and assuming a core set of 50 solutions utilising the PaaS provides estimated potential benefits of c£470mn (exclusive of the cost of the platform).

Taking both content costs and back end support costs together, it is clear that there are significant potential benefits to be gained from the implementation and integration of a SSE platform for both CT and non-CT synthetic solutions.

Additional non-platform direct cost benefits

In addition to the potential development, maintenance and service benefits outlined above, further direct cost benefits are also possible from:

- ▶ Reduction in hosting hardware costs due to cloud hosting reducing the hardware requirement through optimisation of hosting costs, balancing steady-state demand on physical infrastructure and spikes in demand on the cloud.
- ▶ Reduction in procurement/purchasing due to a single contractor and framework for future requirements driving economies of scale and savings on licences through volume discounts.
- ▶ Cost risk reduction in provision and support of synthetic environments due to using a single stable platform over bespoke standalone delivery, resulting, for example, in less integration risk needing to be budgeted.

The benefit of these elements has not been quantified but it is expected to be tens of millions of pounds over the 10 year period, with the significance of such benefits growing, particularly as synthetic training increases over time.

This provides total potential direct quantitative benefits to the MoD of upto and possibly in excess of c£1,280mn, representing a c40% saving against a non-PaaS (i.e., multiple siloed SE's) baseline spend of c£3.2bn. Whilst it is very difficult to estimate such benefits with a high degree of accuracy due to the number of assumptions that have to be made in the absence of any definitive MoD cost data, the estimated benefits for the operational cost aspects of a PaaS SSE (at c40%) are within the range expected when compared with the more generic benchmarks identified at the beginning of this section for cloud/PaaS systems in other IT sectors (c30% – 80% benefits), suggesting they, subject to a number of other factors such as upfront and implementation costs and security issues that are not considered here, are potentially achievable.



Indirect Quantitative Benefits

06

In addition to the direct quantitative benefits, it is expected that a MoD, PaaS enabled SSE will also deliver a number of indirect quantitative benefits. These reflect potential consequential benefits resulting from the adoption of a SSE platform which will allow MoD to operate in a more efficient or effective manner.

£1,000mn-£1,470mn – Indirect Cost Benefits including:

£100mn-£225mn

from the wider adoption of synthetic training due to the benefits brought by a PaaS SSE.

£500mn

from better decision-making across the MoD enterprise.

£350-700mn

reduction in spend on equipment programmes R&D/T&E

£20mn

from more effective use of resources and use of a common commercial model.

£10-25mn

potential value from reductions in the MoD's carbon footprint.

Providing the catalyst for wider synthetic training adoption

The ability to train cross-domain, the increase in speed, agility, quality, interoperability, complexity, relevancy and the reduction in time to deployed solution resulting in more “time on target” enabled by a PaaS SSE has the potential to lead to the MoD converting more live training to synthetic training over and above that currently assumed in the forward programmes/solutions assessed in the direct quantitative benefits section. This delivers a further cost saving because synthetic training is generally significantly cheaper than live training.

To quantify this potential benefit, it is assumed that the total spend on training in the MoD is c£2bn per annum.³⁸ If only a relatively small additional element (2.5% or £50mn per annum) of this total budget switches from live to synthetic training then this has the potential to deliver benefits over a 10 year period of c£100mn – c£225mn (with benefits assumed to start to accrue from year 5).³⁹ It is impossible to accurately predict what might happen, and a sizable shift from live to synthetic training is already planned through programmes such as CTP, but it is certainly conceivable that more military personnel, over and above these planned levels, will want to consume synthetic training as it becomes more immersive and effective, driving better training, planning and decisions and therefore making savings in this area, more likely.

Better Decision Making

It is generally accepted that high quality, fully integrated synthetic solutions, such as a PaaS based SSE, should ultimately lead to better decision making in training, planning and in improved operational outcomes.⁴⁰ It is also likely that these better decisions would contribute to improved defence productivity levels. However, quantifying the impact of improved decision making on operational outcomes and productivity is challenging.⁴¹

Some studies have explored this issue, with one, for example, finding that by using simulation, participants' susceptibility to cognitive bias reduced by c23%. This led to better decision making because they did not, for example, simply place reliance on the first piece of information provided to them (Anchor Bias).⁴² Other studies have found that participants in simulated activities went on to perform more effectively in live events by up to 70%. However, it is not possible to distinguish how much of the improved performance was due to better decision-making.⁴³

Whilst the benefits of a more realistic PaaS based SSE in a training environment are widely accepted by many commentators, it is also expected that a PaaS enabled SSE could see significant improvements in decision making which could permeate across other large (non-training) budget areas of the MoD, such as the logistical support chain/planning. A recent study identified that organisations using a digital twin in a synthetic environment as a virtual replica of their assets, warehouses, logistics and material flows were able to better anticipate risks and make critical optimisation decisions far sooner than previously possible. This enabled sustainable inventory reductions of up to 5% and capex reductions of up to 10% (through better resource planning and investment decisions). They also achieved higher throughput and enhanced service levels.⁴⁴

This 10% reduction was triangulated by a recent study which concluded that organisations who used 'big data' and analysis tools (which is a key advantage of a PaaS SSE) were saving up to 10% of their cost base through more optimised decision-making.⁴⁵ It would be unrealistic to assume a saving could be achieved across the entirety of the MoD budget because large elements of the expenditure (e.g., the equipment programme) are fixed for long periods of time and/or are not addressable through a SSE platform (e.g., salaries and pensions). However, it is more likely that benefits could be achieved from better decision making in certain budgetary areas. One such area is the Defence Support Network (DSN). This is the support framework from which the UK Armed Forces are deployed, sustained, and recovered, covering all supply chains, logistics, etc. Expenditure estimates vary because it is spread across multiple cost centres (Top Level Budgets or TLB's) but £7bn per annum has previously been quoted as a lower end estimate. Because it is spread across TLB's, historically it has lacked cohesiveness and transparency, leading to inefficiencies. A transformation programme was kicked off in 2016 (DSN(T)) but the presence and use of a SSE PaaS, with integrated digital twins, AI and the ability to continuously test and evaluate different support chain scenarios leading to better decisions being made, could drive significant benefits in this area. If we conservatively assume that £1bn of the £7bn expenditure is addressable and the MoD is a potentially more complex, slower moving and less digitally mature organisation than those in the studies above, meaning it may only save 5% instead of the 10% experienced by others, this would still deliver potential benefits in the region of £500mn over a 10 year period, and there is the possibility that they could be much higher if a SSE platform also drives better decision making in other areas of the MoD's £42bn expenditure.

Reductions in Equipment R&D/Test & Evaluation (T&E) costs

A PaaS based SSE would potentially provide an environment for increased, more effective digital R&D/T&E, for example, through the more integrated and repeatable use of digital twins for testing the breaking limits of equipment engines or platforms. Testing equipment to destruction 'live' is very expensive and time consuming, however being able to test new equipment synthetically is far more economical and enables more scenarios to be tested in a far more efficient manner due to the speed at which the test can be reset/rerun and adapted each time.

A large number of private sector companies employ this technology and have seen reductions in time to market (a good proxy for R&D spend) and maintenance costs of c30%. Rolls Royce have been using these synthetic approaches for a number of years and have seen reductions in R&D testing times of aircraft engines of 50% (from 4 months in a live environment to 2 months in a digital environment because of the speed or repeat testing).⁴⁶ In 2018 Gartner stated that **“By 2021, half of large industrial companies will use digital twins, resulting in those organizations gaining a 10% improvement in effectiveness.”**⁴⁷

The MoD currently spends c3.5% of its c£42bn annual budget on R&D.⁴⁸ Industry sources estimate that c25% of the total R&D budget is spent on simulated R&D. If a PaaS enabled SSE were to be put in place which has much higher levels of integration, realism, fidelity and complexity then it is conceivable that this would have the potential to produce a two-fold benefit:

1. More efficient R&D could be undertaken (e.g., the testing of equipment in a more complex simulation than is currently the case) which potentially means less R&D spend is required to physically test that same platform.
2. As demonstrated in an earlier section, a PaaS hosted SSE is likely to be more cost effective than the current stove piped environments. Therefore, even the same current levels of spend put through a PaaS SSE could potentially produce a cost saving or allow for higher levels of testing for the same cost.

If the MoD achieved the 10% efficiencies stated in the examples above from the use of a SSE PaaS this would equate to a saving in the relevant part of the R&D budget of c£35mn per annum, or c£350mn over 10 years. However, this figure has been derived simply from the stated MoD spend on R&D. The MoD also spends considerable sums on testing and evaluation (T&E) of new and existing equipment which is captured in a separate bucket (equipment expenditure/support costs) to the stated R&D spend. Whilst it is difficult to gauge an accurate estimate for T&E spend, the MoD has a 25 year Long Term Partnering Agreement (LTPA) with QinetiQ for T&E services worth c£6bn (or c£2.4bn as a 10 year equivalent).⁴⁹ If similar levels of efficiencies (10%) could also be achieved on the MoD's broader testing and evaluation expenditure, it is possible that these 10 year benefits figures could be increased to £700mn+.

Potential indirect quantitative benefits through headcount optimisation

There are further indirect benefits that could be achieved through the adoption of a PaaS based SSE as a result of headcount optimisation. This would be achieved through adopting a consistent approach to SSE, including a common, single commercial model, across relevant MoD programmes which would allow better headcount resourcing and allocation. Estimated indirect saving from headcount optimisation are £20mn⁵⁰, which could be headcount being used in a more effective manner across the MoD enterprise or could be seen through actual reduced headcount with cost benefits being taken or the budgetary headroom being used to derive further benefits across synthetics/defence.

Environmental value

As highlighted in the qualitative benefits section, the MoD has a significant impact on the environment. The 'headline' emissions declared in the MoD's annual report are 0.94 million tonnes of carbon dioxide equivalent (tCO₂e).⁵¹ However, it is estimated that these are only a small percentage of its actual emissions (being those relating to its estate and business travel), with a significantly higher proportion of carbon emissions being produced by the MoD's equipment and arms and not the estate. The total emissions produced by 'MoD spending' (including on its arms suppliers) has been calculated as being 11 million tonnes of carbon dioxide equivalent, the same as roughly 6 million cars a year.⁵²

A distributed, PaaS hosted SSE, has the potential to achieve a positive net environmental impact through reduced carbon emissions from reduced live training and from reduced live testing and evaluation. Assuming that c10% of the MoD's annual budget of £42bn is linked to training, R&D, T&E and other areas where a higher usage of a SSE PaaS has the potential to reduce emissions, this would suggest associated emissions of c1.1 million tonnes. The 'value' of that level of emissions if the MoD were to purchase carbon credits to offset the carbon dioxide equivalent would be c£10mn per annum or c£100mn over 10 years.⁵³ A SSE PaaS would not remove all of the potential emissions, however given the ability for a SSE platform to enable/accelerate MoD's intent to increase the balance of synthetic training versus live by c10%-20% (which should reduce emissions from live training), and the experience of organisation's such as Rolls Royce (30% – 50% reductions in testing timescales, and therefore emissions, from digital twins) it is possible to see a scenario where the MoD has the potential to drive c£10mn to £25mn of environmental value over 10 years (assuming a ramp up over time).



Wider Economic Benefit

07

Adoption of a SSE PaaS has the potential to drive wider economic benefits beyond those realised directly and indirectly by MoD. These broader benefits are driven by the potential of a PaaS SSE to deliver an early adopter advantage to the UK, encouraging a wider population of businesses, academics and leading experts to provide services to the MoD, which in turn can drive competition and innovation, creating opportunities for positive spill overs into other sectors of the economy and for the export of knowledge and services:

£750mn wider impact potential over ten years, including:

£200mn-£300mn

UK Export opportunities.

£100mn-£450mn

Innovation spill overs across the UK.

Introduction

Platforms such as SSE have demonstrated a significant capacity to drive innovation and business growth, often amongst smaller businesses.⁵⁴ In part this is achieved by reducing the barriers to developing and supplying innovative solutions, which directly addresses some of the known challenges to SMEs supplying services within the defence sector.⁵⁵ The catalytic effect of reducing these barriers can drive a host of benefits, from higher quality employment to improved productivity and competitiveness, all of which support UK Government ambitions for the future of the UK. The remainder of this section focuses on the export and innovation spill over benefits which can be assessed quantitatively.

Export opportunities

The UK is a significant actor in the global defence market and in 2019 was the second largest defence exporter after the United States, with exports worth £11bn amounting to 16% of the global defence export market.

The MoD plays a pivotal role in enabling defence sector exports, acting as an anchor to long term investment and the development of new tools and technologies. For every £1 the MoD spends on procurement, the UK exports on average 38p of defence equipment, training and technology. SSE is recognised as a key element of the future of defence not just for the UK, but for the UK's allies. The interoperability supported by an SSE offers opportunities for more effective collaboration amongst allies; the UK can therefore play a leading role in the development and distribution of platform and application technologies, and their effective implementation.

The potential export opportunities of SSE are not confined to defence. The UK is at the centre of Europe's immersive technology industry.⁵⁶ In the UK alone, the sector is forecast to reach £1.5bn in value in 2021 increasing five-fold from 2015.⁵⁷

The export intensity of immersive tech SMEs suggests exports may outperform historic defence sector export averages. If it was assumed that indicative MoD procurement of PaaS SSE applications and platforms was c£0.5bn over a ten-year period, this could enable export revenues of £200mn based on past defence sector export averages, rising to £300mn with reasonable outperformance.⁵⁸

Innovation spill overs

Innovation spill overs are the benefits of innovation in excess of their private returns, with research and development (R&D) spill over effects typically ranging from 2 to 3 times the private returns from R&D investment.⁵⁹ Government funded R&D in general – and defence R&D in particular – is very effective at driving further R&D investment through the private sector.⁶⁰ These spill overs can extend beyond traditional economic impacts and productivity measures, through their impact on health, education, security and public sector productivity.

In the case of SSE, the range of possible wider applications suggests a significant potential for ideas tested and refined in a defence setting to yield further benefits when applied elsewhere, acting as a proof of concept to encourage further innovation. This is closely aligned to the ambitions set out in the Integrated Review to establish the UK as a global services, digital and data hub; investing in technologies to meet national security requirements will offer further commercial opportunities.

There are certain characteristics of R&D investment that have been found to increase the potential for positive spill over impacts, including wider applicability, strength of knowledge sharing networks and involvement of research institutions.⁶¹ These characteristics suggest a high potential for spill overs from PaaS SSE investment to reach or even exceed the multiplier effects observed for past R&D investment in the UK. This would place innovation spill overs at £100mn-£450mn based on a ten-year period of investment. These spill overs may occur across many areas, with the growing interest in digital twin applications offering a prime example of the potential for PaaS SSE to overcome challenges within defence, wider government and in industry.

Potential negative impacts

The wider economic benefits highlighted above focus on the potential supply side impacts of SSE investment. There may however be negative economic impacts, particularly in the short term, as existing MoD supply chains adapt where services shift towards SSE-focused procurement. These expenditure-driven economic impacts are not considered within the scope of this analysis but are expected to be largely temporary as business adapt to changing MoD demands.

Conclusion

This analysis has revealed that over a 10 year period a SSE has the potential to deliver **quantitative benefits in excess of £3bn** across:

- ▶ **Direct Quantitative Benefits of c£1,280mn** in the form of cost benefits made directly by the MoD, for example from reduced content development costs driven by the reusability of models/applications on a standardised SSE PaaS system versus standalone, non-platform based synthetic solutions.
- ▶ **Indirect Quantitative Benefits of c£1,000mn – £1,470mn** in the form of benefits that might accrue to the MoD at the application level from more indirect sources, for example from increased usage and speed of synthetic training and better decision making brought about through a more realistic single synthetic training environment.
- ▶ **Economic benefits to UK Plc of up to £750mn** from, for example, the greater use of SME's and exportability of the technology.

It is also worth noting that in many areas the potential benefits are exponential. For example, this report makes assumptions regarding the number of synthetic solutions the MoD might integrate into a SSE platform, but the more solutions that are integrated, that reuse content and encourage better decision making, planning and testing, then the more significant the benefits for the MoD are likely to be.

In addition, a SSE platform has the potential to provide significant qualitative benefits across, for example, the environment, interoperability, versatility of application across training, planning and decision support and adaptability, which could deliver a step change in operational outcomes, making them as important, if not more important than potential quantitative benefits.

As part of this report, we have not sought to offset the upfront costs required to implement a SSE PaaS system into the MoD. However, if the cost of an SSE and associated configuration and integrations is estimated to cost in the region of £200-400m, the size of the potential qualitative and quantitative benefits this technology could bring appear to make the case for a PaaS based SSE compelling. There are inevitably some risks/issues to overcome, not least around data policy/management, security standards, the potential for cognitive overload, the implementation needed and the cultural shift required for the Armed Forces to embrace higher degrees of synthetic training. However, these are considered by many to pose surmountable challenges⁶² and the current pathfinders are providing mitigations to these potential challenges, whilst also demonstrating the robustness and maturity of the underpinning technology.

Whilst further analysis utilising more mature data and definitive MoD cost estimates would help to refine the scale of the achievable benefits, overall it would appear that "the use of a SSE as an underpinning enabler to all the other aspects of defence transformation for the digital age will be a pivotal capability in how forces are conceived, designed, commanded and operated"⁶³ allowing the UK to maintain its edge in this 'competitive age' and deliver on the critical defence modernisation aims set out in recent defence narrative.⁶⁴

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35. 50 synthetic solutions represents a prudent estimate of new solutions over the timescale given the intent from the MoD to invest in the Digital Backbone and the number of relevant programmes focused in this area (e.g. CTTP, Selborne)
36. It is believed that a 10 year period represents a reasonable term where upfront investment in a new PaaS SSE system would be required.

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55. See for example 2015 European Defence Agency report, which identified issues for SMEs accessing defence markets such as access to information, involvement in R&D, SME competitiveness and security of supply. See also a similar 2014 report on the US Department of Defense
56. The-Immersive-Economy-in-the-UK-Report-2019.pdf
57. Immersive Technology in the UK – Industry Data, Trends, Stats
58. Businesses specialising in Immersive Technologies in the UK are highly export intensive. In 2018, InnovateUK found that 70% of specialist immersive technology companies were exporting, while Immersive UK estimated 62% in 2019. This compares with just 9% of UK-wide SMEs and around 45% even in export-intensive industries.
59. Centre for Economic Performance discussion paper No 1662
60. BIS – An economic analysis of spillovers from programmes of technological innovation support
61. Frontier Economics – Rates of return to investment in science and Innovation
62. Jeremiah Rozman, <https://www.ausa.org/publications/synthetic-training-environment>
63. General Sir Richard Barrons, LSE paper, August 2018
64. Integrated Review March 21; Defence Command Paper; Integrated Operating Concept 2025; Ministry of Defence's Digital Strategy for Defence April 2021

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