Simulation - Digital battlefields

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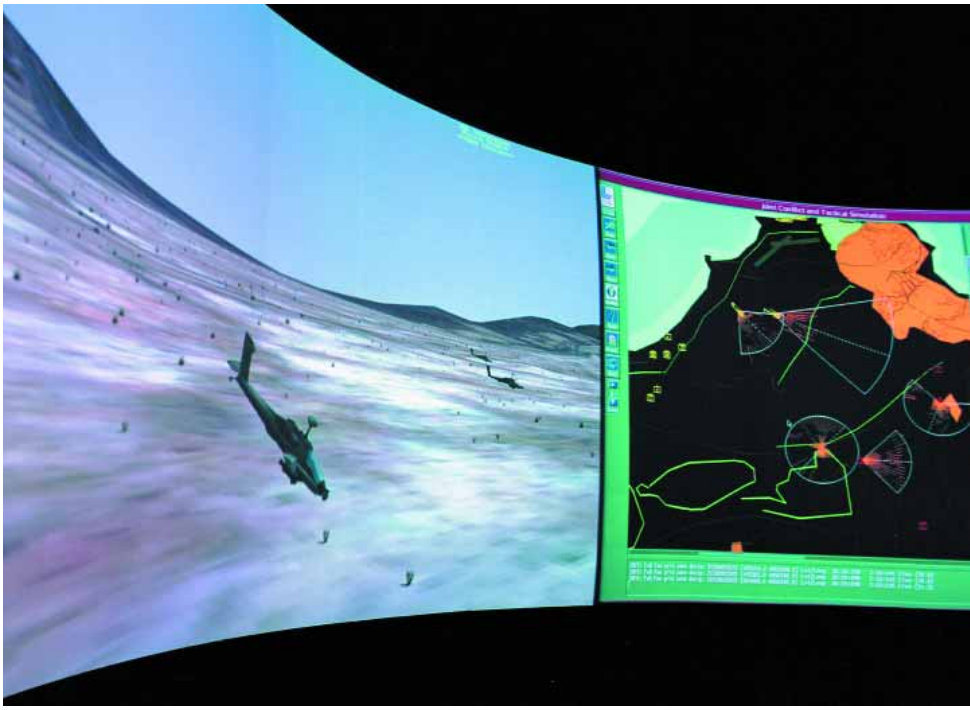
The world of military simulation is about to undergo major changes as the technology base shifts from custom built hardware to low cost commercial off-the-shelf (COTS) hardware. We are now beginning to see the first examples of this technology appearing in use as precursors to a fundamental change in the economics of this important area.

Military simulators, be they for cockpits, airborne mission systems, naval systems or land vehicles have a long and colourful history. Until recently the graphics rendering performance and capabilities of scene projectors demanded top tier custom designed and built hardware - only over the last decade did we begin to see significant numbers of still relatively expensive Silicon Graphics Unix workstations enter the market.



Battlefield application

Military simulators are today used for both 'procedural' and 'combat' training activities. Procedural training is used primarily for maintenance of currency in experienced personnel and development of skills in less experienced personnel. Emergency procedures and potentially dangerous training situations can be practised in simulators until the operator gains enough confidence and skill to tackle the real environment in a real platform. Skills that are very demanding in terms of practice time to develop proficiency can become far cheaper to develop and maintain currency by using simulation technology.

Combat training is where modern simulation returns an even greater payoff, as extremely complex threat and terrain environments can be simulated very cheaply in comparison with physical combat ranges. While the latter will always be vastly more realistic since real platforms are used against real or electronically emulated threats, often with real weapons, the cost of Red Flag and Green Flag style exercises competes very closely with the cost of real combat operations.

High fidelity simulation can permit operators to develop a significant proportion of their skills at very modest cost.

Simulations permit some things that are extremely difficult to do with physical platforms. One is the development of combat tactics against projected threat systems, or hypothetical threat systems. Consider a situation where intelligence sources indicate an opponent has deployed a new missile or radar on their fighter aircraft, with dramatically improved performance in some key area. Rather than face this weapon in combat as a rude surprise, aircrew can fly against its simulation and after being killed enough times in simulation, learn how to best offensively of defensively counter the threat. This technique can also be used to predict the effectiveness of existing platforms in combat with future variants of a threat system.

A good example for the ADF might be the advanced Sukhoi fighters now appearing in the region. With the prospect that these aircraft will evolve it should be feasible to practice in simulation engagements against as yet non-existent future configurations of the aircraft and its weapons and sensor suite. The US Air Force used this technique extensively in the development program for the F/A-22A/YF-23 to optimise aircraft configurations against then non-existent Soviet threats.

Another area in which simulations are likely to become increasingly valuable is in mission rehearsals. When the Israelis executed the pre-emptive air strikes of the Six Day War they were able to practise their air strikes on mockups in the desert without fear of being compromised. This was viable in 1967. Today any attempt to covertly practice operations - especially if surprise matters - is extremely difficult due to the constellation of commercial and government owned digital imaging satellites in orbit. Any mockup no matter how remote will attract somebody's attention. Mission simulators permit the detailed rehearsal and practice of very complex operations, and can include mission plan breakdown contingencies and unexpected hostile intervention during the operation. This permits development of mission familiarity and high personnel confidence levels; it also permits repeated testing of the mission plan to expose weaknesses. Most importantly, it can be done covertly.

The digital nature of modern simulators permits real Intelligence Surveillance Reconnaissance data to be merged with synthetically generated imagery in a mission rehearsal simulation. For instance an air strike could be practiced using satellite, UAV or airborne reconnaissance imagery gathered from the actual target of interest. Some existing strike mission planning tools can already do this, even permitting a 'fly through' presentation of the pilot's view of the planned ingress and egress routes to/from the target.

Since the 1990s the US military have exploited networked simulators, permitting not only single service simulated exercises with multiple players, but also cross service or joint exercises. For the ADF this would permit, for instance, exercises in which warships could practice with RAAF aircraft, while the warship is berthed in port and the air force crews strapped into simulators at Williamtown, Amberley and Edinburgh. The networking of simulators has proven to be a very powerful training and mission rehearsal aid. As broadband services become more widely available in Australia the cost of doing this will further decline.

Moore's Law and the simulation technology base

performance of graphics adaptors for commodity desktop computers - in effect home gaming systems - and home theatre technology will very soon transform the military simulation game, and do so for the better.

To understand the broader and longer term implications of this change it is worth exploring the technology base.

Moore's Law is the defining relationship for the technology base of the late 20th and early 21st centuries. Defined by Dr Gordon Moore during the mid-1960s, Moore's Law is an empirical formula, which shows that the density of silicon integrated circuits doubles every 18 months. When defined such chips typically contained hundreds of transistors, and thousands of such chips were required to construct even a half decent computer.

Like all exponential growth laws, Moore's Law takes a while to bite, and bite it did during the late 1990s when microprocessor chips began to commonly achieve transistor counts in the millions. Today tens of millions are common, and by the end of the decade hundreds of millions will be the norm, if the trend continues unabated.

What is less known is that as transistor sizes shrink, they switch faster. Moore's Law thus has two facets to it, the other being a doubling of switching speed over any three-year period. Switching the transistors twice as fast means clocking the chip at twice as many MegaHertz - or now GigaHertz.

At a hardware level this produces other, less desirable, side effects, the most important of which is heat dissipation. A decade ago most microprocessors did not even have heat sinks to dissipate waste heat. Today nearly all desktop machines have fan driven heat sinks and the overclocked gaming machines often have liquid cooling systems attached to the processor chip.

What does this all mean in the longer term? Clearly faster processor clock speeds will result in exponentially growing computational performance, or potential performance, over time, certainly for established chip architectures. However, much higher transistor counts in chips permit much more elaborate and thus higher performing internal architectures.

The modern Pentium II/III/IV, Athlon and PowerPC chips available today in desktop, deskside and laptop machines internally resemble mainframe computers of two decades ago more than anything else. Fabrication technology has allowed performance enhancing architectural features unthinkable in a desktop or deskside machine to become now commonplace.

This aggressive exponential growth behaviour has been paralleled in memory chips, which are now at ridiculously low costs per hundreds of Megabytes, and importantly in Graphical Processing Units (GPU), the

Simulations can be multi-function, multi-media and serve a variety of training purposes.

Pilots fly the C-130J simulator at RAAF Base Richmond.

battlefield simulation

number crunching engines used to rapidly render images on screens.

Simulations are considered in computing terms to be expensive both in basic number crunching operations and in graphical processing operations, especially as the complexity of the simulation increases. A simulator designed to emulate a tank or helicopter in a complex land battle scenario may devour several times as many computing operations compared to a fighter aircraft simulator emulating a medium altitude dogfight. Rendering complex terrain, trees, vehicles, buildings and personnel, and achieving faithful reproduction of shapes, motion, colour and textures is challenging and ever more so as the amount of necessary detail increases.

The big driver at this time in GPU performance growth is the desktop gaming market - home computers running interactive user games. With consumers often prepared to spend $1000 for a high-speed graphics card annually, and many millions of them in the market, we have seen unprecedented growth in the performance of 3D rendering hardware, and commensurate reductions in cost per performance in recent years. An important technological development was the widespread adoption of the OpenGL standard graphics library across the industry. Available on Microsoft, Unix, Linux and BSD software environments, it provides portability which was unimaginable a decade or two ago, during the era of proprietary graphics software.

The fidelity of the imagery in many off-the-shelf games now exceeds much of what is available in the professional military simulations market. Speed remains an issue for many games though, as military simulations must provide representative timing behaviour - having your fighter interrupt its roll rate as the complexity of the surrounding scenery changes is a non-seller in the military simulations market. However, Moore's Law will address this in coming years.

The commodification of high performance graphics rendering has thus transformed and will continue to transform the computer graphics technology base. Traditional custom-built simulation graphics hardware is heading for extinction.

Another expensive component in military simulation has been external projector technology, used to display scenery outside the simulated platform's crew station. Historically, custom hardware was used, projecting red, green and blue channel imagery on to flat or concave reflector surfaces or domes. This technology has also followed the path of commodification. The business world acquired an appetite for colour projectors during the 1990s, seeing rapid growth in demand for LCD light valve, micromirror and CRT based RGB projectors. This market has recently expanded to encompass the top end of the home theatre market, it in turn feeding off the enormous popularity of the DVD (Digital Versatile Disk) market.

Over this decade we can expect to see home theatre technology appearing ever more frequently in military simulators - projectors and DVD storage used for background scenery libraries.

The COTS commodity technology base will offer affordable simulators on a much larger scale than ever seen before. The principal cost in future military simulators will remain in the software, and to a lesser degree in the custom built crew stations, which must continue to faithfully replicate the real platform.

One technology that could further impact military simulations is Virtual Reality (VR) technology. A VR display and input system would comprise a VR helmet for presenting a synthetic image of the outside world, and VR gloves to sense the operator's hand movements and thus control and switch inputs.

The idea of VR is thus that the user of the simulation sees a wholly synthetic world around him or her, and interacts with that world using VR gloves. For instance a fighter cockpit simulation could be wholly implemented using a desktop joystick and floor pedals, with the pilot sitting in a suitable seat - without a dummy cockpit let alone external projectors. The world inside and outside the simulated vehicle is presented by projecting the image directly into the user's eyes - a completely synthetic world.

VR technology remains very immature at this time but is an area of intense interest to the commercial gaming market. The prospect of a gamer having a complete 'virtual world' surround is an irresistible attraction. As the technology matures and commodifies, it will see increasing applications in military simulation.

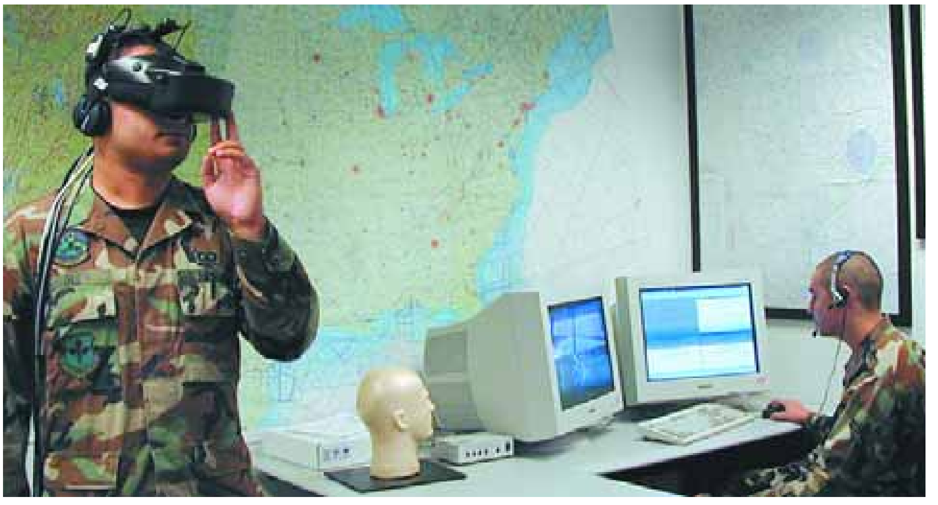
Key technologies for VR will be in high-speed rendering, zooming and panning, head and eye tracking technology, synthetic feel/touch force glove technology, and especially projector technology for helmets or headsets. Key technical obstacles remain with VR eye projectors - LCD and CRT technology does not provide viable resolution in pixels per degree of arc to get the kind of image fidelity needed for a wide-angle display. Experiments with laser projectors, which render directly onto retinas are very promising, although anectodal reports from the US suggest significant problems with eye fatigue and headaches remain.

Conventional external projection for simulations might present 1280 or 1600 pixels in a 15 to 30 degree arc in front of the viewer. A VR system must accommodate an instantaneous field of view, which is essentially hemispherical with unique images for left and right eyes to create depth perception. In practical terms, to achieve high scene visual fidelity, images with around 8000 pixels or better per side must be generated with 100 Hertz frame rates or better. That is challenging for a cinema like environment and extremely difficult for a headset or helmet.

Once VR does mature it will have an enormous impact on the economics of military simulations as commercial commodity hardware can be mated with military unique software to produce very cheap yet highly faithful simulations. Given the trend in most OECD nations to stretch legacy platforms - driven by economics of replacement, it is likely that such a technology will see many existing conventional simulations ‘ported’ across to the new environment, and enhanced in the process. A B-52H or B-1B crew in 2035 might be doing a lot of its training in a synthetic VR environment, using a simulation software package which is a fusion of software from today’s simulators in use, and much new hardware and software.

The technology base for military simulations will in time become indistinguishable from the commodity commercial technology base in use. The distinction will then lie wholly in the software being executed. A fighter pilot in 2035 might practise dogfights in his home office using a service supplied storage module with simulation software, and his home VR gaming headset and gloves plugged into the family computer. That is where current trends are leading longer term.

It is clear that simulations will play an increasingly important role in future training and mission preparation. It is imperative that the ADF develop a coherent strategy for developing and over time fully integrating its simulation capabilities. As the cost of simulation decreases over time, the ADF will need to be positioned to exploit this coming revolution in training technique.



Air Traffic Control Virtual Reality Simulator at Randolph Air Force Base, Texas.