Transformational ChrAVE-ings

by Margaret Davis

"Bravery is still part of it all, but bravery with modern communications at its disposal."

— Deputy Secretary of Defense Paul Wolfowitz, NPS, 2/22/02

The word "transformation" is all the buzz in Pentagon conference rooms, "so popular in defense policy circles," as Deputy Secretary Wolfowitz observed in his February 22, 2002 remarks at NPS, "that at times it almost seems to have lost its meaning."

Nevertheless, the concept emerges grimly ascendant after September 11. Suddenly, evolutionary improvements in weapons and tools, however rapid, are not enough. Never mind the hundredth iteration in the refinement of the widget; this is the hour of the different drummer. "We need smart people," says Wolfowitz, "who can think about old things in new ways that make sense."

Wolfowitz's pet example of transformational thinking is the special-forces captain in Afghanistan who directed air strikes via satellite from astride a horse. This synthesis of Wild West and *Wired* magazine—John Wayne meets Jeff Goldblum—typifies the resourcefulness and technological moxie the Pentagon covets today.

Here at NPS, Marine Corps Major Mark Lennerton has also been taking two plus two and making ten. For his thesis work in 3D simulators at the MOVES Institute (Modeling, Virtual Environments and Simulation), Lennerton has reconceived the flight-training simulator, transforming this well-worn idea through a combination of experimental technology, applied psychology, and vintage Hollywood.

Flight simulators began forty-some years ago as a great idea that went pretty much straight to production without thoughtful preliminaries. "We just

presumed simulators would work," observes Lennerton. "We never took the time to examine what aspects of flying could and couldn't be—or even shouldn't be—trained through simulations, and just went with the assumption that the greater the fidelity to an actual aircraft, the better."

Yet flight simulators have always been more or less disappointing. "Simulators are fine for some functions, like learning instrument-flight procedures," says Lennerton, a CH-53D helicopter pilot. "But I haven't met a simulator yet I liked for terrain navigation."

Navigation and orientation—knowing what's above and below and one's whereabouts on the map—is the fulcrum of any successful mission and typically represent the pilot's greatest challenge. Yet simulators have not been able to offer what pilots need most and real life can't provide: navigational practice over enemy terrain. "You can't practice where the bad guys are," as Lennerton wryly notes.

"You have a keen-edged squadron who've been practicing missions over home ground. You stick them and their helos in a Navy ship for a week or two, unload them on enemy shores, send them up for their first look at the terrain under conditions of war. It's been God speed, God bless, goodbye."

Naturally, a pilot prepares as best he can by studying maps and photos; but reading a flat, two-dimensional rendering and translating it to three-dimensional space is an imaginative leap fraught with subjectivity and approximation. Lennerton posited that by returning without prejudice to the original problem of building a flight simulator, he could find a new answer using virtual-environment technologies—an answer that would include training over any terrain, offering an experience as lifelike as a walk in the park. For his master's thesis, he took on the job.

Lennerton identified poor visuals as the biggest shortcoming of conventional flight simulators, which, at best, offer a big screen or couple of computer monitors to contain the simulated field of vision. But this limitation creates problems. With the eyes locked in place, natural motor skills quickly atrophy. The pilot abandons the casual, habitual movements that tell the mind

what's happening, such as craning around for a view behind or rocking the head slightly to create the parallax that yields depth perception. Instead, he learns to fly as though head and torso were in a vise—overwriting and degrading his real-world skills. Moreover, in such a patently false situation, the pilot never believes he's in any actual danger, and grows sloppy and overconfident in navigation, communications, and coping skills.

To create a world that looks and feels like reality, Lennerton went Hollywood. Borrowing the familiar chromakey "blue-screen" technique by which a TV weatherman appears against a swirling weather map, he designed a chromakey-augmented virtual environment, or ChrAVE. The ChrAVE consists of a simplified generic helicopter cockpit with pilot's seat, basic controls (collective, cyclic, rudder pedals), and a computer monitor that, switched on, becomes the instrument panel.

The cockpit's walls and window frames are built of black cloth and PVC pipe, which obstruct the view and require the pilot to find good vantages, as in real life. In front of the cockpit is a floor-to-ceiling swath of chromakey-blue canvas, wrapping to the right from about 11 o'clock to 6 o'clock. In the simulation, this blue field will carry images representing the viewing responsibilities of the right-side pilot in a two-man crew.

The pilot takes a seat and dons a helmet-like apparatus known as a head-mounted display, or HMD.

The HMD bristles with gadgetry. First, as the name implies, it contains two small computer monitors, mounted in front like a pair of binoculars. The pilot looks through these at all times. An inch above the monitors is a video camera that captures the pilot's view inside the cockpit—the ordinary, actually-present elements the pilot needs to orient himself and carry on navigation: his hands and body, maps, pens, instrument panel, the cockpit's walls and frames.

Atop the HMD, facing upward, are two dime-sized sensors that talk to an inertial-motion tracker overhead. The tracker, a crossbars with microphones at each tip, pulses infrared light to the HMD sensors below, which respond with ultrasonic chirps. The microphones pick up these sounds and send them to a

Windows PC, which in turn identifies where the pilot is looking by calculating the lag between pulses and chirps as the pilot moves his head—analogous to a bat's echolocation, but distortion-free. This coordinate information is key to the simulator's performance.

With cockpit, blue-screen, HMD, tracker, and pilot, the players are in place. Add a bank of satellite-captured images (textured onto terrain geometry), cue the ambient din of chopper blade and radio-squawk, switch on the digital mixer, and the show begins.

If you were to watch someone using the simulator, you'd see a guy wearing headgear sitting in a pretend cockpit hung about with canvas. He's looking all over: now down at his map, now scrutinizing the blank, blue canvas, eyes roving. He's pointing at invisible things on the cloth in answer to Lennerton's questions. He's active, tense, immersed in what he's doing.

He seems to be seeing things.

Step around to Lennerton's triplex of monitors, which show what the pilot's perceiving through his HMD, and you'll understand what's up. On every bit of chromakey-blue field—and only on the chromakey field—the computer has patched contiguous terrain images, creating the illusion of a seamless panorama. Whenever the pilot moves his head, even slightly, the landscape moves with him in tight correlation: he looks up, he sees sky; he looks down, he sees the ground through the "chin bubble" at his feet. Because only the blue canvas is painted with terrain, the cockpit environment is also plainly visible (thanks to the contributions of the HMD's video camera).

What the pilot is seeing is himself in a helicopter, flying over a terrain through which he is being asked to chart a course. The visual logic of the scene tricks him into believing in the flight at a visceral level. And now the transformational benefits roll in.

"We can teach navigation as it really happens, with the pilot looking around constantly, folding and marking maps while coping with flight gloves and a heavy headset. We add huge dividends by cranking up the

stress—speeding things up, introducing fog, mechanical failures, night, teaching him to maintain procedures that tend to go by the wayside under anxiety."

"And obviously, we're giving him experiential knowledge of enemy terrain, which may well save his skin."

Stress, fog and failures are iffy to plan for and costly to train in real life, whether in time, budgets, maintenance, or personnel. Lennerton's simulators are, by any measure, a deal. "You could network a whole squadron to one central computer system. An obvious practical use would be embedded training aboard ship on the way to a mission. Rather than let their skills rust, pilots go down to the hold and get in their own helos to practice flying what they're going to see onshore."

But not necessarily in isolation—Lennerton's system can be expanded to allow multiple users to share the same virtual reality, seeing and communicating with each other as if they were all physically together in the air. With genuine helicopters to practice in rather than a ChrAVE, equipment requirements would be minimal—mainly individual motion trackers, HMDs, and blue-screens (each cut to fit a helo canopy like a tea-cozy).

"You have to train the way you fight," says Lennerton, "because the corollary is, you'll fight the way you trained. I want naval aviators who are on the pointy edge of the spear to fight smart and win because they have the advantage of knowing where they are and what's around the corner."

The project is still in its infancy. "Who knows where it may evolve—this doesn't apply just to helos, but tanks, AAAVs, any combat vehicle," says Lennerton. He expects to see ChrAVEs in general use within "twelve to fourteen years."

Mike Zyda, director of the MOVES Institute, disagrees. "No," he declares flatly. "This is going to transform flight simulation. We'll see it in five years max."

Major Lennerton has flown helicopters for the Marines since 1991. After graduating with his master's degree in April, 2002, he is slated to teach computer science at the US Naval Academy in Annapolis. The ChrAVE project is sponsored by the Office of Naval Research's as part of the VIRTE (virtual training and environments) program.

Sidebar One:

Professor Rudy Darken, MOVES director of human-performance engineering and Lennerton's thesis advisor, describes the ChrAVE project as but part of a larger development in training and simulation.

"We're changing the whole field by adding a step one and step three to the development process." Step one is research into the psychology and potential of training via simulators. Step two—hitherto the only step—has been building the machine. Step three is verification of results.

In contrast with the traditional engineering mindset that sees the final product in terms of new and improved equipment, Darken defines a well-trained aviator as the goal.

"Ultimately it doesn't matter what form the box takes or how realistic the gear; if a magic wand could get results, great. What is crucial is to ascertain what the mind and body specifically require to perform a given task, and to simulate those elements effectively. This is where human-performance and training studies come in."

"We're interested in concepts, in bringing a rigorous process to simulation. Without a bias towards any particular product or approach, we can focus on asking fundamental questions and developing methodologies for analyzing results."

This independent stance is extremely valuable to decision-makers in search of the bottom line. "Sharp guys out there are bewildered by all the competing claims and marketing hype. They turn to us for a scientific, disinterested rationale as a basis for purchasing. I anticipate MOVES serving that role increasingly in the future. "

Sidebar 2, VanPutte

SimSecurity: It Takes One to Fake One

The computer-security (or "information assurance") playing field has always been uneven. Hackers are mavericks—obsessive, patient, crazy like a fox. They need only one way into the system to launch an attack.

Defenders, by contrast, are typically the law-and-order type: conventional, protective, focused on functionality and computer-maintenance routines rather than anticipating new manifestations of abnormal nerd psychology. The system administrator's job is hopeless: to plug all possible holes, many of which he never dreamed existed, while respecting organizational, legal, and ethical constraints.

No wonder the hackers score.

Major Mike VanPutte, a Ph.D candidate in computer security at the MOVES Institute intends to put a stop to this. With his thesis advisor, computer-science professor Cynthia Irvine, the CISR (Center for Information Assurance and INFOSEC Studies and Research) academic group, and MOVES professor John Hiles, VanPutte is creating SimSecurity, a computer game that teaches users how to play cyber cat-and-mouse—and win.

"Frankly, one of our major problems has been that training is horribly boring, consisting of scrolling through pages and pages of online notes. The real challenge is to stay awake." But on the other hand, games are fun. "We're using the same role-playing, competitive techniques that enthrall video-game players. We can convey sophisticated security strategies through an entertaining medium."

VanPutte's program is powered by MOVES' agent-based simulation technology, allowing players to detect threats and block attacks in unscripted interplay. The user plays a system administrator in the program. His mission is

to interact with end-users, managements, computer professionals, and of course, hackers, all the while balancing system functionality versus security versus a limited budget and timeframe.

"We're training computer users to understand the consequences of clicking on questionable email attachments and downloading games and screen savers from untrusted web pages. They also learn how crackers and hackers manipulate users the low-tech way, by chatting them up on the phone."

VanPutte's research goal is to build a networked lab simulating the information-assurance environment, an environment that will evolve as actors hone skills, develop relationships, and change their goals.

"Meanwhile training's no longer a bore. In fact," he winks," workers are going to have to confess to the kids they get to play games all day."