VIRTUAL REALITY FOR AUTOMOTIVE DESIGN EVALUATION

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INTRODUCTION

A general description of Virtual Reality technology and possible applications was given from publicly available material. A video tape was shown demonstrating the use of multiple large-screen stereoscopic displays, configured in a 10' x 10' x 10' room, to allow a person to evaluate and interact with a vehicle which exists only as mathematical data, and is made only of light. The correct viewpoint of the vehicle is maintained by tracking special glasses worn by the subject. Interior illumination was changed by moving a virtual light around by hand; interior colors are changed by pointing at a color on a color palette, then pointing at the desired surface to change. We concluded by discussing research need to move this technology forward.

BACKGROUND

Many of us have seen magazine covers, such as <u>Automotive Industries</u>, describing virtual reality. Today I want to point out to you that virtual reality is not virtual, it's real and being used right now.
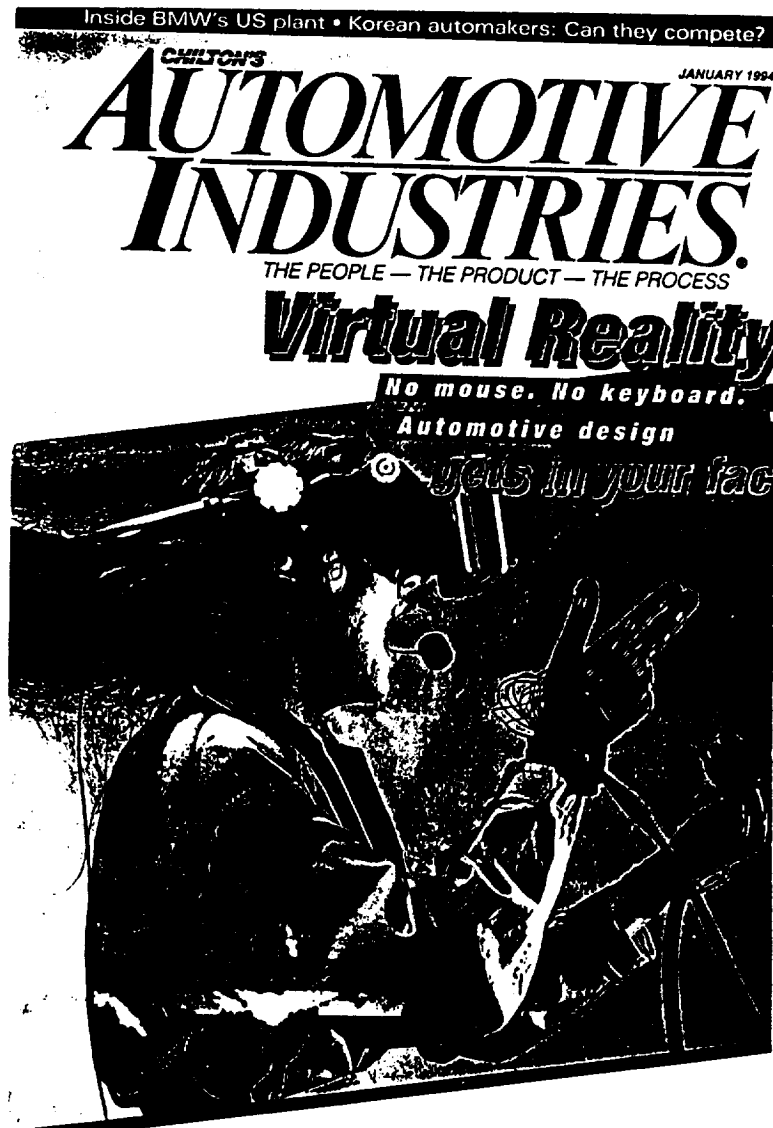

Figure 1.

In this presentation, we'll discuss virtual reality and how it can be used in vehicle design.

What is Virtual Reality?

How can it be used in design?

Figure 2.

Virtual reality has a great deal of promise. If I hear something, I will probably forget it, because it goes in one ear and out the other; if I see it, I may remember; but if I do it, I will understand. Virtual reality allows us to experience an environment or experience a process with "us" as key players.

PROMISE OF VR TECHNOLOGY

If I hear . . . I will forget.
If I see . . . I may remember.
If I do . . . I will understand.

Old Chinese Proverb

Figure 3.

What is virtual reality? Jason Lanier said that it is, "A computer generated, interactive, three dimensional environment which a person is immersed."

The virtual domain provides: (1) a real-time, viewer-centered system in which the viewer is a part of the display and the interaction; (2) a head-tracked perspective so that the image shifts as the viewer moves so that he accurately sees it from any point of view; (3) a large field of view, so the peripheral vision is encompassed in the field of view; (4) interactive control, so that you can control the images of the 3D stereo display.

And last, what is immersion? It is a state of being deeply engaged or immersed in the process. This is what virtual reality allows you to do.

What is Virtual Reality?

A computer-generated, interactive, three-dimensional environment in which a person is immersed

Jason Lanier, founder of VPL

What is a Virtual Domain?

A VR system that provides a real-time, viewer-centered, head-tracked perspective with a large field of view, interactive control, and 3-D stereo display

Carolina Cruz-Neira, EVL

What is Immersion?

The state of being deeply engaged

Webster

Figure 4.

1950'S STEREO VIEWING

Back in the 1950's, people would go to movies wearing glasses as shown in this picture. However, virtual reality is much more than watching a picture in 3D, it is experiencing and being involved in the picture. It surrounds you, with you as the center of attention.

Figure 5.

Virtual reality allows us to have a virtual prototype, which is a 3D computer model made completely with light with which designers and engineers can interact in the same ways they would interact with physical models, but at greatly reduced cost, at greatly increased speed of implementation, and with more flexibility and agility than you can find with physical models.

VIRTUAL PROTOTYPING

A virtual prototype is a 3-D computer model made completely with light that designers and engineers can interact with in some of the same ways they would a physical model, but . . .

. . . at greatly reduced cost

. . . at greatly increased speed of implementation

. . . with more flexibility and agility

Figure 6.

VIRTUAL REALITY KEY CONCEPTS

This slide illustrates the key concepts behind virtual reality. At the graphic terminal, a person designs something such as a seat, which becomes a number of mathematical equations and databases inside the computer. There are three ways to experience the results of the design: (1) the boom; (2) the head-mounted display; and (3) a CAVE.
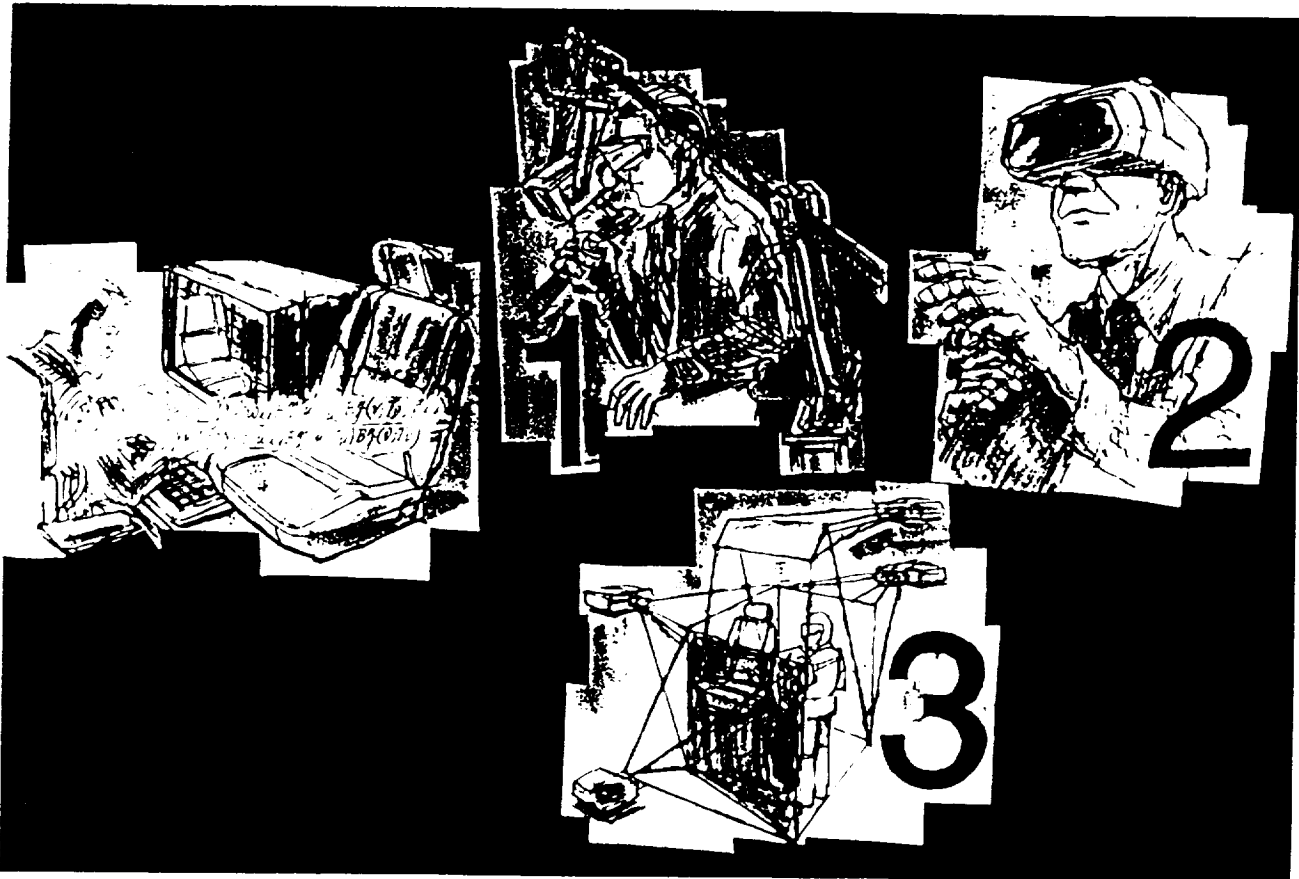

Figure 7.

BOOM DESCRIPTION

The boom is a device that you hold up to your eyes, like you would hold a pair of binoculars. You move around and the computer knows your position/orientation through a linkage mechanism connecting back to the computer. You change the distance to and from the object by pushing one or two buttons on the handles of the boom. You can control the interaction with the object through a data glove, which is then represented on the picture inside the viewing area.

Figure 8.

The characteristics of a boom are as follows:
- It has a very narrow field of view, roughly the same as you would have by looking through a pair of binoculars
- It has accurate and fast tracking, but is a cumbersome periscope with manual sets of linkages to give you limited range of movement
- Virtual hand images are superimposed on the display
- However, the person using the boom is completely isolated from physical surroundings
- It is not very intuitive to use because of the short range and the push buttons
- You can have human factors problems such as dizziness, because you are not tied into the real world. If the image does not track as speedily as your head moves, the delay in movement can cause seasickness.

BOOM CHARACTERISTICS

- ■ **Field of view narrow – 90 ... 120 degrees**

- ■ **Accurate, fast tracking**

- ■ **Cumbersome periscope, manual set of linkages**

- ■ **Virtual hands image superimposed on display**

- ■ **Completely isolated from physical surroundings**

- ■ **Not intuitive to use**

- ■ **Human factors (dizziness)**

Figure 10.

VIRTUAL REALITY HAND DESCRIPTION

This is a picture of a data glove being used in a surgical operation tied to a boom. Note the artificial rendition of the hand.
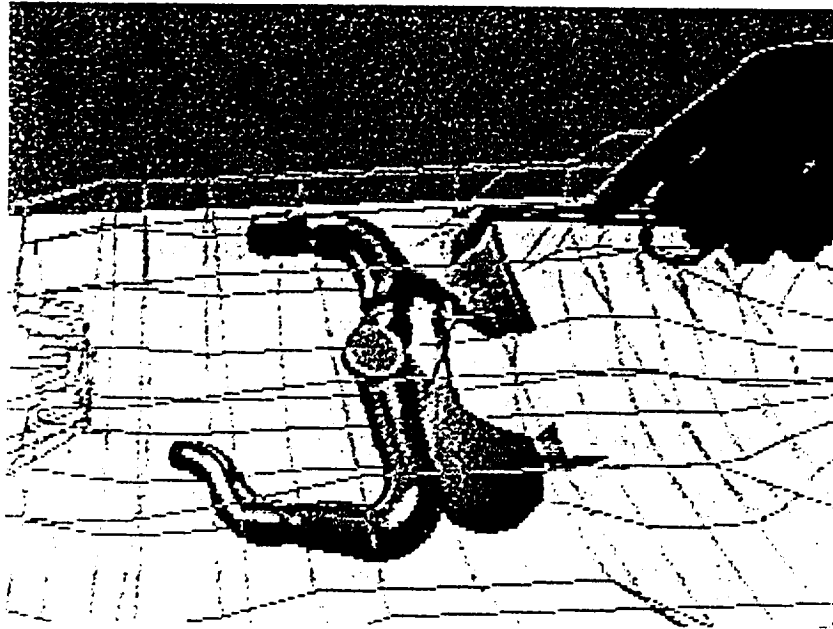

Figure 9.

HEAD-MOUNTED DISPLAY DESCRIPTION

The head-mounted display is a device that is mounted on the head, in which two TV images are projected. Weighing between five and seven pounds, it feels like a football helmet, but it is very cumbersome to wear. Because of the inertia of the weight, when you move your head around you sometimes have an inertia effect that doesn't feel very natural.
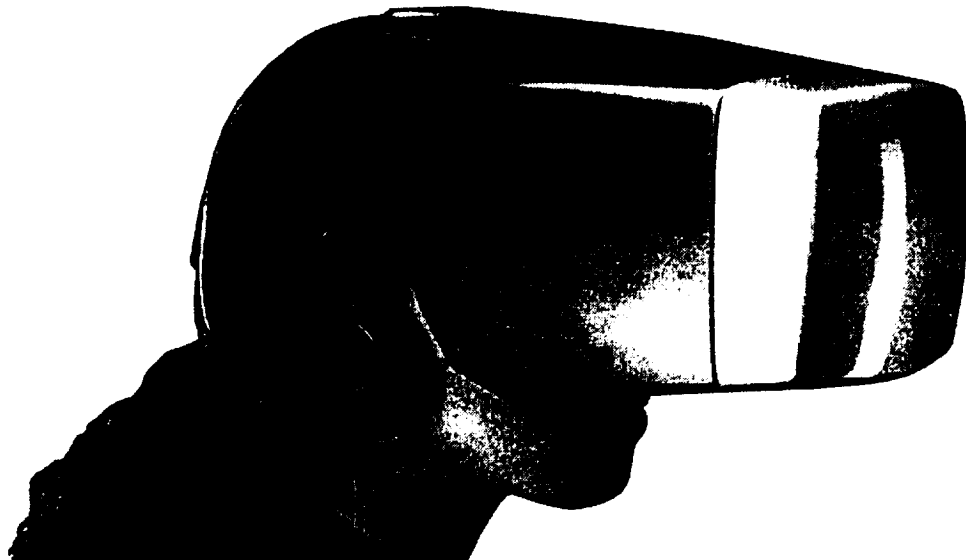

Figure 11.

The head-mounted display characteristics are shown here. In general, head-mounted displays have a wider field of view than the boom, and hands are free to interact. However, we have to display images of the hands on the display within the football helmet-like device. The helmet is cumbersome with tethered wires. Again, you're completely isolated from physical surroundings, with the accompanying human factors problems which could occur.

HEAD-MOUNTED DISPLAY CHARACTERISTICS

■ **Field of view − 100 ... 140 degrees**

■ **Hands free to interact**

■ **Cumbersome helmet, tethered wires**

■ **Completely isolated from physical surroundings**

■ **Human factors (dizziness)**

Figure 12.

CAVE DESCRIPTION

The CAVE is a three-dimensional cubic room. At the General Motors Research & Development Center, it is a room 8' X 8' X 8'. On each of the three walls and the floor is a projected image. When you are inside the CAVE, you get a complete sense of immersion in that you are surrounded by the images made completely with light. Because of the projection onto the floor, the images can rise out of the floor. The person wears lightweight stereo glasses and the head tracking is controlled by a sensor which knows the position of the head within the room and can adjust the picture accordingly.
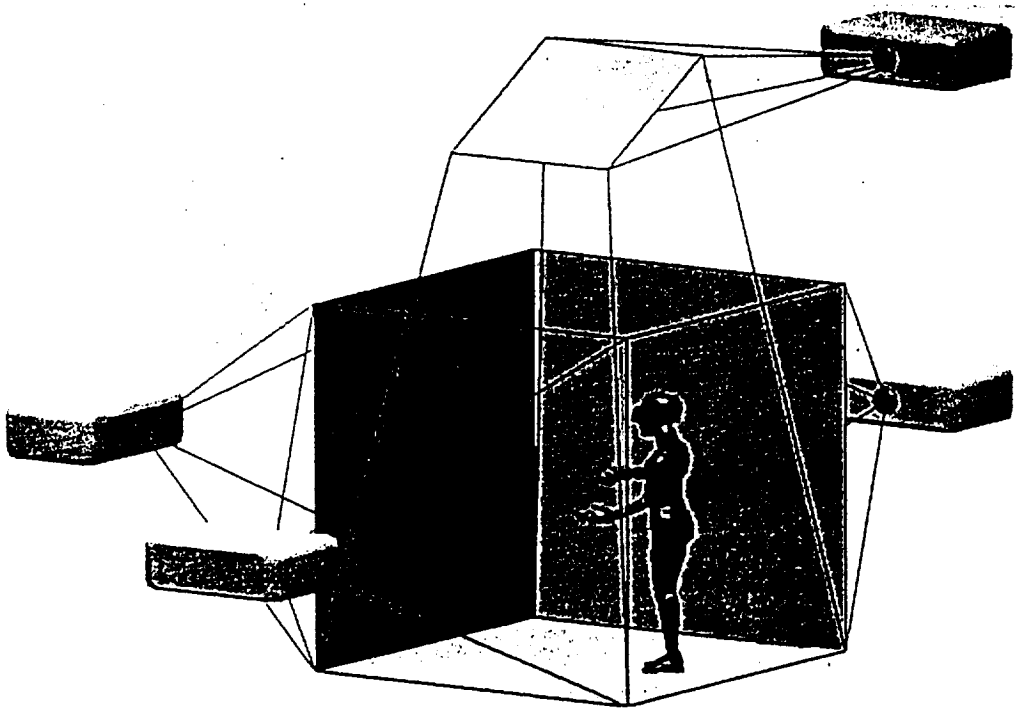

Figure 13.

This picture shows one of our researchers, Randy Smith, with a pair of head-mounted display glasses, standing near a virtual image of a vehicle.
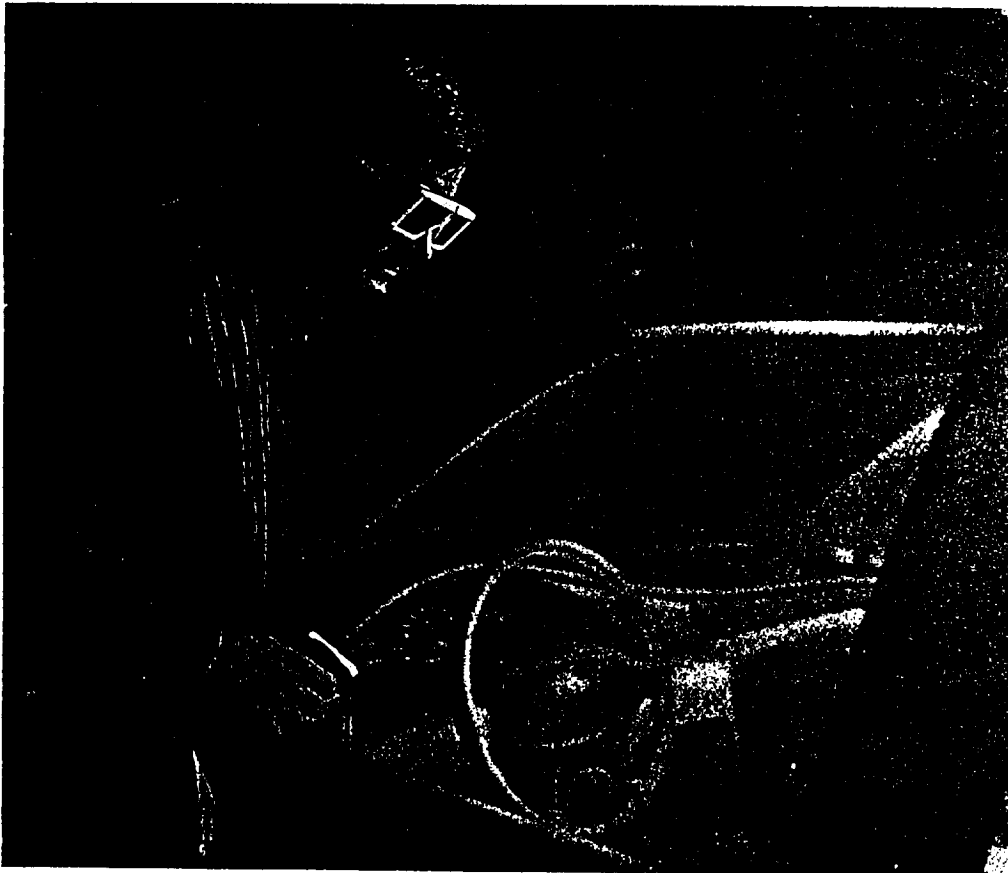

Figure 14.

The CAVE gives you a complete full field of view, in which you are totally immersed. It is the least intrusive of all three virtual reality approaches in that you only wear eye glasses. You don't need to model and track the hands because you can see them as you are involved within the environment. One new characteristic of the CAVE that you don't find in the other two environments is that your can mix virtual and physical objects and do joint simulations of both types of medium. In addition, the CAVE allows for multiple participants to look at and interact with the display. Head tracking applies to one person only, but others standing close to him will see about the same image.

CAVE CHARACTERISTICS

- **Field of view full – Total immersion**

- **Least intrusive – requires wearing glasses only**

- **Don't need to model and track hands / fingers since you can see them**

- **Mix virtual and physical objects**

- **Multiple participants (perspective set for 1 only)**

- **Hands free to interact**

Figure 15.

Virtual reality can be used four ways in the design process: (1) to assess the overall impact of the design, (2) to conduct visual quality inspection, (3) to examine human factors and conduct human factors evaluation of the product, and (4) to study packaging.

How Can Virtual Reality Be Used in Design?

Overall impact of design

Visual quality inspection

Human factors evaluation

Packaging studies

Figure 16.

Design impact is illustrated by modeling the interior of the vehicle. This enables flexible evaluation and modification of a design. By modeling the interior, you can then do "what-if" studies visually. You can look for occlusion and accessibility of instruments. You can study the 'A' pillar, that's the pillar between the door and the windshield, for obscuration and exterior vision. You can study the effects of occupant height variation and overall interior styling of the vehicle.

DESIGN IMPACT

A computer model of an interior concept enables flexible evaluation and modification of a design

"What-if" studies can be performed to visualize:

- Occulsion and accessibility of instruments
- 'A' pillar obscuration and exterior vision
- Effects of occupant height variation
- Interior styling

Figure 17.

VISUAL QUALITY INSPECTION

This image is made completely in a virtual world. The entire vehicle and the surrounding laboratory are all computer generated. No physical models were utilized in designing and displaying this picture.
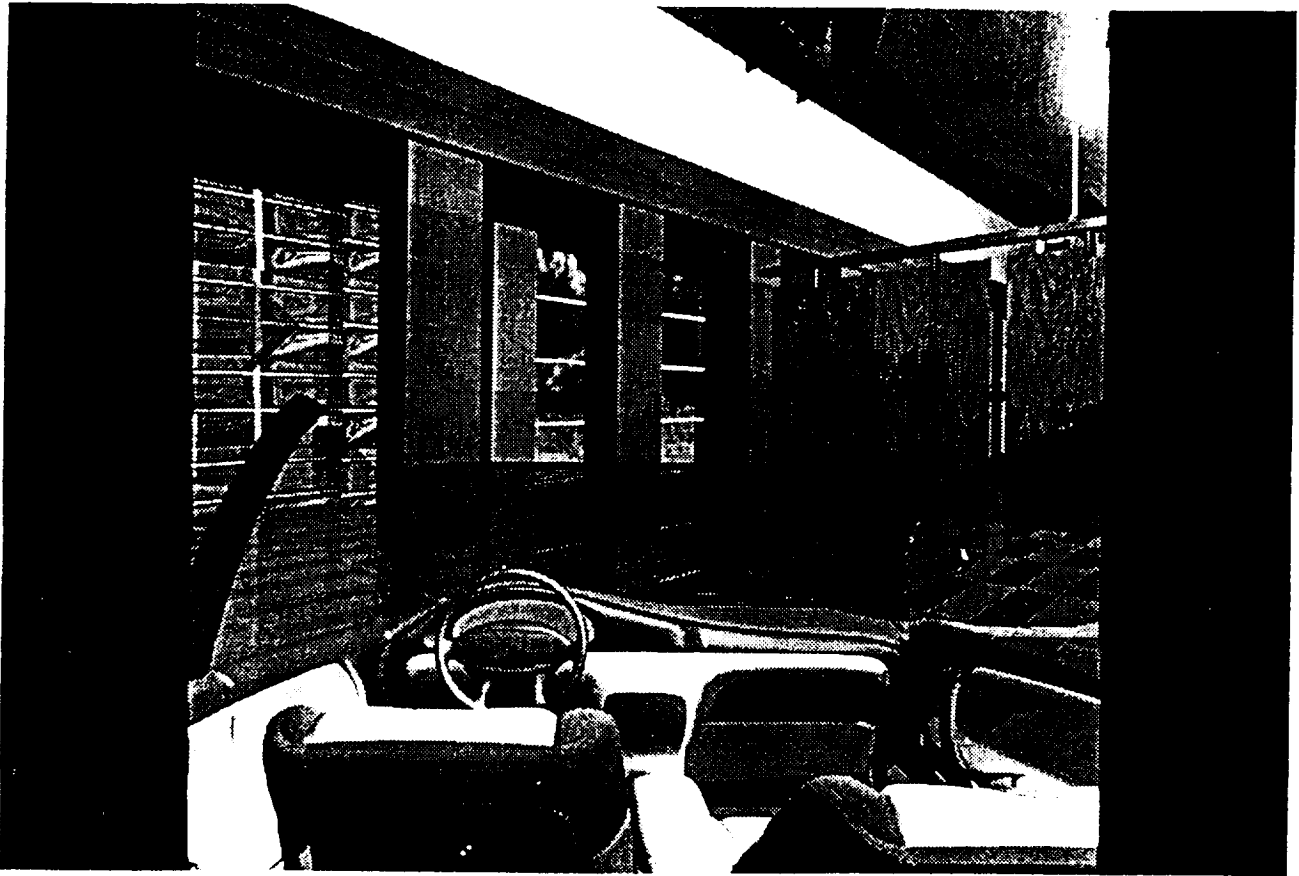

Figure 18.

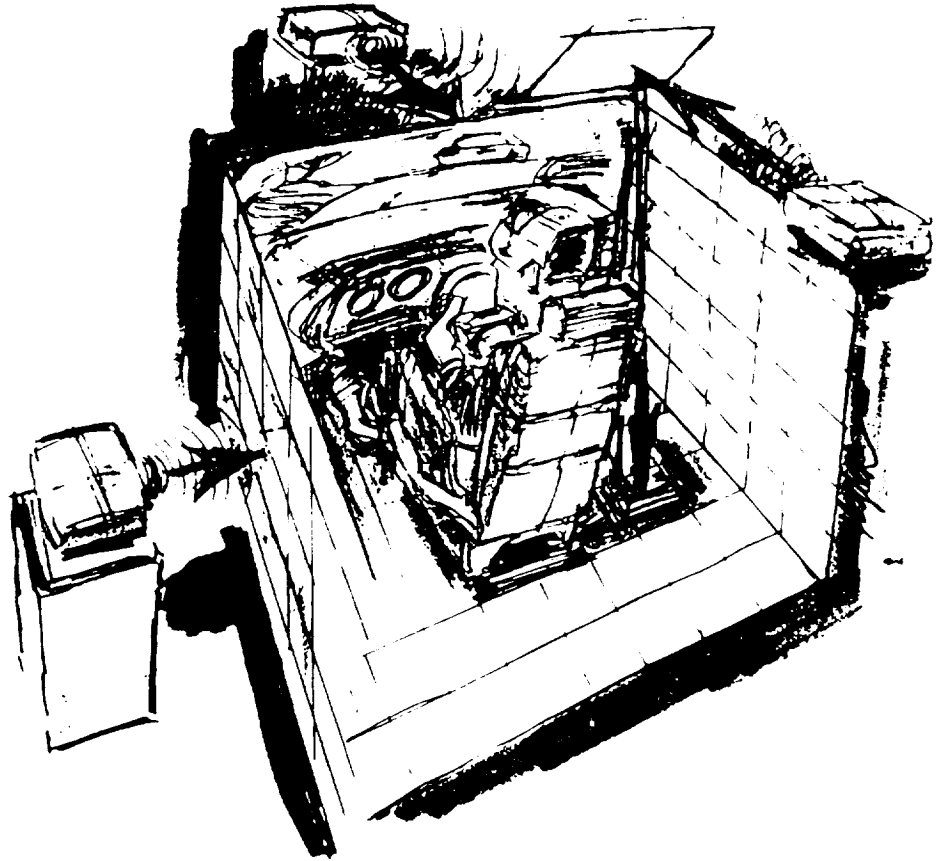Human factors evaluation can be done by immersing the viewer in the display projected in the CAVE.

Figure 19.

PACKAGING STUDIES

Packaging studies can be conducted by assembling the parts of the vehicle, again designed within the computer CAD system without physical models, to study the packaging effects. You can fly through the object and look for interferences and visually inspect the assembly.
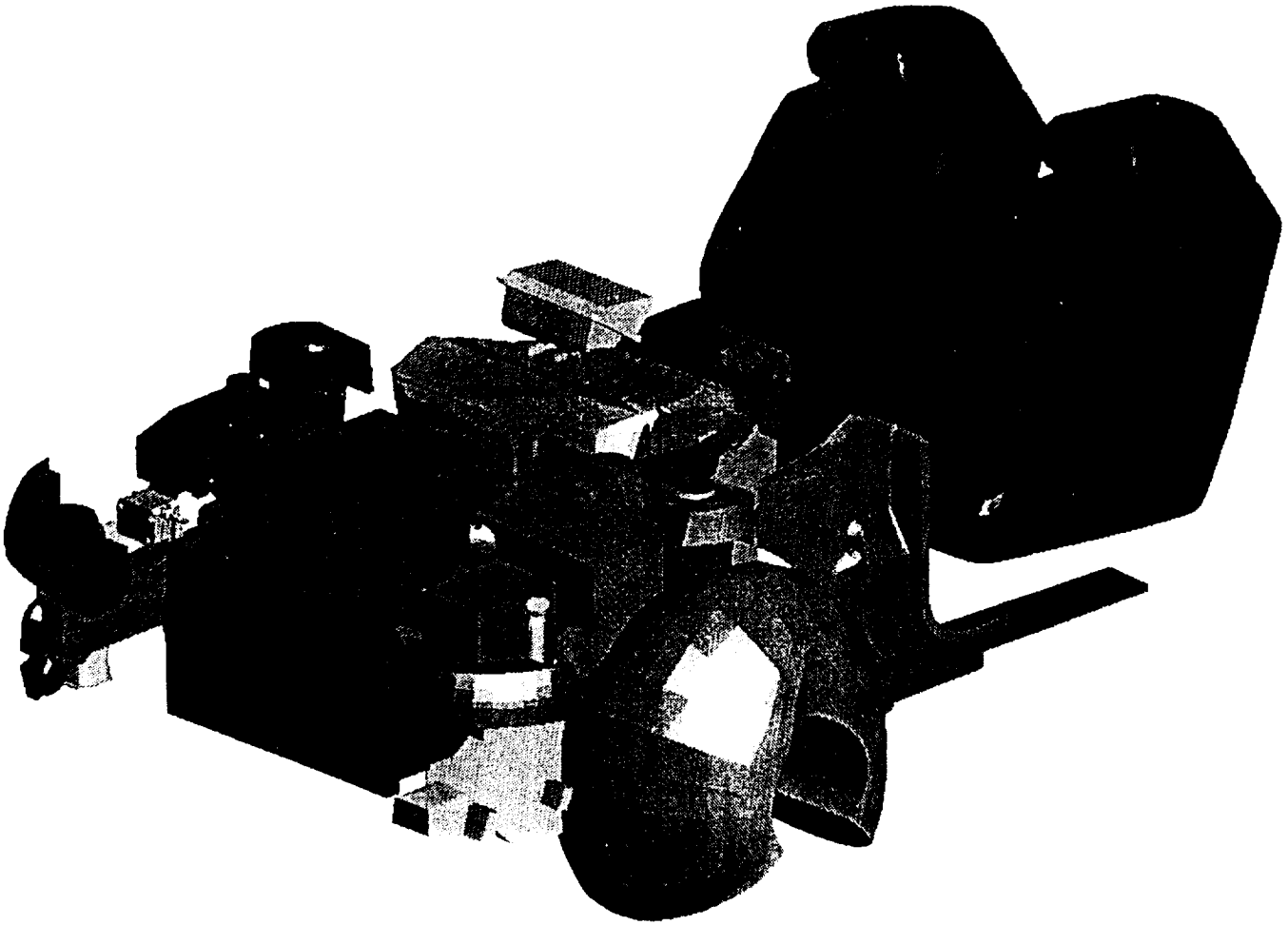

Figure 20.

Virtual reality can also be used for other applications, such as scientific visualization from a dynamic viewpoint. In crash simulation, for example, you can sit inside a vehicle and view the crash from the inside, to determine how metal moves, how the steering wheel might move and make certain that the occupant would be safe in that kind of situation. You can move your viewpoint and study suspensions and mechanisms. In painting, you can study spray dispersal patterns to make certain that you get uniform spray on a piece of sheet metal, especially around curves and the edges of the metal. NASA Ames is using virtual reality for virtual wind tunnels to study aerodynamic effects.

OTHER APPLICATIONS

■ **Scientific visualization – Dynamic viewpoint**

- **Crash simulation – Full-size, viewed from inside**
- **Suspensions and mechanisms**
- **Metal forming**
- **Spray dispersal patterns**
- **Virtual wind tunnel (NASA Ames)**

Figure 21.

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GM R&D's VisualEyes system has four key features: It has a human-in-the-loop simulation, in which the human is immersed in the scene. To do this, we are using the CAVE approach with head tracking to correct their perspective view. In fact it is so good, it allows you to stand up and walk around the interior of the vehicle, to look outside over the vehicle, and so forth. We can show models from any math data which meet GM's C4 standards, which are CGS, Unigraphics, Alias, and IGES.

GM R&D's VisualEyes – KEY FEATURES

- **Human-in-the-loop simulation**

- **CAVE approach**

- **Head tracking**
  - **Correct perspective view, "walk-around"**

- **Shows models from any math data meeting GM's C4 standards**
  - **CGS, UG, Alias, IGES**

Figure 22.

There are several R&D areas in which virtual reality needs more help. We need better software for faster rendering of complex scenes with lots of detail and better control over the detail. People want to have images that track with the head, not slightly behind, which is still the case in our very high resolution images. In addition we need to consider new human interface paradigms for 3D design. How could you sit inside a CAVE and design while you're inside the CAVE is one problem. How might you paint on the wall and have that relate to a display of the design on that wall is a related interesting problem.

R&D Areas

SOFTWARE

■ **Faster rendering with lots of data; detail control**

■ **New human interface paradigms for 3D design**

Figure 23.

A Synthetic Design Environment for Ship Design

Richard R. Chipman
Science Applications International Corporation
McLean, VA

Looking at hardware R&D areas, we need to have tracking which is more precise, faster, multi-point, and with no wires. This permits you to move your head around, turn, bend up and down and have absolute realistic tracking of the eye point. We need high resolution, wide field displays and stereo immersive displays. It would be nice, for example, to use high definition television techniques to get much better quality display than we have today. And last, we need to consider better hardware for tactile input and response so we can simulate humans touching and feeling parts of the display.

R&D Areas

HARDWARE

- Tracking ... more precise, faster, multi-point, no wires

- High-resolution, wide field-of-view stereo immersive displays

- Tactile input and response

Figure 24.

Looking at the system area, calibration techniques for accurate engineering and design work needs to be improved. Right now it takes a considerable amount of time to calibrate displays for realistic human simulation. As we have said before, we need better human-in-the-loop, real-time performance so that we can absolutely simulate the immersive effect in real time. On a more biological note, we need human perceptual studies conducted to determine the limits and requirements of how the psychology of the human eyes and ears interact to understand and interact with realistic displays.

R&D Areas

SYSTEM

- **Calibration for accurate engineering and design work**

- **Human-in-the-loop real-time performance**

- **Human perceptual studies to determine limits, requirements**

Figure 25.