La Cueva Grande: a 43-Megapixel Immersive System

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ABSTRACT

Los Alamos National Laboratory (LANL) has deployed a 43-megapixel multi-panel immersive environment, La Cueva Grande (LCG), to be used in visualizing the terabytes of data produced by simulations. This paper briefly discusses some of the technical challenges encountered and overcome during the deployment of a 43-million pixel immersive visualization environment.

CR Categories and Subject Descriptors: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual Reality; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented and virtual reality.

1 INTRODUCTION

Designed by Fakespace Systems and LANL personnel, LCG is the highest resolution stereo immersive facility in the world. In this paper, we discuss the requirements and design of this facility, its implementation, and its software infrastructure.

2 MOTIVATION AND BACKGROUND

Today, ASC scientists have the capability to perform a single production calculation that generates more data than is contained in the Library of Congress print collection. Currently, a large three-dimensional problem may have 500 million cells with tens of variables per cell. A single time-step dump from such a problem is on average about 150 gigabytes. This means that a single time-step dump from such a calculation is about 100 times larger than the complete time sequence saved from a typical 2-dimensional production run done in 1997. Usually, 350 to 400 of these time steps are saved for a single physics calculation. A comprehensive visualization infrastructure is needed to do post-processing analysis of such large amounts of data.

LANL scientists have had access to visualization facilities ranging from high-end desktops to small multi-panel displays, to a Fakespace RAVE™ (FLEX) immersive system, to a PowerWall Theater, a large multi-panel stereo display seating more than 80. The new LCG was designed as a very high-resolution immersive room for the use of ASC scientists.

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3 REQUIREMENTS

Requirements for this facility were developed from past user experiences with the LANL RAVE immersive system and other LANL visualization systems.

Members of the development team also reviewed publications [1, 3, 7, 10, 12] and visited facilities at the Beckman Institute at the University of Illinois at Urbana [6], where a six-sided immersive system has been deployed, and at the Electronic Visualization Lab at the University of Illinois at Chicago [4], where the first CAVE®, was developed.

1a) Room size. Requirements dictated by the size of the available room forced several design decisions. This room measured 30x30 ft, was two stories high, and this constraint precluded many possible configurations of the system.

1b) Room location. The available room is located on the second floor of the building. This had implications for the weight load that could be sustained.

2) Projector brightness and dynamic range. Digital projectors were required rather than the old CRT projectors for this facility, since digital projectors are much brighter, and because digital projectors provide excellent dynamic range of colors, making it possible to discriminate between slight differences in color in the visualizations of the users' simulations.

3) Resolution and pixel density. Good resolution is a necessity for a high-quality exploration of scientific data. [10] High resolution and high pixel density were important requirements for this facility for the following three reasons: 1) the complexity of user data demands extremely high resolution, so that small, yet important, features can be clearly seen, and 2) individual pixels are much more obvious in a digital projector than in a conventional CRT projector.

Figure 1. Several LANL scientists look up at data from a foam crush simulation visualized in La Cueva Grande. Data courtesy of Scott Bardenhagen, LANL. Photograph by Presley Salaz, LANL.

4) Video formats. Each screen was required to have square pixels, and the same resolution as all other screens, since otherwise, it would have been impossible to genlock the graphics cards.
5) Tracking. The tripping hazard in the small space made wireless tracking a requirement. Wireless tracking also has the advantage of greater resolution than magnetic tracking.
6) Sonics. The environment was required to be relatively free of system noise. It was also necessary to minimize echo.
7) Conformance to the LANL Visualization Corridor. The system had to conform to the standards of the LANL Visualization Corridor. This required integration of the computing platform with the video distribution system, and required consistency of the visualization software environment with that on other systems.

4 DESIGN

4.1 Facility Design

The new immersive display had to meet the space limitation of the room. It also had to meet the demanding needs of pixel density, to compare with the other multi-panel facilities in the visualization corridor of the SCC building. Another design question was the shape and number of surfaces in the facility, and whether all surfaces should be rear-projected.

4.1.1 Facility geometry

La Cueva Grande uses a rear-projected floor. This design choice was made based on prior experience with the LANL RAVE. The RAVE uses a front-projected floor where the projection is onto a durable reflective material, but all the walls are rear-projected onto glass. The display colors thus can never be perfectly matched between these two projection surfaces. The shadows of the users are also highly visible on the floor, because of the brightness and great depth of field of the digital projectors. So, to enable color matching and to eliminate shadows, we chose rear projection.

Because a rear-projected floor had been chosen, it was possible to have a ceiling. Configurations having a ceiling included a five-sided room and a six-sided, totally enclosed room. However, the sixth side was less necessary to LANL needs, and had the disadvantage of producing greater echo than a five-sided space. A permanent non-immersive observation space outside the display area proper was also desired. Thus, a six-sided space was rejected.

4.1.2 User-accessible area

The user area inside of the display space is a volume 15 ft across by 12 ft high by 10 ft deep, which leaves enough room for the light paths to fill the 5 ft wide by 4 ft tall panels. The observation platform outside of LCG proper is approximately 12 ft deep and 25 ft across.

4.1.3 Resolution, projectors and screens

High resolution was desired for this facility. There were, of course, other considerations, including room size and overall cost.

LANL personnel and Fakespace system engineers found that arrays of 5x4-ft panels could be used on each of the five surfaces to give a front wall that was 15 ft wide by 12 ft tall. This front wall uses a 3x3 array of panels/projectors. The side walls were designed to match up with the front wall in 3x2 and 2x3 arrays of panels/projectors for the floor, ceiling, and the two side walls. The front wall uses a direct light path, while the side walls, the floor, and the ceiling displays all use mirrors to get the light to the screens. This maximized the screen surface that would fit into the room. There are 33 panels (and projectors) that make up the full display system, and the pixel density in the facility is 21 pixels per inch.

Human visual acuity, when measured as the ability to resolve two distinct point targets, is about an arc-minute. [12] At the 21 pixels/inch provided in the above scenario, a person would no longer be able to make out distinct pixels when standing about 13.6 feet away, which is a few feet outside of LCG, in the user area platform. Of course, in a facility of this nature, the closer one can approach, the better. For example, for the pixels to be indistinguishable at 4 feet (the middle of LCG) the pixel density would have to be to 71 pixels/inch, which would nearly triple the number of projectors needed to fill the display space, unfortunately leading to much greater cost and also an increased heat load and increased projector noise. In the end, a balance was reached between resolution, cost, and size.

Christie Mirage 2000 projectors were chosen for LCG. The screens are Draper™ screens that fit on top of structural clear Plexiglas screens to maintain the 'flatness' of the walls. The floor uses special 3-in-thick clear Plexiglas in each panel to allow users to safely walk on the display floor. The infrastructure installed in the room was calculated to be able to handle the weight of the display system. The total weight of the display system is 60,000 lbs., and the floor was estimated to be able to handle a dead weight load of approximately 100,000 lbs. Originally, the superstructure of the system, was specified to be steel, but this added too much weight to the system, so fiberglass beams were used to lighten the load.

4.1.4 Tracking system

The Vicon optical tracking is composed of eight high-resolution cameras, which together cover the entire display space, and much of the observation area. Objects to be tracked, such as stereo glasses, gloves, or other interaction devices, are marked with reflective markers, and infrared strobes flash the space at 60 times per second. The cameras capture images of the markers attached to the tracked objects. This tracking system has high spatial resolution, at .5 mm, and also has good temporal resolution.

The cameras are mounted on the ceiling of the facility. Because of the need for coverage, it was necessary to place four of the cameras in front of the LCG ceiling screens. Also, the camera strobes are in the visible spectrum, in contrast to the usual Vicon strobes, which are infrared. This was necessary because the infrared strobes interfered with the infrared emitters that synchronize the stereo glasses with the screens. In practice, the cameras and strobes are not found to be too intrusive.

Two more cameras are deployed on the ceiling just outside the LCG, on each side. The final two are situated on the ceiling in the back of the user area, about 11 feet from the front of the LCG. This placement gives excellent coverage of the LCG screen area, and much of the user platform is covered as well.

The cameras are mounted from behind, so there is no occlusion from the mounting system. The eight cameras provide enough redundancy so that user occlusion is not in general an issue.

A major advantage of this type of optical system lies in its lack of wires and other tethers. This enables a great deal of freedom of motion. Another advantage is the freedom it provides to define gestural and other interfaces.

4.2 Computing System

The 33 projectors and the console designed into La Cueva Grande required new computing power not available at LANL prior to this design effort. SGI had just developed a follow-on SMP system that could address our needs - run CEI's EnSight suite of visualization and analysis tools right out of the box and support the 34 graphics devices we wished to drive. The new SGI system is an Onyx4 3900 with a modular design that was configured with 34 graphics engines (or pipes) based on an ATI FireGL X1. SGI integrated the cards into the architecture so that the cards were genlockable. The system was delivered with 17 GBricks each containing 2 graphics pipes and 20 CBricks (computer modules) for a total of 80 processors and 80 gigabytes of memory with a fiber-channel-based disk system with more than 1 terabyte of storage capacity.

5 CONSTRUCTION OF THE FACILITY

5.1 Construction Sequence

This section comprises a sequential series of illustrations that show the construction of LCG.

Construction Phase 1: The contractor installed the major structural elements and did as much as possible to complete dust-generating activities prior to equipment installation. Major subelements in this phase included the steel floor grid, the user platform and stairway, rough-in of HVAC, electrical, fire suppression, and security subsystems, and a 1-ton ceiling bridge crane.

Installation Phase 1: Fakespace installed the major structural elements, including the four-tier fiberglass mezzanines, the steel and aluminum screen support assembly, the acrylic screens, projector stands, and mirror stands.

Construction Phase 2: The contractor returned to finish installing all infrastructure, including electrical conduit, fiber wireways, HVAC ducting, fire suppression pipes, and sprinklers.

Installation Phase 2: Fakespace returned to install the electronic equipment and wiring (projectors, controller, etc), and do final alignment and color matching of the display images.

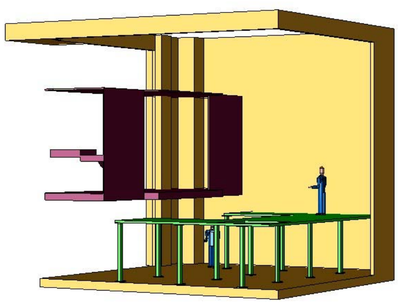

Figure 2. The fiberglass first level is installed.

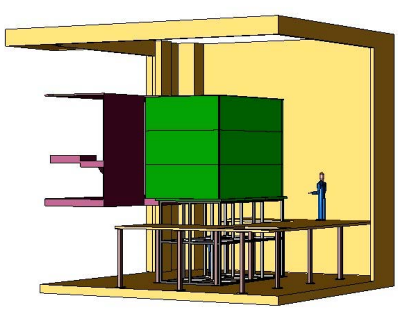

Figure 3. The acrylic screens are set into place over the steel and aluminum supports.

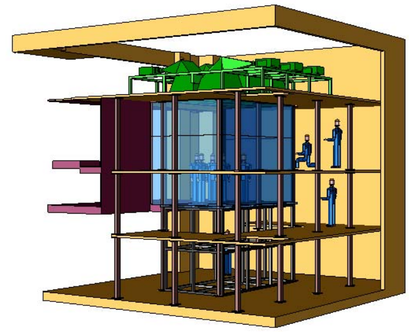

Figure 4. The first projectors and mirrors are loaded into the room.

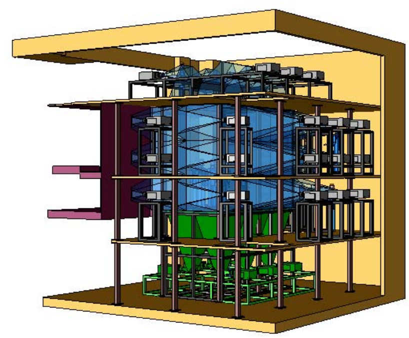

Figure 5. Final assembly.

5.2 Challenging Elements and Lessons Learned

1. Integrating the expectations and practices of two very different trades. Ordinarily, the architectural and construction trades execute as-built tolerances that can be measured in inches. However, the immersive visualization "trade" has significantly tighter requirements for fidelity to design, measured in 1/32-in. or even 1/64-in.increments. This is due to the necessity of keeping the highly sensitive human eye from seeing misalignments in images displayed across multiple screens.

Lessons Learned: Effort should be made to impose strict discipline in this respect during the construction rough-in.

2. Load Management. The steel superstructure initially designed by the supplier was found to be too heavy for the design load of the second-floor slab, so fiberglass was used instead.

Lessons Learned: It would simplify and cut costs if any future installation of this scale were executed on a ground floor level.

3. Life/Fire Safety. Due to the extensive use of fiberglass and acrylic materials in the installation, the Laboratory Fire Marshal was compelled to impose extraordinary requirements to ensure the safety of staff and to minimize risk of damage to other facilities.

Lessons Learned: The need for fiberglass in place of steel for the mezzanine structure greatly increased the flame-spread and the smoke-generation characteristics of the installation. It would simplify such an installation to be executed on a ground floor.

4. Ensuring Serviceable Utility. During design, attention was paid to ensure that construction did not interfere with the servicing of the display equipment. This effort resulted in the early detection of instances where planned infrastructure, such as HVAC ducting and fire suppression pipes, made access to projectors problematic. The supplier pointed these instances out in a timely way, and design corrections followed. It is estimated that about 90% of such potential flaws were caught early in the design cycle.

Lessons Learned: The decision to build in multiple phases logically meant that critical infrastructure would be in place prior to display equipment. It is highly recommended that this approach be taken in the deployment of any similar facility.

5. Quality Assurance, and Fidelity to Original Intent. The pixel count is a principal and defining characteristic of LCG. The pixel count requirement ultimately dictated nearly every design parameter, as it set the requirement for projectors, for screen size, and therefore for the mezzanine structure, power, and cooling.

6 Software Integration

An important part of the post-deployment effort was the integration of the software with the rest of the LANL Visualization Corridor. The visualization corridor was designed so that any user could use any system, once he or she had become familiar with the basic components of the corridor. The LCG had to meet this requirement to maximize ease of use.

6.1 CEI's EnSight software

Computational Engineering International (CEI) EnSight software is the standard scientific visualization tool in use at LANL. It runs on all the ASC architectures on both shared and distributed-memory rendering platforms, and can be used in any of the LANL ASC display environments. Every ASC user code is interfaced to this tool. This software is fully integrated into the multi-panel, non-planar immersive facility. Users can come into the facility, start EnSight the same way that they normally would at their desktops.

6.2 Tracking software

The images gathered by the tracking cameras of the Vicon system are sent to an image processing system that uses the Vicon Tarsus software. Tarsus extracts from the images positional and rotation data corresponding to the objects being tracked. However, the EnSight software does not use the native Tarsus format, but instead uses the VRCO Trackd interface for tracked input devices.

LANL personnel have written a translator between the Tarsus and Trackd formats, so that EnSight could make use of the tracked data. Included is an interface to permit users to define and add their own tracked devices easily, thereby allowing them to take advantage of the flexibility and freedom provided by Vicon.

6.3 Other software

Other software in use in this facility includes StereoMoviePlayer, a LANL movie player, as well as CEI's EnLiten geometry browser and EnVideo movie tool.

7 Facility Use

La Cueva Grande is a very attractive and intimate working space. The high resolution, the small pixel size, the close-up view, and the brightness of the projectors provide an excellent sense of presence and give the objects in the space solidity.

Once the facility was deployed, it became clear that the perceived constraint of small room size was actually an advantage. Many users have remarked upon its usability as a working space and this is due in part to the intimacy of the environment, combined with the resolution of the facility.

An emergent mode of use is when a group allows one person to interact with the visualization, while others observe and discuss. When a change in position is desired, the group asks the driver to make the change, thus putting the user interface at one remove. This was an unexpected mode of interaction, and it is currently the mode of choice by the users. The scientists who are observing are not distracted by the need to interact, and are free to concentrate on the simulation. The need to learn these interactions impedes use, and as more natural interactions are developed, we anticipate greater success.

The LCG is about half as deep as it is wide, so is shallow but non-planar, having side walls at right angles to the front wall. It affords use as a PowerWall with side views to infinity. The viewer has a view as if he or she were looking out a window into the space. Because this view goes to infinity, any object placed in front of the viewer can be seen in its entirety, which is not true of any planar PowerWall.

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