Figure 6.49 *The challenges in implementing the FOX Puck effect were many, and a number of subsystems had to be designed and integrated into a single system. The first was the puck itself. Here is a "FOX" puck and its innards.*

Virtual Graphics

Infrared Hockey Pucks

One thing that FOX is known for is raising the graphics hurdle in every sport they become involved with. The NHL was no exception. In 1989 News Corp., the parent corporation of FOX, acquired a company called Etak, a maker of in-car navigation systems and the digital street maps they use. News Corp. saw the Etak as a content producing company. Although News Corp. sold the company to Sony after a couple of years, the technical core of the group stayed with FOX's parent. Stan Honey, who headed Etak's engineering effort, became News Corp.'s chief technology officer. Fox Sports — initially led by David Hill, with operations led by Jerry Gepner — along with Honey and company set out to find ways to make the FOX brand of hockey coverage an interesting topic at the water cooler. FOX hoped the fallout would be to widen the fan base. Honey went to Hill and proposed a system that would place ads and other graphical information on the walls around the ice. A recurring theme that Honey says he heard on this and succeeding project pitches was "We're not interested in that, but if you can do that, can you do this?"

The "this" was to build a graphics system that would highlight the location of the puck and display a "streak" that would show the puck's trajectory when its velocity reached a selected speed. Honey said he thought they could. A short time later he got a call from Rupert Murdoch, president of News Corp., and was told to drop everything and do it. He had a year until FOX's first hockey telecast, the 1996 All-Star game. This meant the design team could not test it on a real game until its debut. Honey and his team pulled it off on time, for $2.2 million. Although the system wasn't working 20 minutes before the game, the team fixed the problems and it worked well thoughout the game and generated the press coverage and controversy that FOX had hoped for. David Letterman spoofed the system on his show by simulating a "DaveTrax" key that followed his head as he ran around the stage. FOX loved the attention. They felt they got back more than their investment in press.

Honey and company first had to design a puck that could somehow advertise its position on the ice. The puck had to act like a normal puck in every way physically, including weight, along with the physics, like moments of inertia, etc. RF systems were investigated for tracking the puck, but the chance of interference from other sources during the game, and the fact that many arenas will bounce emitted RF around the venue many times before dying out, made radio direction and locating schemes too risky. They settled on an optical system. Besides their obvious purpose as the central object of the game, the pucks also had to be optical transmitters.

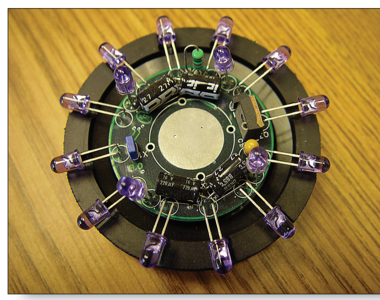


Figure 6.50 *Here is a closer look at the puck electronics. The circuit board housed 12 radial-mounted infrared LEDs. These LEDs emit 100 microsecond pulses in the 900 nanometer light range - 30 times a second. The circular pad in the middle is where the battery is installed, which can power the unit for 20 minutes. Another obstacle was that upwards of 20 pucks are used per game. They can't reuse them because once the electronics are potted inside the rubber you can't extract the printed circuit board to replace the battery for reuse. Each puck had to be designed and built fairly inexpensively. Hockey pucks are frozen by the NHL before use so the puck won't get soft too quickly. They found that the electronic pucks couldn't be frozen at as low a temperature as normal ones because the battery would become too weak. They could only freeze them low enough to be used for four, instead of the usual seven minutes. But this was still long enough to make it from one commercial break to the next during the game.*

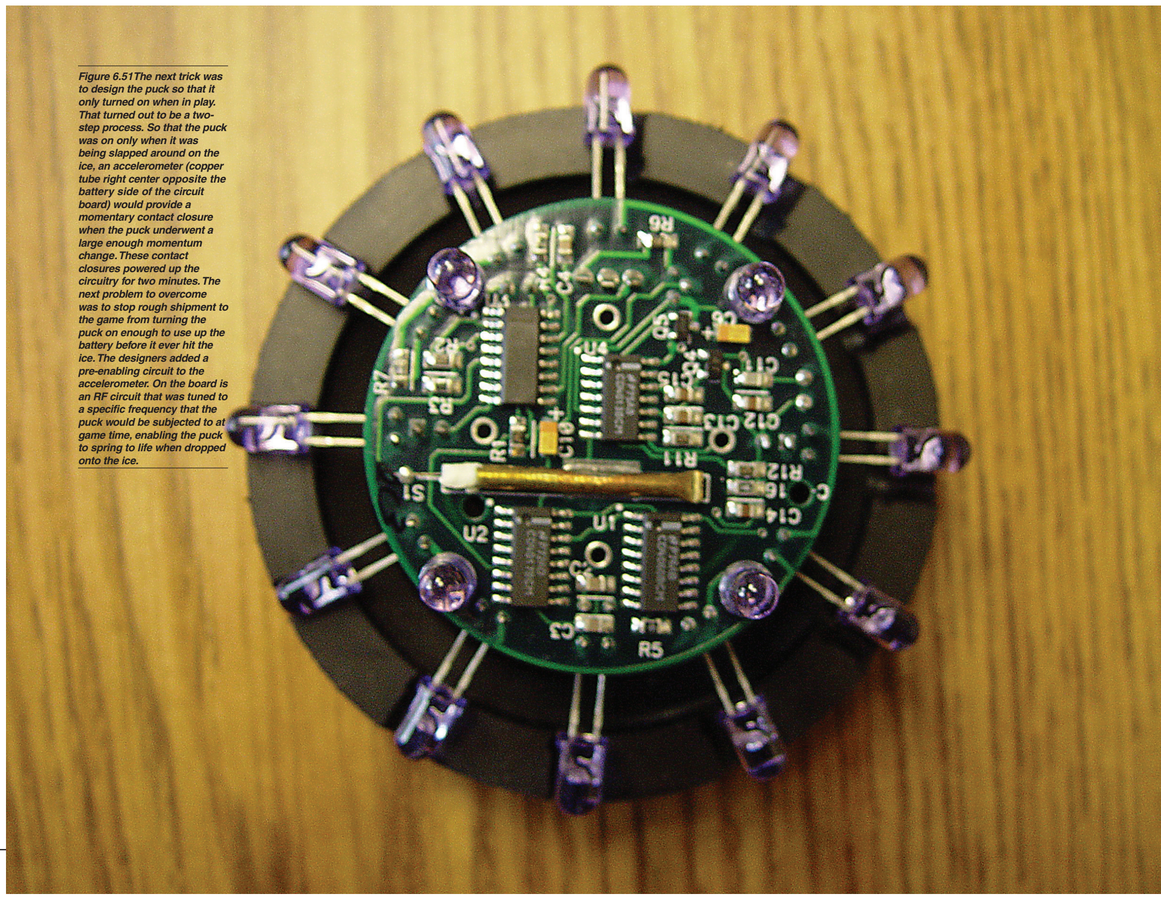


Figure 6.51 The next trick was to design the puck so that it only turned on when in play. That turned out to be a two-step process. So that the puck was on only when it was being slapped around on the ice, an accelerometer (copper tube right center opposite the battery side of the circuit board) would provide a momentary contact closure when the puck underwent a large enough momentum change. These contact closures powered up the circuitry for two minutes. The next problem to overcome was to stop rough shipment to the game from turning the puck on enough to use up the battery before it ever hit the ice. The designers added a pre-enabling circuit to the accelerometer. On the board is an RF circuit that was tuned to a specific frequency that the puck would be subjected to at game time, enabling the puck to spring to life when dropped onto the ice.

Figure 6.52 Pan/tilt head modified to work with the FOX Puck, and other Sportvision systems, such as the 1st-and-ten line.

The receiving end was a group of CCD sensors, essentially television cameras. The CCDs formed an array that could see the LED pulses in two-space. As long as a second CCD sensor could see the puck, the overall system could triangulate the puck in three-space. This system knew where on the ice the puck was. To limit all the infrared clutter, from flash bulbs to hot coffee, one subsystem's job was to look for infrared pulses at the puck's 30Hz rate, lock to it, and tell the other sensors in what window in time to look for the infrared pulse. This boosted the gain over infrared clutter by 300 times. It was realized during the first season that there was a potential spoof that a fan that managed to collect one of these souvenirs during the game could enact. If the puck's battery was still operating a fan could pound the puck on a hard surface and create a second puck to track in the stands. Luckily no one did that. The second season the system was designed to track only the puck in play by paying attention to the phase of the pulses from each puck.

Honey and company had a system to track the puck. How to lay, or key, that information over the camera still had to be developed. The real-time requirements of determining which pixels on the screen to use to highlight the puck's location meant no pattern recognition approach could be used. Also, because of the nature of the scanning used to create the complete video picture, there were often television frames that didn't even capture the puck as it moved. It soon became obvious that the best way would be to equip the television camera with the sensors necessary to determine what area of the action the camera was viewing and use that information to determine placement of the key signal.

This was done by placing resolving units on the camera's pan-tilt head (close-up shown in the left photo, tilt resolver is on the left), and capturing focal length (zoom position) information from the lens.

Notice the large lens on the front of the camera in the photo to the right. Lenses for television are designed to be fast (let lots of light through) and to be able to obtain very sharp focus. The trade-off is geometric distortions, such as barreling and pincushioning, that changes as the lens is zoomed in and out. The graphics system must maintain files on each lens to take these distortions into effect, so as to place the graphics correctly as the focal length of the lens is changed.

Early heads had a set of telemetry cables that ran between the camera head and the truck. Newer modified heads had a computer-based controller mounted on the front of the pan/tilt head. This box collected pan, tilt, focus and zoom telemetry. This compiled data would then be modulated much like a regular computer modem would do and be sent down an unused audio channel, which most professional cameras have available.

In 1998 FOX let Honey's group take the developed intellectual property and go off and start a company called Sportvision. FOX owns 10 percent of the company. This came about so that the technology could be marketed to the industry as a whole, as the FOX Puck technology was enabling new graphical ways of presenting information.

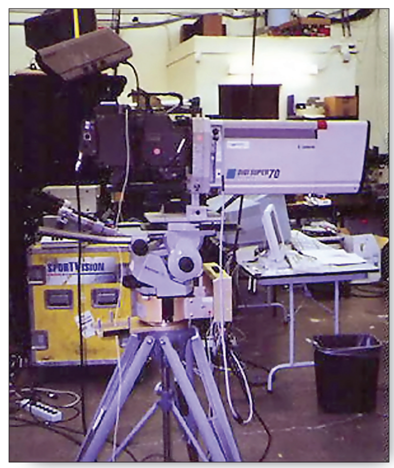


Figure 6.53 Here is a test camera on a modified Sportvision pan/tilt head. This telemetry would be shipped down to equipment in the truck that used massive computing power to turn the telemetry into a keyable graphic. At first that equipment took up most of a 60-foot trailer. Now the required space is down to a couple of racks.

Figure 6.54 Once Sportvision had mastered the art of tracking a moving object from fixed locations they realized there were other graphical overlays that would enhance the telecasting of sporting events. Their next idea was to improve the Telestrator. They proposed a device to FOX that would allow the color announcer to mark up the screen like the Telestrator could, but with the enhancement of only showing up, or being keyed, under the players. The marks drawn on screen would remain fixed in their initial area on the field, even if the camera panned or zoomed. Once again the Sportvision folks were told that wasn't needed, but if they could do that, could they instead graphically show where the first down in American football was currently by keying a line across the field of play. Hence the first-and-ten line. (Source:Sportvision)

The First-and-ten Line and Other Things Not Really There

One of the most interesting graphics overlays today is the first-and-ten line. Both Sportvision and PVI provide these systems, and they are indeed systems. CBS uses systems from PVI, while FOX and ESPN use systems from Sportvision. In the case of Sportvision the ability to know what part of a playing field that a television camera is viewing was combined with trigonometry techniques to highlight a moving hockey puck. Next that ability was applied to stationary objects, such as to where the virtual billboards are to be placed, or where the first-down line is to be drawn. How is this done?

Let's look at setup for the first down line. First, during setup, a spreadsheet of grid coordinates in three planes is collected on the playing field using standard surveying techniques. The X and Y coordinates will describe the field as a plane in space. The Z coordinate is to account for the crown that most football fields have for drainage purposes. But even indoor stadiums have this measurement done so that any unlevel aspects of the field are taken into account when the first-down line is displayed. In general once a venue is measured it can be used for future games.

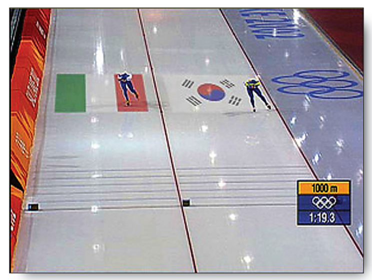


Figure 6.55 Eventually the enhanced Telestrator came to be also, along with the very first idea they proposed to FOX, "virtual billboards." You've seen these "billboards" under the ice at the Olympics showing the flag of the racer, in the crowds at a football game, or behind the batter in baseball, where every inning a new one often takes the place of the old. They don't really exist anywhere but inside powerful graphics computers. The people at the venue don't see them. (Source:Sportvision)

The Sportvision system is downstream from the rest of the production

Figure 6.56 Sportvision is not the only company in the virtual graphics market. The Coca-Cola and Durango billboards in these shots are via Princeton Video Image. Their system is known as Live Virtual Insertion System (L-VIS), and pronounced Elvis in the industry. (Source: PVI)

Figure 6.57 *Here a laser-leveling device is used to characterize the vertical surface of the playing field. (Source: Sportvision/NY Times)*

truck's equipment. As such this system needs the tally computer to determine when one of the first-and-ten designated cameras is on-air. This has to be done because video paths can be very convoluted as they travel through switchers and video effects systems, and thus tally signals can't be trusted. In contrast, the Princeton Video Image system keys the first-down line straight over the video of the designated cameras as soon as it leaves the camera's CCU. PVI uses a proprietary box called an L-VIS (Live Virtual Insertion System) that is based on VME-bus technology. The PVI approach is heavily hardware-based. This results in only seven frames of processing delay. A second PC running a user-interface application controls the L-VIS. Both Sportvision's and PVI's systems require three people to operate.

During the game Sportvision divides the workload as such:

A spotter is inside the stadium with a view of the whole field. The position of each first down is relayed to the truck by radio.

The line-position technician gets the first-down information from the spotter and enters it into the F-Ten computer, and also monitors the position of the generated line and makes adjustments if needed.

The first-and-ten operator monitors the broadcast line for quality and position. The operator uses the matte computer to continually check the colors of the field.

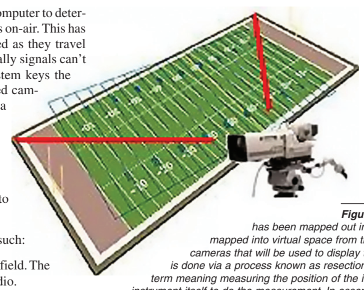


Figure 6.58 *Once the field has been mapped out in real space it must be mapped into virtual space from the view of each of the cameras that will be used to display the first-down line. This is done via a process known as resection, which is a surveying term meaning measuring the position of the instrument using the instrument itself to do the measurement. In essence it lets the camera know its place in space relative to physical field by measuring at least two points on the field. The bearing and elevation angle of each of these points on the field are obtained by pointing the camera at the selected points on the field and storing the pan and tilt values from the special pan/tilt head used. The graphics computers can now use standard geometry and trigonometry to place the camera relative to the field. This allows the system to compute where to place a graphical object, like the first down line, based on what part of the playing field the camera is viewing. (Source: NY Times)*

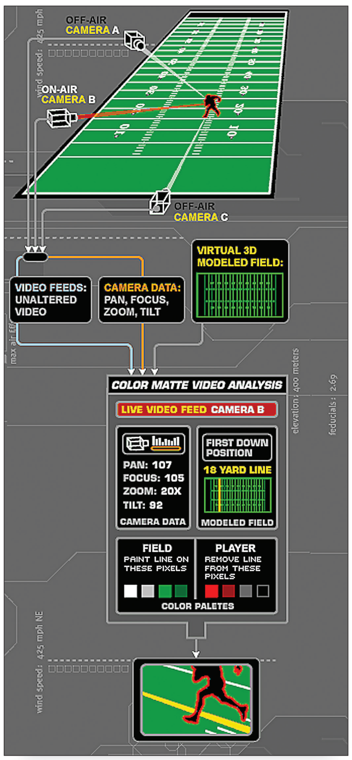


Figure 6.59 *Left: The drawing of the virtual first-down line takes five computers in the Sportvision system.*

GATHER PC - Receives the pan, tilt and zoom data transmitted from the cameras

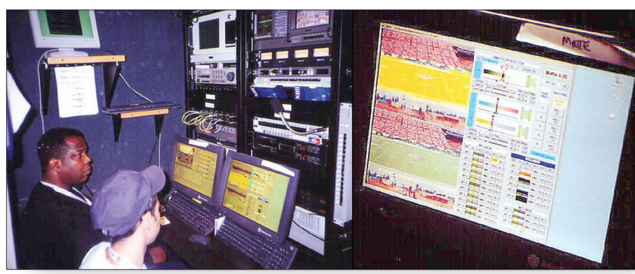
TALLY - Keeps track of the on-air camera and tells the F-Ten computer which computer map to use.

F-TEN - Displays the on-air video, overlaid with the right computer map. The line is drawn by specifying the left or right side of the field and the yard line, to the nearest tenth of a yard. For example: left, 37.8.

MATTE - Tells the render computer how to draw the line so the players will appear to run over the line.

RENDER - Receives data from the other computers, then draws the line.
(Source: NY Times)

Figure 6.60 *Below: Here the lead operator, the line-position technician (left), and the first-and-ten operator monitor and position the line. With the Sportvision system the lead operator will take the line out on close-up shots or during measurements so as not to show any discrepancies between the virtual line and the official measurement. The orange areas on the close-up of the GUI on the right indicate the areas where the system is allowed to insert the line. The palette at the bottom right of the GUI allows the operator to add colors found in the video to the "OK to key over" list, such as the color of the mud on the field. Conversely the operator can add colors that under no circumstance can be keyed over, such as the color of the players uniforms. The final result leads to a virtual yellow line drawn at the first-down mark, in perspective, on top of the field and under the players.*



In this section we have seen how graphics are now embedded into video as seamless objects that appear to be part of the real landscape, and not merely laid on top of the action. These graphics can provide additional information about the action, or virtual placement of ads and merchandise. In the next section we will see how the process of collecting telemetry and other data for use in placing graphics into the video can be used for other applications. ■