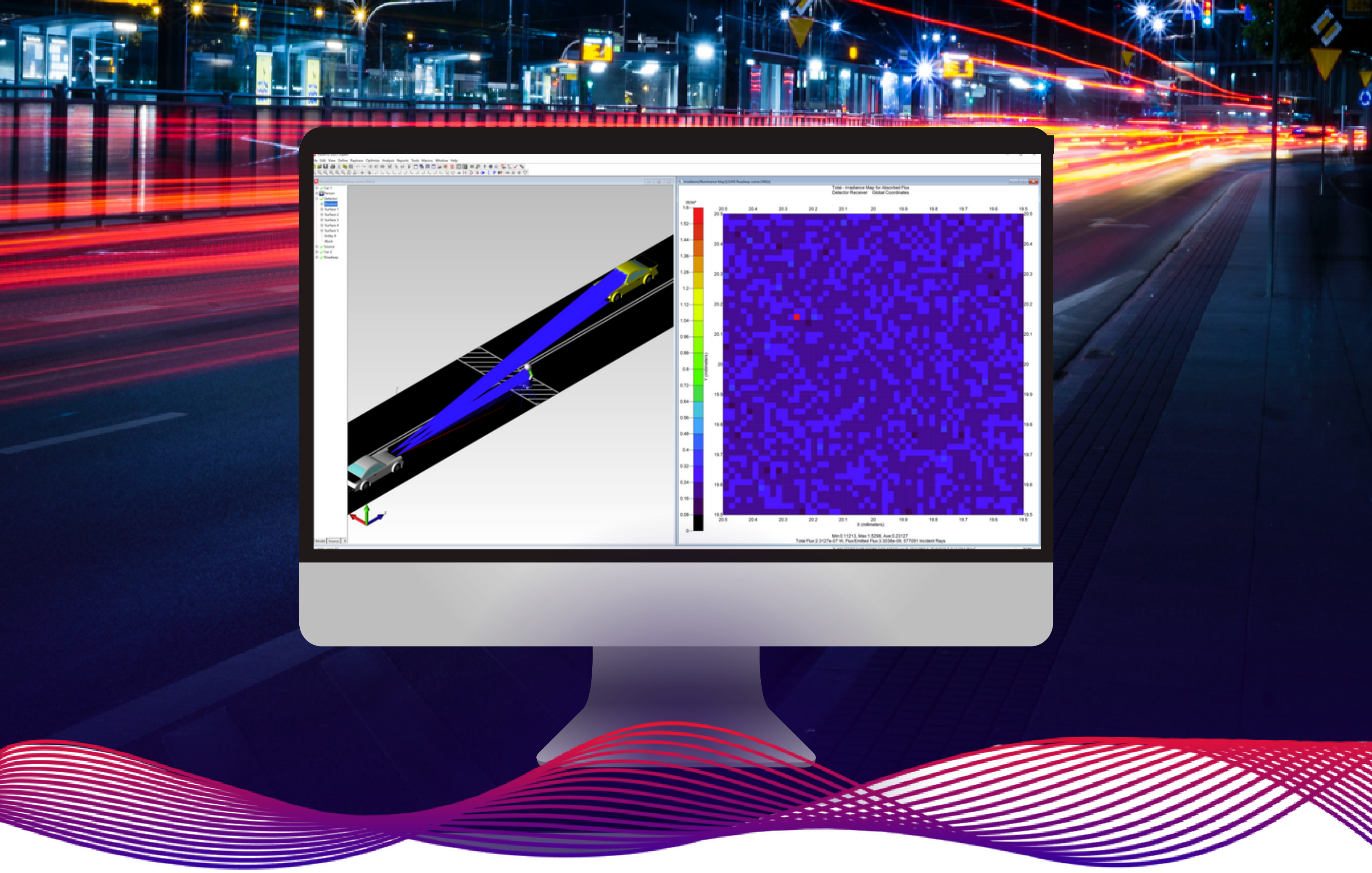


Simulating the Performance of Driver Assistance Aids Using Optical Design and Analysis Software

Optics-based and display-based driver assistance aids such as Head-Up Displays and LiDAR (Light Detection and Ranging) are becoming more and more common in modern transportation.

Many of these devices rely on complex optical systems to function properly. The design and development of these systems can be an involved and time-consuming process. The use of optical design and analysis software like TracePro and OSLO allows engineers and designers the ability to design, optimize, and analyze these systems in a virtual, software environment. The performance of the system can be verified before actual prototypes are built. TracePro and OSLO let users make their mistakes and correct them in a software environment rather than a hardware one. This saves time and money. In this presentation we will look at some of the tools available, workflow options, and design examples.

LiDAR uses a beam of light to detect objects and determine the distance to those objects. In automotive applications this information can be used for collision avoidance, lane keeping, and self-driving. In a LiDAR system a beam of light is emitted from a source, and when it strikes an object a portion of that light is scattered back towards a detector on the LiDAR-equipped vehicle. By knowing the time it takes for the emitted beam of light to travel to the object and back, it is possible to calculate the distance from the LiDAR-equipped vehicle to the object as well as closing speed. **Figure 1** shows the raytrace results where the white car is the LiDAR-equipped vehicle and the pedestrian and approaching yellow car are potential obstacles.

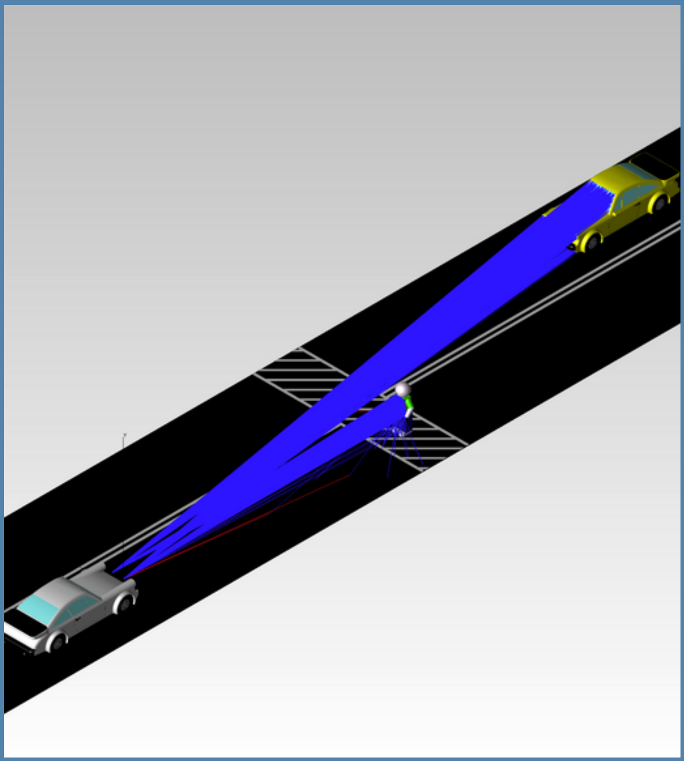
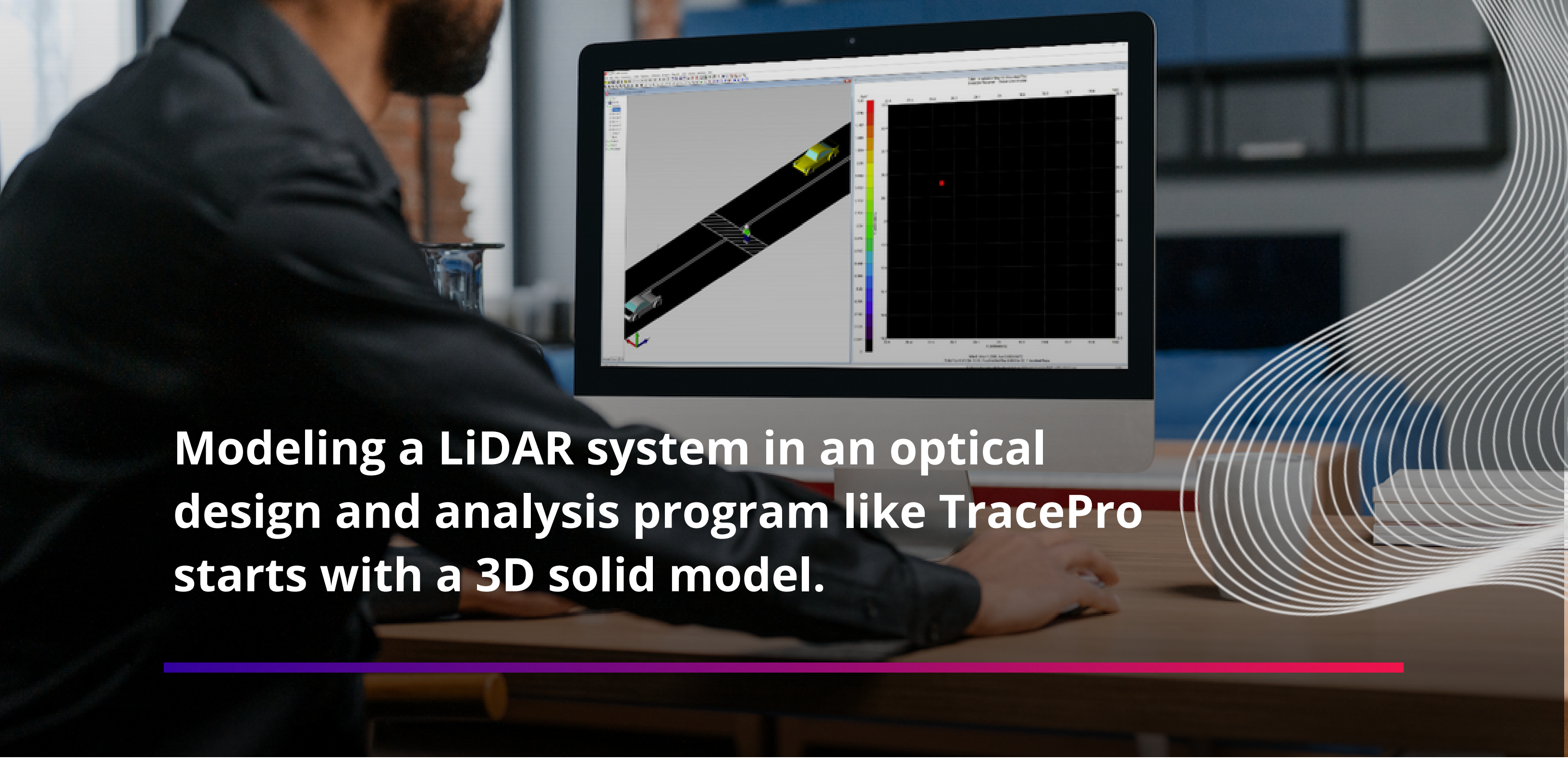


Figure 1: LiDAR system model in TracePro

 |



Modeling a LiDAR system in an optical design and analysis program like TracePro starts with a 3D solid model.

The example in **Figure 1** uses 3D solid models for the two vehicles, the pedestrian, and the roadway. These models can be imported from a CAD program, or they can be built in TracePro. Then one must apply appropriate properties, e.g., surface and material properties, so that the objects in the model have accurate optical properties. The next step is modeling the LiDAR light source. It is important that the beam pattern of the source in the model matches that of the emitter chosen for the system. **Figure 2** shows the beam pattern for a 905 nm commercially-available LiDAR source. Note that the beam has different angular distributions for the parallel and perpendicular planes.

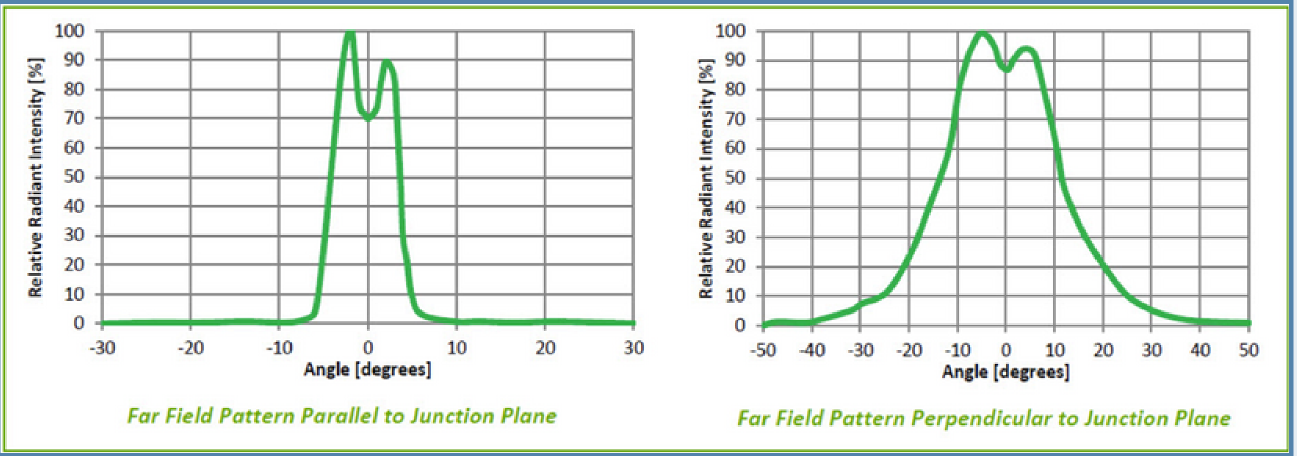
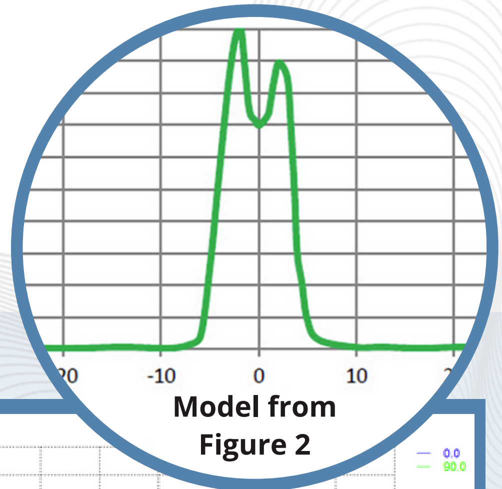


Figure 2: LiDAR source datasheet

Figure 3 shows the source as modeled in TracePro. Note the excellent agreement between the model and the datasheet. This is vital for accurate optical simulation.



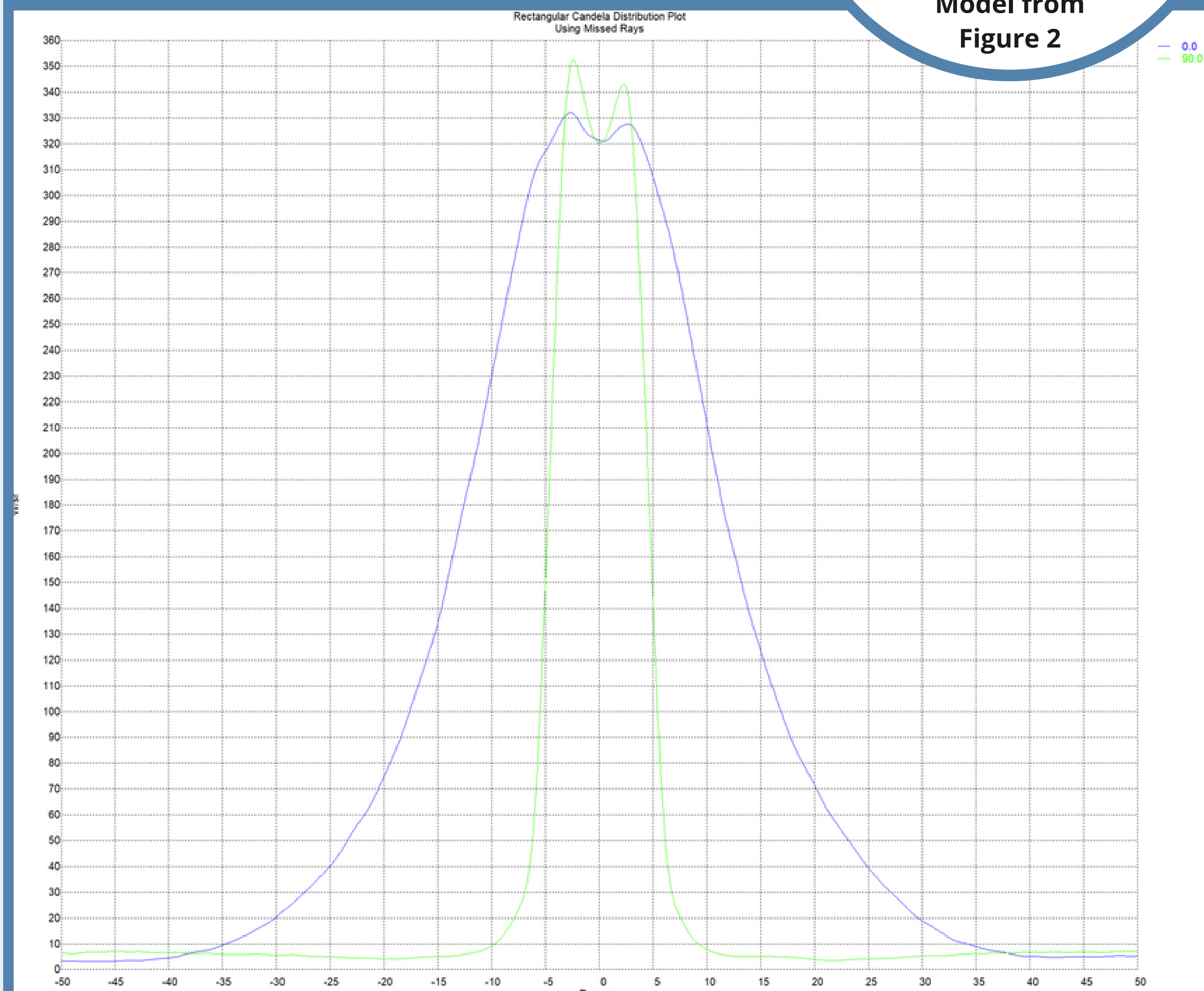


Figure 3: LiDAR beam in TracePro

A major difficulty in modeling systems like this is that the signal that returns to the detector is very small due to the low amount of flux that reaches the targets, and then the even smaller amount of flux scattering from the target objects back towards the detector.

Figure 4 shows a TracePro model with two million rays traced from the LiDAR emitter and only one ray scattered back to the detector. The efficiency of this system is about 7 x 10^{-10}%.

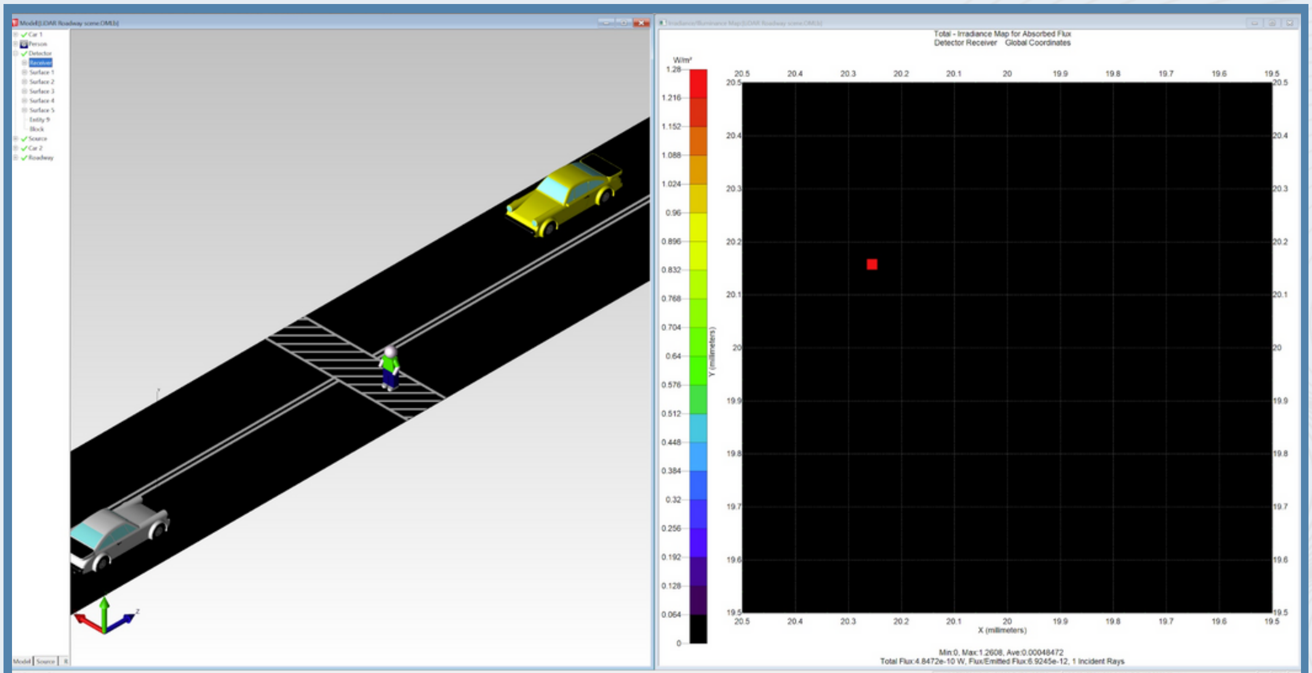


Figure 4: Two million rays traced

To help with situations like this, TracePro has a tool named Importance Sampling that allows users to "bias" rays in particular directions in order to improve sampling and efficiency without changing the amount of flux or power received by the detector.

 |

Importance Sampling can be applied from the source towards the targets and then from the targets back towards the detector. **Figure 5** shows the Importance Sampling targets from the source and **Figure 6** shows the Importance Sampling from the targets back to the detector.

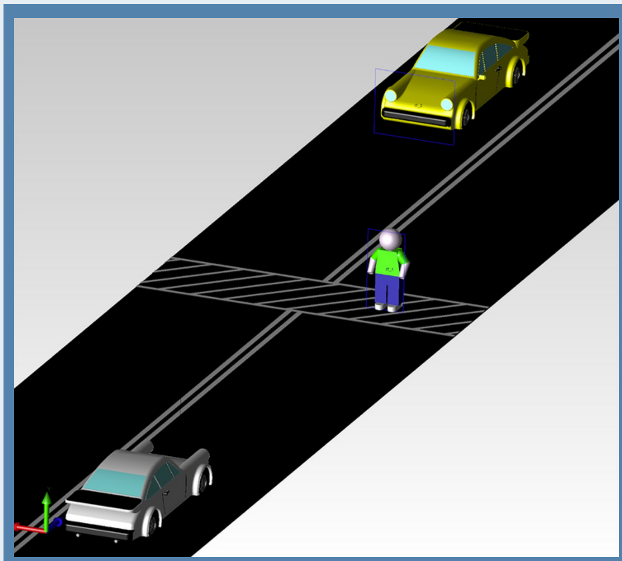


Figure 5: Importance Sampling from the source

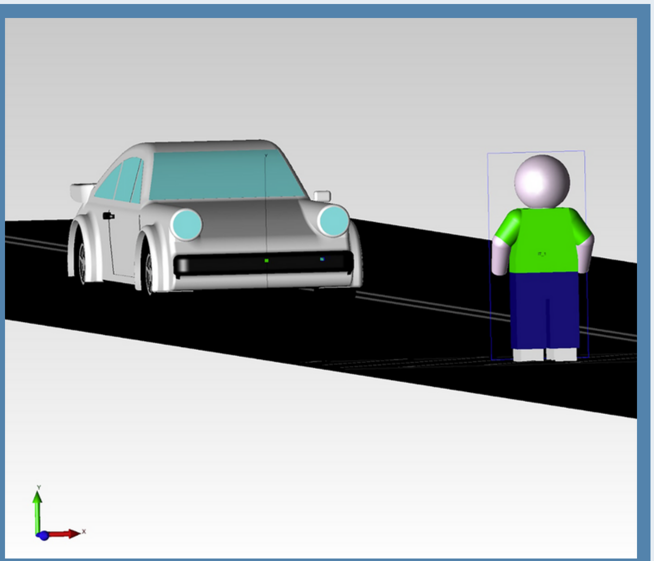


Figure 6: Importance Sampling from pedestrian towards detector

Repeating the ray-trace after applying the Importance Sampling, we can see that there are now over 575,000 rays returning to the detector. The efficiency is still low, but the sampling has improved greatly, and the proper flux values have been maintained.

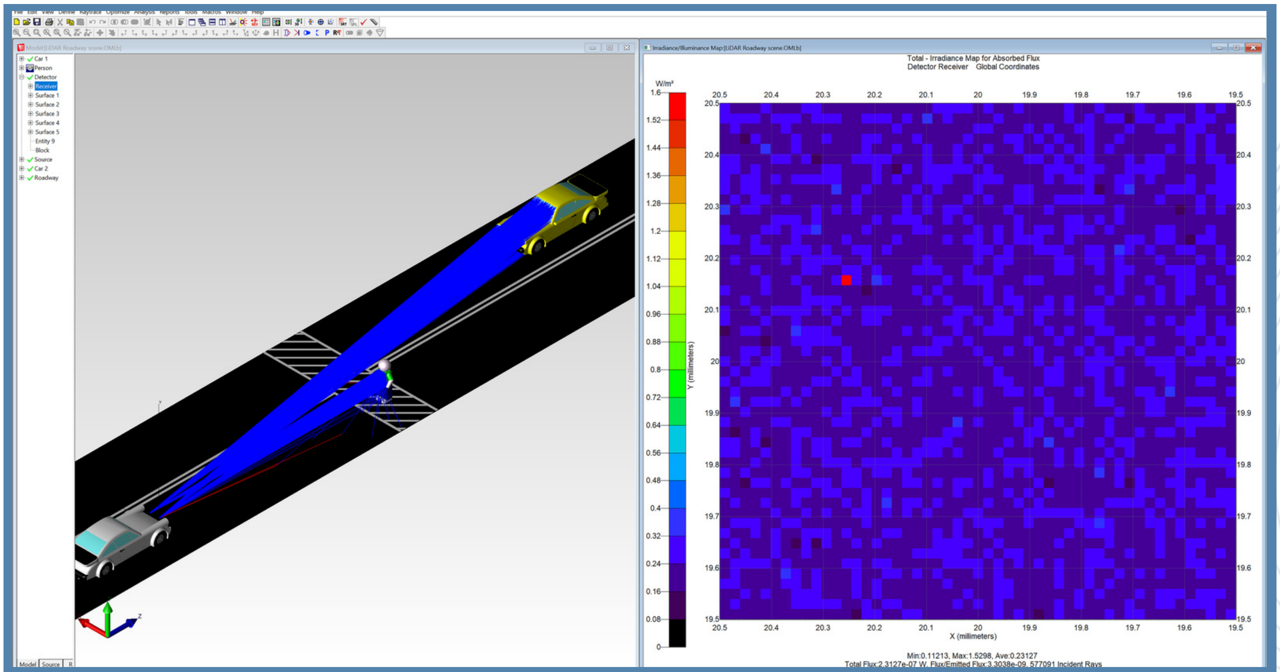


Figure 7: Raytrace results with Importance Sampling applied

The time of flight for the rays returning to the detector from the person and the approaching car can also be determined from the raytrace results.

TracePro and Importance Sampling are key tools in modeling LiDAR systems.

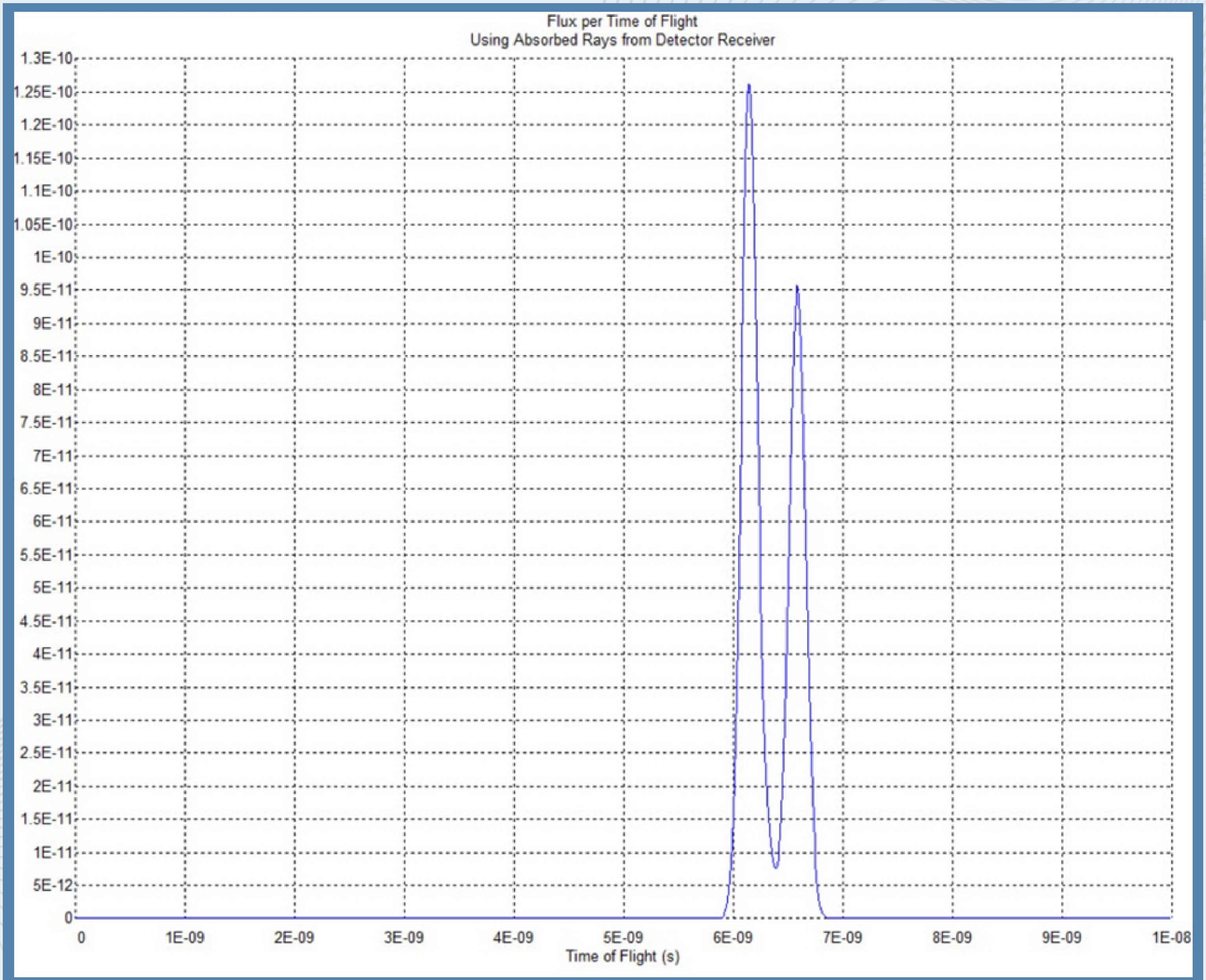


Figure 8: Time of Flight results

Another driver-assistance aid that is becoming more popular is a HUD (Head-Up Display).

The head-up display can show information such as current speed and driving directions as a projection on the windshield in the driver's field-of-view, while also allowing the driver to see through the image and not obscure the driver's vision. The components of a HUD system are a projector or display unit, and some optical elements to direct and project the image from the projector towards the windshield of the vehicle to form a virtual image of the display. When implemented properly the HUD image will float in the driver's field of view. **Figure 9** shows the optical schematic of a HUD system.

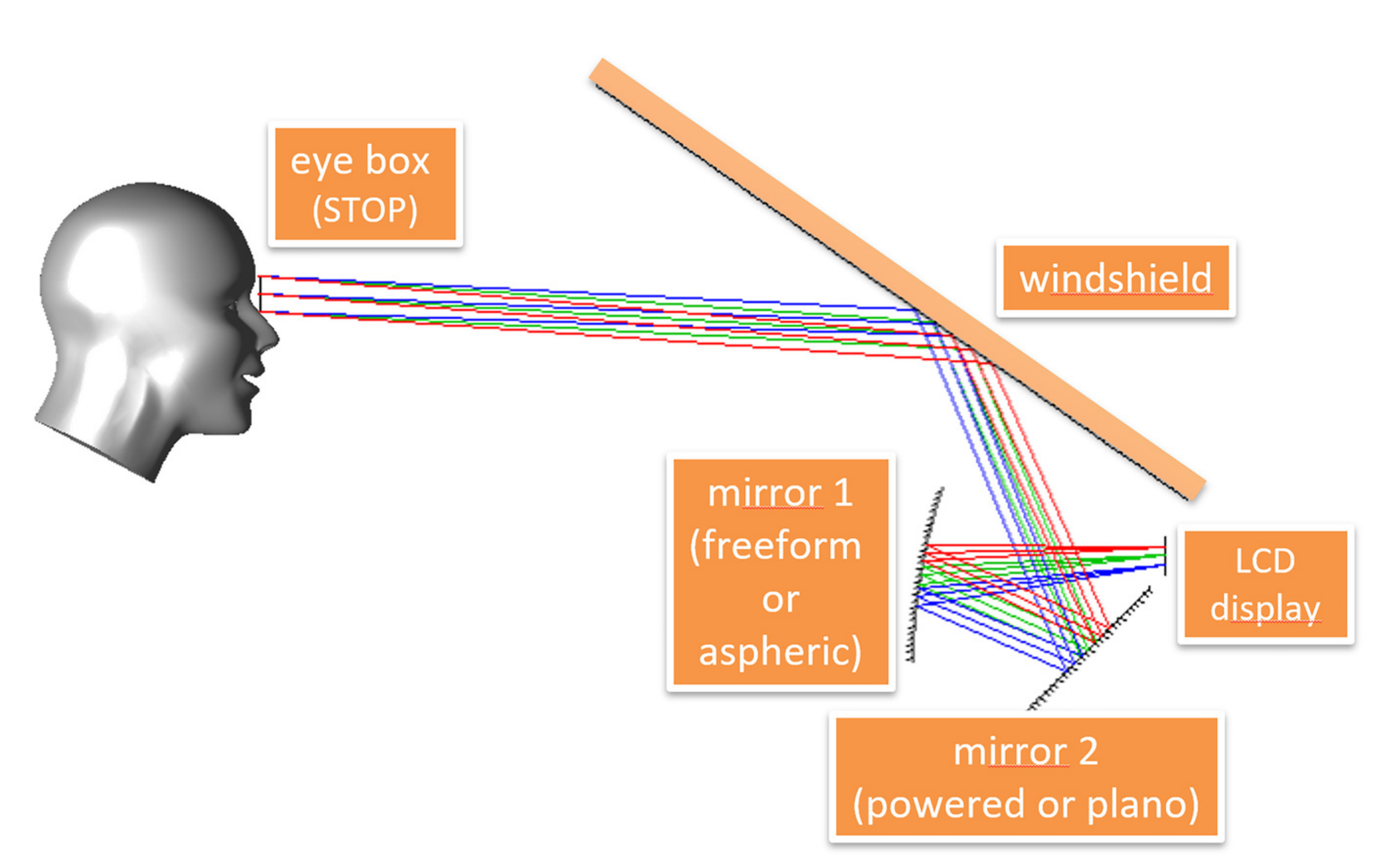


Figure 9: HUD optical schematic

 |

In many cases designing a HUD requires two types of optical design and analysis software. A sequential ray-trace lens and imaging system design program like OSLO is used to optimize the mirror and lens design, and a non-sequential 3D solid modeling program like TracePro is used for system integration and resulting image visualization with appropriate backgrounds, to see the real-world performance of the system. **Figure 10** shows the optical model in OSLO.

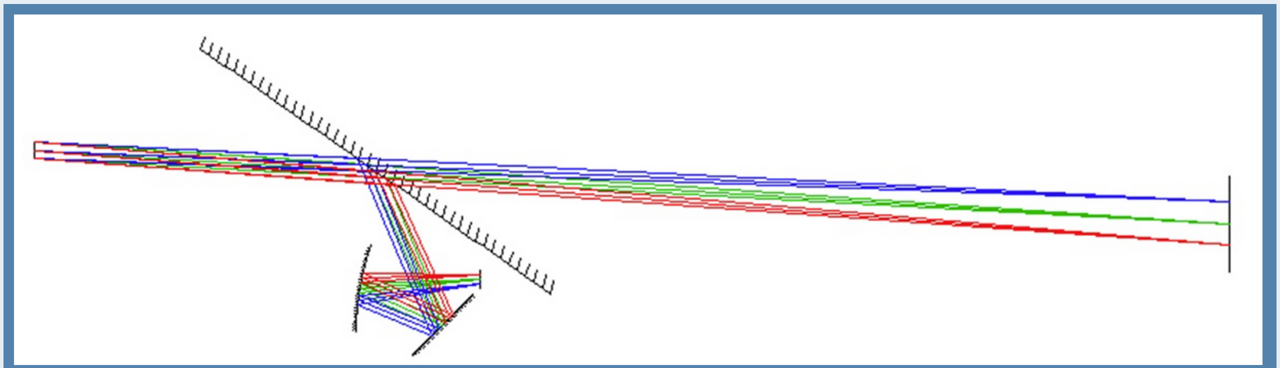


Figure 10: HUD model in OSLO

Figure 11 shows the OSLO model imported into TracePro with additional objects added such as the windshield, dashboard, and driver's head. Some rays have also been traced in the TracePro model.

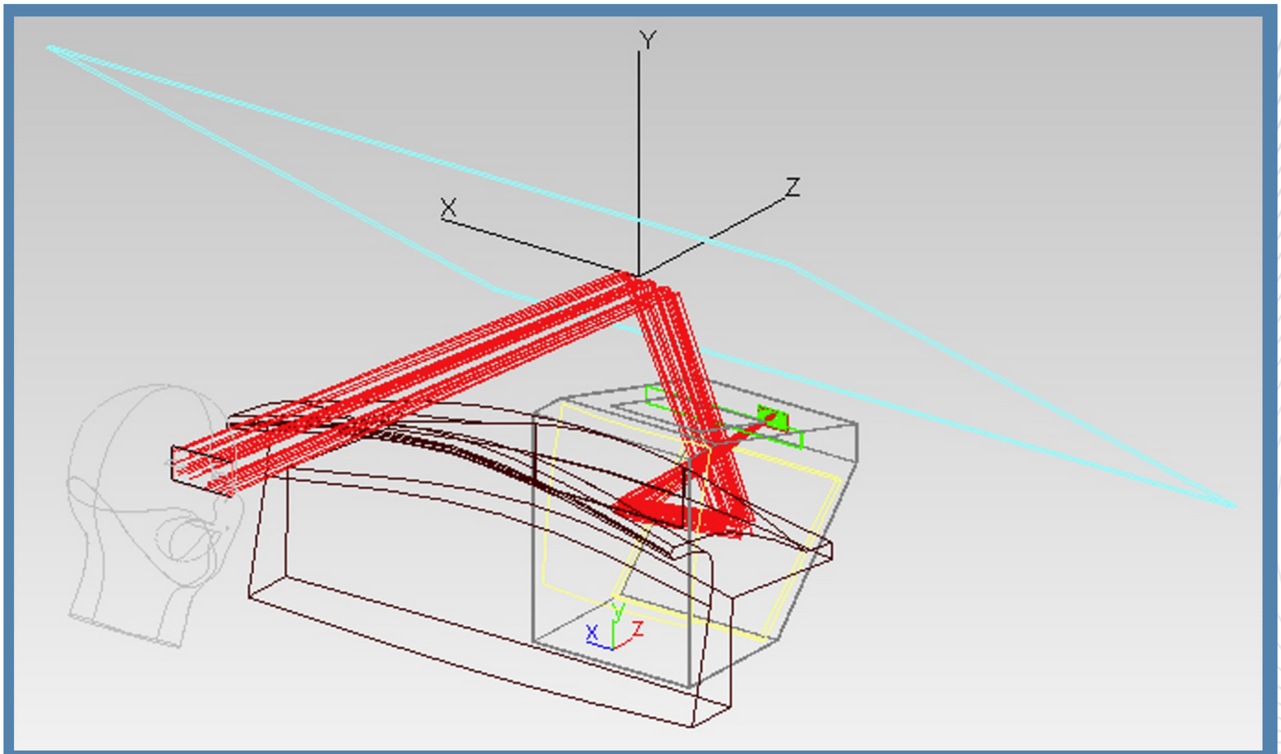


Figure 11: HUD model in TracePro

The Image Source in TracePro was used as the output of the projector. **Figure 12** shows the Image Source File used in the TracePro model.

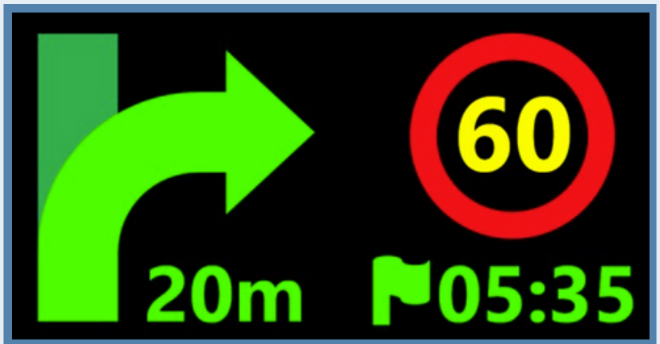


Figure 12: Image Source for modeling

The Photorealistic Rendering capability in TracePro allows the designer to “see” what the driver will see in the virtual, software environment. Looking at the initial results with a windshield that has parallel glass reveals a problem, there is a double image that impacts the sharpness of what the driver sees. This is shown in **Figure 13.**

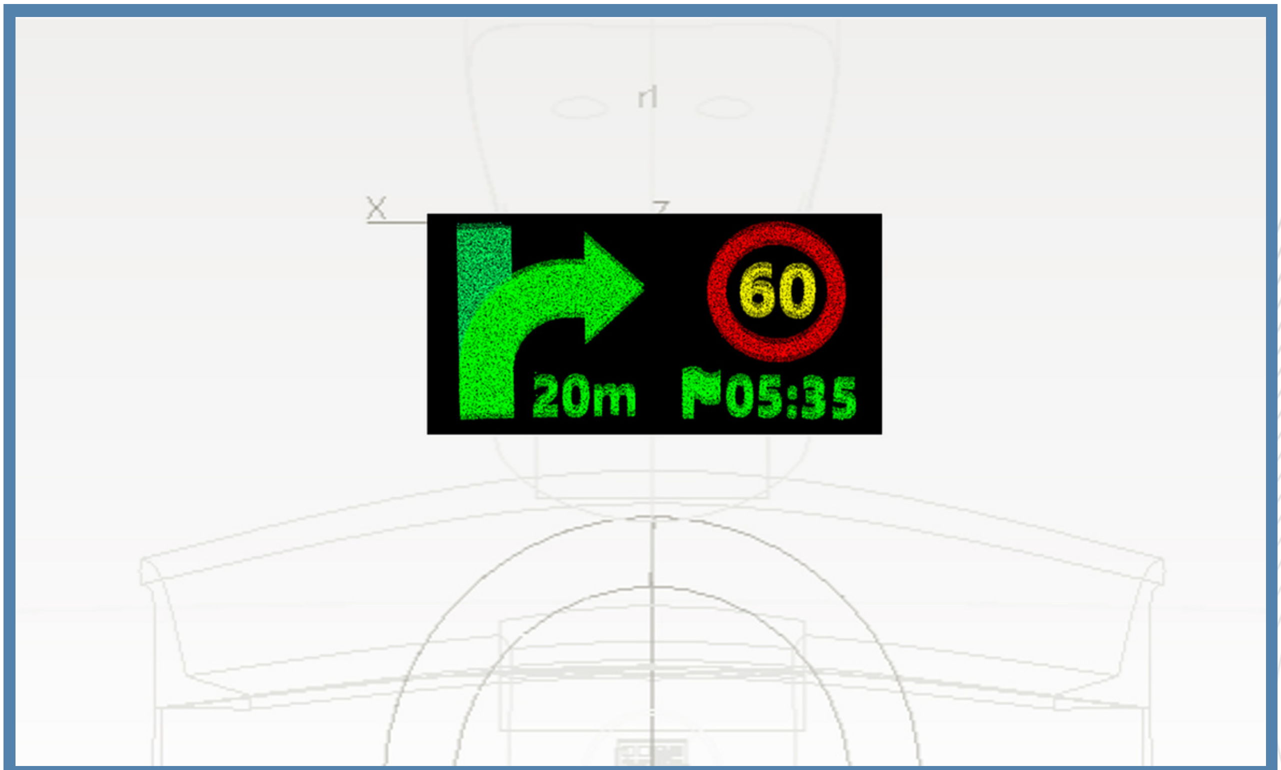


Figure 13: Blurry, double image shown with Photorealistic Rendering

One solution to this is to taper the windshield and eliminate the parallel surfaces to make the double image converge into one. **Figure 14** shows the results of a non-tapered and tapered windshield using the Grid Source in TracePro and **Figure 15** shows the Photorealistic Rendering results with the Image Source.

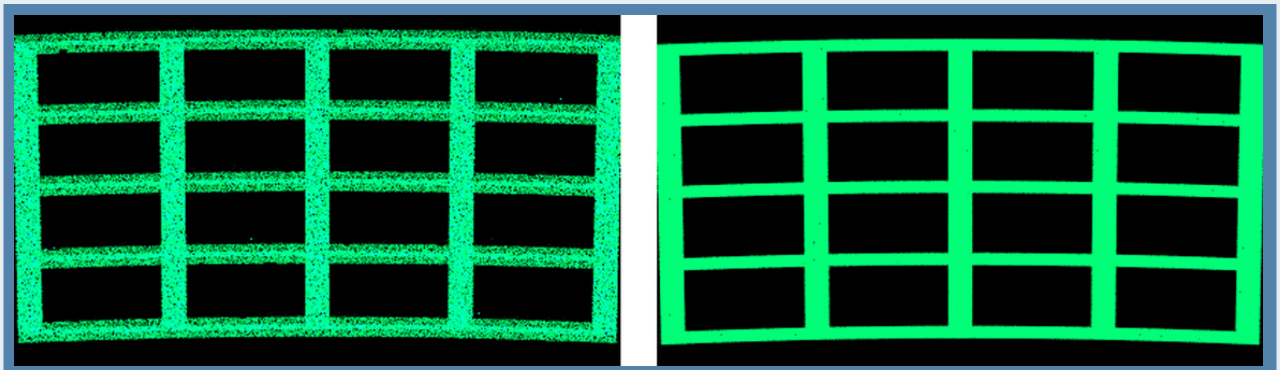


Figure 14: Grid Source results for non-tapered and tapered windshields

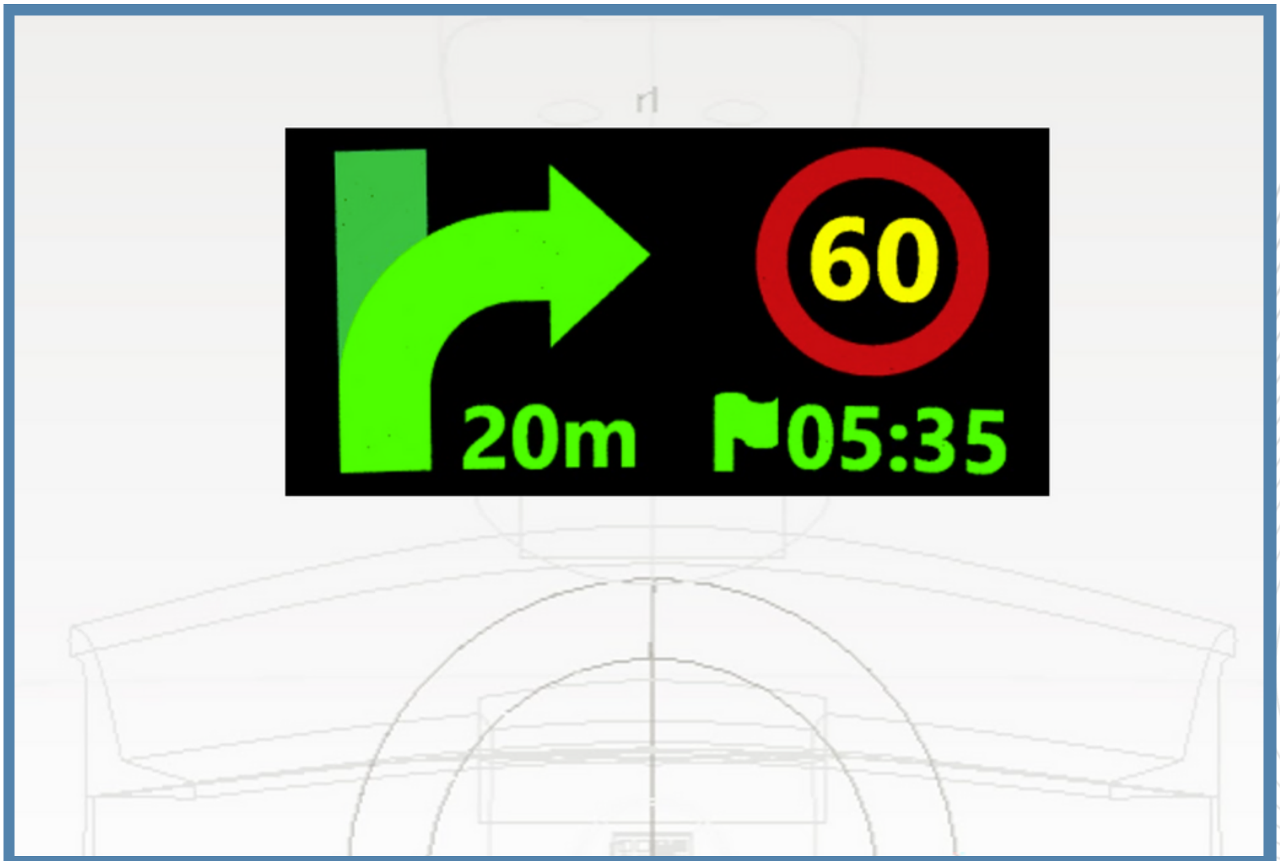


Figure 15: Photorealistic Rendering results with tapered windshield

 |

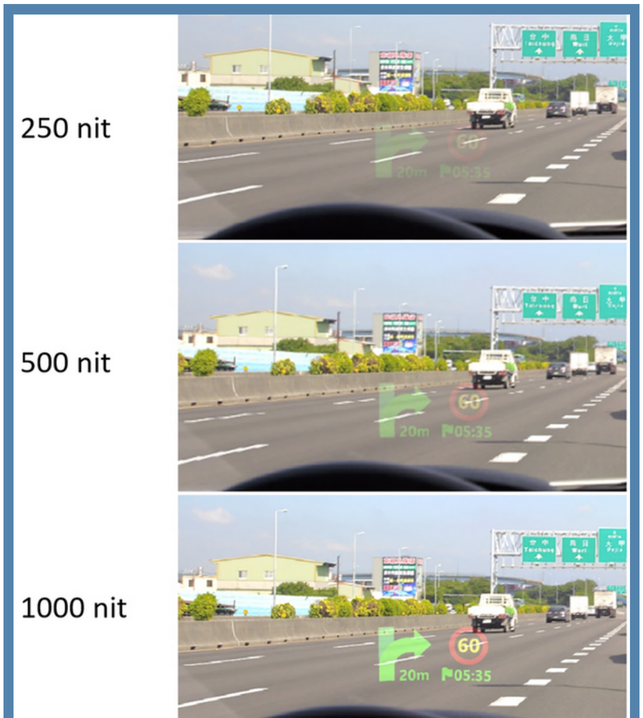
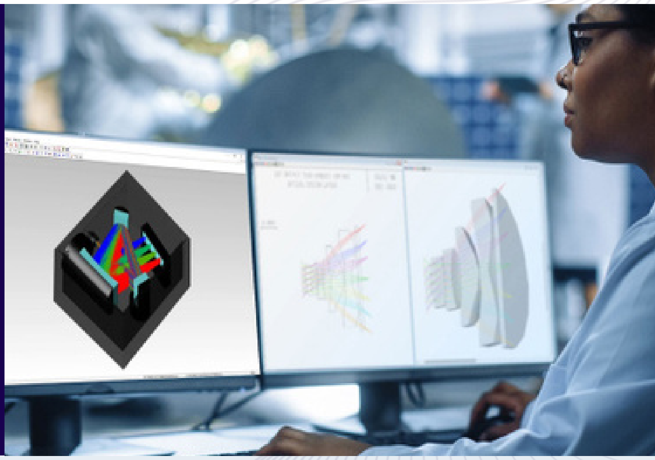


Figure 16: Photorealistic Rendering with background Image Source and varying projector luminance

Modeling a HUD display in TracePro allows the engineer or designer to change parameters easily. **Figure 16** shows an Image Source used as the background and the effect of varying luminance levels from the projector.

OSLO gives engineers and designers the capabilities they need to design and optimize the image portion of a HUD system. That model can then be used in TracePro to visualize how the system will perform in the real world under varying conditions. Together OSLO and TracePro offer the full package of tools that optical designers and engineers need to tackle current and next generation tasks.



LAMBDA RESEARCH CORPORATION

Corporate Headquarters
515 Groton Road
Westford, MA 01886

Phone: +1 978-486-0766

Fax: +1 978-486-0755

sales@lambdares.com

Connect With Us On:

www.lambdares.com