Game Engine Review

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ABSTRACT

There has been a significant amount of interest around the use of Commercial Off The Shelf products to support military training and education. This paper compares a number of current game engines available on the market and assesses them against potential military simulation criteria.

1.0 GAMES IN DEFENSE

> "A game is a system in which players engage in an artificial conflict, defined by rules, which result in a quantifiable outcome."

The use of games for defence simulation can be broadly split into two categories – the use of game technologies to provide an immersive and flexible military training system and a "serious game" that uses game design principles (such as narrative and scoring) to deliver education and training content in a novel way.

This talk and subsequent education notes focus on the use of game technologies, in particular game engines to support military training.

2.0 INTRODUCTION TO GAMES ENGINES

> "A games engine is a software suite designed to facilitate the production of computer games."

Developers use games engines to create games for games consoles, personal computers and growingly mobile devices.

Games engines provide a flexible and reusable development toolkit with all the core functionality required to produce a game quickly and efficiently. Multiple games can be produced from the same games engine, for example Counter Strike Source, Half Life 2 and Left 4 Dead 2 are all created using the Source engine. Equally once created, the game source code can with little, if any modification be abstracted for different gaming platforms such as a Playstation, Personal Computer or Wii.

On its own, a games engine is not capable of meeting any of the key requirements without development. Pre-existing games use variants of games engines to underpin the game, such as the Real Virtuality engine that is used to run the Bohemia Interactive game Virtual Battlespace 2 (VBS2). Without the game engine, the game would not function, but the engine itself is just one aspect of the overall VBS2 product.

3.0 MIDDLEWARE COMPONENTS

In most cases a games engine is made up of a number of interconnected elements. These can be categorized into individual middleware components which together create the full toolset. An example of the components of a game engine is shown below, taken form the Unreal game engine[1].

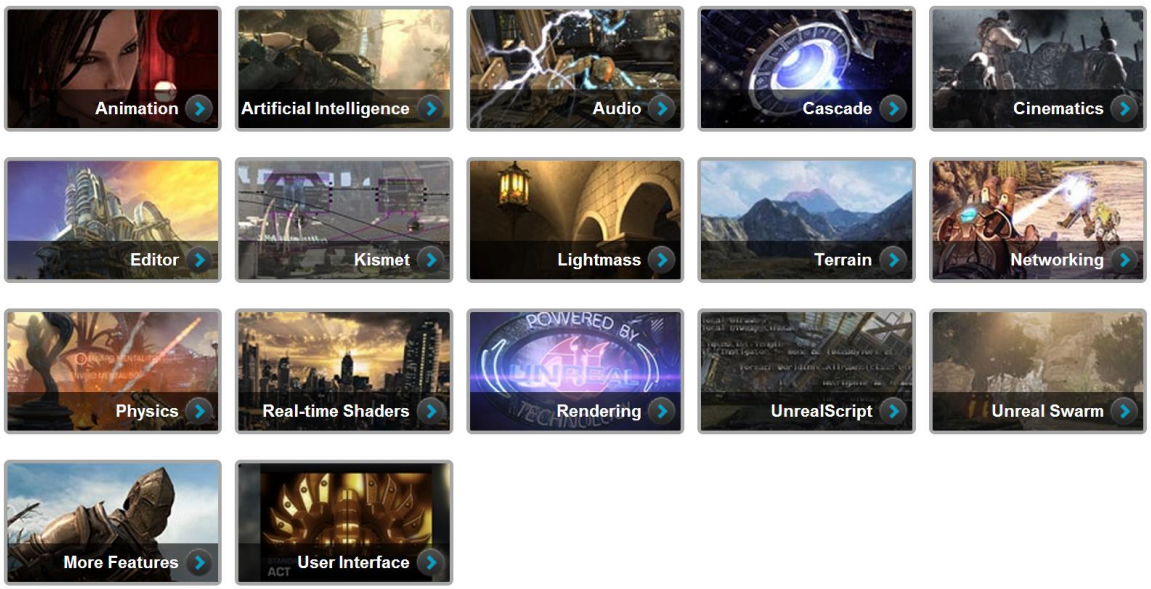

Figure 1: Unreal Game Engine Components

The components as described by the website include:

- Animation – "Make your world more vibrant and add more personality with detailed animations."
- Artificial Intelligence – "Use AI to bring your game world to life."
- Audio – "The Unreal Audio System."
- Cascade – "UnrealCascade, the visual particle effects system."
- Cinematics – "Unreal Engine provides mature tools for creating visually stunning in-game cinematics and cut scenes."
- Editor – "The Unreal Game Editor."
- Kismet – "Unreal Kismet, the visual scripting system."
- Lightmass – "Unreal Lightmass, an advanced global illumination solver."
- Terrain – "Terrain in Unreal Engine is easy to edit and alter to create compelling levels and worlds."
- Networking – "Unreal Engine currently offers full LAN and direct IP connectivity for online game networking."
- Physics – "Unreal Engine physics engine, powered by NVIDIA's PhysX."
- Real-time shaders – "Experience a powerful visual interface comparable to the non-real time functionality of XSI and Maya."

[1] www.unrealengine.com/en/features/

- Rendering – "Unreal Engine brings you Gemini, the multi-threaded rendering system."
- Unreal Script – "Unreal script is a simple, high-level language that gives complete scripting control."
- Unreal Swarm – "Take advantage of Unreal Engine's multi-core support with Unreal Swarm, a distributed computing system."

Each of the engines considered as part of this review includes either dedicated middleware components or supports the integration of third party commercial components. The definition of these components and how they inter-relate is part of what makes each games engine unique. Some engines focus more heavily on the physics representation, while other are more directed towards 3D visuals.

4.0 LICENSING OF GAMES ENGINES

Games engines and other middleware are licensed in a variety of ways, depending on the business model of the owning companies. They can be open source or proprietary, each of which is subject to copyright, licensing and pricing conditions for personal and business use.

Business licenses may vary according to the turnover of the organisation applying for the licence, for instance an academic institute may be able to access a licence at a lower cost than a large corporation. There may also be additional conditions which must be met before a user is eligible to procure a licence. For example before being granted a licence for middleware designed to abstract to platforms such as the iPhone, iPad, iPod, or Wii, the licensee is required to be an official developer of games for those platforms.

Defence needs for licenses might be very different from the original intent of the commercial provider, in particular defence often wants full rights to any software that it purchases or helps develop to prevent vendor lock-in. Some commercial licenses forbid the use of the technology in a military domain, a good example of this is the Nintendo Wii which has an exclusion in the end-user licensing agreement for use in the military.

5.0 ASSESSING GAME ENGINES

Military capability areas can be split into the three main operational domains Air, Land and Maritime, each of which has their own specific demands on a games engine. The joint space, where one or more of these domains is required to integrate and work together offers additional unique challenges, encompassing as it does the demands of each of the domains as well as a requirement for integration of these demands.

For the purposes of this review it was decided to focus on the individual operational domains of Air, Land and Maritime, as any joint use would need to consider suitability for these domains in the first instance and then identify how these could be integrated and used together.

There are several core requirements that all operational domains will require, these allow a comparative review to be undertaken. These are:

- Accurate Ballistics
- Weather Representation
- Visual Effects (Glare, Reflection, Shadows, Lighting, etc.)
- Accurate Physics Representation
- Size of terrain area

6.0 GAME ENGINE REVIEW

The review process was based on the subjective merits of the selected engines, as considered by the review team, with a focus on their technical attributes. A more detailed study would require the development of example demonstrators using the games engines to better understand their applicability to meet the military need.

The engines chosen for comparison, listed in the following section, were considered as representing the best of their class or offering something unique that made them attractive for simulating military systems. Each engine was then compared against a selection of metrics, listed in a later section along with their significance, which allowed a level of judgement to be made with regard to their capabilities.

Beyond comparisons of the games engines, there is brief overview of some of the middleware components such as physics engines that are often included in games engines or games products. The technical details of each game engine are listed, along with their unique attributes and a subjective analysis of their potential capability of simulating in the three operational domains: Land, Air and Maritime.

The final section of the document advises how defence could benefit from the application of games technology in the future.

7.0 GAMES ENGINES CONSIDERED

A subset of available games engines were selected for comparison, providing a good cross-section of available technologies and game programming trends. In addition, only those engines that are capable of producing the level of graphical detail in line with current games industry trends were considered.

The games engines considered were:

- Leadwerks
- CryEngine 3
- Unigine
- UDK (Unreal Development Kit)
- Unity
- Outerra

8.0 ENGINE METRICS

The metrics listed below were used to compare the games engines; each was scored as either YES supported or NO not supported. In the case of Outerra a number of elements were not applicable (N/A) due to the nature of the engine. While this approach has allowed comparison between the games engines, it must be noted that it is inherently difficult to compare the potential of games engines, as much is dependent on the amount of development time spent on them.

Metrics considered:

- Full Dynamic Shadows - The Engine is capable of producing real-time shadows from objects without explicit coding
- Dynamic Lighting - The Lighting changes dynamically dependent on scene materials without explicit coding

- Real time Global Illumination - Light bouncing, specular effects and colour bleeding are achieved in real time
- 3D Audio - 3D sound is integrated into the engine and not required to be explicitly coded
- Standard Development Language - Use of standardised development languages reduce development time and cost
- Real time Scripting - The ability to affect the engine in real time without the need to recompile code
- Source Code Included - The license includes access to all engine source code
- Physics - Physics is an integral part of the engine rather than a module that will need integration
- Real time Editor - The ability to edit the 3D environment in real time, i.e. add and remove objects
- Multi-Platform (PC and Console) - The ability of the engine to output to more than one platform
- Networking - The engine includes standardised networking tools to assist multiplayer development
- Community Support - The engine has a significant user community with support from the developers
- Standard Model Format - The engine can support standard 3D model formats allowing reuse of models

9.0 RESULTS

These results are taken from a UK study conducted in 2010 and give an indication of the capabilities of the reviewed engines. Licensing costs are approximate and taken from open source information.

9.1 Leadwerks

An extremely capable engine that uses a variety of modern graphical engine techniques to output products comparable with current PC games with low licensing costs and a large community following.

Features include:

- Real-time unified lighting with soft shadows.
- Point, spot, and directional lights.
- Normal, parallax, and parallax occlusion mapping.
- Instanced rendering.
- Dynamic visibility determination with hierarchal occlusion culling.
- Displacement mapped terrain with support for up to 33 million polygons
- Seamless transitions between indoor and outdoor areas
- Support for Collada and Autodesk FBX files.
- Animated characters with hardware skinning
- Fast and stable physics simulator.
- Advanced shader effects including volumetric light scattering

Category	Supported as Standard	Comments
Full Dynamic Shadows	YES	
Dynamic Lighting	YES	Additional advanced light available via pureLIGHT plugin
Real time Global Illumination	NO	
3D Audio	YES	
Standard Development Language	YES	C, C++, C#
Real time Scripting	YES	LUA industry standard scripting language
Source Code Included	NO	
Physics	YES	Newton Game Dynamics
Real time Editor	YES	
Multi-Platform (PC and Console)	NO	PC only
Networking	YES	
Community Support	YES	
Standard Model Format	YES	FBX and Collada

Air*	Good examples of general air applications. No fast air capability evident although the engine is theoretically capable.
Land*	Good examples of detailed terrains including foliage.
Maritime*	Some examples of Leadwerks water simulation.
Licensing	$249.95 single user license

Figure 2: Leadwerks Features

9.2 Cryengine 3

CryEngine 3 is widely regarded as the most advanced games engine currently available. It is capable of photo-realistic graphics widely regarded as the best in class across PC and console platforms.

Features include:

- Simultaneous sandbox editor on all platforms
- Integrated vegetation and terrain cover generation
- Road and river tools
- Highly realistic visual effects
- Real time dynamic global illumination
- Artificial Intelligence (AI) editing system
- Streaming environments
- Integrated multi-threaded physics engine
- Ray tracing
- Character animation system

Category	Supported as Standard	Comments
Full Dynamic Shadows	YES	
Dynamic Lighting	YES	
Real time Global Illumination	YES	
3D Audio	YES	
Standard Development Language	YES	
Real time Scripting	YES	LUA as well as a visual scripting system
Source Code Included	YES	
Physics	YES	
Real time Editor	YES	
Multi-Platform (PC and Console)	YES	PC, XBOX, PS3
Networking	YES	
Community Support	YES	
Standard Model Format	YES	

Air*	Limited examples of general air applications. Engine is theoretically capable of highly detailed air simulation.
Land*	Photo-realistic examples of detailed terrains including foliage. Well suited for driver training.
Maritime*	Extremely realistic water effects but limited examples of sea.
Licensing	€500,000

Figure 3: CryEngine 3 Features

9.3 Unigine

Unigine™ is a cross-platform real-time 3D engine containing photorealistic 3D render. The engine supports all modern graphical techniques and is well regarded by the developer community.

Features include:

- Multiple Application Programme Interface (API) render
- Powerful C++ API
- Comprehensive performance profiling system
- Flexible XML-based data structures
- Photorealistic Graphics
- Dynamic data streaming allowing limitless terrain sizes
- Integrated Graphical User Interface (GUI) design tools
- Ready to Use Objects
- Easy-to-Use Tools, including:
    - Export/import plugins for 3ds Max, Maya and Softimage
    - Fast mesh/animation viewer
    - Terrain editor

Category	Supported as Standard	Comments
Full Dynamic Shadows	YES	
Dynamic Lighting	YES	
Real time Global Illumination	YES	
3D Audio	YES	
Standard Development Language	YES	
Real time Scripting	YES	UnigineScript language similar to C++ syntax
Source Code Included	YES	Only with full license
Physics	YES	Unigine custom physics engine
Real time Editor	YES	
Multi-Platform (PC and Console)	YES	PC, Linux, PS3
Networking	YES	
Community Support	YES	
Standard Model Format	YES	
Air*	Limited evidence of being currently in use for flight simulation. Theoretically capable of high detail Air simulation.	
Land*	Photo-realistic examples of detailed terrains including foliage. Well suited for driving training.	
Maritime*	Extremely realistic examples of water and sea states.	
Licensing	$100,000 unlimited projects	

Figure 4: Unigine Features

9.4 Unreal Development Kit (UDK)

UDK is a highly mature engine now in its third iteration with work currently ongoing on the fourth. The engine is widely used in a number of the highest grossing games of all time. It is also the engine used to create the Americas Army serious game.

- Unreal Engine 3 offers a fully integrated editing environment through the renowned Unreal Editor
- Multi-threaded rendering system, Gemini, gives 64-bit High Dynamic Range (HDR) rendering pipeline
- UnrealScript scripting language, high-level programming language that gives complete scripting control
- Ambient occlusion, per-pixel lighting, fill lighting and fully dynamic specular lighting and reflections are all possible
- Artist-driven terrain system lets you place and customize vegetation, structures and countless points of interest throughout your game world
- Fracture tool makes it possible to create remarkably interactive, deformable worlds. Easily craft all types of destructible environments and objects that break apart just as you would expect them to in real life
- UDK supports the automatic creation and use of navigation meshes, giving AI-controlled characters increased spatial awareness of their environment and the ability to make smarter movement decisions

Category	Supported as Standard	Comments
Full Dynamic Shadows	YES	
Dynamic Lighting	YES	
Real time Global Illumination	YES	
3D Audio	YES	
Standard Development Language	YES	
Real time Scripting	YES	UnrealScript language similar to C++ syntax
Source Code Included	NO	Only with full license
Physics	YES	PhysX physics engine integrated
Real time Editor	YES	GUI based drag and drop editor
Multi-Platform (PC and Console)	YES	PC, PS3, Xbox
Networking	YES	
Community Support	YES	Well established community
Standard Model Format	YES	
Air*	Limited evidence of being currently in use for flight simulation. Anecdotal evidence that it would not be well suited.	
Land*	Photo-realistic examples of detailed terrains including foliage.	
Maritime*	Extremely realistic examples of water with dynamic surface changes.	
Licensing	$2500 per seat	

Figure 5: UDK Features

9.5 Unity

Unity is a production focused engine with a great deal of emphasis put on the development tools and production path. The engine also specialises in supporting a wipe variety of mobile platforms, and supports lower end hardware requirements.

- Fully Integrated Editor – Simple, visual and intuitive, the Editor can do everything a published game can do.
- Highly scalable graphical fidelity
- Asset Import - Instantaneous, automatic importing of 3D models, animations, textures, scripts, or sounds from almost all 3D applications
- Texture Handling - Save your multi-layer Photoshop files normally and let Unity automatically compress your images with high quality DXT texture compression. It's all automatic without a single required click.
- One-Click Deployment – for a wide range of publishing platforms
- Scriptable Controllers - A simple, straightforward, fully-featured remote scripting class lets you read data from the Wii Remote™, Nunchuk™, and Classic Controller™ effortlessly.
- Terrains - Vast, densely foliaged landscapes work smoothly on low-end hardware, and they take up almost no disk space.
- Networking - Create real-time networked multiplayer functionality.
- Audio & Video - Mix real time 3D graphics with streamed audio and video

Category	Supported as Standard	Comments
Full Dynamic Shadows	NO	
Dynamic Lighting	NO	
Real time Global Illumination	NO	
3D Audio	YES	
Standard Development Language	NO	Unity uses a GUI approach all coding is via scripts
Real time Scripting	YES	C#, Javascript and a variation on Python
Source Code Included	NO	
Physics	YES	PhysX physics engine
Real time Editor	YES	
Multi-Platform (PC and Console)	YES	PC, MAC, Web, IOS (iphone, ipad etc), Android, Xbox, PS3, Wii
Networking	YES	
Community Support	YES	
Standard Model Format	YES	Industry standard formats supported
Air*	Limited evidence of being currently in use for flight simulation. Theoretically capable of some level of flight simulation.	
Land*	Good quality examples	
Maritime*	Limited examples	
Licensing	$100,000 unlimited projects	

Figure 6: Unity Features

9.6 OUTERRA

Outerra is still in the early stages of development but represents a key fundamental change in engine technology which could suit simulation of all the military requirements. Outerra is a 3D planetary engine for seamless planet rendering from space down to the surface at 1cm resolution. It can use arbitrary resolution of elevation data, refining it to centimetre resolution using fractal algorithms.

- Realistic looking terrain using whole world elevation data
- Unlimited visibility, detail ranging from thousands of kilometres down to centimetres
- Real time atmospheric rendering
- Rendering of vast dense forests
- Seamless transition from space down to the planet surface
- Adaptive Levels Of Detail (LOD) with continuous transitions. Elevation data are pre-processed using special wavelet compression, the required level of detail is extracted effectively on the fly
- Partitioned compressed dataset can be downloaded progressively over the web
- Fractal refinement mimicking the natural processes (erosion, rocks, overhangs)
- Procedural texture generator combining mathematical models and climatic data
- Bitmap overlays for specific areas
- Dynamic shadows
- Stable frame rate system
- Supports arbitrary and varying resolution of elevation datasets, refined to centimetre resolution by fractal algorithms

- Embedded web browser allowing for direct web service integration
- Integrates a Flight Dynamics Model library for high fidelity simulation of aircraft, rockets

Category	Supported as Standard	Comments
Full Dynamic Shadows	YES	
Dynamic Lighting	YES	
Real time Global Illumination	N/A	
3D Audio	N/A	
Standard Development Language	N/A	
Real time Scripting	N/A	
Source Code Included	NO	
Physics	YES	Integrated physics engine and integration of dedicated flight model
Real time Editor	N/A	
Multi-Platform (PC and Console)	NO	PC
Networking	YES	
Community Support	YES	
Standard Model Format	YES	Collada
Air*	Although in early stages the is good evidence that the engine is suited to all air simulation. Well suited for Air/Fast Air.	
Land*	High quality examples of vehicle movement and high detail terrain. Well suited for driving training.	
Maritime*	No examples but planned to be included in the final product.	
Licensing	Due to the early stages of development there are no licensing details.	

Figure 7: Outerra Features

10.0 SUMMARY AND CONCLUSIONS

10.1 Engine Comparisons

The games industry is a highly competitive industry and, while there are differences between the games engines, there is much convergence leading to many similarities between the key characteristics of the engines compared. However there are still engines which stand out as being on the cutting edge of technology. The following details the three main areas of military operation and which games engines would be best suited to achieving their simulation.

10.2 Land

CryEngine 3 stands out as one of the most visually impressive engines on the market and, although comparatively expensive for an unlimited use license, it does provide all the commonly used middleware components as part of the engine. This engine stands out as a good candidate for land-based problems such as driver training with its photorealistic graphics and ability to produce highly cluttered environments such as jungle.

10.3 Air

A possible contender is Unigine, with its ability to stream terrain subjectively, for simulating air platforms. The difficulty with air simulation occurs when trying to simulate fast air assets because of the demands this puts on the engine to seamlessly stream data at high speeds. There is no evidence (for or against) that Unigine is capable of supporting this kind of simulation.

However, the most impressive engine in the comparison is the Outerra engine, which represents a revolutionary approach to the problems associated with air simulation. It has the capability to simulate the entire Earth with Geo-specific data, even for hypersonic flight simulation, making it ideal for fast air applications.

10.4 Maritime

The only evidence of significant maritime simulation was found to be done by the Unigine engine. However, all of the engines listed are capable of simulating maritime operations to some extent but do not have good examples because there is seemingly little demand for maritime-based games. Given the highly commercial nature of the games industry, if there is little demand the games will not get made. This does not mean the engines are not capable, but more specific testing will be required.

11.0 AREAS OF POTENTIAL EXPLOITATION

Technology in commercial games is constantly developing, and with the huge amounts of investment on-going, this trend will not stop in the foreseeable future. Games engines represent a way for defence to get the maximum benefit from this commercial investment.

None of the featured games engines have the potential to be rapidly introduced into the Military training arena. As has been previously described, games engines represent little more than a tool box which shortens development time of a final product. For most defence users, the games engine needs to be developed and implemented in a final product by a commercial organisation, which could then be procured for use.

There is the potential for defence to invest in the use of some engines, to improve current simulations or provide alternatives where there is a defence requirement. The reason the Outerra engine was included within this comparison, even though it is not commercially available at the moment, is because it represents the depth of gaming technology. Defence, although a small investor in comparison to commercial market forces, can still have a big impact on small development teams such as the developers of an engine like Outerra.

There are three main routes which defence could exploit games engines:

- Wait for complete packages to be released such as VBS2 and invest in modifications to adapt it to their needs;
- Make an initial investment in a commercial engine such as Leadwerks or CryEngine 3 and invest heavily in developing a simulation product from it;
- Find innovative products such as Outerra and invest in them early so they incorporate simulation standards such as DIS and HLA, and so that all previously purchased content can be integrated.

12.0 FINAL CONCLUSIONS

The graphical quality of simulations is becoming increasingly important as the ‘gaming generation’ form an ever higher percentage of recruits in to the military. All new recruits will have had varying degrees of exposure to computer games, with a large percentage owning one of the current top-range games consoles. This means that each recruit will have an expectation of how computer graphics should look. It is important that whatever games engine technologies are used, they are capable of similar visual quality to retain credibility with users.

Fundamentally, the simulation requirements of defence are achievable, but not necessarily all within the same engine. The use of VBS2 has exposed defence to what is achievable using games-based technology and has been used to simulate all of the military capability areas to differing degrees, highlighting some of the shortcomings of the engine. Despite these, VBS2 still does a comparably good job at simulating all three of the military operational domains.

If defence were to adopt any of the reviewed engines, there would be a significant element of effort required to generate content for the eventual simulation product. This level of effort can be mitigated by deals such as that negotiated with Bohemia Interactive Simulations, giving defence ownership of content produced for VBS2. This approach will allow defence to transfer VBS2 content to any other engine, reducing replication of work. This kind of deal should be pursued where possible when 3D content is generated for defence.

Defence has an opportunity to carefully shape its future simulation requirements. The process of defining future simulation requirements will allow a more focused approach to evaluating games technologies. A more tightly defined set of requirements will make approaching commercial games companies a much simpler process for future assessments