View from a height

Most ship bridge simulators emphasize the horizontal field of view, but maritime pilots must be able to look down at piers and other low-lying objects. **Ken Boyd** of Display Solutions explains how the challenges of providing a look-down capability in a large simulator were overcome.

When the Maritime Pilots Institute in Covington, La., ordered a full-mission ship bridge simulator, the project posed some unique challenges.

The primary purpose of the simulator was to support the training of pilots, whose ship-handling tasks include docking and undocking at piers, bridge transits, anchoring, working with tugs and lines, and lightering operations alongside other ships. To perform these close-in operations, the pilot needs to be able to walk up to the ship's bridge windows or bridge wings and look down to see the relative position of the ship's deck and hull, the dock area, tugs, lines, bridge piers, buoys and other ships. The visual display system, therefore, required a much larger vertical field of view than is normal for ship bridge simulators. The system also had to provide a large horizontal field of view.

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The dome screen inside the MPI Bridge Simulator is 22 feet high and 28 feet in diameter and is composed of 42 sections.

Typical ships bridge simulators are configured on a stationary or motion platform with a bridge mock-up and the visual image projected on a cylindrical or conical screen surrounding the mock-up. The projected visual image typically has a horizontal field of view of 240 degrees to 360 degrees and a vertical field of view between 20 degrees and 45 degrees, with a range of 23 degrees to 26 degrees being the most common. Technical constraints, such as projector throw distances, distortions because of projection angles and reasonable physical dimensions of the bridge mock-up, usually dictate that the cylindrical/conical projection screens be 20 feet to 30 feet in diameter. As a result, there is typically 8 feet to 10 feet of floor space between the perimeter of the bridge mock-up and the bottom of the screen. A viewer standing at the ship's bridge "window" or bridge wing and looking down sees unlit dead floor space between the bridge and the screen (commonly referred to as the "black hole").

To meet the MPI objectives, George Burkley, who oversaw the design, construction and installation of the simulator for Locus LLC, developed the concept of a visual display system providing a vertical field of view of about 30 degrees up and 60 degrees down, and a horizontal field of view of about 300 degrees. Display Solutions was tasked with developing and installing a system that would satisfy these demanding requirements. The only way of accomplishing this was to use a dome-shaped screen, similar to that used in flight simulators. In flight simulators, the small size of the simulated cockpit allows for reasonable line-of-sight access between the projectors and the dome surface. The projectors in a flight simulation dome can be located out of sight above and below the cockpit or, in some instances, outside the dome surface and projected through a lens hole opening in the screen at a point where it is not visible to the viewer.

In the case of the ship bridge simulator, the size of the bridge mock-up is such that it occupies much of the space inside the dome. This puts a significant constraint on where the video projectors can be located. At the available projector mounting locations, the lines of sight to the interior dome screen surface create steep angles of incidence for the projected images. Covering the required area of the screen with a projected image of reasonable image quality was a major challenge.

BUILDING THE SIM

The MPI Bridge Simulator consists of a generic bridge mock-up with the controls and displays found on the oceangoing ships that travel the Mississippi River between the Gulf of Mexico and Baton Rouge, La. The bridge is a 14-foot-diameter octagon with a 7-foot ceiling. Bridge windows face outward with about 300 degrees horizontal field of view from the pilot eye-point. The bridge house originally had glass windows installed, but these were later removed to reduce glare and improve image visibility from inside the bridge house.

The entire bridge mock-up is mounted on eight 7-foot-high steel posts anchored into the concrete floor. Access to the bridge is via a runway from the bridge mock-up

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The MPI Bridge Simulator gives maritime pilots a virtual view – horizontally and vertically – from a ship's bridge.

to the second floor of the facility, where the instructor station is located.

The dome screen is 22 feet high and 28 feet in diameter and was designed by David Carambat of Industrial Object Design of Covington. The screen is composed of 42 spherical sections. The panel sections are hand-laid, solid polyester fiberglass, made in a limited production mold. The section mold was computer-machined from a block of solid foam, finished with a sprayed-hardener and mounted in a commercial mold frame. The mold used a waxless mold release system to make finishing the pulled panels easier.

The dome assembly was a two-part process. First, the upper dome sections were assembled on the floor around the bridge structure and a structural compression ring of metal-strapped wood was fabricated around the upper ring of the dome.

The upper-dome section was hoisted aloft to the ceiling by six hand-crank hoists and a wire suspension system. Conscious weight control in the materials kept the upper dome total weight at about 800 pounds assembled and the lower dome at 1,500 pounds. Once hoisted into place, wood columns were placed under the upper dome to straighten the dome shape and relieve the suspended load.

The project pushed the technology to the limits of what is feasible with commercial off-the-shelf equipment.

The interior seams were caulked, taped and floated with common construction materials. The interior paint is Glidden's Luminous White latex interior, which provided a better picture in our tests than custom screen paint.

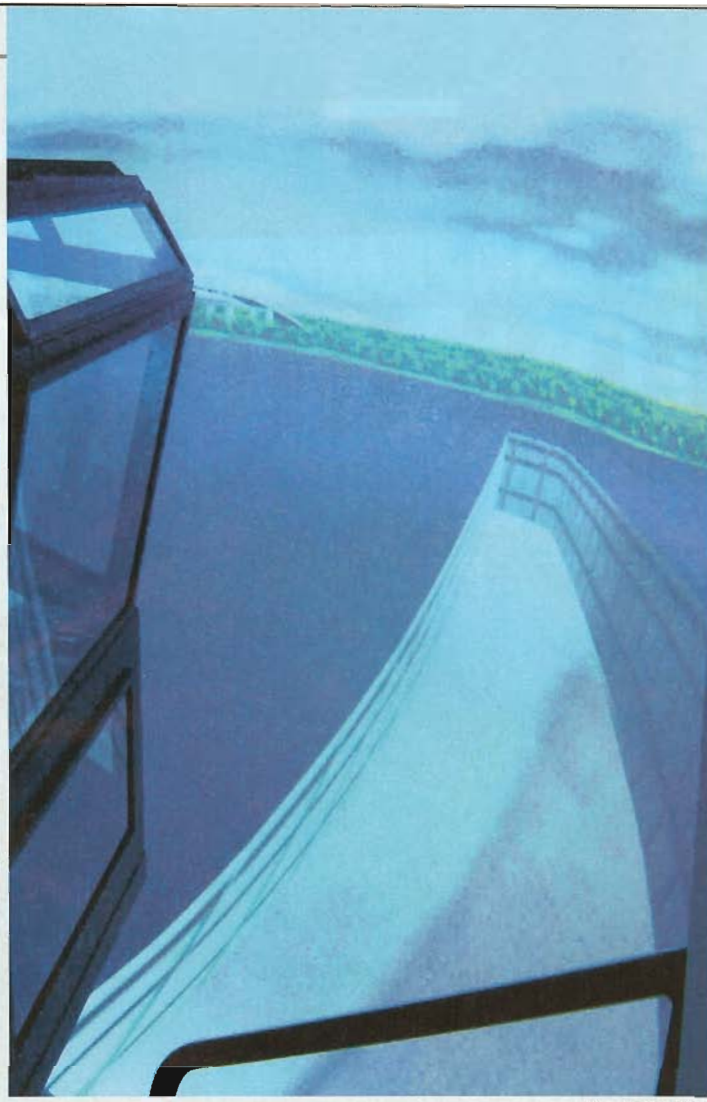
The initial physical layout of the projectors and screen was done using the CompactDesigner software from 3D Perception, Asker, Norway. 3D Perception is a provider of video post processors for warping video signals to compensate for the optical distortions created by projecting flat-format video images onto curved screen surfaces. CompactDesigner is a low-level computer-aided display (CAD) program that allows the basic theater design to be done in three-dimensional format. With the correct projector and lens modeled in the software, various layout configurations can be developed and evaluated for feasibility and performance.

As a result of the CAD design phase, we determined that 14 projectors would be required to illuminate about 300 degrees horizontal by 90-plus degrees vertical on the screen. The 14 projectors are grouped as a 2 x 7 matrix. Seven projectors are above the bridge roof, shooting downward, and the other seven are at the base of the bridge house mounting posts. The mounting location of the lower seven projectors was quite constrained. The projectors had to be staggered to achieve as much throw distance as possible.

Sanyo PLC-XP46 LCD projectors were selected for the project. The XP46s have 4,100 lumens light output at XGA (1024 x 768) native resolution. The key features of the XP46 that were critical to the success of the project were the availability of optional wide-angle projection lenses, electronic vertical lens shift and a LAN control interface. A 0.8:1 throw ratio lens was chosen to maximize the screen coverage from the available projector locations.

The bottom projectors had to be positioned as low as possible to avoid image shadowing from the bottom of the bridge mock-up structure. As a result, the projectors had to project at a fairly steep angle to the screen perpendicular. This was compounded by the fact that the screen was curved in the vertical axis. This position and angle of projection placed severe requirements on the depth of focus of the projection lens. It also created significant keystone distortion in the projected image. Wide-angle lenses typically have a reduced depth of focus performance. Initial testing on the XP46 with the 0.8:1 lens showed it to have nearly +/-15 feet of "acceptable" focus depth. The lens shift feature on the projector was used to minimize the keystone distortion as well as the depth of focus requirements. These features were critical to the feasibility of the display.

The upper level projectors were mounted from a plywood platform base 7 feet above the roof of the bridge. Space was available so it was not necessary to stagger the projectors. However, the angle of projection to the screen again required taking full advantage of the vertical lens shift feature on the projector. The projectors were positioned for maximum vertical screen coverage to minimize the requirements on the more confined lower projectors.



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Unlike most ship-bridge simulators, the MPI sim allows maritime pilots to look down from the bridge.

CREATING AN IMAGE

When all of the projectors were mounted and positioned for maximum screen coverage and maximum image overlap, the process of creating an undistorted, blended composite image began. The horizontal field of view of each projector (channel) is about 45 degrees, although the projectors can cover a larger area. The vertical field of view of the upper projectors is about 55 degrees (30 degrees up to 25 degrees down). The vertical field of view of the lower projectors is about 45 degrees. Allowing for overlap, the total vertical field of view is 90 degrees (30 degrees up to 60 degrees down).

The 3D Perception video warper post processor, the CompactUTM, was used for the image manipulation functions. CompactUTM provides a complete package of image-manipulation tools. The primary function of the processor is to remap the input video signal from the image generator (IG) to correct for the geometric distortions caused by projecting onto the spherical surface.

For simple curved surfaces, such as large radius cylinders with fewer than five channels, the geometric corrections can easily be made manually because the warping processor responds in real time while looking at the projected images. For more complex configurations, such as a dome screen with 14 projected image channels, a manual correction is extremely time-consuming and results in marginal overall geometric accuracy.

In this case, the CAD layout developed for the original feasibility study was updated in detail to match the physical configuration as closely as possible. Exact projector locations, angles and lens shift settings were input to the CAD model. The image generator field of view and overlap settings were also input to the model. The resulting CAD model can then be used by the CompactControl software to automatically generate detailed geometry-correction parameters.

After downloading the auto-generated correction map to the warping processors, the resultant image is about 90 percent correct. Final detailed geometry adjustments can then be made manually. To facilitate the geometry adjustments, Computer Science Corp. created a multiaxis grid pattern that was projected on the screen by the IG computers. In this case, most of the geometry-correction controls were pushed to their limits.

After the image geometry corrections were completed, the next step was to normalize the 14 independent projected images for color match. Matching channels for color and brightness can be the most daunting part of the alignment process. The CompactUTM /CompactControl software has all the handles needed to achieve this match. In addition to brightness and contrast controls, the tool set includes individual red, green and blue offset (brightness), gain and gamma (signal linearity) controls. Additional optional features include spatial gain control for hot-spot compensation an automatic color matching via a color spot photometer interface.

When the 14 individual images are matched as closely as possible, CompactControl can be used to blend the images in the overlap region. In the case of the MPI dome, blending in both the horizontal and vertical planes was required.

The final complete set of set-up parameters were then downloaded into the firmware in the warping processors.

TECHNOLOGY LIMITS

The MPI Full Mission Bridge Simulator has been in operation for about 12 months. The visual system installation was successful, but it pushed the technology to the limits of what is feasible with commercial off-the-shelf equipment. The success can be attributed to the interaction between the dome/bridge designer and Display Solutions in the early stages of development. CAD files were exchanged several times, and the bridge design was modified to provide good line of sight between the projectors and screen. There is some shadowing of the bridge structure in the image plane in several places. The flexibility built into the CompactUTM software allowed us to conform the edge blend zones around these shadows, rendering them invisible in the final image.

Budgetary constraints for the project dictated the use of XGA resolution LCD projectors. Although the projectors used resulted in good image quality, future simulators are recommended to use higher resolution (SXGA+ or higher) projectors with higher contrast ratios and adjustable iris in the optics path for improved night simulation. The newer single-chip digital light processing, or DLP, projectors are ideal for such applications. Newer versions of the geometry warping software also offer the option of automated color balance setup for improved color uniformity and edge blending. ■

Ken Boyd is the founder and president of Display Solutions in Stow, Mass. This is an edited version of a paper presented at the IMAGE 06 conference in Scottsdale, Ariz., in July.