Applying integrated systems in industry, engineering and commerce

Making 'Wargames' computers compute required innovative programming

Special effects integrate on-screen displays with offscreen computers and software

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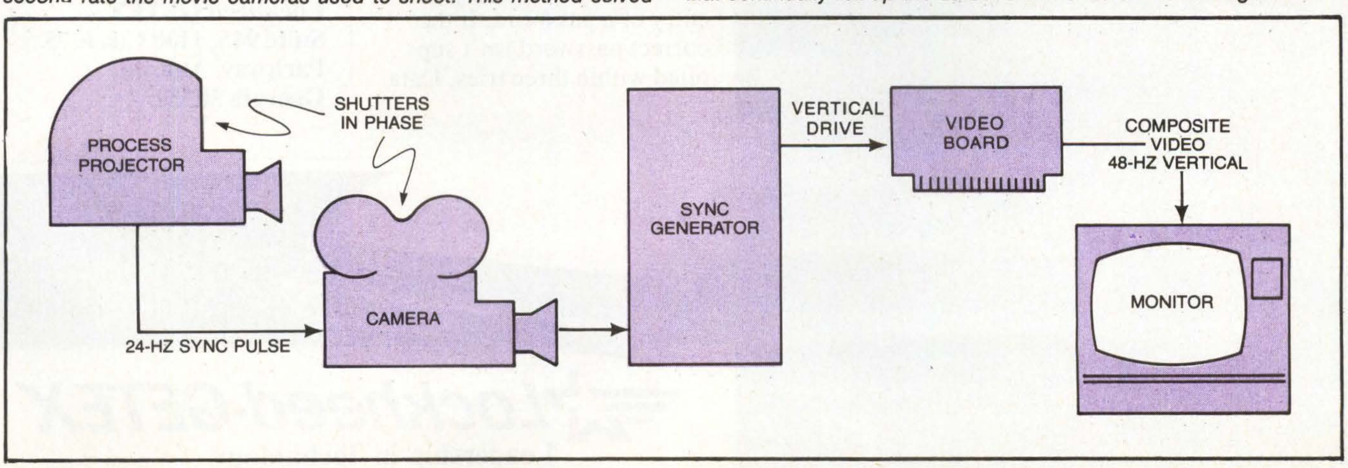
One of the main characters in the film "Wargames" is a supercomputer. Called WOPR (whopper) after the fictional North American Defense Command's (NORAD's) War Operation Plan Response, the computer plans missile deployment and controls the huge display screens in NORAD's war room. WOPR is the brainchild of a warped genius, a pioneer in artificial intelligence, who programmed the machine to learn from its mistakes. To help it learn decision making, he programmed in a variety of games and gave WOPR a strong desire to win.

As the film's title suggests, one of the games WOPR wants to win is global thermonuclear warfare. When the film's protagonist, a teenage computer buff named David Lightman, discovers a "back-door" password that gives him entry into WOPR, global thermonuclear warfare is the game he wants to play. Just for fun, he chooses to play for the Soviet Union and launches "missile strikes" against Las Vegas, Nev. and Seattle. WOPR begins working out a nuclear response, even though it can't distinguish between games and reality. To make matters worse, the computer has gained control of the nation's missile strike force. So when Lightman begins his attack, WOPR prepares to launch real missiles against the Soviet Union in retaliation.

"Wargames" is an exciting film, but it was difficult to make and especially to get the computers and terminals to operate realistically. In one scene, when Lightman doctors his high school grades by gaining access to the school computer, the audience for the first time sees Lightman's computer installation. The machine looks the way an uninformed audience expects it to look—with a front panel that has lights and switches. Yet it must also convince more knowledgeable members of the audience that it could be within the financial reach of an affluent teenager. To complicate matters, the computer must be able to generate at least crude graphics to display the maps produced by WOPR when Lightman begins playing global thermonuclear warfare.

It quickly became clear to the special-effects group that no teenager could afford a computer with the required computing power. Lightman's "computer" would simply be a prop, with the actual computing piped in from an offscreen machine. One of the first personal computers, made in the mid-'70s by now-defunct computer manufacturer IMSAI, met the appearance criteria, so it became Lightman's on-screen computer.

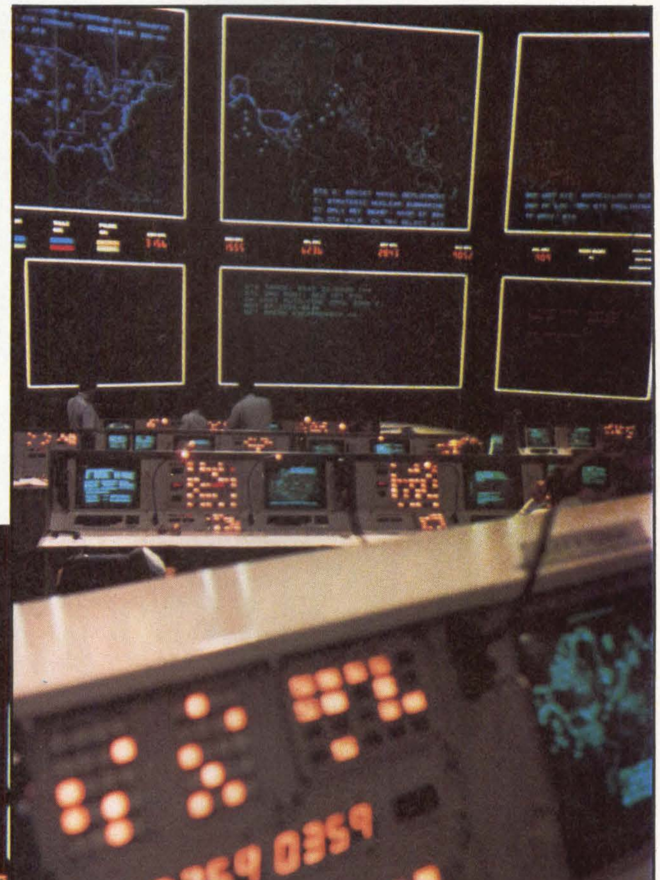
Modified video boards *scanned CRTs at the same 24-frame-per-second rate the movie cameras used to shoot. This method solved the synchronization problem that results in flickering horizontal bars that continually roll up the screens of monitors in low-budget films.*

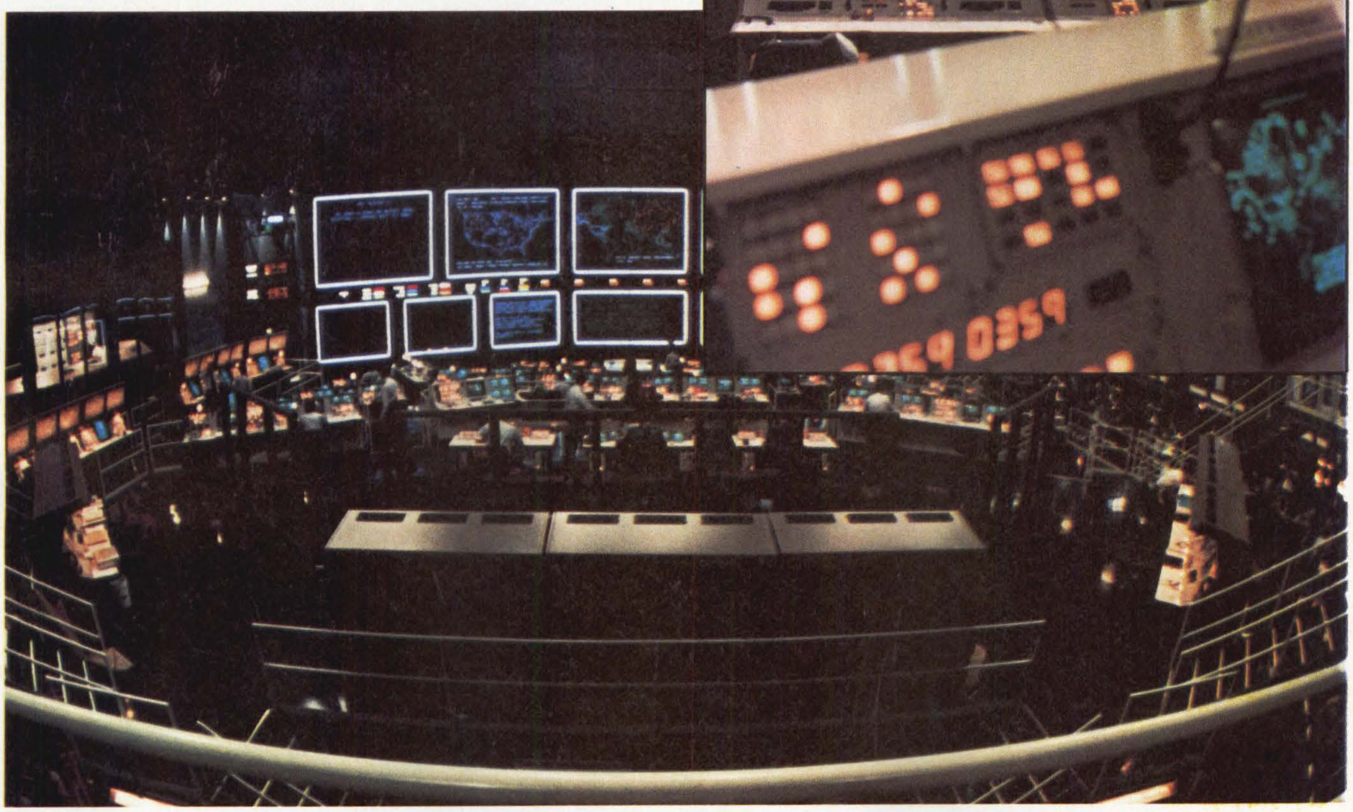


The Integrator

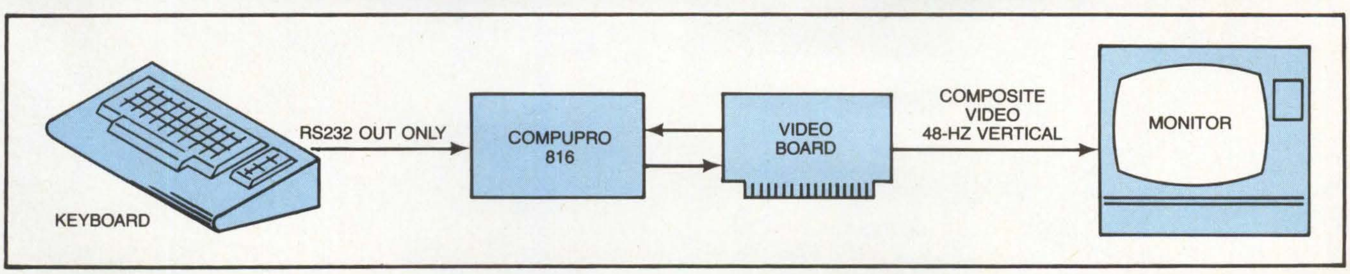
Offscreen machine pulls the strings

With the appearance of Lightman's computer out of the way, the special effects people next had to choose the offscreen computer, which would have to drive the CRT in Lightman's terminal, among other things. They first had to resolve a timing problem. Conventional CRT monitors scan 60 interlaced fields, displaying 30 frames per second, but movie cameras shoot 24 frames per second. This asynchronous operation results in the flickering horizontal bars that continually roll up the





The set for the war room's command headquarters *had 52 functional consoles complete with keyboards, 120 monitors and 12 large, overhead display screens. Making them look realistic was the task of the special computer effects crew.*



Echo-replacement software *automatically displayed a predetermined message on the monitor, one character at a time, no matter what key the actor hit. Software also replaced the input signal with a predetermined output signal and sent it to the monitor through the video board.*

screens of monitors in low-budget films. The "Wargames" visual effects supervisor, Michael Fink, insisted that these scrolling bars were unacceptable for a film built around computer displays.

To solve the synchronization problem, the crew used modified video boards to scan the CRTs at 24 frames per second, synchronizing them with the camera. Most specialized boards conform to the IEEE-696 standard, and their fast timing speeds make them unable to interface with the cameras. This drawback limited the offscreen computer to machines that use an S-100 bus, which handles much lower speeds. To further complicate matters, the offscreen computer needed a large on-board memory to accommodate real-time graphics. And, even more important, it had to be extremely reliable to avoid wasting expensive shooting time.

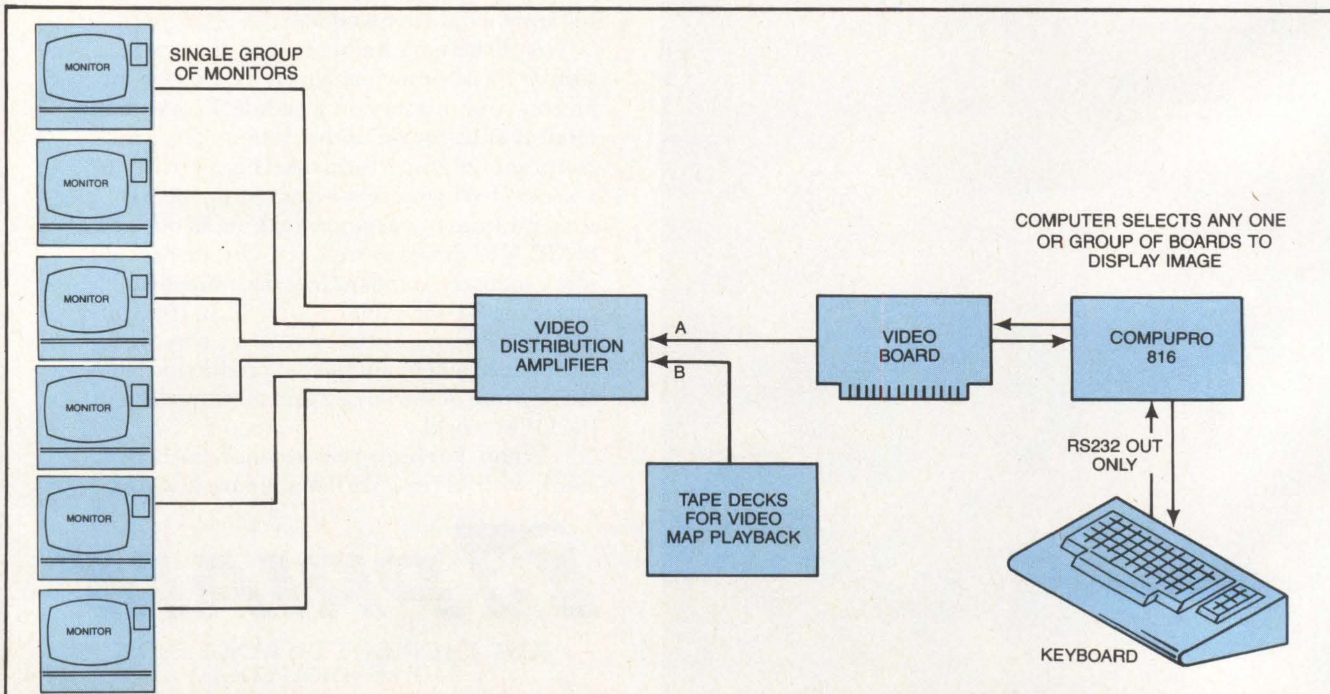
The job of choosing the computer fell to Steve Grumette of Artificial Intelligence Research Group, Los Angeles, who was responsible for programming. Grumette settled on using two CompuPro System 816s equipped with a 1M-byte M-drive/H solid-state disk. "The CompuPro is the most reliable S-100 computer available," he claims. "With production time running about $50,000 per day, we simply could not afford to chance the computer going down while we were filming."

With the hardware defined, the next problem was making the IMSAI appear to be interactive with WOPR. It was easy enough to wire Lightman's terminal to the CompuPro System 816 and make it look like the IMSAI was actually doing the computing. A parallel-to-serial converter board in the terminal transmitted keyboard commands to the CompuPro through an RS232 interface. The CompuPro, in turn, sent composite video signals back to the terminal's CRT through coaxial cable.

The trick was making the offscreen computer respond to Lightman's keyboard commands so the IMSAI appeared to communicate interactively with WOPR. Although Grumette could have used a simple interactive program, most actors aren't proficient typists. Every keyboard error would mean reshooting the scene. At $50,000 a day, reshooting scenes can get very expensive.

Software makes it look real

Grumette solved the problem by creating an echo-replacement routine that automatically displays a predetermined message—one character at a time—on the monitor in response to keystrokes. The program displays the next character in the message string each time *any key* is hit. So Lightman needed only to hit the right number of keys to put an error-free command message on his monitor. When the monitor displayed the last character in the echo-replacement string, the offscreen computer automatically sent an answer



Dividing the set's 120 monitors into 20 groups of six, *each controlled by a single S-100 bus video board, enabled 20 different images to show simultaneously. The crew positioned the monitors so that each one in a scene displayed a different image.*

message from WOPR to Lightman's terminal.

Putting graphics displays on Lightman's monitor for the war-game maps remained a problem until Grumette noticed that the S-100 bus video board had a complete ASCII character-generating font in ROM and that none of the 32 control characters ever appeared on the monitor. With those 32 characters and two other unused special characters, he had 34 alphanumeric characters that could be replaced with special graphics characters.

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Grumette wrote code for the graphics characters that produced a set of line segments, each displaced by a few degrees. After debugging the code, he had it burned into a new programmable read-only memory (PROM), along with the remaining active alphanumeric characters. The new PROM, which replaced the original, gave the alphanumeric video board what might be called "pseudographics" capability.

Using Grumette's software and the modified video board, visual effects coordinator Linda Blain Fleischer created the war-game graphics displayed on Lightman's monitor. After placing the monitor's cursor at the desired point on a 24-line, 80-character-cell display, she called up the line segments one at a time by using one of the arrow keys. Each keystroke made the next segment appear, in effect spinning the line through 360 degrees. Another arrow key could reverse the direction of the spin by calling up the previously displayed segment.

When the correctly angled segment appeared, Fleischer saved the segment's character code by striking the return key. She then moved the cursor to another character cell on the screen and repeated the process until she had drawn the entire map display. After she created a file to hold the screen's memory contents, Fleischer made several copies, adding appropriate missile tracks and attack submarine symbols to each. Once in memory, each map file could easily be called up for display on Lightman's terminal to show how WOPR's game playing progressed.

War room required large-scale simulation

Making NORAD's war room computers and screens come to life was more complicated. The set boasted 52 functional consoles complete with keyboards, 120 monitors and 12 large, overhead display screens. To facilitate programming, the special-effects crew divided the monitors into 20 groups of six. A single S-100 bus video board in both CompuPro System 816s controlled each group of monitors, so that 20 images could be displayed simultaneously. The crew positioned the monitors so that all those appearing in a scene displayed different images.

Conventional CRT monitors scan 60 interlaced fields, displaying 30 frames per second, but movie cameras shoot 24 frames per second.

The film's director requested that certain screens display specific images for predetermined time periods. To accomplish this, Grumette created these displays and created a file containing lists of the displays, where they were to appear and for how long. The computer then retrieved specific image files from memory, as instructed by the display file, and put them on the appropriate monitors for the specified times.

The script also called for several console operators to communicate simultaneously with WOPR through their console keyboards. However, the director decided that no more than four keyboards needed to be active at once. To simplify programming, Grumette divided the 60 keyboards into four groups of 15. But he still had to create a way to run four keyboards simultaneously from a single-user computer.

The answer lay in a polling program that used the CompuPro 6-MHz clock rate to monitor the keyboards sequentially. Although Grumette programmed the computer to lock out specific keyboards, he added insurance against extraneous monitor displays by converting the "Caps Lock" key on all the keyboards to an on/off switch and by activating only the four keyboards that had to be in use. He again used an echo-replacement program to generate the correct command messages in response to any keystrokes executed by the non-typist actors.

The large overhead screens required intensive design and programming. Images developed on a Hewlett-Packard Co. HP9845C desktop computer with a monochrome vector CRT were then filmed through color filter wheels with movie cameras. According to visual effects supervisor Fink, the film crew printed 128,000 feet of film to provide images for the 12 overhead screens. To complete the task, three programmers and three camera operators worked 10-hour shifts, 24 hours a day, for five months. A dozen process projectors projected prints of the graphics displays onto the big screens. In addition, selected monitors interspersed with the war room's interactive alphanumeric terminals played back some of the high-resolution graphic images, which had been tape-recorded at 24 frames per second.

Synchronizing the hardware

The special-effects crew had to synchronize the video displays and the cameras with the process projectors used for the big-screen displays. Because the projectors were much less stable than the two CompuPro computers or the cameras, one projector became the master clock to which everything else would be synchronized. The projectors themselves were already synchronized to each other through a high-gain servo loop.

In the process projector, a set screw in a shaft passing a Hall-effect transducer generated the synchronous pulses. Because of friction and varying mechanical loading, the pulse train produced by the projector had too much jitter to serve as a master synchronous pulse. But the crystal oscillator in a synchronous generator corrected the projector's pulse train, which could then act as a master to lock the computers, tape decks and cameras to the process projectors.

"WarGames" box office success unquestionably comes from an exciting story line that pits a teenage computer buff against the military. But part of the credit must go to Michael Fink, Linda Blaine Fleischer and Steve Grumette who integrated the on-screen props and offscreen computers with novel software to produce the special computer that gave the story credibility. ☐

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Interest Quotient (Circle One)
High 807 Medium 808 Low 809