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PC-Based Technology Invades Army Simulation

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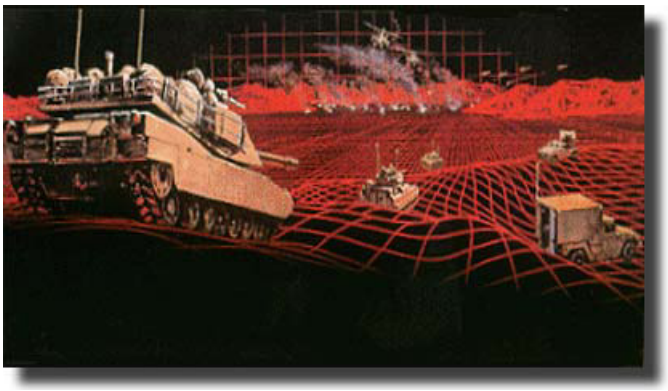


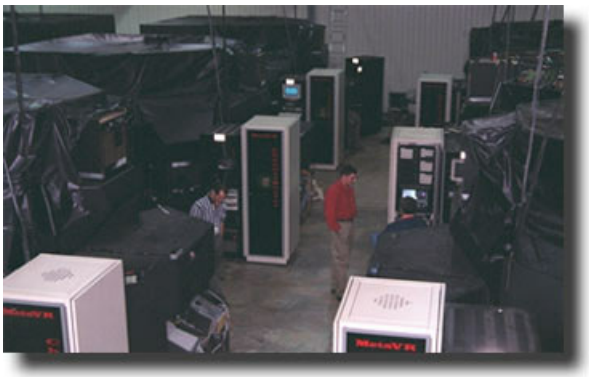
In the late 1980's, the Defense Advanced Research Projects Agency (DARPA) helped create a revolution in simulation, known as SIMulation NETwork, or SIMNET. The SIMNET program was the first step in moving from individual task-based simulators to a network of low-cost simulators that fought on a virtual battlefield to provide "synchronized execution of collective warfighting skills in a combined arms and joint arena". With the advent of new technology, the US Army PEO Simulation, Training, and Instrumentation (PEO STRI) is harnessing the revolution occurring in the Personal Computer (PC) three-dimensional (3D) graphics market to breath new life into these venerable SIMNET simulators. PEO STRI has recently updated the Aviation Test Bed (AVTB), Ft. Rucker, Al. SIMNET training facility with fully operational replacements of the SIMNET devices with personal computer based solution.

In creating and fielding large numbers of SIMNET simulators, DARPA sought to develop low-cost simulators that provided sufficient fidelity to train the collective warfighting skills. Thus, the GT series of Image Generators (IG's) were developed to provide a low-cost combination of host computer and IG in a single physical system. As these systems are over 10 years old, the operation and maintenance costs were significant, and the visual scene quality was poor in comparison to modern IGs. In order to modernize one of these SIMNET sites as a prototype, PEO STRI replaced the legacy SIMNET GT-111 host/IG at the Aviation AVTB and delivered a completely PC-based distributed simulation environment that exceeds the capabilities of the original devices. Both the visual systems and host simulation were migrated to PC's.

U.S. Army's Core DIS Facilities

Since the initial fielding of SIMNET, two types of facilities have evolved: SIMNET-T (training) sites that specifically provide collective troop training, and SIMNET-D (developmental) sites that serve as Research and Development (R&D) "Test Beds". These Test Beds service customers from the three domains of Distributed Interactive Simulation (DIS): Advanced Concepts Research (ACR); Research, Development and Acquisition (RDA); and Test, Evaluation and Military Operations (TEMO). The AVTB is one of the three SIMNET-D facilities (now known as "Core DIS Facilities", or CDFs) run by PEO STRI's Product Manager for the Combined Arms Assessment Network (PM CAAN) under the Advanced Distributed Simulation Technology II (ADST II) indefinite quantity contract with prime contractor Lockheed Martin Information Systems (LMIS).

As noted by many AVTB and ADST II customers, the main limitations of the SIMNET devices are the limited visual range of 3.5 kilometers (km) and a graphics display limited to 320 x 240 pixels (which is exacerbated by an update rate of only 15 frames per second). Given the large the number of SIMNET Rotary Wing Aircraft (RWA) devices at the AVTB and a shrinking Defense budget, the feasibility of replacing the GT-111's was investigated because of the performance, affordability, and upgrade potential offered by numerous image generation vendors' PC-based IGs that used commercially-available 3D graphics accelerator cards to render the 3D imagery.



One of the CDF Upgrade tasks focused on replacing the simulation host computer ("rehosting") of the GT-111 host/visual system for the AVTB's

RWA devices. The purpose of this helicopter simulation rehost was severalfold: (1) upgrade the simulation from the SIMNET protocol to the Distributed Interactive Simulation protocol; (2) use a higher performance CPU to increase simulation capability; and (3) develop a "Generic IG Interface" that would allow the SIMNET GT-111 IGs to be easily replaced. Many customers use the AVTB facility because of the unique capability to provide up to eight man-in-the-loop simulators in a distributed interactive simulation with correlated Computer Generated Forces. The AVTB uses the Modular Semi-Automated Forces (ModSAF) application that also was ported from high-end UNIX workstations to PCs as part of the CDF Upgrade.

Early in 1997, PEO STRI and LMIS began investigating the feasibility of using Microsoft Windows-based PCs as a low-cost replacement for the AVTB's GT-111's. Two factors piqued the interest in PC-based IGs: (1) the economies of scale of PC commercial graphics vendors established performance and price points such that real-time visual capabilities were sufficient for replacing the GT-111's; and (2) the availability of commercial PC-based IGs that provided three-dimensional (3D) databases correlated with ModSAF's Compact Terrain Data Base (CTDB) format. In the summer of 1997 MetaVR, Inc., was selected to build a "prototype" of a multi-channel, PC-based replacement IG for the AVTB devices. At the time, the MetaVR "Virtual Reality Scene Generator" (VRSG) was the only commercially available PC-based IG that rendered 3D imagery that was derived directly from the ModSAF CTDB databases. The resulting prototype and subsequent site upgrade was a landmark event in the history of military simulation: The first advanced distributed simulation facility that fully exploits PC-based products as its primary simulation capability.

The PC-based Invasion at the AVTB

Interoperability was key to any upgrade to the RWA simulators at the AVTB. Therefore, it was critical that terrain correlation exist between the man-in-the-loop RWA simulators and ModSAF. Thirteen databases were generated as part of the Topographic Engineering Center's Rapid Terrain Visualization effort. These databases were converted from the ModSAF CTDB format into 3D databases for use on PC-based "stealths", which provided a means to maneuver through the virtual environment without being seen by any of the battlefield combatants. The CTDB format uses 125-meter elevation post spacing to create gridded terrain databases for ModSAF, which results in a robust terrain representation. Previously, these CTDB databases were too "dense" to be rendered at any more than 5-to-15 Hz update rates on PC-based IGs, but 30 Hz update rates and excellent terrain/feature correlation were demonstrated between the MetaVR VRSG stealth, the legacy GT-based

RWA's, and the ModSAF systems. This correlation was key to the selection of MetaVR to build a prototype PC-based IG replacement for the GT-111 IGs.

From the beginning, it became obvious that the prototype PC-based IG would require a rendering approach that was different to that of "traditional" image generation. Whereas the traditional IG architecture generally manages multiple "graphics pipelines" within a single chassis, every channel in a PC-based system has a separate, dedicated PC that manages its own graphics pipeline to render the imagery for a particular display. Another difference between the two architectures is that in a traditional IG, scene management software is used to control the update rates of each visual channel, while the PC-based approach at the AVTB uses the SimHost as a server to control the "clients" (individual visual channels). Each display view is defined at initialization and the corresponding scenes are individually controlled by each PC, which run their own Windows 95 runtime application. In this configuration, each PC maintains its own copy of a terrain database that is demand-paged from its own disk, very different from the traditional IGs that manage the multiple channels by paging in the information for all channels from a single disk. Instead of having dedicated sensor channels like a traditional IG, all of the visual channels in the AVTB's PC IGs can support dynamic run-time switching between out-the-window, forward-looking infrared (FLIR), and daylight TV views.

With the selection of PC workstations for the prototype PC-based IG, there was no denying that the CDFs were smack in the middle of a PC-based invasion. Not only were the CDFs some of the first military simulation facilities to seriously look at using PC-based IGs for replacing legacy networked IGs, the CDFs have also selected PCs to run their stealth, ModSAF, communication, network infrastructure, and host computer applications.

Prototype PC-based IG successes

The RWA prototype PC IG demonstrated that each channel was able to maintain a 30 Hz update rate using a 5000-meter far clipping plane for each of the five out-the-window display channels. The new PC-based IG obtains viewpoint information from the SimHost on an isolated 100-Megabit Ethernet network to avoid any network collisions, thereby providing efficient viewpoint updates. The SimHost filters out Entity State Protocol Data Units (PDUs) that are beyond the 5000-meter far clipping plane of the PC-based IG. This range-filtering method allows for the new PC-based IG to display up to 800 entities across the five out-the-window visual displays. The sixth channel is a dedicated sensor channel that extends the previous sensor range of the GT-111 from 7500 meters to 10 km for a 3-degree horizontal FOV with two-dimensional symbology overlays. Similar to traditional IGs, all of the PC-based IG channels include level of detail (LOD) model switching to reduce scene complexity. As terrain correlation is a dominant requirement in a distributed simulation environment, a single LOD is used for the terrain databases.

From a life-cycle maintenance standpoint, the cost of maintaining the aging GT-111 IGs was further justification for the PC-based replacements. Vendor repair of the GT-111 had all but ceased to exist, and it was costing over $4000 to repair a single card (and there were a lot a cards awaiting repair!). With the new PC-based IGs, $4000 can replace an entire channel. There have not been any estimates to the corresponding reduction to operation & maintenance hours, but the mean-time-between-failure rate and overall reliability of the new hardware and software has been demonstrated during recent simulation exercises at the AVTB. The new PC SimHost and prototype PC-based IG survived the entire 2 » weeks of the Joint Combat Search and Rescue Virtual Simulation 2 (JCSAR VS2) exercise without any downtime due to hardware or software failures. This is especially remarkable since the long-haul, multi-site JCSAR VS2 exercise had to repeatedly "reboot" the other RWAs that were still using the GT-111 IGs.

PC-based IGs: For better or for worse?

The current generation of low cost game PC-based 3D cards have the capability to provide millions of triangles per second and large pixel fill rates. There are new 3D graphics chipsets being announced all the time, with several OEM's using the same chipset and trying to differentiate their particular 3D board from the others. A common theme in the 3D graphics game community is the tremendous support of drivers for the Microsoft DirectX Application Programmers Interface (API) over Open GL or proprietary standards. In order to take advantage of the largest set of potential hardware as upgrade paths for the PC IGs, the AVTB's PC-based IG is written to support DirectX.

One limitation of low-cost graphics cards is that they currently do not support multi-channel scene management, and image post-processing. Most of the current 3D cards do not support polygon antialiasing, probably because these cards have been primarily targeted at the PC gaming or location-based entertainment markets, which demand low-cost 3D graphics. Most 3D cards do eliminate texture antialiasing artifacts through tri-linear filtering, but polygon antialiasing has been, for the most part, a feature that the gamers

may have been willing to live without. However, some of the latest PC 3D graphics cards support polygon antialiasing, and future 3D graphics card performance increases are very likely to include polygon antialiasing (especially now that some of the 3D vendors realize that the military simulation market demands it for their applications).

Another current shortcoming is the lack of a multi-channel load manager for most PC-based IGs. Most traditional IGs have a load management capability that maintains a fixed IG update rate, and only drop the update rate as a last resort in order to control the processing load. In contrast, current PC-based IGs are usually a collection of multiple independent channels that do not have a single, cohesive scene manager (like the traditional IG). The reliance of the PC-based IGs on the non-real-time Windows Operating System currently inhibits them from running at a fixed frame rate, and most PC-based load management usually involves a reduction in a channel's update rate to handle any processing overload. The problem with this approach, however, is that other channels continue to update at their own rates, resulting in mismatched update rates across all channels (which can be visually distracting to the observer). To deal with this issue, a hardware-based multi-channel synchronization was supplied by MetaVR to provide a means to synchronize multiple displays.

The last major limitation of the current generation of PC-based IGs is that most have simplistic sensor image post processing of the rendered imagery, and can only display 8-bits per color component for the sensor imagery. Since many military simulators have some type of sensor display, many times a sensor "post processor" board is required between the display processor and the displayed imagery to add in two-dimensional symbology (e.g., Heads-Up Display or reticles) and sensor effects (e.g., noise or blooming). Even though some IGs can calculate more than 8-bits for each color component, the values are usually dithered down to 8-bits due to display buffer limitations of the current generation of PC-based 3D graphics accelerators. The 8-bits per color component of displayed sensor imagery limits the range of intensities that can be displayed in the simulated sensors. This too is changing rapidly, as several 3D cards are due out in 1999 that include 10 bits per color component in the display buffer.

Even though the current 3D PC cards have some limitations, the performance, low cost, and upgrade potential of the PC-based IGs are good reasons to warrant serious consideration for many simulation applications. The performance of the PC-based 3D cards is starting to rise to heights that were previously only achievable by high-end graphics workstations or traditional IGs. Since the PC-based prototype IG concept was conceived in the spring of 1997, the CPU speed has nearly doubled (266 MHz to 450 MHz), the hard drive access performance for demand paging of terrain has doubled, and the pixel fill rate has increased from 45 to 180 Megapixels per second. The original 3D card for the prototype PC IG was the Quantum3D Obsidian 50:4400, as it was one of the fastest 3D cards available at the time with a pixel fill rate of 45 Megapixels/second. Only a year later, the Canopus Pure3DII card using the 3Dfx Voodoo2 chipset began using Scan Line Interleaving to attain a pixel fill rate of 180 Megapixels/second - a performance increase of 400 percent in just one year!

These performance increases for PC-based IGs are being driven by the commercial marketplace, which is in contrast to the way traditional IGs drive their requirements (i.e., primarily by military applications). Allowing the commercial market to drive the IG requirements allows military customers to take advantage of the economies of scale derived by commercial competition and the sale of large quantities of PC-based IGs. The consumer demand for low-cost, high performance 3D cards will likely ensure that their performance continues to rapidly increase and remain low in cost. One thing is for sure - the future looks bright for the performance potential of PC-based 3D graphics due to the demands of the commercial marketplace.

The rapid development pace of newer, faster CPUs and PC graphics cards also allows for unprecedented upgrade potential for the PC-based IGs. For example, since the Pentium II CPU is easily upgradable, system performance increases can be easily realized simply by replacing the CPU with a faster Pentium II Processor. Unlike traditional IGs, PC-based IGs offer the flexibility of 3D APIs to open standards (e.g., OpenGL or DirectX). Since most 3D graphics cards are compliant with the Microsoft DirectX or OpenGL standards, the old 3D cards can be easily replaced with newer, faster (and often cheaper) cards. Never before have IGs for military simulators had such potential for low-cost Pre-Planned Product Improvements (P3I), especially since the upgrades can be performed on-site without the normal downtime incurred by sending the IG to the vendor for the upgrades. A good example of the ease of upgrades is with the integration and evaluation of the new Canopus Pure3DII Voodoo2 card, which took less than ten (10) minutes to install and get running in the AVTB prototype. No modifications were required to the application code to support the new hardware.

Conclusion

There will certainly always be a need for "traditional", expensive, high-end IGs for high fidelity applications such as Combat Mission Simulators and Weapons System Trainers. However, image generation for military simulators is on the brink of a revolutionary change for the medium- and low-fidelity networked IGs: a paradigm shift from using the proprietary networked IG to using Windows©-based PCs for real-time image generation requirements.

The prototype PC-based IG effort at the AVTB is an indicator of this paradigm shift, as it demonstrated the feasibility of replacing legacy networked IGs with Windows©-based PC's. As a result of the success of the

prototype, the CDF Upgrade program conducted a competitive source selection for replacing the GT-111 IGs at the AVTB with PC-based IGs. As a result, in September of 1998 all eight RWAs were modified with run on low-cost, synchronized, correlated, multi-channel PC-based IGs and PC simulation host computers. These upgrades were purchased for a fraction of the cost of "traditional" IGs, and provide normal and degraded out-the-window images, FLIR, and DayTV views for the RWA devices. PEO STRI is currently working to include a nighttime simulation for the new IG systems at the AVTB.

While the performance of the PC-based IGs do not match those of a high-end IG, it was relatively easy to exceed the performance of the lower-fidelity GT-111 image generators. The AVTB has hitched their future to the commercial PC market, which is making rapid advances in CPU speeds and the performance of graphics accelerators. The economies of scale of the commercial PC market are bringing the system costs down and shortening the time span between the introduction of faster chip sets. The PC graphics card industry is driven by a demand for realism in the game market that is showing no sign of abatement, as illustrated by games such as Apache Longbow II and the upcoming QuakeIII Arena. Along with the rapid performance increases, ties to open standards allow for unprecedented ease and low cost upgrade potential for customers using PC-based IGs - who wouldn't want to increase their performance by 50% or more every year for several thousands of dollars per channel (or less)?