White Paper: VBS2

Release Version 2.0

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Table of Contents

Classification

Revision History

Date	Reason For Changes	Version
07/07/09	Initial release	1.0
09/07/09	Added para 3.2.2.3 Aircraft	1.1
13/07/09	Minor text changes	1.2
31/08/09	Minor modification to VBS2 introduction, added link to Visitor 4 handout on page 34	1.3
13/01/10	Added section on IED capability in VBS2	1.4
24/01/10	Numerous text edits, updated release dates of VBS2FAC and VBS2Fusion 2.0	1.5
02/02/10	Added VBS2 IG++ to development roadmap	1.6
08/08/10	Corrected URLs to point to bisimulations.com	1.7
27/08/10	Added information on non-military use of VBS2 to history, added information about RV3, modified formatting, added additional information on VBS2Fires and VBS2Fusion	1.8
20/09/10	Removed reference to BI Past Performance document	1.9
16/12/11	Added para 3.2.2.9 VBS2 Tank Gunnery Added para 3.3.2 VBS2Strike Added para 3.1.1 VBS2 v2.0 Added information to roadmap VBS2 1.6 & 2.0 Minor Modification to VBS2Fires Added information 2.3 - Bohemia Interactive Simulations (UK) Added para 3.2.6.4 VBS Developer Network	2.0

	Added para 3.3.5 VB-Edit Added para 3.3.6 VBS2 Behavior Modeling Console Added para 3.2.2.10 Maritime Enhancements Numerous minor text edits in regards to updates Various Image updates and additions	

1. Executive Summary

The paper firstly introduces the Bohemia Interactive Group, and provides a detailed history of both Bohemia Interactive and the VBS2 product. This section describes how the first computer game released by Bohemia Interactive – Operation Flashpoint – formed the basis of numerous "serious games" including DARWARS Ambush! and VBS1. The chain of events that lead to the development of VBS2 is also covered; the primary event being the ADF enterprise license purchase of 2006. The first section concludes by presenting five key enablers for the success of VBS2.

The second and final section of this paper provides a high-level technology roadmap that describes the features of past, present and future Bohemia Interactive products. It also contains a detailed description of the capabilities of VBS2 v1.60.

2. The History of VBS

The Bohemia Interactive (BI) Group consists of a number of privately owned software development companies based in the United States, Australia and the Czech Republic. Until the release of VBS1 in 2004, the primary focus of Bohemia Interactive was the development of computer games for entertainment. Czech-based Bohemia Interactive Studio (BIS) released Operation Flashpoint (OFP) in 2001, a landmark title that was the first to allow players to explore massive, geo-typical virtual environments. In OFP, players were free to use any means at their disposal to defeat the virtual enemy, including attacking from any direction, and using a wide range of vehicles and aircraft.

Operation Flashpoint is the basis of the military training application DARWARS Ambush! developed by US-based BBN Technologies in 2004. DARWARS Ambush! aimed to provide a flexible training environment for soldiers to learn important lessons regarding both mounted and dismounted operations in conflict zones such as Iraq and Afghanistan. DARWARS Ambush! is widely considered a great success and this positive outcome was only possible due to the flexibility and extendibility of the OFP game engine.

2.1 VBS1

The Australian branch of Bohemia Interactive, Bohemia Interactive Australia (BIA), was formed in 2001 with the mandate to develop "serious games" based on the Operation Flashpoint game engine, for use as simulation platforms outside the entertainment sector of the commercial market. BIA released VBS1 in 2004, and delivered to the United States Marine Corps (USMC) who used the product in a similar manner to the way the US Army was using DARWARS Ambush!.

VBS1 was a successful game-based 3D virtual environment tailored for "serious" usage, suited for training and education in multiple domains, despite serious limitations. VBS1 mission editing and after-action review (AAR) features were limited, it did not support real-world terrain import, and it wasn't HLA or DIS compliant.

From as early as 2004, the US Army and the USMC have used Bohemia Interactive's original game engine as the basis for their desktop tactical training simulation.

Despite the early success of VBS1 in the USMC, it was Australian Defence Force (ADF) funding that enabled VBS to succeed as a training tool. The ADF was first exposed to the potential of VBS "serious game" technology during the Headline Experiment in 2003, when an early version of VBS1 was used to analyse the effectiveness of various sized Infantry Section structures (the Virtual Infantry Section Experiment[1]).

In 2005, the Australian Defence Simulation Office (ADSO) funded a range of improvements in VBS1 to make the product more suitable for mission rehearsal and training, as part of Mission Rehearsal Exercises (MRE) for deployments to Iraq. At this time, the AAR system was improved, the Instructor Interface was developed, and HLA/DIS compliance was implemented over a 12 month period of development. The majority of this development was sponsored by ADSO through a Deed of Standing Offer for the provision of Software and Software Support Services.

ADSO also contracted Bohemia Interactive to develop a VBS1-based military history training product titled 'Australians in Vietnam', designed to teach soldiers, sailors and airmen about the Battles of Long Tan and Coral. The end product was highly successful: a stand-alone computer game tailored for education.

2.2 Aircrewman Virtual Reality Simulator

In 2006, Bohemia Interactive was selected by the ADF to develop six Aircrewman Virtual Reality Simulators (AVRS), which combined VBS1 simulation technology with the latest in Virtual Reality tracking and display systems. Over a 12-month period of development, Bohemia Interactive developed and delivered a system that is arguably the most successful simulation project in ADF Army Simulation Wing history: an affordable turnkey solution for

aircrewman training delivered both on time and budget. This development is notable because it highlights the capability of Bohemia Interactive to provide turnkey simulator solutions in addition to commercial off-the-shelf (COTS) software development services.

2.3 VBS2

BIA began developing VBS2 after the ADF purchased an enterprise license of VBS1 in 2005. Building on three years of feedback regarding VBS1, VBS2 represents a powerful "serious game" platform that is now the worldwide benchmark for desktop-based simulation, particularly in the areas of tactical training and mission rehearsal.

Many requirements for VBS2 were derived from ADF experience with VBS1 during mission rehearsal exercises conducted in 2005. For example, the requirement for geo-specific terrain was paramount, but it took over six months to develop the city of As Samawah in VBS1. In contrast, it took only a few hours to generate the same terrain in the armor simulation 'Steel Beasts', because it supported VMAP (shape data) import. The need for run-time authoring became obvious due to time constraints during MREs: only a short amount of time was available for simulated training, and offline scenario editing would cost valuable minutes (bringing down the network session, modifying the scenario and restarting the network session). This need for rapid scenario modification resulted in the requirement for the VBS2 Real Time Editor (RTE). In addition, a robust AAR capability was important to allow the instructors to reinforce learning points.

VBS2 development commenced in December 2006 and was largely completed after 18 months. During development, Bohemia Interactive partnered with Calytrix Technologies to develop the VBS2 HLA/DIS gateway. In 2007, a second Czech-based development team was established to focus on improving the VBS2 Development Suite to support real-world terrain import.

In 2006, the USMC purchased an enterprise license of VBS1, with an upgrade to VBS2 upon release. Following initial delivery of VBS2 in 2007, they funded a range of enhancements that resulted in the development of the VBS2 Virtual Training Kit (VTK). Notably, the USMC did not provide any data for the VBS2 VTK development: Bohemia Interactive relied instead on publically available reference information for all aspects, thereby enabling the full VTK functionality to be incorporated in to the standard VBS2 product for use by all civilian and military licensees of VBS2. The USMC was then

provided with full access to VBS2 configuration files and unencrypted models to allow them to incorporate classified or export controlled data as required.

This flexible development model has proven very successful: it allows Bohemia Interactive to conduct independent research and development from a relatively generic requirement, and allows the customer to configure settings to suit their domain, be it military or otherwise.

The VBS2 VTK was delivered to the USMC on time and budget in June 2008, and rolled out later that year to all USMC simulation centers and on all DVTE laptops. VBS2 quickly became the simulation of choice for USMC mission rehearsal and tactical training up to the combat team level.

While the ADF and USMC have been central to the success of VBS2, enterprise licenses have also been purchased by the United Kingdom Ministry of Defence (UK MoD), the US Army and the Canadian Forces. In all cases, Bohemia Interactive has modified the VBS2 product to suit the requirements of these organizations, while still maintaining a common international baseline. VBS2 is also in daily use by NATO and many countries across Europe. Bohemia Interactive has also made improvements to suit non-military clients in the first response and mining industries.

VBS2 has become a defacto simulation standard, and a market is rapidly forming as industry begins to employ VBS2 for research and development. VBS2 includes development tools, an Application Programming Interface (API) and a scripting language in every release. The VBS2 International User Group meets bi-annually and VBS2 is a key component of upcoming joint simulation exercises.

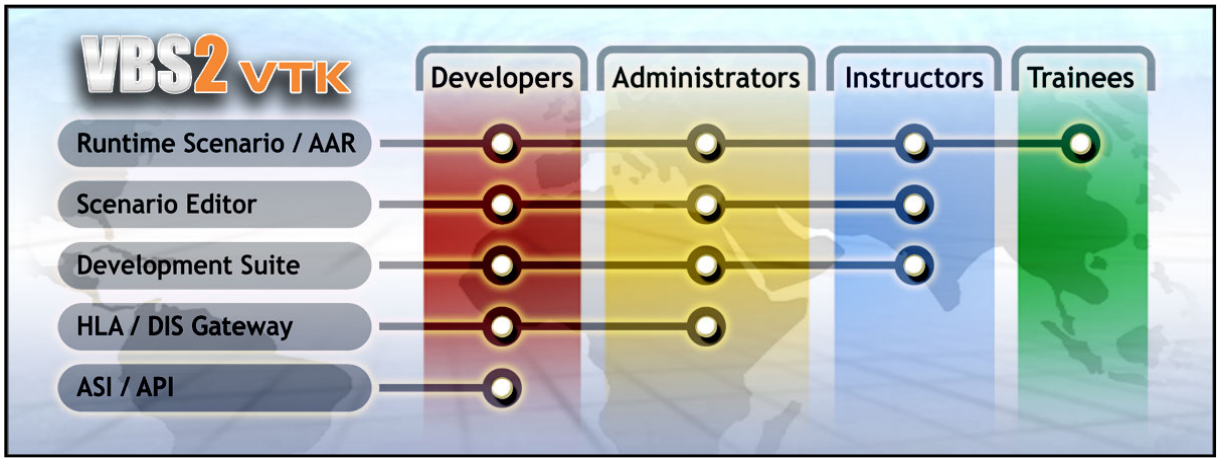

Image 1: The VBS2 "Open Platform" and typical users

The core of VBS2 development is coordinated by Czech-based Bohemia Interactive Simulations (BISim), consisting of approximately 90+ full time and contracted staff, the majority of whom are highly experienced software developers. Bohemia Interactive Studio (BIS), also located in the Czech Republic, maintains the core simulation engine (upon which VBS2 is based) and continues to regularly release mainstream computer game titles. Bohemia Interactive Australia (BIA), sister company of BISim, remains the primary point of sale for Bohemia Interactive's simulation products and contracts directly to numerous government agencies worldwide including the USMC. Bohemia Interactive Simulations LLC (BISim US) in Orlando, Florida is the point of sale for VBS2 licenses and development work in the United States. Finally, a new member of the Bohemia Interactive Group has recently been established in Farnborough UK as the point of sale for VBS2 licenses and development work in the United Kingdom. Bohemia Interactive Simulations (UK) is growing quickly, aiming to provide a significant, stand-alone VBS2 development capability, and support to the UK MOD.

2.3.1 VBS2 in non-military domains

VBS2 is not designed solely for military use. In addition to developing and supporting the VBS series for military training and mission rehearsal, Bohemia Interactive has experience in developing applications outside the military training domain, using the baseline VBS2 product. Bohemia Interactive supplied VBS2 for Project Canary[2], a game-based training product that instructs on occupational health and safety for the Australian mining sector. In addition to VBS2 software, Bohemia Interactive provided support and on-site training for the software developer.

Bohemia Interactive also developed the VBS2-based Virtual Responder Trainer, a version tailored for first responders. This product simulated events such as fires and floods and including police, ambulance and fire-fighting vehicles.

2.4 Real Virtuality 3

While BISim has been focusing on the VBS series, the game developer BIS has continued to improve the Real Virtuality

[2] http://www.projectcanary.com

engine for the entertainment market. Real Virtuality 3 is the result – a state-of-the-art game engine that is recognised worldwide as a leading next-generation software platform for first-person simulation. Real Virtuality 3 is the game engine behind the highly successful ArmA2, released in 2009, and also ArmA2 Operation Arrowhead. The most obvious improvement is graphical fidelity – years of effort have been applied to making the virtual environment as visually realistic as possible – but in addition to amazing graphics, the new engine has many other improvements including animation enhancements and multi-core support. Multi-core support enables the engine to be highly efficient, as simulation tasks are spread over multiple processor cores. Very efficient operation results from both AI and rendering being split up over multiple cores.

Bohemia Interactive has commenced development on VBS2 v2.0, based upon the Real Virtuality 3 (RV3) game engine. The game engine behind VBS2 v2.0 is four years more advanced than VBS2's RV2, and is due for a release in 2012.

Image 2: Screenshots from ArmA2: Operation Arrowhead, using Real Virtuality 3

2.5 Five Keys to the Success of VBS

To conclude the history of VBS, it is worthwhile examining the reasons why VBS2 has achieved remarkable success, especially considering its origins in the game industry, and that it was entirely developed in Australia and the Czech Republic – neither of which have been known as simulation development hubs.

1. Bohemia's long-term, evolutionary development methodology has produced a robust training tool, capable of easily incorporating new middleware.

The VBS2 development methodology can be best described as **evolutionary**, and this is the first factor in its success. Rapid prototyping has ensured that the product has evolved and improved at great speed, with each design decision aimed at facilitating future development. In addition, all of the different parts of the simulation engine – rendering, physics, artificial intelligence (AI), animations – have been built to work together from the start, as opposed to forcing off-the-shelf middleware products to interoperate. As we have shown, it is now relatively straightforward to incorporate new middleware into VBS2 because the wider framework is already in place and working well.

2. VBS2 is developed by an agile and responsive team, with a proven track record in delivering a reliable product.

Bohemia Interactive has developed a reputation for responsiveness, and for delivering and supporting a product that has always worked. Being the underdog in the simulation industry, and operating on a much smaller budget than US-based (and often government-funded) competitors, Bohemia is very agile and able to move quickly when patches and updates are required. Therefore, the second factor in the success of VBS2, is that it 'works as advertised'.

3. Bohemia aims to establish partnerships of mutual benefit by sharing development costs and delivering back to the user community the outcomes of this development.

Bohemia Interactive aims to meet government sponsors halfway – establishing partnerships whereby new capability is part-funded by customers and part-funded internally. For example, the USMC provides Bohemia Interactive with relatively broad statements of work, and Bohemia Interactive is

encouraged to come up with innovative solutions that meet both the needs of the USMC and further the product as a whole. A good example is the terrain tool Visitor 4: the USMC requirement could have been satisfied by patching an older application, but BI delivered a completely new tool that greatly exceeded the requirement and this has benefitted all VBS2 customers in whatever sector they are operating. Bohemia Interactive provides new capabilities to all members of the VBS2 International User Group at no extra cost, and this community-driven approach has enabled VBS2 to flourish.

4. VBS2 is an "Open Platform" where users are empowered to use development tools to create and modify content.

The fourth factor in the success of VBS2 is that it is an "Open Platform". Bohemia Interactive includes development tools for content creation (terrain, 3D models) and a fully functional API in every copy of VBS2. In addition, the VBS2 script language is extremely comprehensive (having evolved over a 13 year period) and enables almost any imaginable scenario to be created or any aspect of the simulation to be modified. Bohemia Interactive has scripted police chases, apartment fires, Harpoon missiles, UAV recovery mechanisms, radars, fast-roping and a multitude of other functions, and the USMC even scripted a complete call-for-fire capability with no assistance from the software developers. The success of VBS2 has proven that source code access is not required for a simulation to be successful. In fact, who better to manage the source code than the entity that developed it over a decade?

5. Game development is more art than science.

Finally, it has been acknowledged that game development is more art than science, and as such a large number of creative people from varying backgrounds have been involved in the development of VBS2. Many Bohemia Interactive employees have been sourced from the online Operation Flashpoint and Armed Assault communities. This has resulted in a unique development environment where the software developers not only truly believe in the potential of the simulation engine and the product, but have the vision, enthusiasm and dedication to make it succeed. This is certainly another key to the success of VBS2: it would have cost considerably more and taken much longer to complete the product had Bohemia Interactive staff not possessed such passion and drive. You can't buy a team like the one behind VBS2 – **it must be grown**.

3. Technology Overview

This section initially presents a high-level technology roadmap that extends from Bohemia Interactive's first release, Operation Flashpoint, through to the short term future. A detailed explanation of the current technical capabilities of the VBS2 product follows the technology roadmap.

3.1 Technology Roadmap

The following table describes the features of all major Bohemia Interactive "serious game" products since the release of Operation Flashpoint. Planned future releases are also included. Note that capabilities of planned future releases may change without notice.

Product	Key Features	Key Limitations
Operation Flashpoint - 2001	• Powerful 2D mission editor • 25km x 25km terrain areas • Freely available 3D model and terrain editing tools • Highly customizable, relatively easy to modify (mod) • Large online community and freely available add-ons (downloadable content) • Powerful scripting language included	• Maximum number of networked players was between 30 – 40 • No run-time authoring capability • No after-action review capability • Proprietary network protocol, no HLA/DIS compliance • Very difficult to create geo-specific terrain • Very little official documentation • EULA prohibits training use
DARWARS Ambush! - 2004 - Based on OFP - Developed by BBN	• Many US Army entities included • Several geo-typical Iraqi and Afghan terrain areas included • Voice-over-DIS capability (BBN Talk) • Crude external AAR capability • Very good documentation	• BBN did not have source code, and therefore scope of enhancements were limited • Ambush! was basically a simple 'mod' of OFP • AAR relied on a 'hack' and was very inefficient
Virtual Battlefield System 1 - 2004 - Based on OFP	• Many USMC entities included • Several geo-specific USMC training areas included • First in-game AAR was included • Basic call-for-fire capability	• The AAR could only support recording of 8 BLUEFOR entities
Virtual Battlespace 1 - 2005 - Based on OFP	• Greatly improved AAR, supporting 3D in-game replay • VBS1 'Instructor Interface' allowed run-time authoring • Included geo-typical As Samawah and Green Zone terrains • Included ADF, NZDF, USMC and US Army content • Later versions supported HLA/DIS via a	

	gateway • IED simulation capability	
Aircrewman Virtual Reality Simulator - 2007 - Based on VBS1, later VBS2	• Developed a new version of VBS1 with many visual enhancements to support training of helicopter aircrewman • Integrated Newton physics engine into VBS1 for realistic rope simulation and helicopter load carrying • Integrated theoretically correct RotorLib UH-60 flight model into VBS1 • Integrated VBS with Polhemus 6DOF tracking • Most AVRS capabilities were added to VBS2 at a later stage	
Virtual Battlespace 2 - 2007 - Based on Armed Assault[3]	• 3D and 2D mission editors • Highly capable in-game AAR • Full run-time authoring • Common user interface for mission editor, run-time authoring and AAR • Support for up to 256 networked players • Robust HLA/DIS gateway included • Supports rapid, real-world terrain generation • Streams objects and textures, allowing up to 200km x 200km terrains with up to 4 million objects	• Flat earth model • Does not support streaming terrain • 4 million object limit per terrain area
VBS2 Virtual Training Kit 1 - 2008 - Based on VBS2	• Theoretically correct thermal imaging model • In-game group, unit and weapon editing • Basic C2 functionality • Supports display of real-world topographic map on 2D map view • Destructible environment, deformable terrain • Application Scripting Interface (ASI) included (first VBS2 API)	
VBS2 Virtual Training Kit 2 - July 2009 - VBS2 v1.3 - Based on VTK1	• Includes Visitor 4, a brand new terrain import tool that understands geo-referencing, very easy to use • Includes face texture editor • CREW simulation, improved IEDs • Upgraded physics model, now supports PhysX by Nvidia • CASEVAC simulation • In-game customizable forms • UAV, UGV simulation • HLA/DIS gateway enhancements • VBS2Fusion available separately, allowing AI plug-ins such as Kynapse, AI Implant, etc	

[3] For more information on Armed Assault visit http://www.armedassault.com

VBS2Fires - November 2009 - US version June 2010 - Module - Requires VTK2	• An external VBS2 module • Provides highly realistic, validated, indirect call-for-fire simulation • Correct ballistics from gunline to impact • Includes terminal ballistics simulation • Seamless integration with VBS2 editors, AAR and scenarios • Supports all indirect assets (naval gunfire, self-propelled artillery, etc) • Developed to meet ADF, UK and US Call-For-Fire protocols	
VBS2 v1.4 - September 2010 - Based on VTK2	• Enhancements to support amphibious operations for USMC • Improved agility modeling • Support for limb amputation by script • Curved earth (implementation of horizon) • Render-to-texture support • Full rotation of objects in OME/RTE • Formation flying improvements • Includes VBS2Fusion 2.0 runtimes	
VBS2Strike - April 2011 - Module - Requires VTK2	• An external VBS2 module • Extends VBS2Fires to provide highly realistic close air support simulation • Supports both fixed and rotary wing assets, including UAVs • Seamless integration with VBS2 editors, AAR and scenarios	
VBS2 v1.50 - April 2011 - Based on VTK2	• Terrain rendering enhancements • Final USMC VTK2 items • Combat realism improvements • Import pipeline from 3D Studio Max • Move embedded terrain objects • Multi-optics support • Long view distances • Support for large objects • Underground objects • Editor tree improvements • Curved earth visualisation • Hovercraft simulation • Full rotation of editor objects	
VBS2 v1.60 - Jan 2012	• Support for MGRS and Lat/Long coords • Multi-channel support • Vehicle and building search • Improved amputations • Agility modelling • Improvements for higher fidelity gunnery simulation	

	• Improved IR laser visualization • Improved boat and ship physics • Support for logistics operations using forklifts and cranes • Alternate path-planning system to allow AI to move more freely on large objects	
VBS2 v2.0 - Summer 2012	• Real Virtuality 3 (RV3) engine based • Full terrain paging • Armored enhancements • Aviation enhancements • Realistic Underwater & Scuba Diving • Realistic Parachuting & Free-fall	

3.1.1 VBS2 v2.0 – the future of game-based training, mission rehearsal and IG

Bohemia Interactive has commenced development on VBS2 v2.0, based upon the Real Virtuality 3 (RV3) game engine. The game engine behind VBS2 v2.0 is four years more advanced than VBS2's RV2, and is used as the basis for both the highly successful ArmA2 and ArmA2: Arrowhead computer games. The engine alone is much improved, with significant enhancements in graphics, efficiency (through multi-core exploitation) and AI. VBS2 v2.0 will include all VBS2 capability, plus exciting new enhancements funded largely by the US Army. VBS2 v2.0 is presently scheduled for limited release to US customers in March 2012, and wider release in the summer of 2012. The most exciting engine enhancement in VBS2 V2.0 is the implementation of paging terrain. Paging terrain refers to loading terrain 'on-the-fly' from a data repository, such as a hard disk drive. This and other IG enhancements have been sponsored by the US Army, including:

- Larger terrain (up to 500km x 500km)
- Paging (streaming terrain)
- Increased view distance up to 40km
- Direct fire support from armored vehicles in support of an infantry maneuver
- Support for shape data overlays
- Scuba Diving
- Increased terrain detail and dynamic grid
- Fixed-frame support
- Multi-core support
- Particle effect improvements
- Micro AI
- Parallax Mapping
- Parachuting

The goal of both Bohemia Interactive and the US Army is to enable VBS2 v2.0 to support massive terrain areas at high resolution, thereby solving terrain correlation issues and providing a game-based simulation capability more suitable for mission rehearsal.

3.2 VBS2 Capabilities

This section presents the current capabilities of VBS2; that is, the capabilities that exist in VBS2 VTK2 v1.60. All of the capabilities presented in this section are included in the standard VBS2 product. The following section, VBS2 Modules, describes additional capabilities that are available through add-on modules.

3.2.1 Architecture Overview

The VBS2 simulation architecture is similar to most modern computer games; however, it has been developed from the ground up over a thirteen year period and offers numerous features that most other game engines do not. The core simulation engine handles all aspects from rendering through to physics and AI calculations, and is designed to run on a single desktop PC. The VBS2 product itself is very modular in nature, and highly configurable through text-based configuration files that describe all aspects of the application, from the look and feel of user interfaces through to sound effects and AI behaviour. Content (3D models and terrain) are loaded by the simulation engine during runtime to provide highly realistic, large-scale and heavily populated virtual environments.

3.2.1.1 Virtual Environment

The VBS2 simulation engine real-time renders large, high-fidelity terrain areas with an emphasis on accurately simulating the real world. Features of the simulated environment include:

- Variable wind that affects particles such as smoke, and weather effects including rain, fog and snow
- Definition of different surface types that affect vehicle speed and the sound of movement on the surface types
- Definition of environmental sounds for different areas, such as wind at high altitudes or birds
- Variable sea states and waves on beaches
- Accurate day and night shadow and lighting effects (including rendering shadows on 3D objects)
- Simulates diurnal rotation of the earth for correct day/night cycles

- Tides based upon latitude and longitude of a terrain area
- Accurate star field (it is possible to navigate by the stars in VBS2)
- Dynamic range lighting effects (simulates dilation of the pupil when moving from a well lit area to a dark area and visa versa)
- Ground clutter for realistic grass, rocks and other ground cover
- Ambient life simulation including insects, birds and small animals

Image 3: Day-afternoon-dusk cycle in VBS2

Image 4: Weather in VBS2

The VBS2 virtual environment is highly dynamic; terrain will deform as a result of explosions, and explosions will also crater the terrain. Both deformation and craters are sized dynamically depending on the strength of the explosion. All VBS2 objects have a destruction model, meaning that buildings and vegetation may be destroyed by explosions. VBS2 does not use 'block' forests seen in typical military simulation: in VBS2, forests are made up of hundreds of thousands of individual trees. Therefore, armored vehicles can drive through forested areas and run over trees and other small objects (such as

fences) in a realistic fashion. Some buildings also have destructible walls, doors and windows, allowing weapon platforms to 'punch through' certain walls to create new entry points.

3.2.2 Run-Time Scenario (Game-Play)

VBS2 is an entity-level 'first-person' simulation, with the lowest entity level being that of a simulated human character. Within VBS2, character entities operate as infantry, drive vehicles, fly aircraft or operate other weapon platforms. Great attention to detail has been paid to realism: an M1 tank will have four character entities as crew, operating the same stations in the tank as in the real world (driver, loader, gunner, commander). Character entities can either be AI or human controlled, and can operate either personal or vehicle-mounted weapon systems. Character entities can be wounded[4] or killed, and the wounding model is quite realistic when compared to other games: a hit from one round will incapacitate or kill, depending on where on the simulated body the round hits.

In a VBS2 scenario, every human participant will have their own character entity which they must control. This provides for a very immersive training experience. Unlike in constructive simulation, where the representation of the battlespace can be quite abstract, VBS2 participants are *in* the virtual world, and if their character entity dies then they are essentially removed from the session. As will be further described, the concept of 'chain of command' does exist in VBS2 but at all times every character entity within an organization (squad, platoon, etc) will be simulated to a high degree of fidelity. Character entities can perform the following actions within VBS2 (not an all-inclusive list):

- Walk or run in any direction
- Move sideways (strafe)
- Kneel, or move at a crouch
- Lie down, or move at a crawl (slow or fast)
- Operate personal weapons systems such as a rifle, grenade or rocket launcher
- Operate personal equipment such as a compass, CREW device or binoculars
- Place IEDs or other explosives, and detonate explosives
- Breach walls or break windows
- Drag units, or carry stretchers
- Carry and deploy equipment such as wire, traffic cones, spike strips, and load/unload such equipment from vehicles
- Operate UAV or UGV control stations

[4] Medical Capabilities in VBS2:
http://distribution.bisimulations.com/docs/VBS2_Medical_Discussion_Paper.pdf

- Interact with vehicles, such as opening doors or trunks
- Open doors of buildings and move through buildings
- Operate sensors such as thermal cameras
- Operate fixed weapon platforms such as static machine guns
- Enter and drive vehicles (both land and sea)
- Enter and fly aircraft

Image 5: A VBS2 character entity dragging another

3.2.2.1 Vehicle Simulation

VBS2 inherently supports simulation of land, sea and air vehicles. Any land vehicle can be simulated including motorbikes, wheeled cars and trucks, eight-wheeled APCs, and tracked vehicles. Small and large boat simulation is included, and fixed and rotary wing aircraft.

VBS2 ships with a massive number of character and vehicle types. Almost the entire US Army, the USMC, the US Special Forces, the ADF and the UK MoD vehicle and aircraft fleets are included –

over 400 unique 3D models in total, each simulated to the aforementioned level of detail. A wide range of Russian, Iraqi insurgent and Taliban OPFOR entities are also included, as well as civilian models.

A full listing of VBS2 content can be viewed at http://resources.bisimulations.com/content.

This wide range of vehicle types allows VBS2 to simulate combined arms, and allows training and mission rehearsal possibilities that were previously not feasible in first-person military simulation. Example VBS2 scenarios include (not a comprehensive list):

- Aircraft insertion or extraction
- Fast-roping from helicopter
- Static line parachute or HALO insertion
- Direct fire support from armored vehicles in support of an infantry maneuver
- Convoy ambush using heavy weapons, such as Javelin launchers
- Realistic CASEVAC
- Indirect fire support from howitzer, self-propelled artillery, mortars, naval gunfire or MLRS
- Close air support from rotary or fixed wing aircraft, with support for lasing targets
- Small boat insertion from ships
- Logistics support, such as airdrops of ammunition or medical supplies

Bohemia Interactive can provide example scenarios or video of any of the above.

3.2.2.2 Configuration Settings

All entities within VBS2 are highly configurable through text-based configuration files, with a wide range of modifiable parameters available.

For vehicles, configurable settings range from speed and turning radius through to flight envelopes for aircraft. Vehicles may have multiple turrets, and turrets on turrets (eg machine guns mounted on a tank turret). Weapon platforms are correct to the simulated character entity or vehicle: for example, infantry soldiers may be equipped with a personal weapon system with a certain caliber of round with tracer, and the amount of tracer can be easily configured. Character entities may be equipped with grenades of different types (HE, flashbang, or smoke), or a grenade launcher (single shot or automatic), or a rifle with an underslung grenade launcher. Vehicles are also configured to have realistic load-outs: for example, the main gun on an M1 tank might be equipped with sabot, HEAT or APERS, in addition to a co-axial machine gun.

Bohemia Interactive developers have been careful to ensure that weapon and ammunition types are configured to closely match real-world performance. Muzzle velocity and air friction are configured to match real-world ballistic curves, and round damage and penetration values are all meticulously researched and defined. AI engagement ranges are defined on a per-weapon basis, as well as the priority for AI targeting (eg a tank will be more interested in engaging other tanks or dangerous aircraft before infantry). This level of attention to detail has resulted in an overall simulation of combat that is regarded by customers as very realistic.

3.2.2.3 Improvised Explosive Device (IED) Simulation

IEDs are a leading cause of killed and wounded in current combat operations, and therefore VBS2 simulates a wide variety of these devices for training purposes. VBS2 includes a large number of different types of IEDs from Vehicle Born (VBIED) and Personnel Born (PBIED) through to roadside bombs and even soda cans packed with explosive. Example IEDs are shown in Image 6 below.

Image 6: Improvised explosive devices in VBS2

In VBS2, IED objects have properties that allow them to operate automatically, link to triggers (in-game events), or be detonated by command (eg a radio command). IEDs can be set to kill, wound or

'do no damage'. IEDs set to operate automatically will explode when entities of a certain side approach within a certain distance: for example, when BLUEFOR forces approach within 20m of the device. IED properties are defined in the IED 'editor object', as shown in Image 7 below.

Such flexibility provides the scenario author with many options for employing virtual IEDs in order to meet training objectives.

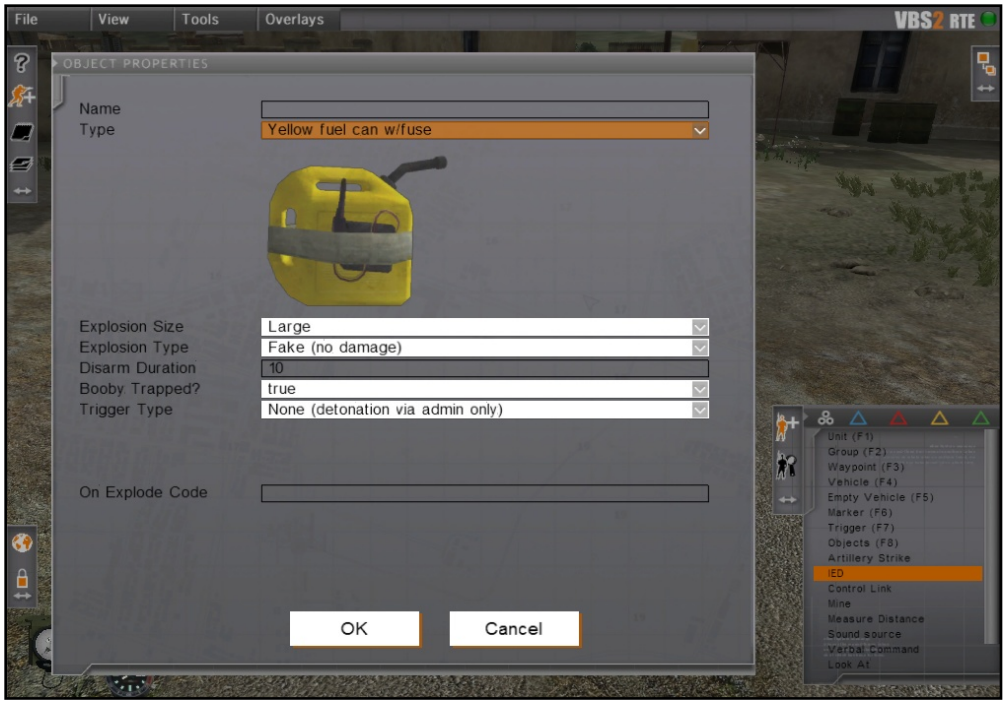

Image 7: IED properties

VBS2 supports the ability to counter IEDs with the use of bomb dogs, Explosive Ordnance Disposal (EOD) technicians, and Counter Radio Controlled Improvised Explosive Device Electronic Warfare (CREW) devices. Bomb dogs will alert their handler if they detect explosives near them by sitting and barking while facing the explosive. The EOD technician entity has the special ability to disarm IEDs if the given IED objects are able to be disarmed.

Image 8: EOD technician

CREW devices, both mounted and dismounted versions, work

as they do in the real world by jamming radio controlled IEDs when the CREW device is within range of a radio controlled IED. Line of Sight (LOS) also affects the range of CREW devices, due to simulated radio interference from objects in the environment (such as buildings).

The operation and performance of CREW devices is also shown in the AAR. Image 9 shows CREW performance as

displayed in the AAR, with a range circle visible in both the 2D and 3D views.

Image 9: CREW device LOS shown in the VBS2 After Action Review (AAR)

VBS2 also supports Counter IED (CIED) operations through simulation of Unmanned Ground Vehicles (UGV) and specialized engineering vehicles such as the Buffalo and Husky. UGVs may be equipped with a range of optics including normal, IR and thermal cameras, all with zooming capabilities. Some UGVs are also equipped with operational robotic arms that can raise, lower and turn. Via robotic arm, UGVs may have the ability to disarm IEDs or place and then explode such devices with a stay-behind charge. The Buffalo's hydraulic arm raises, lowers and extends to allow the operator to manipulate IEDs. The Husky gives an audio signal when it detects an IED.

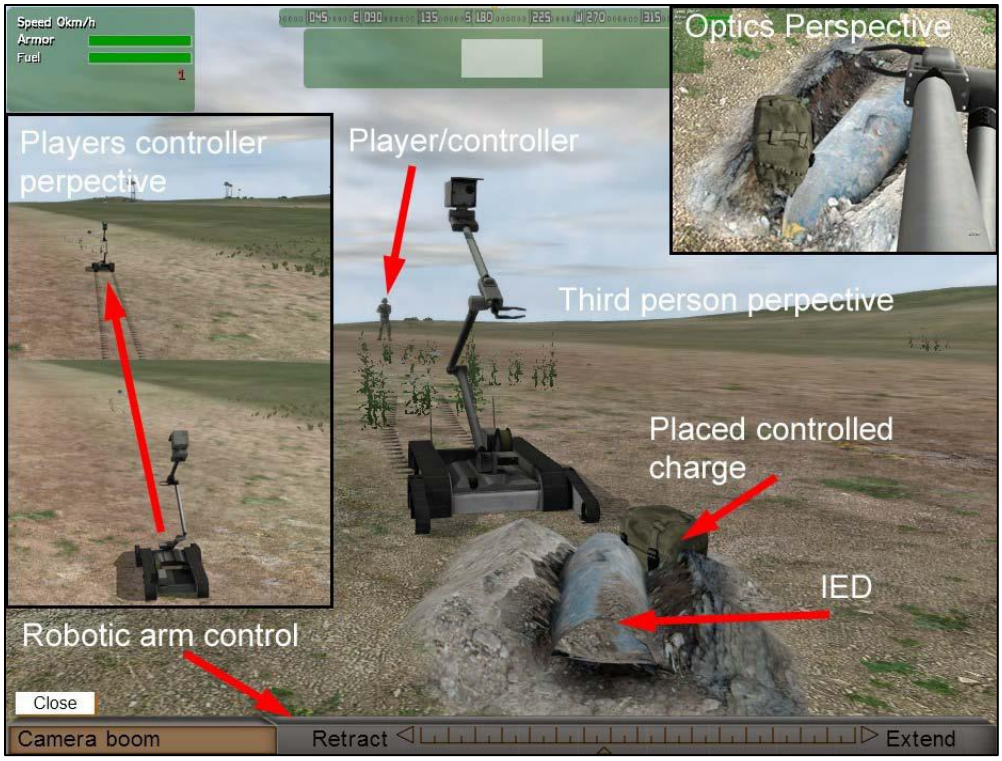

Image 10: Generic UGV operation in VBS2

As described below in paragraph 3.2.2.5 (Sensors), VBS2 supports thermal imaging. Within VBS2, thermal devices may 'see through' clothing to detect suicide vests. This is particularly useful when simulating static checkpoint operations where suicide bombers are a real and continuing threat.

Image 11: Infrared and thermal views of an entity with a suicide vest

3.2.2.4 Aircraft

VBS2 supports generic flight simulation of both fixed and rotary winged aircraft. VBS2 is not designed to train aircraft pilots, but it performs well as a mission simulator where aircraft operate in a joint environment in support of ground or naval assets. Aircraft can be equipped with a range of generic weapon systems including cannon, bombs and missiles. VBS2 supports visualization out to 10km from an aircraft by default, but larger view distances are supported on more powerful computers.

VBS2 flight models are highly customizable through configuration files, and parameters include take-off speed, landing speed, maximum speed, stall speed and lift envelope. Aircraft can be crewed with multiple AI or human participants and can carry either cargo (eg ammunition crates) or character entities. Aircraft cockpits can also be simulated including indicators, and any of the information available to indicators can also be displayed on an aircraft heads-up display. Indicators include:

- Radar and barometric altimeter
- Artificial horizon
- Airspeed indicator (ground speed only)
- Vertical speed indicator
- Various compass types
- Fuel gauge
- RPM gauge
- Indicators for control surfaces (flaps, gear, elevator, rudder, ailerons)
- Clock

Image 12: A simulated A-10 cockpit in VBS2

Image 13: Character entities fast-roping from a Blackhawk in VBS2

3.2.2.5 Sensors

VBS2 supports infra red (either night vision or thermal) and basic radar simulation out-of-the-box. Thermal simulation in VBS2 is quite advanced and has been constantly improved since the USMC funded the initial development in 2008. Within VBS2, the primary source of heat buildup on objects is the sun, so objects will appear hot during the day and cold during the night, but this is calculated dynamically depending on the time of day. Objects can also create heat themselves: for example, human body heat, a running car engine or friction from movement of tank tracks or rotor blades. The simulation considers all of these elements in order to present a very realistic and dynamic representation of thermal imaging; even dead bodies cool down over time. The simulation supports any color palette (grey, green, orange, etc), and can be attached to a simulated device on any personal weapon or vehicle (weapon scope, UAV camera, tank fire control system, etc).

It is important to note that VBS2 doesn't simply swap out textures when in thermal mode – each vehicle model has been carefully constructed so that the various parts heat at the appropriate rate. This is a true simulation based upon a correct mathematical model.

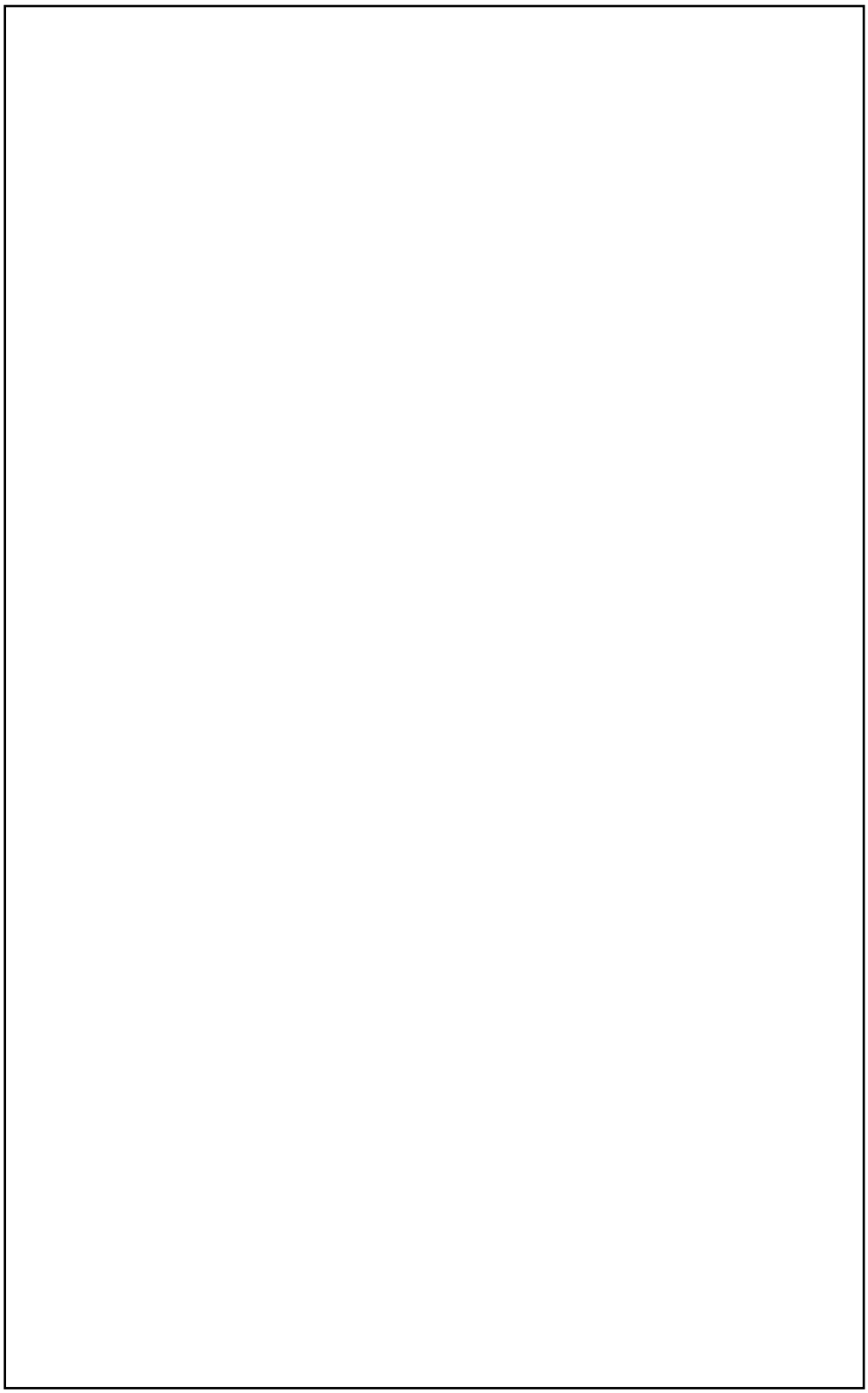

Image 14: Contrasting visual, night vision and thermal modes in VBS2

The following are examples showing real (unclassified) thermal imagery contrasted with in-game VBS2 screenshots. The real thermal imagery shown here was provided by the UK MOD.

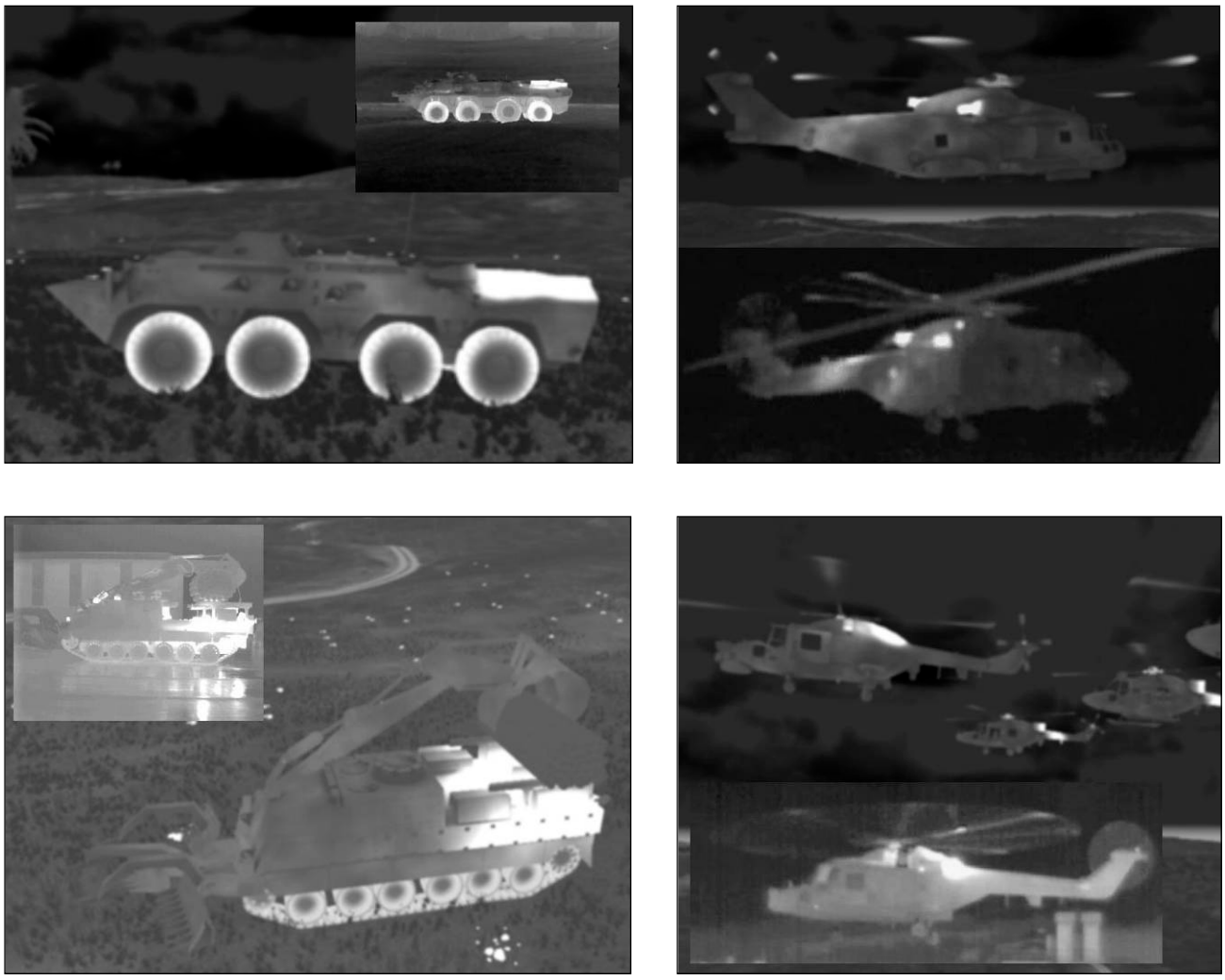

Image 15: VBS2 models viewed through simulated TI, contrasted with real TI photographs

VBS2 also includes a basic surface radar simulation that was developed for the US Navy. The system employs DirectX shading to simulate shadowing of terrain, and contacts are displayed and updated in a semi-realistic fashion. This is not designed to train radar operators, but rather to provide the participant with this capability for enhanced situational awareness.

Image 16: Basic radar simulation within VBS2 (in-game screenshot)

3.2.2.6 Physics

VBS2 uses its own proprietary physics engine for ballistics (both external and terminal), particle effects and physical simulation of vehicles. Recently, Bohemia Interactive also implemented support for PhysX by Nvidia[5], which is used for rope simulation (eg helicopter load carrying and fast roping), vehicle recovery (towing by rope or bar), articulated vehicles, UGVs (enabling them to climb stairs), and high-fidelity simulation of certain vehicles as requested by customers: for example, the HMMWV improvements for the USMC. Aircraft are simulated to a reasonable degree of fidelity, and the simulated aircraft employ basic theoretical flight models to give the appearance of accurate behavior. It should be noted that Bohemia Interactive can integrate new flight models if requested, and has completed such work in the past[6]. VBS2 also includes realistic sea states, waves and ship wakes. Meanwhile Bohemia Interactive will continue to convert all land vehicles to PhysX and by VBS2 v2.0 all vehicles including ships, helicopters and planes will use PhysX.

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[5] http://www.nvidia.com/content/graphicsplus/us/index.html for more information on PhysX
[6] The RotorLib (http://www.rtdynamics.com) UH-60 flight model was integrated into VBS1 for ADF aircrew training

Image 17: An articulated vehicle in VBS2 (a truck towing a trailer)

Image 18: Realistic ship wake in VBS2

3.2.2.7 Artificial Intelligence

Numerous possibilities for artificial intelligence (AI) exist in VBS2 depending on the user requirement. By default, game AI is implemented, whereby AI agents are controlled entirely by the VBS2 simulation engine.

The capability of VBS2 game AI has steadily improved over the course of the last decade in an evolutionary fashion. Game AI employs real-time path planning (based on an A-Star algorithm) to determine routes, and the AI factors all aspects of the virtual environment into their decision making – both external (eg enemy presence, orders from an AI or human commander, obstacles) and internal (”eg damage state, morale, ammunition state). Like human participants, AI can either operate as infantry, drive vehicles or fly aircraft and they are capable of operating in teams (eg an infantry squad or a four-man tank crew).

Game AI is semi-autonomous in nature and tasked through waypoints, allocated in either the offline mission editor (OME) or the real time editor (RTE). Example waypoint types include MOVE, DESTROY, SEARCH AND DESTROY, LAND, LOAD and UNLOAD. Waypoints are used to direct AI behavior: for example, rules of engagement (open fire, hold fire), combat mode (safe, aware, combat), formation and movement speed can all be specified. Waypoints can be synchronized with other waypoints to facilitate coordinated maneuvers and they can also be branched depending on scripted conditions.

Finite State Machine (FSM) scripting allows the development of autonomous agents and has been used to great effect to script new behaviors. Examples include the USMC bomb detection dog and civilian behavior. Civilians have FSMs to determine what to do if they experience danger, and they are scripted to run and hide. FSMs also provide the backbone of the new autonomous AI development that aims to provide populated cities complete with civilians on sidewalks, busy marketplaces and traffic. FSMs are developed in the VBS2 FSM Editor, and each FSM state (the various shaped boxes in the image below) calls VBS2 script commands to influence AI agents.

Micro AI, which is due for release in VBS2 v2.0 uses a much finer AI path-planning grid and will provide the AI with a much better understanding of their surrounding terrain, allow them to move through much smaller spaces, use various features of the terrain for cover, and generally act in a much more smarter, tactical and realistic way.

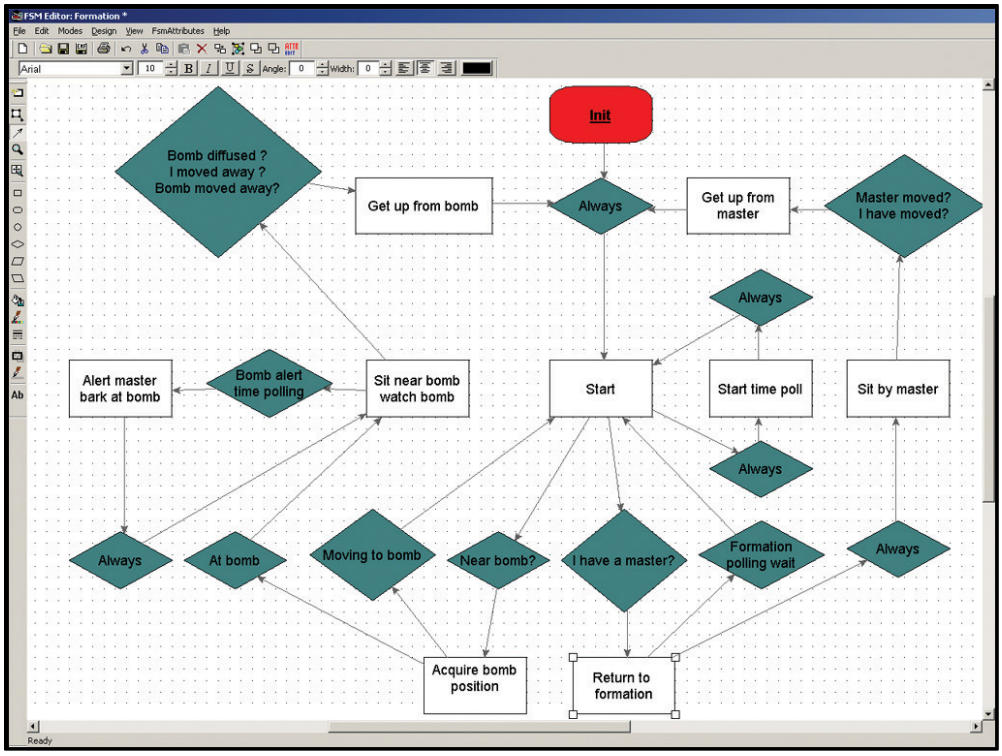

Image 19: An example FSM script for the VBS2 bomb detection dog

It is also possible to develop AI externally to VBS2, and then integrate by one of the available APIs. Bohemia Interactive has already integrated VBS2 with Kynapse and Xaitment via VBS2Fusion (see Paragraph 3.3.3 below for more information on VBS2Fusion). In such an integration, the 'brains' of the AI units are controlled by the external path-planning engine however they move in and react to the VBS2 virtual environment, as they have an understanding of the VBS2 world.

The following AI engines have been integrated with VBS2 at the time of writing:

- Virtual Role Players (VRP) by Alelo, the developers of Tactical Language[7]
- CoJACK by AOS[8]
- Kynapse by AutoDesk[9]

[7] http://www.alelo.com for more information on VRP
[8] http://www.agent-software.com.au/products/cojack/index.html for more information on CoJACK
[9] http://gameware.autodesk.com/kynapse for more information on Kynapse

3.2.2.8 Unmanned Vehicles

VBS2 simulates a wide range of airborne and ground-based unmanned vehicles, and provides a generic unmanned vehicle user interface for operating vehicle cameras, sensors and onboard weapons. At the time of writing the following unmanned vehicles are included with VBS2:

- Desert Hawk III
- MQ-1 Predator
- MQ-9 Reaper
- RQ-11 Raven
- RQ-7 Shadow
- Scan Eagle
- Watchkeeper
- TCOM Aerostat
- Talon EOD and SWORDS
- iRobot packbot EOD
- iRobot/Boeing SUGV
- Exponent Marcbot
- MAV
- GBOSS Security Camera

UGV capabilities include driving outside or inside buildings (including moving up and down stairs), operating multiple cameras mounted on robotic booms or arms (cameras may display visual or infra-red feeds), recording camera views to the hard disk for later replay in Windows as a video file, taking screenshots and sending them over DIS or HLA, operating weapon systems such as a machine gun or rocket launcher mounted on the UGV, and laying explosives or disarming IEDs. UAV capabilities are similar: multiple camera feeds and weapon systems (such as hellfire missiles) are available, and aircraft types include both rotary and fixed wing. UAVs can be directly flown (as if by remote control) or allocated waypoints in real-time. VBS2 supports UAV launch and recovery by both traditional means (eg a runway) and UAV-specific systems such as for the Boeing Scan Eagle as shown in Image 20. UAV cameras can be locked to targets and provide a wide range of realistic information such as geo-referenced position in MGRS or lat/long. UAVs can also laser designate targets and Rover III simulation is also available.

Image 20: Scan Eagle launch mechanism in VBS2

Static cameras are also provided, referred to in VBS2 as GBOSS (Ground Based Operational Surveillance System) cameras.

Image 21: Example unmanned vehicles in VBS2 (Raven, Aerostat, Predator, Talon)

3.2.2.9 VBS2 Tank Gunnery

The UK MoD contracted Bohemia Interactive to develop high-fidelity tank-gunnery simulation in VBS2, and plans to use VBS2 as a virtual environment for Challenger II crew procedural simulators. Many improvements have been implemented to support this integration, from improved user interfaces to support for in-game switches, through to highly accurate simulation of tank round ballistics. The development is complete and related improvements are included in VBS2 v1.60. Not only was the Gunnery aspect improved, but many other features of the Challenger II where improved upon, including realistic simulation of gears, support for boggy ground and much more. The most exciting aspect of this enhancement however is the improvement of armour simulation in VBS2 in general, meaning that other tank types can be (relatively) quickly and affordably included by all VBS2 customers in the future, indeed at the time of writing we are currently looking at a similar project for one other customer. Improvements include:

- Parallax error correction
- Aided Lay
- Validation of Ballistics
- Correct Internal Model
- Support for Boggy Ground
- Simulation of gears
- Significant AI improvements
- Realistic sounds
- Correct TI & day optics
- Tank transporter simulation
- Realistic loading
- FCS simulation
- Realistic impact effects
- Range add / correct
- Support for tank ditches
- RWS simulation
- Floating aiming mark
- Gun / optics stabilization
- Correct voices
- Deep water fording

Image 22: A Challenger II in VBS2, and a Bohemia Interactive team recording high-fidelity sounds at Lulworth Ranges

3.2.2.10 Maritime Enhancements

The UK Royal Navy and Royal Australian Navy contracted Bohemia Interactive to develop a number of Maritime enhancements[10]. These enhancements are due to be released into the VBS2 baseline in VBS2 v1.61. Features include:

- PhysX ship simulation allowing other PhysX vehicles to interact realistically, including improvements of the current Type 45 "Daring" Destroyer
- Avatars can freely move around transiting ships
- New capability to allow avatars to move through interior spaces below the waterline whilst inside ships
- Improved AI navigation across large ships through improved AI technology
- Increased limits on vertex count per model, allowing larger detail objects
- Increased limits on model size, allowing easier creation of large ships
- Addition of Canberra class LHD vehicle
- Addition of LCM8 landing craft
- Addition of LARC-V amphibious vehicle

Image 23: LHD Work in Progress

[10] Discussion Paper on Maritime use of VBS2:
http://distribution.bisimulations.com/docs/VBS2_Maritime_Discussion_Paper.pdf

3.2.2.11 C2 Interface

Every VBS2 participant has access to a command and control or 'map' screen that is either displayed as the Real Time Editor (RTE) or C2 Interface depending on user privileges. The RTE is explained in detail in Paragraph 3.2.3.2 below. The C2 Interface includes a map screen that can display a VBS2-generated topographic view, geo-referenced imagery or a real-world geo-referenced topographic map. The C2 interface includes the following tools:

- Distance measurement
- Compass and a GPS that displays the participant's current location
- Watch that displays the current in-game time
- In-game forms for reports and returns (CASEVAC request, etc) that may be customized

Image 224: In-game VBS2 C2 interface tools

The C2 interface displays NATO standard military symbols for known contacts through a fog of war algorithm. Users may draw additional military symbols on the map to create an overlay, and new military symbols will automatically appear on other VBS2 workstations assuming that the participants are of the same virtual side

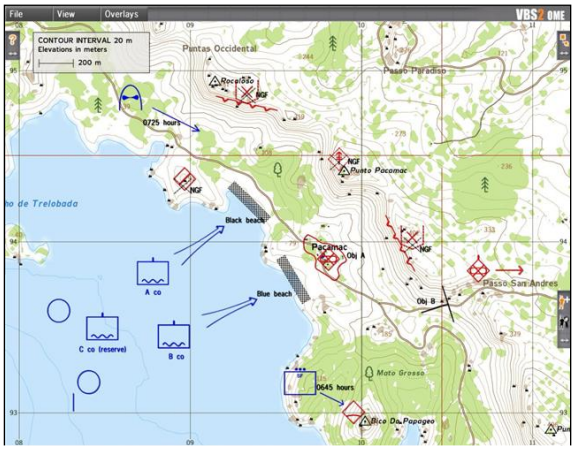

Image 235: A user-generated overlay within VBS2

(eg BLUEFOR) as the person drawing the symbols. In addition, 'chains of command' may be defined in the Offline Mission Editor (OME) prior to the scenario commencing, enabling participants to direct friendly forces in real time via waypoints.

3.2.3 Mission Editing and Run-Time Authoring

VBS2 ships with two mission editors: the OME that allows both 2D and 3D editing of a scenario, and the old VBS1 / OFP / DARWARS Ambush! mission editor that is more limited but allows users of these older products to develop scenarios in VBS2 without retraining. VBS2 also includes a run-time variant of the OME known as the Real Time Editor (RTE). VBS2 uses a common user interface for mission editing, run-time authoring, command and control (C2) and after-action review functions to facilitate ease of use. For additional information on the VBS2 OME and RTE please view the online help[11].Offline Mission Editor (OME)

The OME is a powerful scenario editor that allows any imaginable situation to be created within VBS2. It is titled 'offline' because it is design to be used on a stand-alone computer, before training or mission rehearsal commences. The OME can be used in either 2D or 3D modes and it generally takes about one day of self-paced tuition for a typical administrator to learn to operate most functions. The OME interface is displayed in Image 24 below.

The VBS2 OME is powerful because it employs customizable, scripted 'editor objects' to populate a scenario. Editor objects can include entities (such as characters and vehicles), objects that influence behavior or events such as triggers or waypoints, 3D representations such as buildings and vegetation, or representations of scripts that might be running in the background such as artillery scripts.

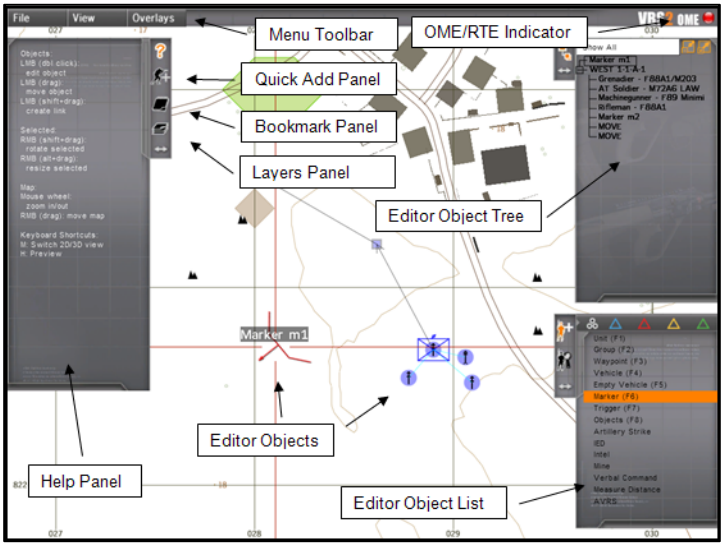

Image 246: The Offline Mission Editor

[11] VBS2 User, Administrator and Editor Manuals may be viewed at http://www.bisimulations.com/support/manuals.

Complex scenarios can be created by simply creating and linking different types of editor objects together. It is not necessary to have any programming or scripting knowledge to develop VBS2 scenarios.

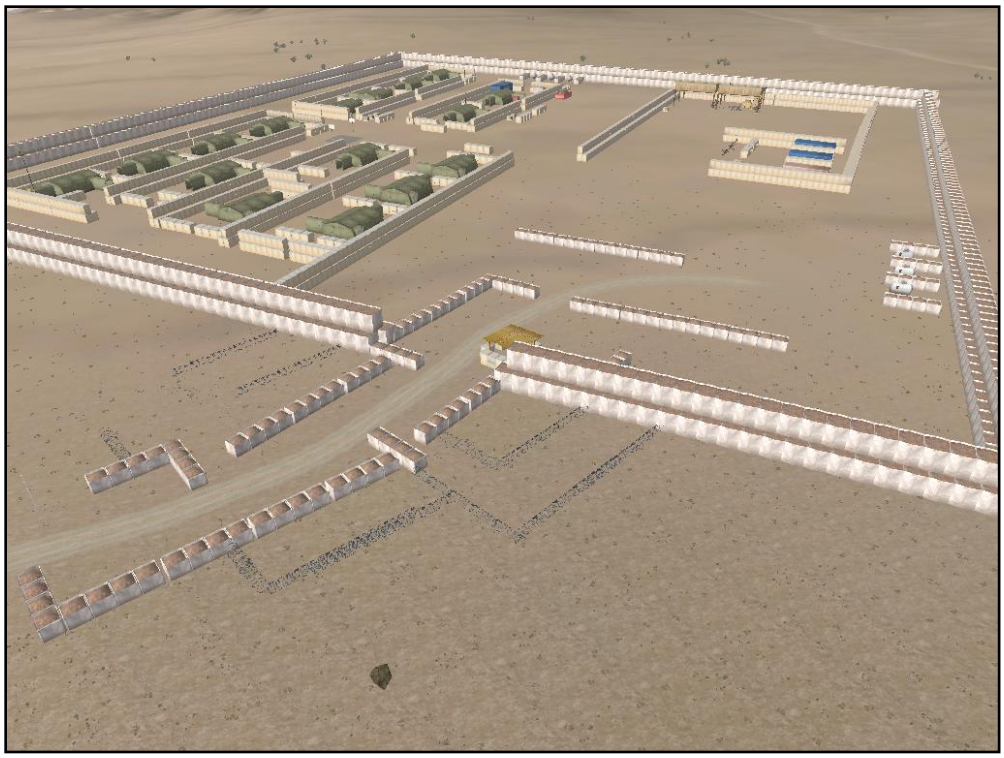

Image 257: A FOB developed in the VBS2 OME

3.2.3.1 Real Time Editor (RTE)

The RTE is a run-time version of the OME, and almost all of the same functions are available. This allows an administrator to modify any aspect of the scenario at run-time, without needing to interrupt the training or mission rehearsal exercise. Changes occur instantly: if the administrator creates a new building, then that building will instantly be visible on all computers on the network; or if a waypoint is linked to an AI character entity, then that avatar will instantly move off on the new assignment.

3.2.3.2 VBS2 Scripting

VBS2 includes a powerful scripting language that developers or appropriately trained administrators can use to create complex events and behaviors within VBS2 scenarios. The script language has over 1300 script commands that tap directly into the simulation engine, and is supported by a comprehensive

command reference[12]. VBS2 script is very fast, and is used extensively by Bohemia Interactive to extend the capability of the product. VBS2 script is used either within editor objects or in separate script files, depending on the complexity of the script being created. Examples of scripted systems include:

- Scan Eagle UAV launch and recovery mechanisms
- Battlefield clearance (dragging units)
- CASEVAC
- NBC suit / M22 Gas detector / Sarin Gas shells
- Active Denial System / Non lethal weapons
- Air to Air refueling
- CREW
- Fast Roping
- Artillery support and CAS
- Automatic building door animations for AI
- Ambient AI
- Bomb detection dog
- Shooting from Humvee windows
- Harpoon ship launch
- Entire UAV/UGV/Security camera interface
- Handsignals
- Submersible vehicles/ocean borne weaponry (torpedoes)
- AI surrender
- Helicopter sling load system
- Automatic chopper door/ramp animations for AI embarking/disembarking

3.2.4 Networking

The VBS2 network architecture is a typical client-server model, but has been extended and optimized to allow up to allow over a hundred human participants to operate in a networked scenario at any one time. VBS2 can be used over a LAN or a WAN (such as the Internet).

In the current version of VBS2 only one server is permitted, which contains a master copy of all objects and entities located within the virtual environment. All clients then subscribe to this master copy to ensure that the scenes rendered by all clients are coherent and correlated, but perform their own simulation to minimize bandwidth usage. Conducting simulation on client computers is a fairly unique feature of VBS2, but is critical to allow for a large number of human participants. The network architecture allows any installation of VBS2 to operate as the server.

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[12] See http://resources.bisimulations.com/wiki/Category:VBS2:_Scripting_Commands for a listing of all VBS2 script commands

The proprietary VBS2 network protocol does not presently allow VBS2 servers to interoperate, but multiple VBS2 servers may be linked via HLA or DIS.

3.2.4.1 HLA and DIS Connectivity

VBS2 employs the HLA/DIS gateway product 'LVC Game' by Calytrix Technologies for HLA and DIS connectivity. This robust gateway has improved in an evolutionary fashion in parallel to VBS2.

LVC Game supports all versions of DIS:

- Version 1.0 Draft (1992)
- IEEE 1278-1993
- Version 2.0 Third Draft (May 1993)
- Version 2.0 Fourth Draft (March 1994)
- IEEE 1278.1-1995 and IEEE 1278.1A-1998

LVC Game also supports HLA 1.3, 1516, HLA 1516 evolved, C2 and all RTIs that are Dynamic Link Compatible with the DMSO RTI NG6 1.3, which includes RTIs from the following companies/organizations:

- MÄK Technologies
- BAE/Pitch
- Raytheon-VTC
- Portico[13]

The following HLA FOMs are presently supported:

- Real-time Platform Reference 1 and 2 (RPR1 and RPR2)
- ERF (widely used within the US Army)

Through LVC Game, VBS2 has been connected to a wide range of virtual and constructive simulations. Some examples follow.

[13] See http://www.porticoproject.org/index.php?title=Main_Page for more information on Portico

The **US Army's Counter-IED Operations Integration Center (ARCOIC)** uses LVC Game to interconnect VBS2 with OneSAF. ARCOIC puts heavy demands on LVC Game by placing VBS2 into an environment with tens of thousands of OneSAF entities. At the annual OneSAF User's Group Meetings in 2008 and 2009, ARCOIC personnel informed the OneSAF group of ARCOIC's successes federating VBS2 with OneSAF.

Raytheon Missile Systems uses LVC Game to support the Maneuver Battle Lab at Fort Benning, Georgia. The Maneuver Battle Lab conducts simulations and experiments with VBS2 participants as part a larger distributed environment.

The **US Army's National Simulation Center (NSC)** uses LVC Game to put VBS2 participants into various DIS or HLA based distributed environments that include JCATS and C2 systems. LVC Game's bidirectional data handling permits VBS2 players to see and interact with JCATS' entities, and vice versa, while C2 systems display the combined action.

Boeing used LVC Game to integrate VBS2 with MAK Technologies' 'VR-Forces' software, permitting VBS2 players to interact with computer-generated forces controlled by VR-Forces.

SAIC used LVC Game to integrate VBS2 into SAIC's 'Virtual Convoy Trainer' (VTC). The VTC driver drives his vehicle through a VBS2-based virtual world, interacting with entities controlled by OneSAF.

Fort Lewis's Battle Command Training Center (BCTC) uses LVC Game with VBS2 for Stryker Brigades' training simulations.

3.2.5 After-Action Review

The VBS2 After-Action Review (AAR) operates by recording network traffic received on the VBS2 server, and replaying saved data in the AAR replay interface. AAR files can be replayed on any computer on the VBS2 network (VBS2 includes a facility to transfer saved AAR files from the server to clients). The relay provides an accurate 2D and 3D recreation of all in-game events, including movement, hit, fire weapon, killed, get in and get out actions. Vehicle turret positions and UAV/UGV video camera direction, zoom and mode (thermal, etc) are all replayed. Particle effects (smoke and dust) and terrain deformation and cratering from explosions are also re-created. Replay of voice communications is also possible.

The replay can be viewed from any perspective including first person (through the eyes of the character entities in the AAR). The AAR system supports bookmarks, whereby an administrator can add a note during AAR recording that can be viewed in the replay system. All in-game forms (reports and returns) that were submitted by participants during the network session are embedded in the AAR file and can also be viewed during the replay. The AAR replay interface also displays basic statistics.

3.2.6 Development Suite

Bohemia Interactive understands that the **end user** has a requirement to generate terrain and 3D representations for virtual simulation. All of our tools are developed in-house with an emphasis on rapid development and ease of importing 3D models. The VBS2 Development Suite is shipped with every copy of VBS2 at no extra cost.

Documentation for the VBS2 Development Suite is available online[14].

3.2.6.1 3D Model Import

Accurate 3D models are a key feature of VBS2 and we provide a proprietary modeling tool, Oxygen 2, to import or generate 3D models. Oxygen 2 is a 3D modeling and texture mapping tool designed by Bohemia Interactive which works hand-in-hand with the VBS2 engine. Import and export to other modeling platforms is possible via the 3DS and FBX formats and basic OpenFlight model import is supported.

3D vehicle representations can be brought to life through the addition of turreted weapons, crew positions, instrument panels and animation. Bohemia Interactive also offers comprehensive motion capture services to generate animations from human or animal movement and actions. 3D representations are highly configurable, as previously described in Paragraph 3.2.2.2.

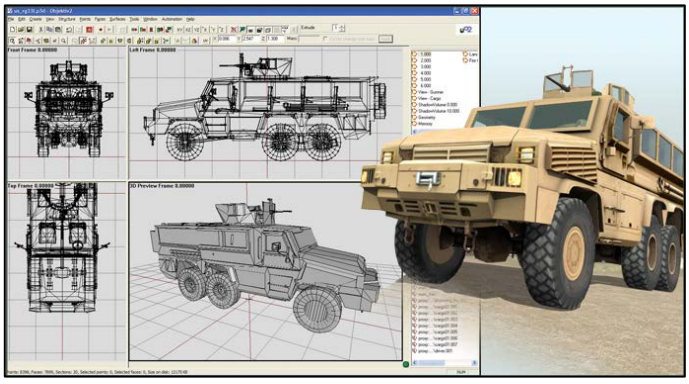

Image 268: The 3D modeling tool Oxygen 2

[14] Development Suite manuals are available at http://www.bisimulations.com/support/onlinehelp

3.2.6.2 Terrain Import

At the heart of VBS2 terrain development is Visitor 4, a lightweight GIS application designed to import raw DTED, vector data and imagery to create high-fidelity VBS2 terrain areas. Visitor 4 is supported by an advanced shape file management application named Visual Landbuilder, which allows automated processing of shape files to create roads cut into hills, realistically dispersed vegetation and even automatic generation of enterable buildings based upon shape file building footprints. Visitor 4 exports a VBS2 world-file, ready to be loaded in the scenario editor as a basis for tactical training or mission rehearsal.[15]

A single VBS2 terrain tile is limited to a heightmap of 4096x4096 nodes. The spacing of heightmap nodes determines the final terrain size. This allows a 16km terrain with 4m post spacing or a 160km terrain with 40m post spacing.

Multimap support was introduced in VBS2 v1.50. This allows multiple terrain tiles to be stitched together and streamed in at runtime, with the appearance of a single large terrain area in VBS2. A terrain of 500x500km has been created to prove the technology, it has 12.5m post spacing and composed of 400 individual terrain tiles in a 20x20 array.

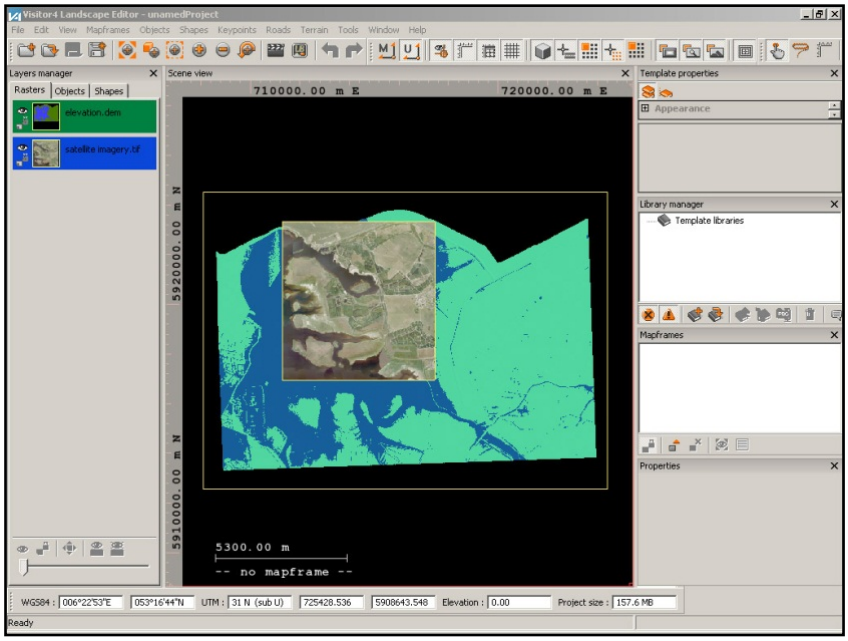

Image 279: Visitor 4 terrain tool

[15] See http://distribution.bisimulations.com/media/docs/Visitor4_leaflet_preview.pdf for more information on Visitor 4 and Visual Landbuilder

3.2.6.3 Additional Development Tools

The VBS2 Development Suite includes a number of additional tools:

- Animation Converter – converts custom FBX animations to the VBS2 animation format
- Face Editor – allows VBS2 character models to have custom face textures created from photographs
- Lip Sync – enables character lip synchronization with audio files

3.2.6.4 VBS Developer Network

The VBS Developer Network (VBSDN)[16] is a subscription-based product tailor made and available to commercial entities. It is an all-in-one package that provides:

- VBS2 (Latest version)
- Updates to future VBS releases
- VBS2 Development Suite mentioned in para 3.2.6
- VBS2 Fusion
- VBS2 Multi-Channel
- VBS2 Content SDK

3.2.6.5 Third-Party Terrain Conversion Tools

Either TerraVista by Presagis[17] or TerraTools by TerraSim[18] can be employed to export terrain to the VBS2 format. These tools allow almost any military terrain format to be exported to VBS2 (OpenFlight, CDB, etc). The following image shows terrain outputted by TerraTools, correlated in both VBS2 and OneSAF.

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[16] See http://armory.bisimulations.com/products/vbs-developer-network/overview for more information on VBSDN
[17] See http://www.presagis.com/products/content_creation/terra_vista/more/vbs2 for information on the VBS2 Output Compiler for TerraVista
[18] See http://www.terrasim.com/products/plugins/ms_export.php for more information on the VBS2 exporter for TerraTools

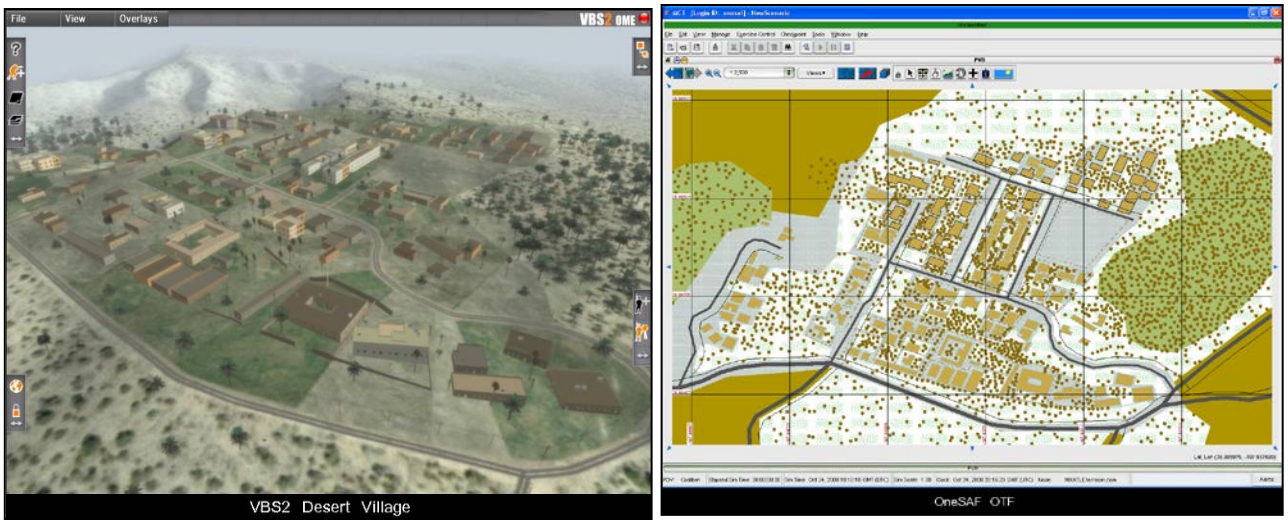

Image 30: A correlated terrain database exported by TerraTools, shown in both VBS2 and OneSAF[19]

3.3 VBS2 Modules

VBS2 Modules are external applications that provide additional capability to the VBS2 product, and are integrated by some form of API.

3.3.1 VBS2Fires

VBS2Fires[20] is a comprehensive call-for-fire module that simulates fire support from artillery, MLRS and naval gunfire platforms. Simulating call-for-fire workflow, VBS2Fires manages virtual gunlines that fire a wide range of munitions on ballistically correct trajectories, complete with realistic terminal effects. Key features of VBS2Fires follow:

- **Highly detailed ballistics models.** VBS2Fires simulates both exterior and terminal ballistics through a validated ballistics model. Gravity, drag, wind drift, air pressure, temperature, spin drift and Coriolis effects are incorporated. The ballistics simulation is modular and can be replaced with classified military ballistics kernels as required.

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[19] Images courtesy of TerraSim

[20] For more information on VBS2Fires visit:

http://armory.bisimulations.com/products/vbs2fires/overview

http://www.simcentric.com.au/wiki/index.php?title=Fires.

- **Seamless integration with VBS2.** VBS2Fires simulates indirect fire from the gunline, and is therefore very easy to integrate in VBS2 scenarios via the VBS2 OME. Weapon platforms are placed in VBS2, and then linked to a VBS2Fires editor object which configures basic parameters such as radio callsigns. All VBS2Fires activity is replayed in the VBS2 AAR.
- **Wide range of ammunition possibilities.** Munitions include HE, WP, Smoke (multiple colours), SADARM, DPICM, RAAMS, ADAM, ILLUM (multiple colours), and Copperhead. Fuses include Quick, VT, Time, Delay, Seek and Destroy, and Laser guided.
- **Support for both Commonwealth and US Call-For-Fire doctrines.** VBS2Fires can be switched between Commonwealth (ADF, UK MOD) and US doctrines on-the-fly.

VBS2Fires has been bought at the enterprise (unlimited licenses) level by the USMC, US Army, Canadian Forces, UK MOD, Netherlands MOD and Australian Defence Force, and is undergoing constant improvement in accordance with military feedback. VBS2Fires is suitable for use on both desktop computers and full Forward Observer simulators.

Image31: Self-propelled artillery in VBS2

3.3.2 VBS2Strike

VBS2Strike is an add-on module for VBS2Fires which enhances the VBS2Fires capability to support training for Forward Air Controllers. It allows FACs or JTACs to move freely through the VBS2 virtual environment from the first person perspective, while interacting with an instructor who is operating the VBS2Strike control panel. This control panel allows the instructor to control Fixed and

Rotary Wing aircraft flying a variety of attack profiles. VBS2Strike contains its own ammunition effects, flight dynamics, aircraft AI and data entry interface for CAS instructions. The system supports the 9 line format and facilitates the talk on procedure, making it a complete and easy to operate FAC trainer. VBS2Strike is completely integrated into the VBS2 AAR system. Bookmarks can be dynamically added and all aircraft paths and projectile effects are captured and replayed. In addition, terrain and ballistics analysis tools are included. The pod view supported by VBS2Strike allows the instructor to zoom and lock onto targets while conducting the talk on with the trainee. Aircraft attack profiles can be altered based on the locked pod target.

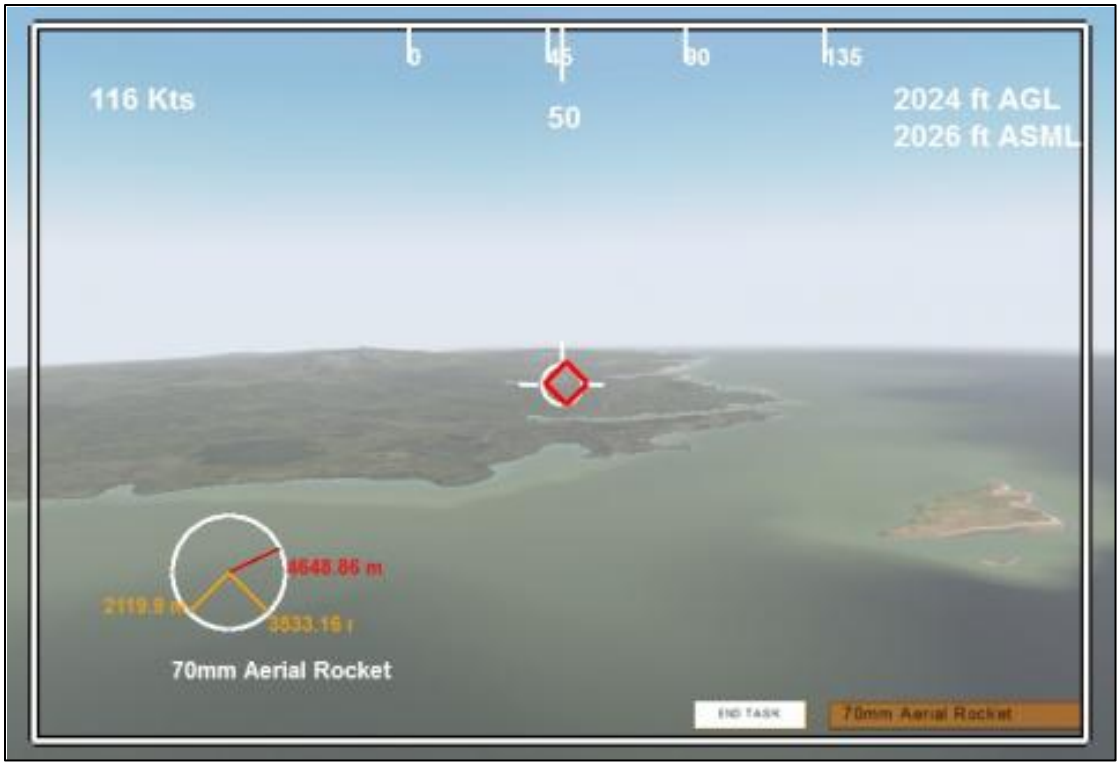

Image 32: VBS2Strike HUD

VBS2Strike can be used as either a stand-alone training tool or in conjunction with VBS2Fires, the highly successful call-for-fire trainer.

3.3.3 VBS2Fusion

VBS2Fusion[21] is the primary VBS2 API which can be used to programmatically access and modify the VBS2 virtual environment and the objects within it. It is designed in C++ and removes the requirement for developers to learn the VBS2 scripting language.

VBS2Fusion offers significant advantages over the VBS2 Application Scripting Interface (ASI). It provides:

- Direct core access
- No VBS2 scripting knowledge Required
- VBS2 drawing support
- Multiplayer compatible
- Compatible with C++ libraries
- HUD support
- Includes VBS2 executables
- VBS2 type handling
- Expanded function library
- Specialized unit and vehicle classes
- Multi-Threading capable
- Monitor, modify and control VBS2 triggers
- Support for VBS2 events
- Supports VBS2 groups
- Monitor and modify VBS2 waypoints
- Camera handling support
- Floating aiming mark
- Collision and visibility testing
- Skeletal control
- Low level movement control

The VBS2Fusion 2.0 distributable is composed of two sets of Dynamic Link Libraries (DLLs).

Development configuration: This DLL is intended for use during the development of a VBS2Fusion based plugin. All plugins linked to this library will automatically generate a log file which will display information on all operations performed during its execution. This file will also include all relevant error information to assist with debugging.

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[21] For more information on VBS2Fusion visit:
http://armory.bisimulations.com/products/vbs2fusion/overview
http://www.simcentric.com.au/wiki/index.php?title=Fusion.

Run-time configuration: The run-time version is intended for use within a user-ready plugin for VBS2. Plugins that have been developed and tested using the development configuration can be linked to the run-time library prior deployment. DLLs linked to the run-time DLL will not generate any log files.

VBS2Fusion is provided with extensive documentation and example plug-ins. It is ideal for integrating VBS2 with external hardware and software systems, enhancing the fidelity of the simulation (e.g. integrating new flight models), improving artificial intelligence and developing new user interfaces.

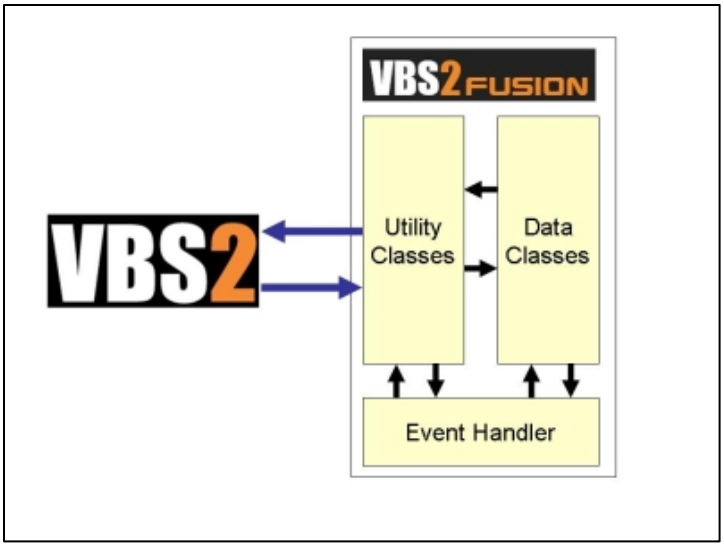

Image 283: The VBS2Fusion framework

3.3.4 VBSWorlds

VBSWorlds is the first major product launch from the Joint Venture created by Bohemia Interactive Simulations and Caspian Learning. VBSWorlds is an agile new, groundbreaking theatre training platform that was designed and developed to solve major educational and training issues experienced by defence customers. It complements existing VBS2 training solutions. VBSWorlds is the first of the VBS suite of products to fully support browser-

Image 294: VBSWorlds

based and IOS4 /IOS5 (iPad/iPhone) distribution. This means that a vast range of training simulations (anything from pre/post-deployment part task trainers to lessons learned tactics, techniques and procedure scenarios) can be created and redeployed by experts in the field within hours of the actual event taking place. VBSWorlds' easy to use authoring canvas gives operational experts in the field (not just programmers!) the power to edit existing scenarios and distribute them via standard internet browsers, standalone PCs or iPad and iPhone IOS4 / IOS5 devices.

3.3.5 VB-Edit

Bohemia Interactive partners Eurosimtec have recently created VB-Edit[22], a VBS2 add-on module. With VB-Edit you can directly place objects within the 3D environment of VBS2. Together with its multiuser capabilities, VB-Edit allows the rapid generation of high quality VBS2 terrain. For example, several users can effectively work together in parallel on the same project. A large number of object placement and productivity tools are provided with VB-Edit for time-effective and creative development. VB-Edit also provides easy and fast access to all objects in the VBS2 database. Completed projects can be exported in VBS2 Visitor, Mission or Script format.

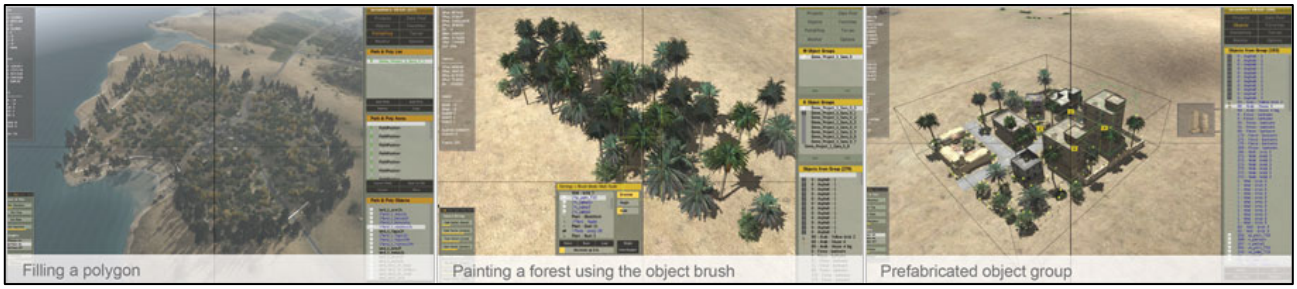

Image 305: VB-Edit Functionality

3.3.6 VBS2 Behavior Modeling Console

The Discovery Machine® VBS2 Behavior Modeling Console[23] enables instructors (non-programmers) to create intelligent adversaries and indigenous populations that communicate with the trainee and each other, follow patterns of life, and dynamically react to their situation. As part of Discovery Machine's

[22] For more information on VB-Edit please visit http://armory.bisimulations.com/vbedit

[23] More information on the VBS2 Behavior Modeling Console available here: http://armory.bisimulations.com/vbs2-behavior-modeling-console

continued efforts to facilitate intelligent behavior construction by non-computer experts, Discovery Machine has created the VBS2 Behavior Modeling Console. This powerful software facilitates the creation of behavior models to control characters in VBS2 with sophisticated Artificial Intelligence (AI). Discovery Machine has created a set of pre-built behavior templates that are used to create customized intelligent behavior models. Resulting models can then be used to control characters in a scenario with artificial intelligence.

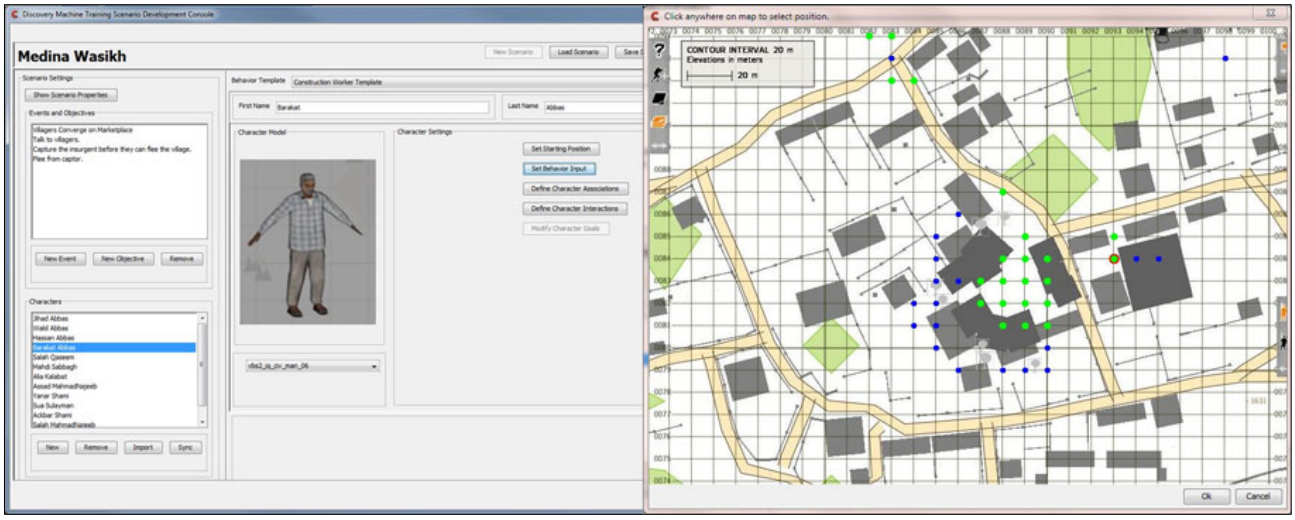

Image 36: VBS2 Behavior Modeling Console

In order to be effective, training efforts must incorporate communication. Discovery Machine's VBS2 behavior models allow trainees to communicate with characters in the simulation via a chat window. Characters are also capable of communicating with each other, enabling new information to be disseminated between any simulated entities forming a social network for those entities. If new information is learned by one character in a simulation, they can relay that information to a teammate causing their missions to adjust themselves based on the new information at hand.

3.3.7 Combat Net Radio (CNR) Simulation

CNR-Sim by Calytrix Technologies is another optional add-on module for VBS2. CNR-Sim is a versatile voice-over-DIS radio application that operates in parallel with VBS2. CNR-Sim is easy to use and allows teams to communicate over a simulation network. A simple push-to-talk interface is included, supporting multiple teams and switching quickly between any number of configurable

communication channels. CNR-Sim also supports the saving and replay of voice traffic in the VBS2 AAR. The CNR-Sim manuals are available online[24].

CNR-Sim has also been integrated with other military radio simulation devices (the DIS voice packets communicated by CNR-Sim are in the standard military format). From v1.40, VBS2 includes both CNR-Sim and CNR-Log allowing voice traffic to be replayed in the VBS2 AAR.

3.3.8 JCOVE Lite

JCOVE Lite[25] is a free version of VBS2 that includes a range of UK MOD content. The application provides an excellent introduction to VBS2 including a range of units, vehicles and scenarios, and a basic mission editor. If you are curious about VBS2, JCOVE Lite is an excellent place to start.

Image 37: JCOVE Lite

3.3.9 VBS2 NATO

VBS2 NATO[26] is a lightweight version of VBS2 that can be freely used by NATO member countries for individual or collective training. It includes many of the capabilities of full VBS2 including a mission editor and extensive 3D content (units, vehicles and terrains). For individual training, VBS2 NATO includes a range of individual CIED training scenarios based on the "Insurgent Mindset Training" concept. These scenarios allow a participant to operate from an insurgent's perspective in

[24] For more information see 'VBS2/CNR/LVC Integration' and 'Calytrix LVC Game SUM' at http://www.bisimulations.com/support/manuals
[25] Please visit http://www.jcove-lite.co.uk/?pageid=about_jcove for more information on JCOVE Lite
[26] For more information on how to acquire VBS2 NATO see: http://nato.bisimulations.com/

the virtual environment, and therefore become more knowledgeable in the tactics used by such threats.

Image 38.: VBS2 NATO

For collective training, NATO Allied Command Transformation (ACT) possess a number of VBS2 NATO Server licenses that can host networked training sessions. VBS2 NATO Clients can connect to these servers for collective training. When connected in this manner, a wider range of VBS2 features including real-time mission editing becomes available.

Appendix A: Contact Details

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Appendix B: Glossary

3D:	Three Dimensional
AAR:	After Action Review
ADF:	Australian Defence Force
ADSO:	Australian Defence Simulation Office
AI:	Artificial Intelligence
API:	Application Programming Interface
BFT:	Blue Force Tracking
BI:	Bohemia Interactive
BIA:	Bohemia Interactive Australia
BIS:	Bohemia Interactive Studio
BISim:	Bohemia Interactive Simulations
C2:	Command and Control
CNR:	Combat Net Radio
CREW:	Counter Radio Controlled Improvised Explosive Device Electronic Warfare
DIS:	Distributed Interactive Simulation
DVTE:	Deployable Virtual Training Environment
FAC:	Forward Air Controller
FAQ:	Frequently Asked Questions
FSM:	Finite State Machine
GAA:	Game after Ambush!
GBOSS:	Ground Based Operational Surveillance System
HALO:	High Altitude Low Opening
HAHO:	High Altitude High Opening
HLA:	Higher Level Architecture
JTAC:	Joint Tactical Air Controller
LVC:	Live Virtual Constructive
IED:	Improvised Explosive Device
MRE:	Mission Rehearsal Exercise
NATO:	North Atlantic Treaty Organization
NZDF:	New Zealand Defence Force
OFP:	Operation Flashpoint
OME:	Offline Mission Editor
PC:	Personal Computer
PEOSTRI:	Program Executive Office for Simulation, Training and Instrumentation
POI:	Plan of Instruction
RTE:	Real Time Editor
TI:	Thermal Imaging
TIS:	Total Immersion Software
UAV:	Unmanned Aerial Vehicle
UGV:	Unmanned Ground Vehicle
UK MOD:	United Kingdom Ministry of Defence
USMC:	United States Marine Corps
VTK:	Virtual Training Kit
VMAP:	Vector Map