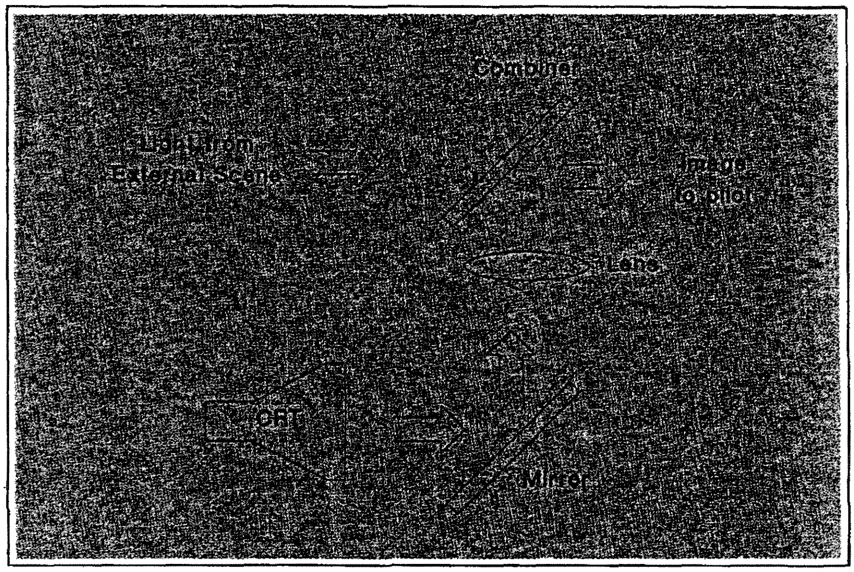
Heads Up Displays let you see down while looking up

Editor's note: Take time out from technical papers and Society news for "The light touch," a fresh Optics & Photonics News column meant to be shared with students and children of all ages.



Schematic view of a Heads-Up Display system

A Heads-Up Display is one example of an optical device that does pretty interesting things in rather clever ways, yet is based on principles that a kid can understand.

A Heads-Up Display (HUD) is essentially a system for displaying information such as aircraft speed to a pilot so that he can see it even when he's looking out the aircraft. If you're working with a youngster, you might let him or her sit in a car and notice that there are a lot of things on the dashboard, such as the speedometer, that a driver must look down to see. This means looking away from the traffic. The HUD allows the pilot to see his speed, altitude, and so on, even as he looks out the windshield.

The basic components of the HUD are illustrated in the figure. Starting at the bottom, you have a monitor, which displays the desired information. Somehow we have to get the information on the monitor up to where the pilot can see it. So next comes a mirror to bounce the light up, a lens to focus it, and finally a combiner to allow the pilot to see it. The combiner is the component that combines the image from the monitor with the light coming from outside, so that the pilot can see both.

A simple type of combiner one can use for demonstration is a beam splitter—actually, a common household item. (In fact, my beam splitters are desperately in need of washing, but writing this is more fun!) I am referring to the windows. If you turn on a bright lamp at night and have your youngster go outside, he or she can look through the window to the light: this is the transmitted light. Going back inside, the child can also see the light, just as if the window were a mirror. It is a little dimmer, because the window only reflects part of the light. During the day, the same thing happens, but the skylight coming in is so bright that it is hard to see the reflected light from the lamp.

So a beam splitter is something that takes a beam of light and lets some pass through while it reflects part back at you, thus splitting it into two parts. Through use of a beam splitter in the Heads-Up Display, the pilot can see the transmitted light from the outside as well as the reflected light from the monitor.

At least conceptually, a HUD takes everyday optics—a monitor, mirror, lens, and beam splitter—and uses them in a unique way. But here's where the real fun comes in for the engineers. There are a number of reasons why a simple system, with regular mirrors and a beam splitter, won't work. It's in solving some of these real puzzles that a lot of talent is required on the part of the team designing the system.

One problem is best explained by going back in the car and looking at

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the windshield. Suppose you've got your HUD system and it has projected a number up on the windshield. If you put your finger against the windshield and look at something across the street, your finger will be out of focus, and you may notice that you can see two fingers. In the same way, numbers projected on the window area will be difficult for the pilot to see. It would really be better to make the numbers look like they are somewhere several feet outside the airplane.

But this involves looking at something that's not there—namely, a virtual image. You might demonstrate the concept of a virtual image in this way. Most kids have at some point tried taking a cheap lens, bringing it outside, and holding it at just the distance from their hand so that they get a nice image of the sun on their hand. This is a real image, because the light actually hits the hand. You know it's real in this case, because you feel the heat and have to curtail the experiment abruptly.

Instead, have the youngster try going into the bathroom and putting a finger on the mirror. The image of the finger can be seen directly behind the real finger, inside the mirror. As he pulls his finger back toward himself, the child can see the image receding further into the wall. This is a virtual image, which is inside the mirror, even though no actual light has penetrated back of the mirror. With a HUD, they actually focus the lens so that the image of the numbers is placed, not on the beam splitter, but some distance outside the aircraft. That way, the pilot does not see the double images we talked about earlier.

There were a lot more interesting problems engineers had to solve. For example, how do you make the numbers bright enough to see? And how do they keep the sunlight from going through the system the other way and heating up the monitor. Heads-Up Displays illustrate something of what optical engineering can be like. It's really not magic—most of the principles make pretty good sense. But it's solving problems like these that can really make it fun.