Realistic Battlefield Visualization and Simulation Software (RBVSS)

Defence and Security Accelerator Competition: Populating the World of Training, Phase 1.
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Introduction

I am seeking funding to develop a software that realistically simulates platoon level combat and command from the viewpoint of a drone on the battlefield. This software will be designed to assist professional commanders with strategy formulation, acting as a "sandbox", whereby battlefield scenarios can be visualised, tested and amended prior to operations. It does this in a form of both Collective and Individual training.

I am a member of Exeter University Officer Training Corps and intend applying to the Royal Military Academy, Sandhurst. Realistic Battlefield Visualisation and Simulation Software (RBVSS) is therefore relevant to my interests and future career.

This product is intended to be a new form of battlefield simulator, which capitalizes on the return of conventional warfare and new tactics. Post-soviet era war philosophies have been largely ineffective since the start of the Ukraine war in 2022 *(Robinson, 2022)*. This has moved the vast majority of militaries away from irregular warfare strategies and back to conventional ones. In addition, technology in battle has changed drastically with mass use of drones and digital warfare. Therefore, because of the devolution of military strategy and the evolution of military technologies, I believe a new and tailored simulator is required.

Realistic Battlefield Visualization and Simulation Software (RBVSS) is designed to give the commander a method of simulating hundreds of battlefield scenarios using real time imagery from drone and satellite technology. This is to simulate the future operations of troops under their command at a platoon or company level. Once the commander is satisfied with a suitable strategy for multiple different scenarios, it can be easily displayed in a shortform video for troops to view and study in their downtime.

Contextual Research

Virtual military simulators are a vastly growing and increasingly important industry (Spherical Insights, 2023). However, military simulators can be split into two categories for target consumers; Military organizations and casual video gamers. There is a strong military simulator genre when it comes to recreational computer gaming. There are very few similarities between commercial games, and professional simulators, despite being in the same subject setting. The target market for this proposal are the professional simulators.

Professional simulators can be further split between two categories; Individual and Collective.

Table 1. Types and levels of conventional military training

Type of training	Level	Content	Training methods
Individual	—	Physical proficiency, weapon/equipment handling, map reading, etc.	Field training with actual systems
Collective	Unit	Training imparted to individuals in combined exercises up to battalion/ regiment level	Field exercises
	Formation	Brigade/division/corp level exercises	Sand model, tele-battle and manual wargame, etc.

Figure 1 (Dutta, 1999) – Table giving brief descriptions of the two different levels of training.

Current Individual Training Simulators

Some examples of currently used simulators are the 'One Semi-Automated Forces (oneSAF) Simulation' and the 'Interim Combined Arms Virtual Simulation (ICAVS(D))' systems (Elbit Systems UK, 2022). These are both examples of Individual simulators, where a person will operate a virtual system that replicates their exact task and objectives when in the field or in combat. An example of this could be a tank driver who, using a VR headset, can utilize and navigate around a virtual tank interior to drive it around a battlefield and eliminate enemies. This is a form of training designed to improve a soldier's combat skills and abilities with certain equipment at a substantially lower cost compared to real-world training within a tank. After many studies this form of simulated training has provided overall positive results for professional combatants. A review was conducted for pilots in the armed forces, determining whether the virtual training translated to real-world skill improvement: *"For surface attack training, six studies were found. Five of these demonstrated positive transfer for conventional weapons delivery." (Bell and Waag, 1998)*

Although little public research has been conducted for infantry or armored personnel, Individual simulator use has only increased in popularity for state militaries: it would be reasonable to infer similar levels of positive skills' transfer.

Not only are these simulations cost effective, they also provide a safe training environment, and the ability to organize training exercises with units in completely different parts of the world through online connections. Despite this, they still require units to have computers, controllers, headsets and the electrical infrastructure for each individual user in each training session, which is an expensive and significant logistical undertaking. That being said it is becoming an increasingly easy training method to organize, as in 2022 the ICAVS(D) (Elbit Systems UK, 2022) British Army simulator achieved its 25th training exercise and received very positive feedback:

"*ICAVS(D) is easily deployed to the point of need, with minimal planning and usage constraints, and encourages tactical innovation by immersing the training audience in an adjustable, rich, challenging and complex environment." (Administrator, 2022)*

The comment was made by Nick Taylor, DE&S' (Defence Equipment & Support) Soldier, Training and Special Projects team leader. This suggests that the soldiers and users themselves think it is an efficient method of training. This is a good indicator for ensuring that future simulators are actually used by troop on the ground, not just pushed by commanders who think they are a good idea because they are a new technology. However, despite these improvements, this is a method of training which is still not feasible in remote locations or the theatre of operations, due to its extensive personnel and technical requirements.

Current Collective Operational Simulators

Collective training opposes Individual in almost every way. The requirement, purpose and formats of collective training focus on completely different aspects of war and combat training. *"Once a trainee has perfected in operating an equipment/weapon through a simulator, the need arises to train the crew to react under different combat situations that include enemy actions and also coordination among friendly forces." (Dutta, 1999).* Collective Operational Simulators such as Command Professional Edition (Command PE) and Raytheon UK's CERBERUS are frequently used by military organisations. These simulators are perfect for operational command practice in campaigns or entire conflicts. They require a single piece of software, on an average-specification computer, with a single operator. They focus on command simulation, of entire operations or even campaigns, but can also venture into smaller battles visualized on a 2D plane with indicators for units. Individual soldiers cannot be controlled, only structured formations. However, the logistical requirements for these simulations to be organized is little to none, allowing it to be a tool for strategising in the field and on operations, something of increasing regularity. Command PE is an app accessible to all MoD personnel which was proposed by the Royal Navy after UK Strategic Command's DMSO (Defence Modelling & Simulation Centre) awarded a 1-year contract, which highlights its popularity and effectiveness.

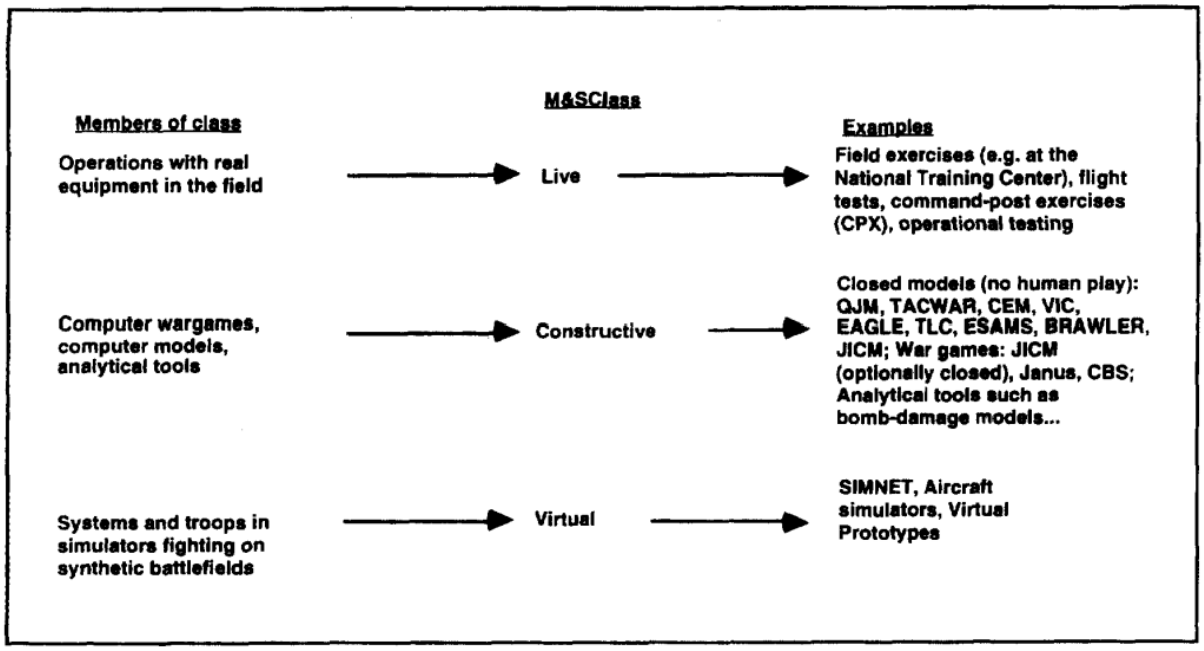

Figure 2 (Davis, 1995) – A table with short briefs describing the forms of modeling and simulations.

Classes of Modelling and Simulation

P.K. Davis describes the three forms of military models and simulations in Figure 2. This is a universally adopted classification, and further helps us to define a gap in training available to soldiers. The constructive and virtual classes can be easily combined to create a simulation that incorporates training aspects for both soldiers and their commanders in unison, which is the ultimate goal of this project. P.K. Davis continues to define many more aspects of simulators and how they can be classified. The diagram in Figure 3 has been helpful in developing the right simulator to fit the goals I have set out to achieve.

The level of perspective measurement perfectly describes the current gap in the market. Developers can find it difficult to develop a simulator to accurately depict Mission, Battle, and Theatre-Level perspectives. This is for several reasons, the first simple one being the lack of data, which is supported by P. Robinson, who states in his conclusion of 'The Russia-Ukraine Conflict and the (Un)Changing Character of War':

"Comparing the Russia-Ukraine war with the past 30 years of theorizing on the changing character of war, one is forced to the conclusion that very little, if any, of that theorizing applies." (Robinson, 2022)

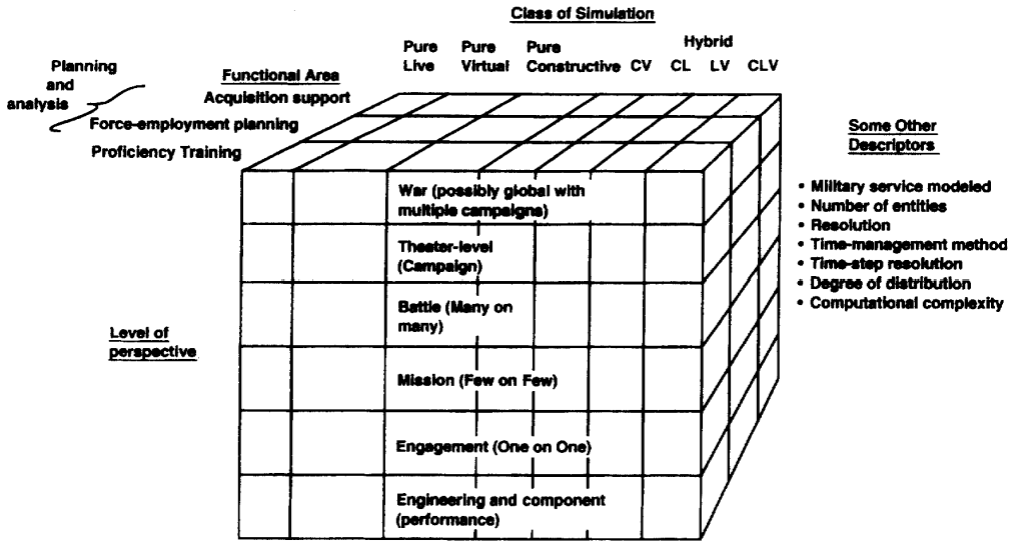

Figure 3 (Davis, 1995) – A detailed diagram which shows the intricacies of simulation classifications.

Battles, and campaigns have had a very different appearance since the fall of the Soviet Union and have almost exclusively been Irregular warfare conflicts with unconventional military forces. Since the beginning of the Russian-Ukraine Conflict, both the *New Wars (Kaldor, 2013)* and *Hybrid Warfare (Hoffman, 2021)* theories have been disproven; theories previously hailed as gospel by most western militaries. Most modern simulators created before the Ukraine war began in 2022 were created with primarily irregular warfare in mind, or, as Carlo J. V. Caro puts it: *"Russian military doctrine reflects the traditional concepts of non-linear warfare and deep operation." (Caro, 2022),* a statement that looks increasingly irrelevant as the first conventional European war since 1945 evolves.

As the technology for digital military simulators has been almost exclusively developed within the past *'30 years' (Robinson, 2022),* P. Robinson states, it is reasonable to expect there is a limited number of simulators that focus on conventional warfare. This list grows even smaller when asking for simulators that account for modern technologies found in the Ukraine war', resulting in a probable answer of 0. This is as much an issue for any modern military as it is an opportunity to be the first to produce one.

Another reason there are limited simulators in this field is the accuracy and realism at which soldiers can be portrayed by AI. As mentioned before with Individual or Collective simulators, they either focus on the simulation of scenarios for real soldiers to experience, or they simulate basic rectangles on a screen replicating units of 5 soldiers, to 5000 soldiers. Creating realistic and authentic individually simulated soldiers is very difficult to do, and has to consider psychology, skill, training, organic movements and realistic decision making. In a study conducted by Sweetser. P, Johnson. D, Sweetser. J, & Wiles. J, they determined the most important factors in creating an AI that simulates and suitably portrays human players:

"In terms of intelligence, people want AI that is not predictable, that doesn't cheat, that is cunning, flexible, challenging and original, and that adapts and varies according to the changing environment." (Sweetser, Johnson, Sweetser, Wiles, 2003)

However, the combination of these characteristics makes for an unbeatable opponent. Such an opponent is not realistic, nor is it an efficient use of training time (as the human opponent of the most-

advanced AI chess computer would atest). This balancing act of difficulty along with well-made animations are the foundations of creating realistic and accurate AI which can be used in a simulator. The individual AI soldiers in any proposed simulator must be indistinguishable from a human player's performance, because if they are, it will result in a different outcome to reality, deeming the simulation completely pointless. Human-AI technology is currently used in operational level simulations: the rate of AI development is now creating a positive environment for development of an individual soldier AI in a new simulator, whereas it was previously pointless to try for the reasons above *(Goecks et al., 2022).* These factors make the return value of creating a medium-high level perspective simulator far more rewarding than it ever has been since the invention of virtual digital battlefield simulators.

The Ability to Combine

There are clear differences between Individual and Collective, with pros and cons for each type. However, there is a gap between these two types of simulation. A key benefit of Individual training is its ability to accurately depict a battlefield in 3D for the user to navigate, which is completely lacking in Collective training as it relies mostly on 2D satellite imagery and topographical mapping. This is an aspect which can be included in a Collective training simulator if it is detailed and low-level enough. I intend to combine these elements to form a relevant and useful simulator for today's militaries. I will be specifying the exact needs of the simulator in this project by using both of the categorisation methods above. This should help define the exact gap in the industry and all aspects/features needed to create the desired product.

Figure 4 (Savage, 2013) – Men of War Assault Squad 2, displaying a detailed graphical representation of a battlefield at the visual level we intend RBVSS to reach.

As described above the two categories of Individual and Collective simulations tackle either the proficiency of the individual soldier, or the operational ability of a unit or formation. However, it is not the same for recreational commercial simulators. There is a third category. These are birds-eye real time strategy games, which focus on individual AI soldiers fighting within a formation that the player controls, also known as RTS (Realtime Strategy). This genre of game is clearly demonstrated by the game 'Men of War: Assault Squad 2' *(Men of War Assault Squad 2, 2014)* (shown in Figure 4). A realistic and detailed graphical terrain is used by AI to simulate a battle, where the victor is determined by the tactics, skills and the equipment of individual troops. This format of visualizing the battlefield combines Individual training of a commander, and Collective training for the soldiers who can study the movements and strategy the commander chooses to take. As an added bonus, the camera angles of these RTS games are perfect to be substituted for a drone camera and controls, an aspect of modern warfare becoming increasingly relevant.

Summary of research

Almost all digital simulators have been developed within the age of irregular and insurgent warfare, prioritising strategies and therefore less-relevant to conventional conflicts like we have seen emerge in Ukraine. A new simulator must be developed that accounts for this form of warfare. Therefore there are some clear needs outlined from the research above. The first need is battle and mission simulation reform, as it is a scale of combat which has been very different in the irregular warfare era. The diagram of *Figure 3* created by P.K Davis *(Davis 1995)* describes this as the 'level of perspective'. *"A **battle** is a violent fight between groups of people, especially one between military forces during a war." (Collinsdictionary.com, 2019).* However, there are some clear differences from the battles of irregular warfare and conventional. Using the highest estimates of casualties, the most deadly western battle of the Irregular warfare era was the battle of Mosul in 2016 with a higher estimate of 71,000 casualties. The Ukrainian war has already surpassed this number in two separate battles being Mariupol

Figure 5 (Fazal, 2014)

with 85,000, and Bakhmut with 165,000 *(Merkx, n.d.)*, both starting in 2022 and lasting as long as the battle of Mosul. This is then paired with the wounded-to-killed ratio. In Afghanistan it was an unprecedented 10:1, which was historically very uncommon for any armed conflict. In the Ukraine war, the deadlier traditional 3:1 is present, which historically was the ratio expected in almost every armed conflict (Figure 5) (*Fazal, 2014).* These potentially disparate ratios should be represented in a future simulator. It will require the product to simulate potentially tens of thousands of actors and adversaries, whilst maintaining a high level of authenticity, realism and graphical performance.

With regard to simulator type, the competition requirements state the need for a Collective training simulator. When looking at the research of current Collective simulators, they are very high-level operational simulators. Therefore it should be in the developers interest to investigate slightly lower-level collective simulators such as "sandpit" battle tactics. The requirements of the competition also state that the product cannot rely on the provision of live players. This means a fully simulated environment and characters (this is not to say multiplayer capabilities should be fully discarded. The research is also clear that Live, Constructive and Virtual training simulations can be molded together. Having this ability to operate in all 3 fields is a valuable trait and therefore could be pursued for a more universal product.

Project Information

The conclusion of the contextual research outlines a clear gap in the professional market for simulators. My intention is to take inspiration from several popular commercial games to create a modern and relevant simulator that prioritizes all the most fundamental elements of modern conventional warfare, such as new military technologies and strategies. It will be presented in a new format, representative and accurate to commander perspectives. There shall also be a focus on the "Battle" perspective of combat which is growing increasingly important. The simulator's purpose will be to train personnel outside of theatre with any current and new technologies, and to inform active combatants for future combat and operation scenarios. It should have a universal use for military personnel.

This project will be named:

Realistic Battle Visualization and Simulation System (RBVSS)

This section of the proposal will outline the desired finished product I intend to develop alongside all production and budgetary information to make it possible. The software development and games industry can at times be unreliable, which often occurs because of unpredictable errors that teams can encounter in-engine mid-development. For that reason this section will be constructed with both the best and worst case scenarios in mind for each functional requirement outlined by the Defence and Security Accelerator in the competition details this project is based on.

Product Function

Accessibility will be one of the foremost features of this simulator. As powerful commercial devices such as the 'Steam Deck' *(Valve Software, 2021)* become more common and popular, the accessibility of software and simulators becomes more prevalent. The intention is to make RBVSS accessible on low level devices that are accessible to both commanders and soldiers, such as phones, tablets, or even just screens. The only individual who requires a powerful enough device to render and control the simulations would be the commander. This means that in theory, once the software is developed, the only additional cost to the Armed Forces for each application of RBVSS would be between £300-£1000 (for a powerful enough device) for up to a company worth of soldiers. This would make it one of the most cost-effective simulators in the market when comparing to Individual simulations.

RBVSS operates in 3 stages: Scenario Generation, Simulation Analysis, Summary Distribution. The following sections will cover each stage in detail:

Scenario Generation:

For the first stage of use, the commander will utilize a sandbox within the software to create any desired scenario. This is comprised of several components and stages, which utilise many different technologies, in particular drone/satellite imagery generation and advanced AI. *(The advanced research and technology utilised in RBVSS is investigated in detail within a later section of this proposal).* The following list defines each element of the sandbox scenario generator.

1. Battlefield generation and editing
2. Friendly and Enemy equipment and personnel
3. Friendly and Enemy objectives and strategic ethos

Battlefield Generation and Editing

This is the first and likely most time consuming element. We can use the example of a dawn attack for a platoon, and it is currently 6pm in the evening before the attack. The commander's role is to create a detailed and explicit battle plan for what the objectives of the attack are. His first job is to gather all available imagery and information on the enemy i.e. all locations, equipment and personnel that have been surveyed or estimated. The two easiest ways to accomplish this are drone and satellite imagery. This can give accurate, recent and informative visibility of the battlefield. Drone and satellite imagery can be cross referenced to provide accurate 3D depictions of the battlefield *(Emimi, Khaleel and Alkrash, 2023).* However, there are obvious flaws in this system: obstacles such as buildings, tree canopies and camouflage make many features of the battlefield difficult to represent or show. This is where the commander makes his first adjustments through the edit feature. This feature allows the commander to create approximate but detailed representations of dead zones *(areas of the battlefield with little to no information gathered to describe it - they have to be considered hostile areas, even if no threats are actually there).* Trench lines, woodlands, buildings and tunnels will be fully constructable for the commander, using simple and accessible tools. The goal is to allow incredibly quick and accurate placements of 3D representations on the battlefield.

Figure 6 (Freshcan 3d, 2021) – Depiction of Unreal Engine 4 editor, which represents the form of editor RBVSS will utilize.

Friendly / Enemy Equipment and Personnel

Now the terrain and battlefield have been constructed with accuracy, it is time to create the scenario which will take place upon it. Firstly, the units being utilised, and secondly the equipment they obtain. This should be a detailed system that allows the editor to alter skill, training, competency, morale, equipment and the personnel reserves available (this should make clear the skill difference when conscripts engage with regular infantry, for example). Variables will affect marksmanship, manoeuvrability, and initiative. There will also have to be a vast and updatable catalogue of weaponry and equipment. The goal is to have a detailed system that is only visible in a very simple format to the editor.

Once each unit type is defined, including civilians, they will have to be manually placed across the battlefield. Once complete, and the number of units is defined, the approximate command structure of either team must be established, where known. If unknown the AI will use military philosophies from the nations the units are representing to estimate the most likely structure.

The competition follows a categorisation of personnel in a warzone known as A3E (see below). It is an essential component of the specification, and piece of terminology to account for all individuals that may be present on a battlefield. Many of the new technological advancements in AI allow developers for simulators such as RBVSS to create more realistic and authentic characters within the simulator. This will create realistic scenarios including civilians and hostile, unarmed adversaries, which lie in more of a grey zone compared to generic actors and enemies.

Below is the definition of A3E, and how it will be an important design pillar for the simulator:

- *Audiences:*

groups and individuals whose perceptions and interpretation of events and subsequent behaviour contribute to the success or otherwise of military action.

- *Actors:*

individuals or groups who take action or directly exert influence. They include British forces and allies, as well as others who are friendly, neutral or hostile.

- *Adversaries:*

hostile sub-set of actors; those groups and individuals who seek to prevent friendly forces from achieving their objectives.

- *Enemies:*

those who seek to oppose friendly forces through armed, lethal means

Finally, the addition of experimental or theoretical weapons and equipment. This could be anything from the newest specialist rifle, to a new type of drone camera. If the entire battlefield is being simulated, then a new technology can be easily added to the simulation. This will allow a form of testing no other type of simulation could do. It would allow for practical testing of technology with all other variables of a battlefield impacting its effectiveness, therefore providing valuable efficiency information to both manufacturers and consumers. This should be a significant selling point of RBVSS if an easily configurable and adaptable technology creator engine can be incorporated into RBVSS. This will likely come in the form of an in-built engine accessible from the menu screen.

Friendly / Enemy Objectives and Strategic Ethos

Aside from the physical parameters of the simulation described above, objectives and strategic ethos must also be applied to each side. The computer will use existing military training philosophies from either side to determine their most likely course of action. This will be dependent on the objectives provided by the editor for either force. An offensive example would be “Capture this building”, with a defensive example being, “Hold current positions”. These are simple and will help the AI determine their overall goal, however additional orders can be provided for specific circumstances, such as “at all costs”. Additional orders such as these will help the AI simulate real combatants as accurately as possible. This is something only recently available with recent developments in AI, whereby the AI interprets the instruction, whereas previously you would have had to manually define in code every single possible order a commander could give. Now there are limitless options.

The stage of creating the simulation will be proportionally time consuming to the other stages of use, however, the goal is to make this element as streamlined and fast as possible. Again, this technology should be usable on only a tablet in the backlines of a battlefield, so speed and time efficiency will be of paramount consideration.

Simulation Analysis:

19th century Field Marshall, Helmuth von Moltke coined the term, "No plan survives contact with the enemy". It is a phase regularly considered in modern militaries. This simulator attempts to create rough guidelines and examples for combatants to follow in unique scenarios that can take place on the battlefield. Some of these include loss of comms for one section or all sections, often leading to chaos. However, if all friendly combatants are shown the best manoeuvres chosen by the computer in these specific scenarios, they can have a better idea of what to decide themselves when on the battlefield in such scenarios. This is not designed to provide the gospel of battle strategy, thereby making commanders obsolete, but rather provide visual references for section and platoon commanders to help them decide the best course of action. It is effectively making a previously unknown terrain more familiar to the soldiers in a unit.

Once the parameters of the scenario are completed and any errors in test runs have been debugged by the user, it is now ready to multitask multiple different simulations, with a vast array of potential scenarios within the set parameters. The computer can now run many different scenarios at a faster speed of 1.5-3x speed and allow the user to visualize all these scenarios. Each scenario will be different and take place within the plausibility parameters determined by the user.

The user will also be able to take control of scenarios to partake in Individual training, improving their own strategic capabilities. The user will command friendly forces and, whilst controlling all units, attempt to achieve the objectives. This style of training will help the commander make a final plan of action for the troops.

Scenario contingencies:

These scenario contingencies will include different plausible strategies that the enemy force will use, as well as potential risks or events on the battlefield that change the scenario to a significant amount. To give some examples:

- Direct scenarios
    - Minefield explosions
    - Artillery/Air strikes
    - Drone strikes

- Indirect scenarios
    - Loss of comms
    - Weapon failures
    - Vehicular issues

- Strategic scenarios
    - Enemy flanks
    - Accurate enemy anticipation
    - Fog of war under/over-estimations

- A3E scenarios
    - Civilian actions
    - Civilian Hostility Rating
    - Civilian placement
    - Adversary actions
    - Sabotage

These scenarios and many more will help guide the user to determine the best initial plan off attack, and any necessary contingency plans in order to mitigate the consequences.

The computer will run and visualize all of these simulations for the user. Once the user is satisfied - and has also had hands-on experience commanding in the simulator – they can begin the final stage of concluding and displaying their analysis to any related combatants.

Summary Distribution:

With likely over 50 different simulations completed, the user will select 5-10 that they think are the most relevant and best show the information gathered from the simulations. These can include ideal outcomes, retreat strategies, scenario signals, most probable outcomes and section-specific walkthroughs. These will be concluded with the definitive strategy determined by the commander.

This compilation of simulations will be formatted into an mp.4 video which will then be securely distributed throughout a unit. This distribution can take place via secure intranet, or by handheld screens with airdrop. It will be designed to be as accessible as possible to as many necessary devices within a secure network, so as not to compromise sensitive information. This video should aim to be between 15-25 minutes long.

Any combatant provided a copy of the video can study and familiarise themselves with the terrain, scenarios, and strategies of all sections. It aims to be a short and digestible mass of information accessible to all troops within a unit.

Post Use:

Once the simulator has been used and the video is distributed, any parameters and battlefield scenarios are saved and retained by the computer and on the cloud for later referral and updating by the user. It also acts as a learning tool for the AI within the simulator, to adapt and improve its function of simulating and replicating human actions and decisions.

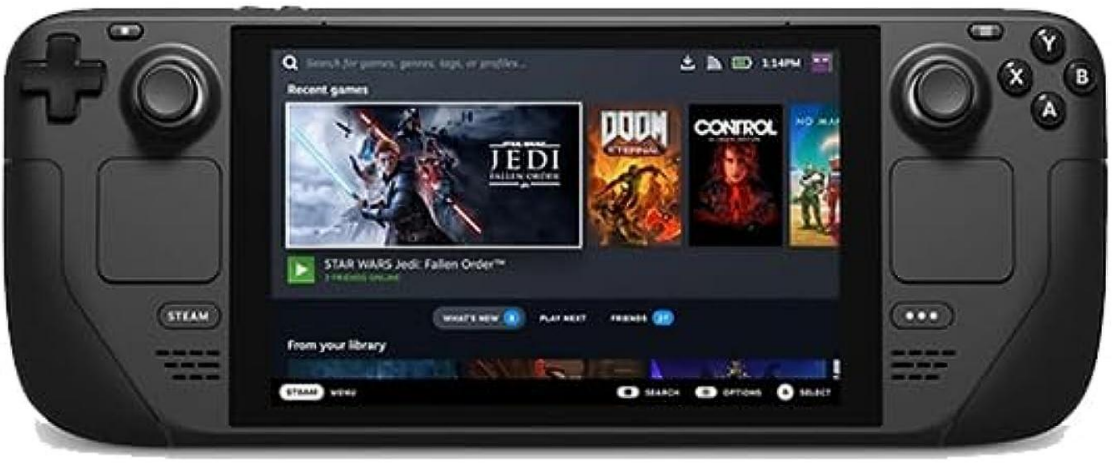

Figure 7 (Valve Software, (2021) – A commercially available Steam Deck which retails for approximately £350. Which is the target device for full utilization of RBVSS by a commander. An extremely cost effective device.

Specification Comparison

From sections 2.3, 3.1 and 8.1 of the competition brief (Ministry of Defence, 2023), there is a specific set of criteria that the contract will be awarded for. A great deal of the criteria include requirements concerning A3E. This is a focus in the British Armed Forces, and therefore it will be a keystone design pillar of this simulator. This will therefore include realism and educational information for the personnel using the simulator. Because of this design strategy for the simulator, all A3E design requirements for the competition have been of utmost priority.

Section 2.3 clarifies the technology and realism to be represented in the simulator. It includes armoured vehicles, thermobaric weapons, advanced electro-magnetic equipment and much more. All of these technologies will be represented within the simulator. It will also include features to allow the easy inclusion of new technologies within the simulator - via a simple weapon creation engine: which not only meets any currently MoD requirements, but any new requirements as well. This is to create an adaptive simulator which can account for newly developed technologies on the battlefield which combatants must consider. This feature will also allow for currently developing technologies to be virtually tested in conjunction with all other variables that come on a real battlefield (something very few methods of testing can accomplish).

However, there are also criteria for information and online display, which is also clearly outlined in section 3.1. This considers information gathering and social media perception. Information gathering is an integral part of an active battlefield and so will be an incredibly important aspect of active missions. However, Social media is much more difficult to include and simulate, as it is far more unpredictable. Instead of social media being a constant feature of every scenario simulated, it will be a form of mission type, such as in irregular or insurgent warfare. This is the only clear concession from the requirement criteria. One way forward would be to release the main version of the simulator and then research and

develop a further expansion of the simulator to consider social media. This simulator is clearly more focused towards modern conventional conflicts rather than irregular warfare which is becoming less prevalent for Western forces. However, despite this concession, RBVSS comfortably meets the criteria for section 2.3.

Section 8.3 clarifies the purpose and use of the simulator. This is where RBVSS meets the exact requirements. It would be difficult to create a simulator that matches all these different aspects of training. RBVSS can be used for Collective training away from a theatre of operations, whilst also being mission and combat ready, to not only simulate and replicate a battlefield, but actively represent and advise actors on how to immediately engage in a real-time operation.

The scenario system has the ability to re-create the most difficult situations for combatants to be a part of, and includes enemies who range from untrained militia to vastly superior foes. A core element of research for this project is AI. The nature of the simulator allows, but does not require live users, meaning a single player can operate the simulator. RBVSS is a comprehensive training and simulation utensil that seamlessly meets all requirements (including A3E) of section 8.1.

Finally, section 3.1 gives an example scenario for the required simulator. Its focus is orientated towards irregular warfare or enforcement, which although a feature, is not the sole purpose of RBVSS. Non-conventional warfare is more reliant on social media. As stated before this requires a great deal of research and further features and consideration. This will be something the team researches throughout the development of RBVSS, to be integrated either by release or post launch. The main reason for this is resource management. It would be difficult to accurately convey social media in a realistic way. In addition it is also a cause of scenarios, not a scenario itself. Therefore it would likely fit within longer term simulations instead of short mission long scenarios taking several hours. Longer missions or battles are a feature of RBVSS, where social media is important to information and disinformation. These will be scenarios that the research will primarily focus on. This research will only strengthen the A3E capabilities of the simulator.

To summarize, the criteria of the competition are comprehensive and specific. RBVSS meets all these requirements with the only exception being Social Media simulation. The battlefield fundamentals and simulations are much more important to create realistic and authentic scenarios for actors to watch and study, whereas Social Media can be taught and studied separately to the simulator. However, it is the intention to add social media research and mechanics to the simulator once the fundamentals have been correctly implemented.

Project Specifications

Development platform

RBVSS will be developed as a modification to the popular consumer military simulator – Arma Reforger (Bohemia Interactive, 2022). Bohemia Interactive, the studio behind Arma Reforger has been recently purchased by BAE (British Aerospace) systems in 2022. BAE is the largest weapons and military technologies manufacturer in Europe (Roth, 2017) and acquired Bohemia Interactive for their military simulator technologies. As a pre-existing consumer-grade simulator, Arma Reforger would be a secure, accurate and substantive platform upon which to develop a modification.

The ideal structure for release would be an isolated copy of Arma Reforger that includes the embedded modification of RBVSS. This would require the permission of Bohemia Interactive, which may include a service fee. This isolated version would not contain any unnecessary content from the public release. The RBVSS version would then be available to armed forces personnel, with real-time information and technological updates, including strategy and tactical information sensitive to the army.

Public Release:

If permitted, RBVSS will be split into two editions; Professional and Standard editions.

- ***Professional Edition:***

The initially developed version of Arma Reforger kept internally within the armed forces and other exclusive license holders, holding real-time data and sensitive military information.

- ***Standard Edition:***

A re-release of Arma Reforger containing RBVSS that has been substantially simplified. It will contain limited current technological advancements, and will not include advanced AI that has real world strategic data, instead using simplified but still realistic AI just like any other computer game. It will be intended for normal video game consumers who should not have access to sensitive data. It will also not include any ‘Summary Distribution’, with severely limited ‘Simulation Analysis’ and ‘Scenario Generation’ capabilities. The purpose of Standard Edition is a simple return-on-investment policy that would also require only limited additional development once Professional edition is launched.

Target Utilization Platform

RBVSS will be used on the average consumer grade gaming device with Windows. This could be a PC worth £1000, to the recently released Steam Deck hand-held device (shown in Figure 7), which costs around £350. A single individual is required to operate RBVSS for an entire platoon or more, making it an incredibly cheap product to maintain.

Product Function Research and Areas of Required Technological Advancement

For RBVSS to function as designed it requires two significant areas of development from the base Arma Reforger, which will likely take up the majority of the development cycle: (1) Satellite and drone imagery generation, and (2) High-level adaptive AI logic. The following sections will discuss research into these two areas of development, and how they would be used within RBVSS.

Satellite and Drone Imagery Generation:

For the simulator to be effective on real time battlefields it requires real time imagery. Satellite images cross-referenced with drone imagery, if correctly developed, could accurately represent a 3D terrain with civilian and military structures and objects. This technology already exists. Its most common form is the "*Lidar (Light Detection and Ranging) Sensor: Lidar sensors emit laser pulses and measure the time it takes for the laser light to bounce back to the drone. This data is used to create highly accurate 3D maps of the terrain, buildings, and other objects on the ground." (Kim, 2021)* These Lidar sensors would be attached to drones which have proven themselves effective on battlefields. The reason for their success is described perfectly by Emimi, M., Khaleel, M. and Alkrash, A, who state, in relation to drones in military settings:

"Equipped with high-resolution cameras, thermal imaging, and other advanced sensors, drones provide real-time aerial imagery, video feeds, and situational awareness to military personnel. They can monitor enemy movements, identify potential threats, and gather critical information without risking personnel lives." (Emimi, 2023)

This is where the RBVSS team will direct our attention for the translation of Lidar imagery into a 3D playable terrain within a game engine, such as in Arma Reforger. There are already many methods of generating 3D objects and terrains in video games from LIDAR, however what is required for RBVSS are interactable and editable objects. The software will include methodology for the automatic recognition of certain objects, such as trees, buildings and bunkers. A landscape in the form of a single 3D object will require conversion into thousands of individual objects upon a terrain: this will likely be the greatest challenge to overcome for the development team.

Several media outlets online are reporting extensive use of LiDAR in Ukraine already (Giangiulio, 2024), with much research describing use of LiDAR for mapping across the world for agricultural purposes, geographical surveying, and flood prone areas. There are also lots of commercially available LiDAR drones. One of current uses of LiDAR within the Ukrainian conflict is mine spotting, which could be one of the secondary purposes for combatants whilst information gathering for RBVSS.

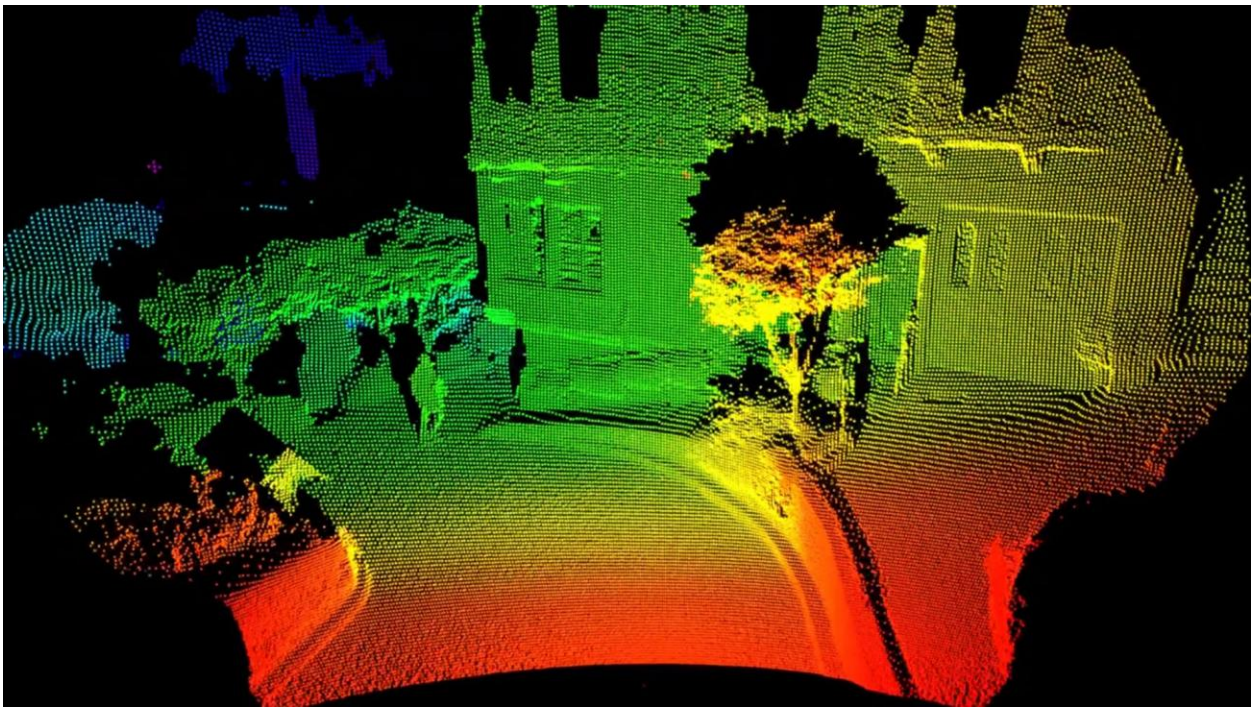

Figure 8 (Markus, 2021) – Showing LiDAR in use.

For Drone-Satellite communication, this is already a regular occurrence, as Drones frequently use GPS to return to their original position. *"Drone-To-Satellite communication is essential for transmitting real-time coordinates via the Global Positioning System (GPS)" (Emimi, 2023).* This level of communication can be also utilised to coordinate image accuracy, as shown. In a study researching drone image accuracy of geographic terrain modelling: "*The accuracy of drone modelling was 98.53% (98.68%), 95.2% (96.1%), and 94.4% (94.7%) for each altitude of 40, 80, and 100 m after comparing against Google Earth." (Budiharto, 2021).* This level of accuracy would be perfectly acceptable for an early stage simulation such as RBVSS. This will be a corner stone of development and research for the team developing RBVSS.

High Level Adaptive Human AI Logic:

Recent advances in AI make this type of simulator possible. Advanced AI has the ability to mimic Human actions and decisions, whilst also learning from use to improve its functionality and effectiveness. AI in Arma Reforger is far more simplistic and must be overhauled. One of the most-important factors for the success of RBVSS will be the ability of the AI to accurately represent Human soldiers in a combat situation, so that commanders and soldiers can plan correctly.

AI Pathfinding

Pathfinding is one of the most important visual and behavioural aspects of AI in video games. It is often the first indicator players use to evaluate the general intelligence of the AI. If AI can't avoid walls, or proceeds into the open with little-to-no cover, the player knows what they are dealing with and immediately knows how to combat them. Therefore the AI must act with the same intelligence and unpredictability that real humans have. There are several different ways of conveying this.

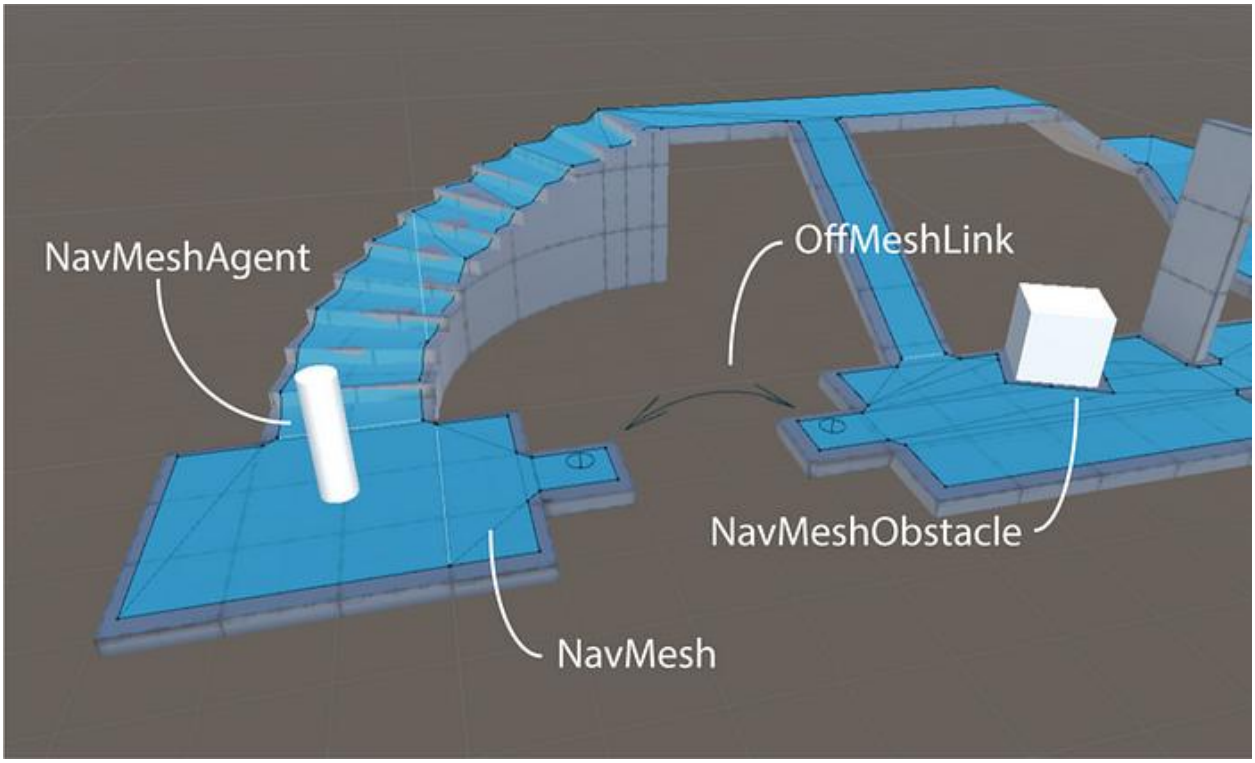

Figure 9 (Lafritz,2021) – An annotated rendered diagram showing Nav-Mesh and how it adapts to terrain.

The vast majority of games utilise Nav-Meshes, and Waypoints. These are calculated formats of static game worlds which determine the acceptable routes the AI could take from A to B. These routing calculations are then paired with pathfinding decision making algorithms: Undirected or Directed. The first is rarely used in video games for its very routine and basic solutions, which are more commonly found in search engines with Breadth-first and Depth-first searches to find the correct path. Directed pathfinding is far more common, and does not blindly check every route to take. It uses a cost variable to examine each route, which can be calculated with many different algorithms. However, the most often used algorithm is A*.

"A will not only find a path between two points (if one exists!) but it will find the shortest path if one exists and do so relatively quickly." (Graham, 2003)*

A* works with three key variables:

- ***g*** *is the cost of getting from the start node to the current node i.e. the sum of all the values in the path between the start and the current node*
- ***h*** *stands for heuristic which is an estimated cost from the current node to the goal node (usually the straight line distance from this node to the goal)*
- ***f*** *is the sum of g and h and is the best estimate of the cost of the path going through the current node. In essence the lower the value of f the more efficient the path. (Graham 2003)*

A* is an algorithm that struggles with dynamic nav-meshes (for example, a new crater being formed that the AI must avoid), but there are solutions for this such as *"the D* algorithm (which is short for Dynamic A*)" (Stentz, 1994)*

The main issues with believable AI outlined by Graham, Ross; McCabe, Hugh; and Sheridan, Stephen are:

- *Handling dynamic objects*
- *Using up too many resources especially on game consoles, which have limited memory*
- *Leave the AI until the end of the development process*

We intend to solve all three issues by tackling specifically the third of "Leaving the AI until the end of the development process": it will be a primary target of our team from day one of development.

Realistic Human Body Modeling

Realism is an important factor for the role of RBVSS. However, this characteristic is more dependent on the decision making and intelligence of AI, not necessarily its aesthetics. That is not to say it is unimportant, as realistic animations and body movement matter when it comes to projectile hitboxes, and weapon handling. Zhang, X concluded:

"Digital human motion modelers are working towards somewhat conflicting goals: (1) to increase the realism of synthetic humans; (2) to develop real-time human motion simulation. Fulfillment of these two goals simultaneously has been hampered by the inherent trade-off between biomechanical sophistication and computational efficiency" (Zhang, 2001)

However, there is a solution suggested in Zhang's paper, whereby movement efficiency can be prioritised as long as a similar outcome of realism is achieved i.e. effectively taking shortcuts. For RBVSS, where hundreds if not thousands of AI characters will be present in a single setting, this realism is not required for aesthetic purposes, therefore reducing the complexity required. But, as long as the hitboxes and realism are consistent, it should not matter. The movement of singular characters will not be relentlessly scrutinized as they would be in some single player commercial games, so the same level of detail is not required.

Methods of AI Decision Making

There are many different techniques used across multiple different industries for different purposes, not just games. Some of the most common and regularly used are Finite State Machines (FSM). FSMs are common because, *"they are simple to program, easy to understand and debug, and general enough to be used for any problem" (Rabin, 2002)* . However, they rely on simple yes/no Boolean variables, making them predictable and not particularly dynamic.

FSMs are contrasted by Fuzzy Logic, which has much vaguer states which can easily be described as: *"The power of fuzzy logic lies in the ability to represent a concept using a small number of fuzzy values" (Sweetser, 2002).* This obviously comes with the drawback of not being able to clearly define mathematical states easily like an FSM would. Which brings us onto the molding of both methods to create Fuzzy State Machines (FuSM).

FuSMs use both Fuzzy logic and FSMs to create a broader spectrum of states, allowing for much more varied behaviors by AI, such as "Slightly On" and "Almost Off" *(Sweetser, 2002).* FuSMs can be paired with Flocking, another form of AI behavior calculation in which the AI will determine its state from scratch for every update. This is frequently used for multi-enemy simulations and can make AI operate in a coordinated manner *(Sweetser, 2002).* These two methods in combination would create a much more complex and believable AI, whilst also being relatively simple to develop and computationally efficient for performance.

The final methods of AI decision making focus on learning capability. These methods include Decision Trees, Neural Networks (NN) and Genetic Algorithms (GA) *(Hamilton, 2011).* These are advanced models, however they are both time-consuming and complex, and as such are to be explored as enhancements only. Neural Networks was developed with inspiration of how the human mind works, improving its realistic human capabilities, such as non-linear and non-deterministic results. *"NNs are techniques that can be used in a wide variety of applications. Some common uses include memory, pattern recognition, learning and prediction." (Sweetser, 2002).* GA's are based on evolutionary decision making, however they are very complex and not too helpful for more simple applications such as the RBVSS simulator *"They are resource intensive and require much time in development and tuning, which does not make them ideal for in-game learning" (Sweetser, 2003).*

Technique	Advantages	Disadvantages	Applications	Games
Finite State Machine	- simple - general - use in conjunction with other techniques - computationally inexpensive - lots of power relative to complexity	- can be poorly structured - poor scaling - need to anticipate all situations - deterministic	- manage game world - manage objects / characters	- Age of Empires - Half-Life - Doom - Quake
Scripting	- simple - can be used by non-programmers - safe environment	- deterministic - need to anticipate all situations	- events - opponent AI - tell the story - automate tasks - conversation trees	- Black & White - Unreal - Dark Reign - Baldur's Gate
Fuzzy Logic	- when no simple solution - when expert knowledge is needed - non-linear problems - more flexible, variable	- not good when there is a simple solution - complicated to build from scratch	- decision making - behavioural selections - input/output filtering - health of NPC - emotional status of NPC	- SWAT 2 - Call to Power - Close Combat - Petz - The Sims
Flocking	- purely reactive - memory requirements - realistic / lifelike	- limited applications	- unit motion - groups of animals / monsters	- Half-Life - Unreal - Enemy Nations
Decision Trees	- robust to noise / missing values - readable - efficient training / evaluation - simpler than NNs	- need tuning	- prediction - classification - learning	- Black & White
Neural Networks	- flexible - non-deterministic - non-linear	- need tuning - choosing variables is difficult - complicated - resource intensive	- memory - pattern recognition - learning - prediction - classification - behavioural control	- Black & White - BC3K - Creatures - Heavy Gear
Genetic Algorithms	- robust search method - effective in large, complex, poorly understood search spaces - non-linear - non-deterministic	- resource intensive - slow - need a lot of tuning - complicated	- optimisation - learning - developing game strategies - evolve behaviour - pathfinding	- Cloak, Dagger & DNA - Creatures - Return Fire II

Figure 10 (Sweetser, 2003). Above is a table that describes the different applications, benefits and setbacks from each technique of AI decision making

Optimisation for High Numbers of AI combatants.

There are several methods for achieving optimization of multiple Non-Player Character (AI) in video games. However, *"there is a trade-off between having complex NPCs and having many NPCs. When the game demands too many NPCs, developers may have no choice but to employ simple game AI. But if the AI is too simple, the game will exhibit predictable uniformity" (White, 2007).* This is an issue for two reasons: (1) Arma Reforger has its own current cap of maximum Player/AI, which is likely below RBVSS requirements, and (2) RBVSS needs to replicate all characters at the same high standard of intelligence.

These are problems that are possible to overcome. Firstly, Arma Reforger will have many unnecessary components from its commercial model that will not be necessary for RBVSS, therefore expendable, likely improving performance and so allowing for additional AI. Secondly we can use techniques such as SGL (Scalable Games Language) *(White, 2007)* which can mathematically improve the amount of queries available to the computer. The ethos behind solving this problem of scaling number vs complexity is data management i.e. it will be treated as a data issue to be addressed.

This approach has precedence: games exist such as UEBS 2 (*Brilliant Game Publishers, 2023)* which regularly fields millions of basic level AI units, and Planetside 2 *(Daybreak, 2012),* which has recorded multiplayer battles of up to 12,000 people all controlling First Person Shooter characters. It is an issue the games industry is familiar with and has a great deal of experience overcoming. The team will need to pool these many different methods, and apply them to a pre-existing game, rather than building from scratch.

Conclusion of difficulty:

These three key hurdles to overcome are all current areas of both research and development across multiple different industries. All of the above issues have real world examples of current commercial applications in different industries, but also solutions of how to apply them in a setting similar to the development of RBVSS. When it comes to measuring the difficulty of this research and development, it will likely depend more on the resources available, rather than the complexity of finding the solution. As they are the key components for the simulator, a significant proportion of available resource will be directed towards them.

Development Logistics

All of the following data, calculations and conclusions are hypothetical, to as indicative of a potential development format. The development of RBVSS if placed into a commercial setting would be likely very profitable. Any excess expenses used on RBVSS will give a proportional return of quality and accuracy within the simulator.

Personnel costs

Role Title	Likely Development Number Required	Average Annual Salary	Annual Salary Upper Band	Cumulative Upper Annual Salary
AI Specialist	1	£62,664	£70,000	£70,000
Software Engineer	1	£53,983	£65,000	£135,000
UI/UX Designer	1	£49,024	£55,000	£190,000
Game Designer	1	£34,025	£50,000	£240,000

(Glassdoor, 2024)

Total Personnel Cost: £240,000
Ideal Additional Personnel:
1x AI specialist
1x Software Engineer
Total Ideal Personnel Costs: £325,000

Administrative costs

Each individual would require a work PC that meets the graphical and performance requirements to work on game engines, and to run Arma Reforger at an acceptable standard. They would also require all necessary office equipment, such as desks, electrical necessities and servers.

Upper estimate = £5000 per person (£20,000-£30,000 depending on staff numbers).

Legal and Accounting contingency = £10,000

Office Space costs (very broad) = £10,000 - £50,000

Cost Description	Lower Estimate	Upper Estimate
Personnel Cost	*£240,000*	*£325,000*
Equipment Investment	*£20,000*	*£30,000*
Legal and Accounting	*£5,000*	*£10,000*
Office Space Cost	*£10,000*	*£50,000*
Total Pre 20% Contingency	*£275,000*	*£415,000*
Total Post 20% Contingency	*£330,000*	*£498,000*

These expenses slightly exceed the target expenses outlined in the competition criteria, which stated the ideal bracket of between £100,000 and £300,000. However, it is also stated that genuinely compelling submissions that provide greater value for money will be considered. I feel confident that this proposal has not only displayed value-for-money but also potential for ROI (return-on-investment) with consumer grade commercial versions. It is possible to develop these commercial versions for a video game genre that is not only popular, but also a key inspiration for the development of RBVSS.

Timeline

The competition requires completed development within 1 year. This is possible: RBVSS is based on a relatively new pre-existing commercial simulator, therefore the vast majority of the legwork has been developed. Arma Reforger is an excellent choice, as it is provides modern optimisation, coding techniques, graphics and current development with updates. Development of RBVSS would essentially act like a traditional game Mod (modification), which is where independent, and often voluntary individuals take a pre-existing game, and modify them to either add or alter game features. These are common place, and Arma Reforger is one of the most easily mod-able games currently available.

The expected development timeline of RBVSS:

- 2 months:
    - All necessary research, personnel and equipment procured.
    - Detailed technical development targets will be outlined
    - First prototype examples of important features
- 4 months
    - Development of a cohesive build begins
    - Further feature prototyping
- 6 months
    - First Alpha build of RBVSS
    - Mid-Development evaluation
- 8 months
    - First real-world testing
    - Beta release and polishing
- 10 months
    - Late Development Review
    - Beta polishing
    - Regular outsourced QA testing
- 12 months
    - Finished Release
    - Product Evaluation
    - Market Analysis of Commercial Copy

This timeline includes three review stages: Mid-Development Review, Late Development Review, and the Product evaluation. These reviews will determine development efficiency, targets and scrutiny of the timeline. At the Late Development Review, the decision will be made to extend development by 2 months, or to maintain the current trajectory and release date. This decision will have to take into account staff and accounting, as well as the requirements of the Defence and Security Accelerator.

Potential Impact

For the development of RBVSS, our team will be working with King's College London and Falmouth University Launchpad. This joint partnership will have the benefit of the extensive history KCL holds with the Ministry of Defence in research and education, whilst also utilising Falmouth University Launchpad's practical development experience in game studios and software development. With these partnerships, the development of RBVSS will have access to some off the most experienced consultants and researchers in relevant fields. I am greatly excited to work with both of these organisations.

Once released RBVSS will make an immediate impact upon any theatre of war. The distribution of such vast amounts of preparatory information in a digestible and accessible way will considerably improve the decision making of combatants. The ability to test and simulate an infinite amount of scenarios with an infinite amount of equipment and personnel types makes it an important resource to any

potential user. The purpose of this simulator is different to most others currently in use: most virtual simulators used by militaries today focus on the training and improvement of tactics or strategies either by individuals or collective units, whereas RBVSS is designed to actively inform the user and to generate new and innovative solutions to problems faced on the battlefield.

This simulator, after extensive research, fills a gap in modern simulators. The new age of warfare has begun, discarding post-soviet military theories. RBVSS provides a cutting edge solution for predicting modern warfare strategies, whilst also allowing for irregular warfare including civilian populations. Once released the simulator will require only minimal resources to operate, needing a single device with sufficient computational power, which would likely cost the same as a consumer grade games console. This means RBVSS would be an initial short term investment, which would provide a product that is extremely cheap to maintain, whilst being widely diverse in its capabilities. Additionally, it will have the potential to make a vast return-on-investment via the release of a public consumer grade version into a demanding industry for a popular genre.

This project brings together three of the most cutting-edge and significant technologies for military and commercial applications:

1. Hardware such as LIDAR will only grow in importance for geographic applications across the globe. The capability to visualise and edit the information provided will prove vital for countless industries.
2. AI software is possibly the hottest tech topic across the globe at the moment. Its ability to replicate believable human movement and decision-making cannot be under-estimated in this project. Getting ahead of the curve on this topic will only benefit the Armed Forces in the future.
3. Finally, the data management of AI numbers and complexity. New methodologies for managing both will prove valuable for multiple industries, for example in the military (use of drone swarms), and in the commercial arena (video games handling vase quantities of data).

The contextual, developmental and functional research for this project have seamlessly blended together, creating a simulator that I am proud to have proposed. I truly believe that RBVSS's role as an informative tool (rather than just a training simulator, which can be outperformed by real world training) makes it so much more valuable for combatants, including for those who have plenty of experience and deep knowledge of the battlefield. RBVSS meets all the requirements of the competition, with minor appropriate compromises.

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