Comparing User Experience in a Panoramic HMD vs. Projection Wall Virtual Reality System

A brief report summarizing a June '06 event held the 3D Lab in the University of Michigan, Ann Arbor

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Executive Summary

This report summarizes results of a new study that compares user experience within the Sensics panoramic HMD to the experience inside a projection-wall virtual reality system. The study was conducted in June 2006 during an exclusive industry event held at the University of Michigan, Ann Arbor. The study reveals that on average, expert users prefer the Sensics HMD over CAVE-like system in all surveyed dimensions including image quality, field of view, and degree of immersion.

31 experts from major automotive, aerospace, defense, CAD and virtual reality companies participated in the study, most with substantial prior exposure to VR systems. Participants were invited to the 3D Lab at the University of Michigan, Ann Arbor and had an opportunity to comparatively experience immersive 3D models on both the Sensics piSight 150 HMD and a new projection-wall system recently installed at the lab. Various automotive, aerospace, and architectural 3D models we obtained through independent sources and were loaded on both VR systems. Participants filled Web-based surveys immediately upon completing use of both VR systems.

Key survey results include:

- On a scale of 1 through 6 where (1) is "very poor" and (6) is "excellent", 94% of participants rated the piSight field of view as (5) or (6),, 83% rated the resolution as (5) or (6), and 68% had a (5) or (6) overall impression of the Sensics HMD.
- Comparing the piSight HMD to the "CAVE" on the same 1 through 6 scale, 75% preferred the image quality in the piSight HMD to the "CAVE", and the average score of all other dimensions of the comparison (such as field of view, degree of immersion and overall performance) favored the piSight HMD.

This report provides detailed survey results, additional information regarding test conditions, as well as commentary on the use of HMD vs. "CAVE" systems.

Introduction

The possibility of using head-mounted displays for high-end virtual reality applications has always intrigued users. Compared with projection-wall systems (often referred to as “CAVEs”), HMDs conceptually offer many advantages such as size, cost, effort to set up, portability and more. However, field of view and resolution limitations have so far prevented HMDs from being seriously considered in those applications where the limitations of CAVEs were acceptable.

Using patented technology that was developed over nearly a decade of research, Sensics engineered a new generation of HMDs, capable of ultra-wide field of view and high resolution in a lightweight, portable package. We believe that this new product is at least comparable to the performance offered by modern “CAVE” systems.

To test this hypothesis as well as to expose interested users to our system, we partnered with the 3D Lab at the University of Michigan, Ann Arbor, to set up a unique virtual reality event, showcasing the Sensics piSight and the 3D Lab CAVE-like system side-by-side, allowing virtual reality users to compare different high-end approaches to immersive virtual reality displays:

High-quality 3D content that is relevant for auto design, training and simulation, architecture and education applications was acquired from various sources and was available for side-by-side comparison. In addition, some participants brought their own proprietary content for viewing.

After experiencing both the Sensics HMD as well as the projection wall systems, participants were asked to privately fill a short Web-based survey. After the event, Sensics tabulated and analyzed the results.

Projection Wall System ("CAVE")

The 3D Lab operates a CAVE system that was first installed at the University of Michigan in 1997. During 2005/2006, almost all components were replaced with the latest, state-of-the-art technologies. As a unique resource, the CAVE is available to the UM community for research, education, and exploratory projects. Key specifications:

Size	10' x 10' x 10'
Screens	Three walls with rear-projection, one floor with down projection, for a total of four projection screens
Projectors	Four Christie Mirage S+4K projectors with mirrors, one for each screen.
Resolution	1024 x 1024 per screen
Stereo	Time-sequential projection of stereo images at 120 Hz
Glasses	Stereographics' liquid crystal shutter glasses, synchronized via IR (Infra Red) emitters with projection sequence
Input Device	Hand-held wand with three buttons and pressure-sensitive joystick
Tracking	Vicon MX system with 8 cameras Optical six degree-of-freedom tracking system
Computers	Four Dell Precision 650 (P4 2.4GHz) with NVidia 3000G video cards One control computer One tracking computer

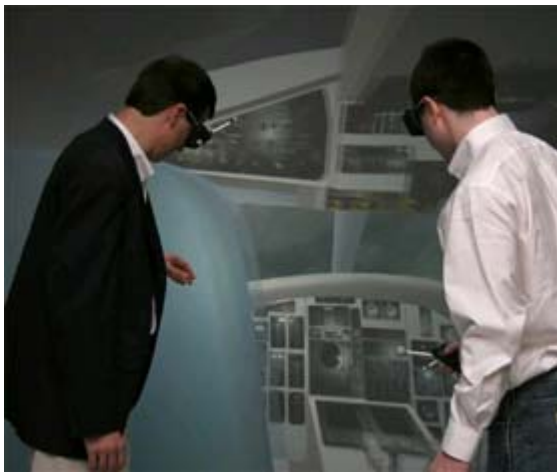
Sensics piSight 150 HMD

Field of view	150° diagonal 145° wide 60° high
Binocular overlap	90° diagonal 75° wide 60° high
Resolution	3200x1800 pixels per eye 20 pixels/degree 3.0 arcmin/pixel
Color	24 bit color, 75% of NTSC gamut 100:1 contrast
Frame Rate	60 Hz
Tracking	Predictive 6 degrees of freedom
Tracking Resolution	0.75mm position, 0.05° angular
Tracking accuracy	3.0mm position, 0.25° pitch, roll, 0.50° yaw
Head-supported weight	2 lbs (1 kg)
Computers	12 Linux computers, AMD Athlon XP 3200+, nVidia GeForce 5400 video cards One control computer

Models

Several 3D models were used in the comparison:

"Cockpit" – a 3D model acquired through Dimension Data, a Sensics partner. This model was generated performing a 3D laser scan of a Navy plane and later augmented by U of Michigan 3D Lab staff. This model is representative of interior design work for automotive and aerospace.

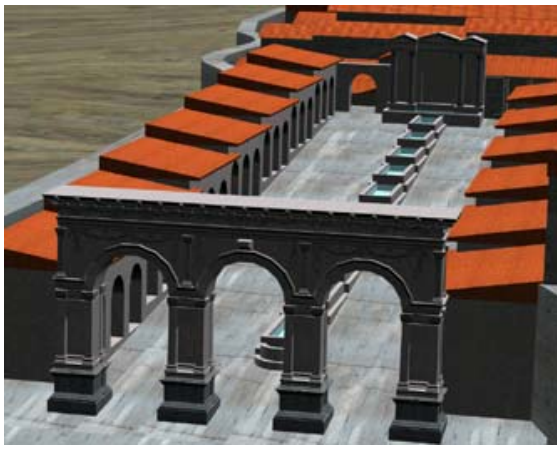


"Rome" – a reconstructed 3D model of the Roman Forum as it existed some 2000 years ago. This model was provided courtesy of Prof. Bernard Frischer, Director, Institute for Advanced Technology in the Humanities at the University of Virginia. This model is representative of architectural design visualization.

"Classroom" – a model of a proposed lecture hall for the Ross School of Business at the University of Michigan, prepared by Steffen Heise and Eric Maslowsk

"Mustang" – a public-domain model of a Ford Mustang

"Antioch" – a reconstructed model of of Antioch of Pisidia in Asia Minor (Turkey)-a Hellenistic city refounded by Augustus in 25 BC as a Roman colony. Model is was provided courtesy of the Kelsey Museum of Archeology at the University of Michigan.



Several participants sent Sensics their own proprietary 3D models in advance, with a special focus on automotive and heavy machinery design. These models were only shown to their respective owners on both the Sensics system and the "CAVE". Because of confidentiality agreements, we are unable to reproduce images of these models in this report.

Participant Profile and Administrative Aspects

31 event participants filled confidential Web-based exit surveys upon completing the demonstration. Most participants are using VR devices today or have had substantial exposure to VR technology. The industry background of the surveyed group is shown in figure 1:

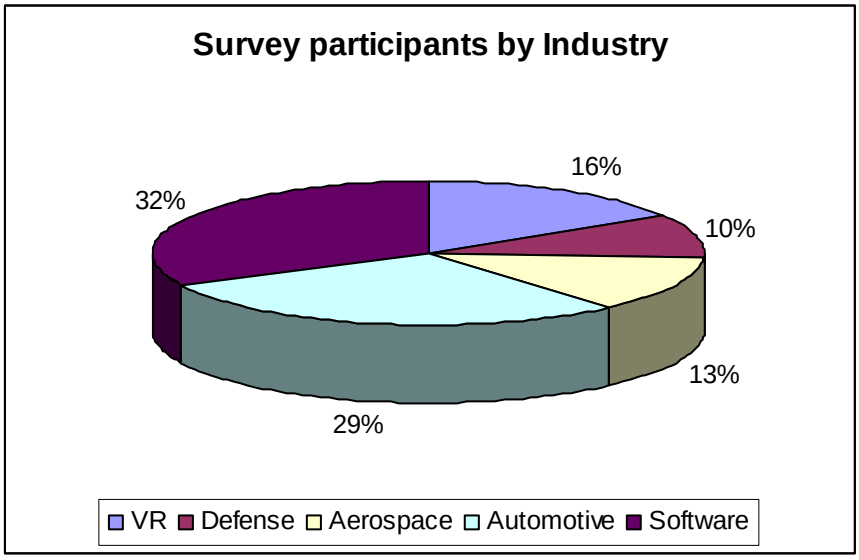


Figure 1: Survey participants by Industry

As can be seen, over half the participants came from automotive, aerospace and defense companies, while about 1/3 of the participants were from software companies with substantial 3D and VR offerings.

Participants were also asked to comment on the administrative aspects of the meting and provided very positive feedback (see table below). As such, we have reason to believe that their responses to the rest of the questionnaire were provided after ample thought.

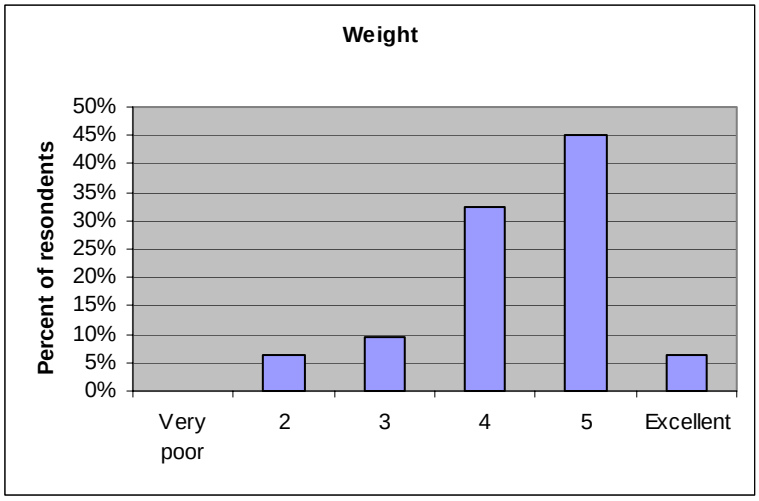
3. On a scale 1 through 6 where (1) is "completely disagree" and (6) is "completely agree", please indicate whether you agree to the following statements regarding your visit

	1: completely disagree	2	3	4	5	6: completely agree	Response Average
Setting up the meeting was easy	0% (0)	3% (1)	3% (1)	0% (0)	13% (4)	**80% (24)**	**5.63**
The meeting room was comfortable	0% (0)	3% (1)	0% (0)	3% (1)	32% (10)	**61% (19)**	**5.48**
The demonstration was well organized	0% (0)	0% (0)	6% (2)	3% (1)	19% (6)	**71% (22)**	**5.55**
There was sufficient time allotted to the meeting	0% (0)	0% (0)	0% (0)	0% (0)	19% (6)	**81% (25)**	**5.81**
I felt that my hosts knew the material well	0% (0)	0% (0)	0% (0)	0% (0)	13% (4)	**87% (27)**	**5.87**
The demo met or exceeded my expectations	0% (0)	0% (0)	6% (2)	10% (3)	**55% (17)**	29% (9)	**5.06**
I'm glad I attended this demonstration	0% (0)	3% (1)	0% (0)	0% (0)	20% (6)	**77% (23)**	**5.67**
I felt welcome at the Sensics/U of Michigan demo	0% (0)	0% (0)	0% (0)	0% (0)	6% (2)	**94% (29)**	**5.94**
						Total Respondents	**31**
						(skipped this question)	**0**

Impressions of the Sensics System

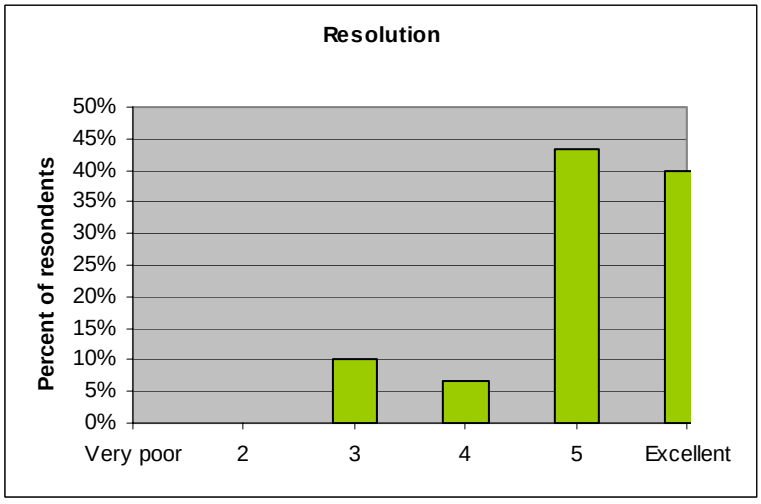
We asked survey participants to report on their impressions of the Sensics piSight. The question was presented as : “On a scale 1 through 6 where (1) is "very poor" and (6) is "excellent", please rate the Sensics HMD on each of the following dimensions:”.

The results were:



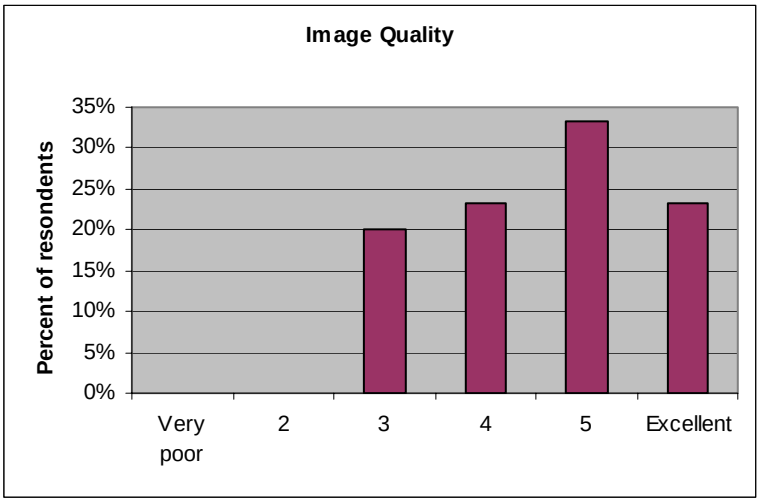
Average score: 4.35
Most common: 5

84% of respondents evaluated the system weight to be good to excellent (4 to 6 on the scale)



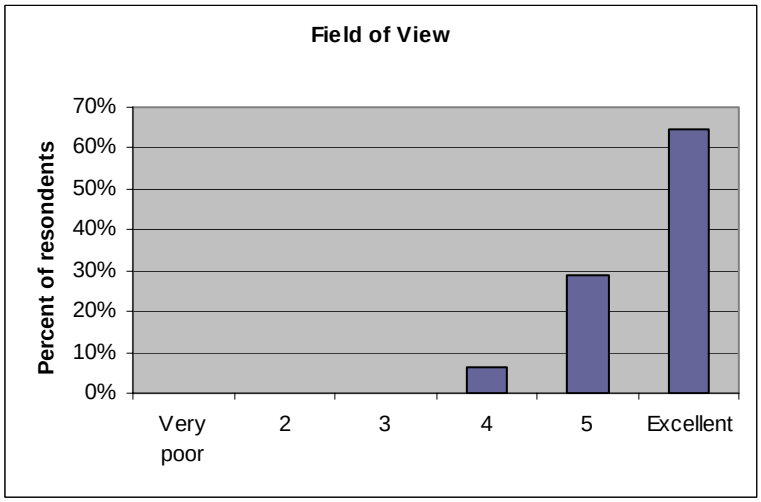
Average score: 5.13
Most common: 5

90% of respondents evaluated the system resolution to be good to excellent (4 to 6 on the scale)



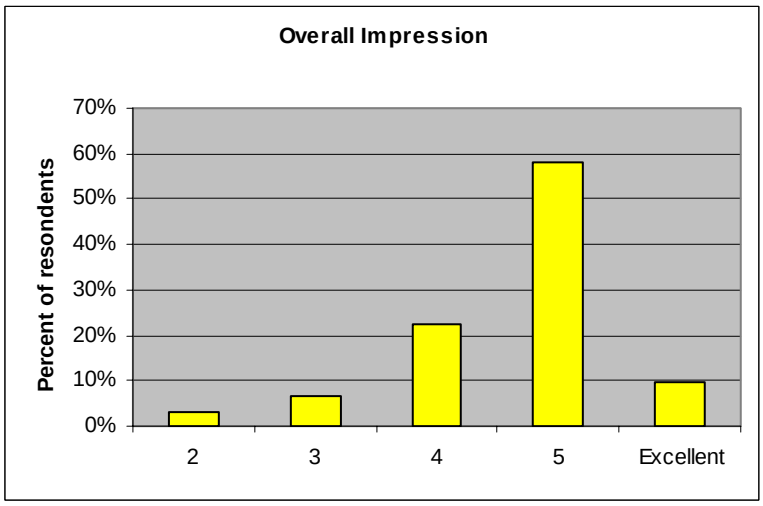
Average score: 4.60
Most common: 5

80% of respondents evaluated the image quality to be good to excellent (4 to 6 on the scale)



Average score: 5.58
Most common: 6

100% (!) of respondents evaluated the field of view to be good to excellent (4 to 6 on the scale)

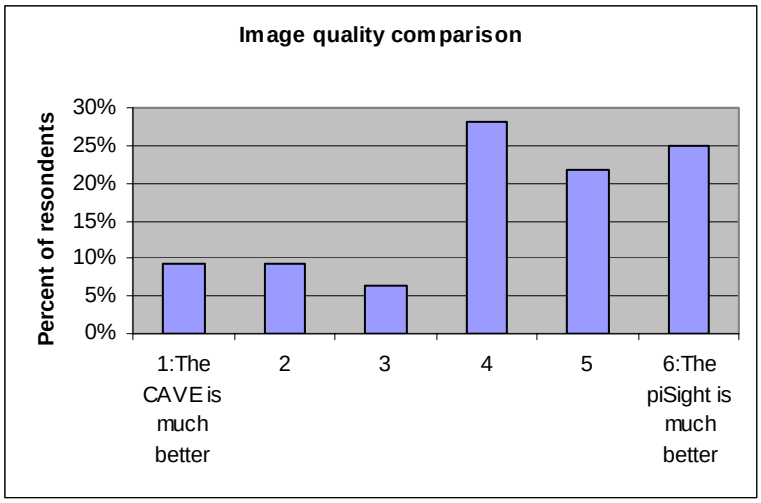


Average score: 4.65
Most common: 5

90% of respondents evaluated the image quality to be good to excellent (4 to 6 on the scale)

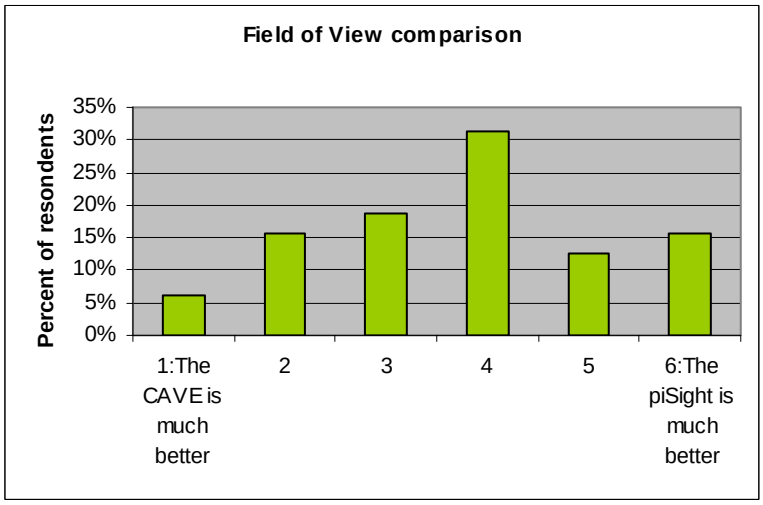
Comparing the Sensics HMD with the University of Michigan "CAVE"

The survey then asked participants to compare on the Sensics piSight to the "CAVE" system. The question was presented as: "On a scale 1 through 6 where (1) is "the CAVE is much better" and (6) is "the Sensics piSight is much better", please compare the CAVE and the Sensics HMD along the following characteristics:" The options were: (1) The CAVE is much better, (2) The CAVE is better, (3) The CAVE is slightly better, (4) The Sensics piSight is slightly better, (5) The Sensics piSight is better, (6) The Sensics piSight is much better.



Average score: 4.19
Most common: 4

75% of respondents considered the piSight to be of better image quality (4 to 6 on the scale)



Average score: 3.75
Most common: 4

59% of respondents considered the piSight to be of better field of view than the 4-wall CAVE (4 to 6 on the scale)

We also asked participants to compare degree of immersion, motion tracking performance, image generator performance and overall performance. The survey results showed that on these dimensions, participants found the piSight on par or slightly better than the "CAVE" (average responses 3.66, 3.60, 3.66 and 3.66), though the results did not show a statistically significant advantage.

Additional Comments from Participants

We asked participants to note "What were the things that most impressed you about the Sensics system and demonstration?". Representative comments include:

- "1. Edge blending of tiled displays was much better than I expected 2. Level of detail (e.g. dials and gauges) was surprisingly better 3. Demo went virtually without flaw 4. Lightness of HMD was impressive"
- "Quality of the image in the Sensics system was considerably better than any immersive experience I've had before"
- "The field of view on the HMD. This HMD has the best of field of view I have ever used."
- "The degree of immersion was very impressive. You felt more like you were in the actual environment as compared to a CAVE."
- "The field of view was far and away better than any other HMD I've seen."

In order to improve the Sensics system, we also asked "What probably needs improvement with regards to the Sensics system and demonstration?" Some comments and actions that Sensics took since the demonstration include:

Comment	Sensics improvement since
"better frame rate would help"	The image generator used at the U of Michigan demo was based on three year-old Linux computers and graphics cards. We have since upgraded the system to new Windows computers and top-of-the-line graphics boards, thus substantially improving frame rate.
"Ability to interact with the environment through visualization of my hand/arm in the virtual environment."	The new Windows cluster is now supported by several commercial VR software packages that include animation, avatar, haptic and wireless wand support.
"Ease of fitting the HMD needs to be improved"	We made improvements in the process of quickly achieving the right HMD position. At SIGGRAPH 2006, we used this process to demonstrate the system to over 200 people in 3 days.
"A wireless headset would be nice also"	We agreed, but the vast amount of image data currently being sent to the HMD, makes it a wired product today. However, Sensics has taken special care to design a thin and long cable so that the HMD can be used at significant distance from the image generator

Another question that was posed was "Which part of the demonstration do you most vividly remember?". Representative comments include:

- "The navy cockpit was the most vivid memory where I could be seated and lean in toward the imagery and the instrument panel got perceptually closer. This brought the whole experience together."
- "The demo does make you feel very immersed into the environment."

Discussion

Projection-wall “CAVE” systems have always been considered the vehicle of choice for demanding VR applications, in spite of their being inherently large and cumbersome, costly and complex to build and maintain. We’re pleased to propose that the panoramic Sensics HMD meets or exceeds the performance of a “CAVE” in all key parameters including image quality, immersion and field of view. This is in addition to obvious advantages in cost, size, complexity, and portability.

The main remaining advantages of the “CAVE concept”over HMDs are that CAVEs provide “instant on” (e.g. wear stereo glasses, walk in the start exploring the data) and that multiple people can simultaneously stand inside a “CAVE” – though since only one person is tracked, other people co-using the “CAVE” often see substantial image distortions which impact the viewing experience as well as the ability to effectively collaborate.

CAVE systems also exhibit counter-intuitive behavior when a user moves closer to the wall in order to better see an image. Because the number of pixels per wall surface unit is fixed, moving closer to the wall actually reduces the spatial resolution. In contract, when a user moves closer to a virtual object with an HMD, the motion tracking indeed presents greater levels of detail and image clarity is improved, as expected.

To take full advantage of the piSight HMD, users need to correctly position the HMD on their head, a process that today usually takes about 30 seconds for first-time users and is practically instantaneous for frequent users.

Is Sensics asking people to “get out of the CAVE”? Not yet, but we encourage demanding VR users to give a the Sensics panoramic HMD very serious consideration, instead of just defaulting to a projection-wall solution

About Sensics

Sensics, Inc., is the panoramic virtual reality display company. Based on patented technology developed over nearly a decade of research, Sensics delivers lightweight panoramic head-mounted displays that combine ultra-wide field of view and high resolution, thus enabling a new generation of virtual prototyping, training, visualization and remote presence applications. Sensics is headquartered in Baltimore, Maryland.

The Sensics piSight™ is ideal for numerous applications including training and simulation, virtual design, visual analytics, education and more. The piSight head-mounted display offers:

- Panoramic 150° field of view that delivers full peripheral vision and complete immersion
- High resolution: 3200x1800 pixels per eye in vibrant color, providing 20 pixels per degree throughout the entire visual field
- Integrated precision motion tracker with six degrees of freedom
- Lightweight design: less than 1 kg (2 lbs.)

To learn more about the Sensics products and to schedule a demonstration, please contact us at:

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