Going Beyond Reality:

to Create Extreme Multi-Modal Mixed Reality for Entertainment

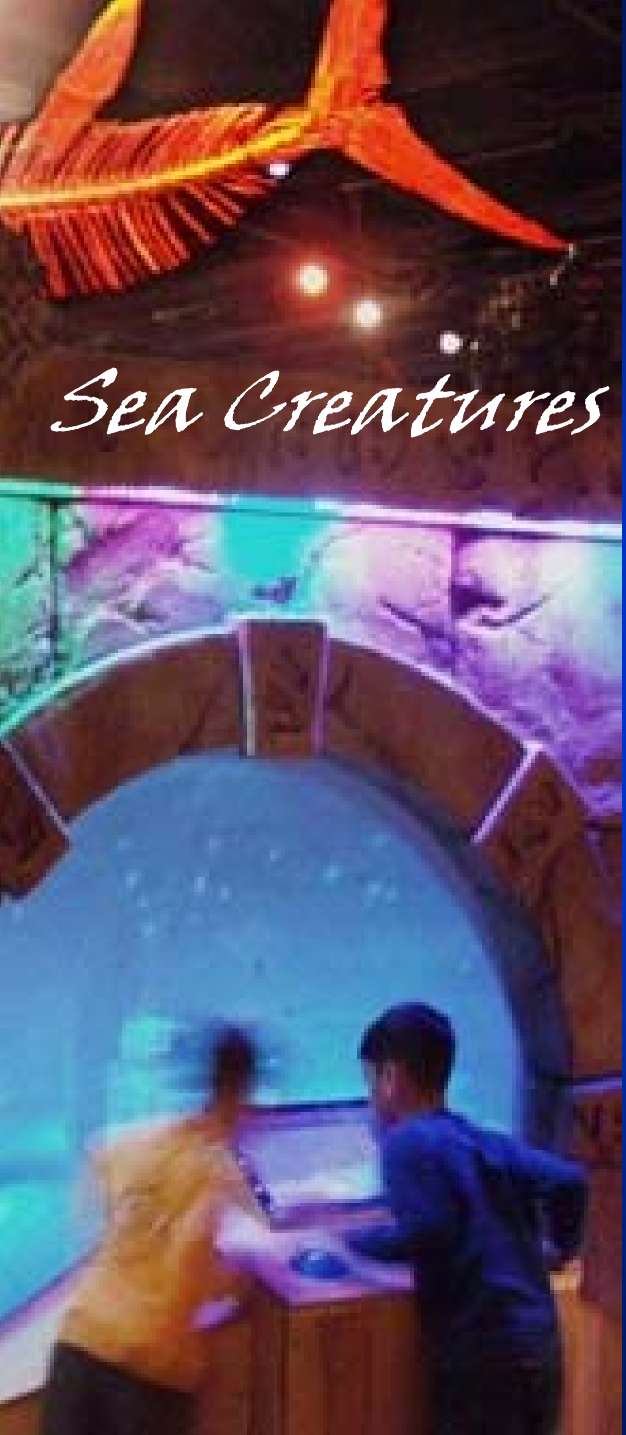
Christopher Stapleton, **MCL** Director
Dr. Charles Hughes, MCL Chief Scientist

Scott Malo, Digital Production Supervisor

Media Convergence Laboratory
University of Central Florida

A Partnership of

Institute for Simulation and Training
School of Computer Science
College of Arts and Science



We wish to thank our partners

U.S.ARMY

Canon

brand experience lab

EIDS
EMBEDDED TRAINING FOR DISMOUNTED SOLDIER

RDECOM
Technology to the Warfighter Quicker

ORLANDO SCIENCE CENTER

NAVAL RESEARCH LABORATORY
WASHINGTON, DC

NICKELODEON

Metro Goldwyn Mayer
TRADE MARK

MCL
media convergence laboratory
Vision Projects Partners Initiatives

Experiential Movie Trailer

Going Beyond Reality

Session I: Achieving Next Generation Extreme MR

- Objective: Extreme MR
- Mixed Reality Continuum for Entertainment
- Evolution of Mixed Reality through out history
- Art of Extreme MR
- Case Studies: Cross Industry Transfer Projects
  - MR MOUT
  - Sea Creatures
  - Experiential Movie Trailer

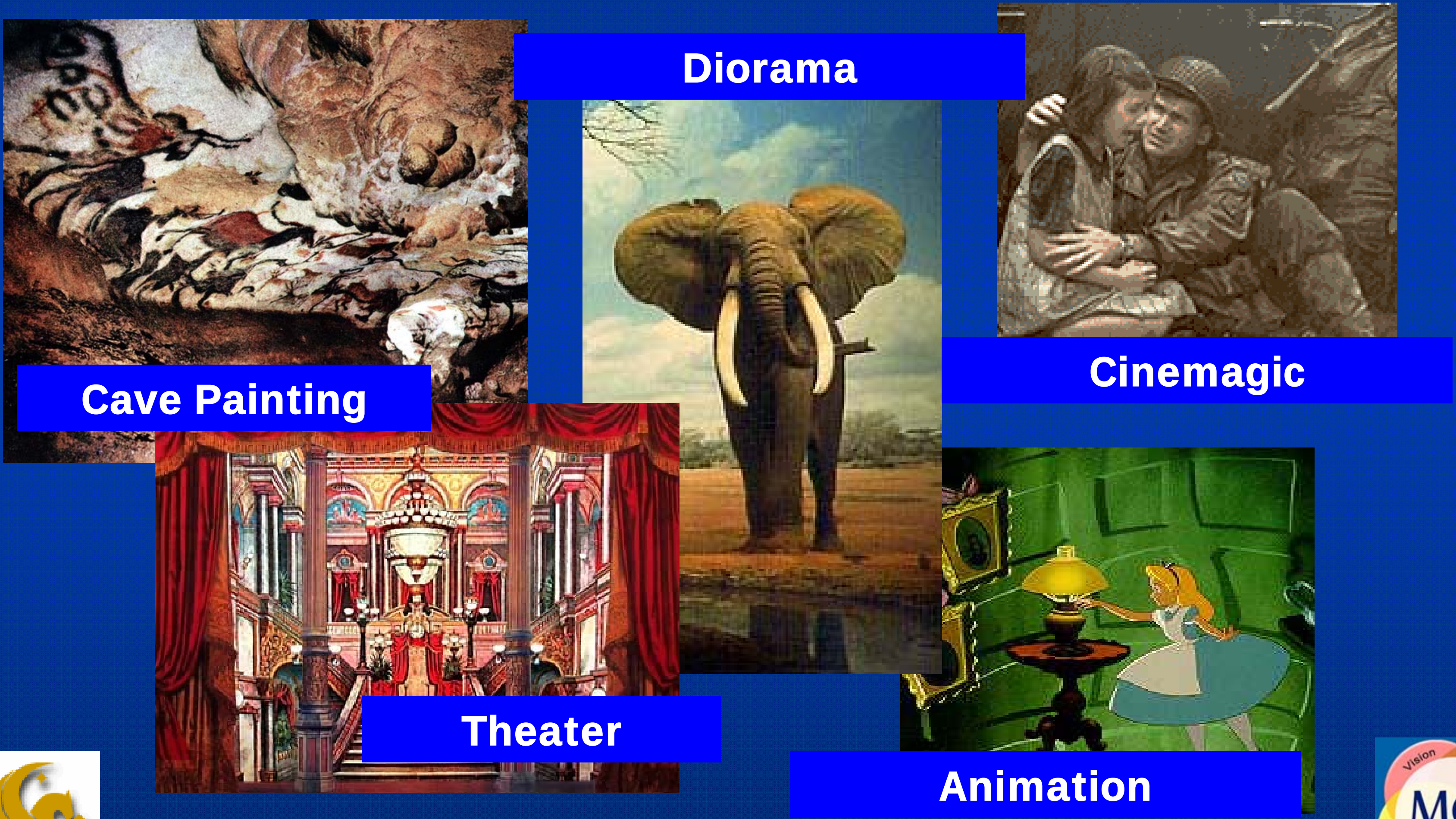
Experiential Marketing

Going Beyond Reality

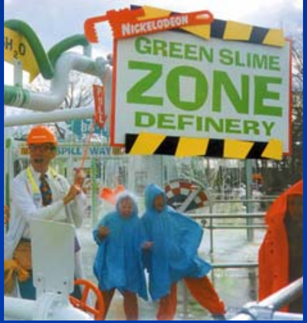
Session II: Achieving Next Generation Extreme MR

- Engine of Extreme MR
- Science & Technology of Extreme MR
- From invention to innovation
- Future Research Directions

The Art and Science of Experiential Entertainment



MR Research:
Convergence of Media



As Intuitive
as Play

As immersive as Military
Simulation

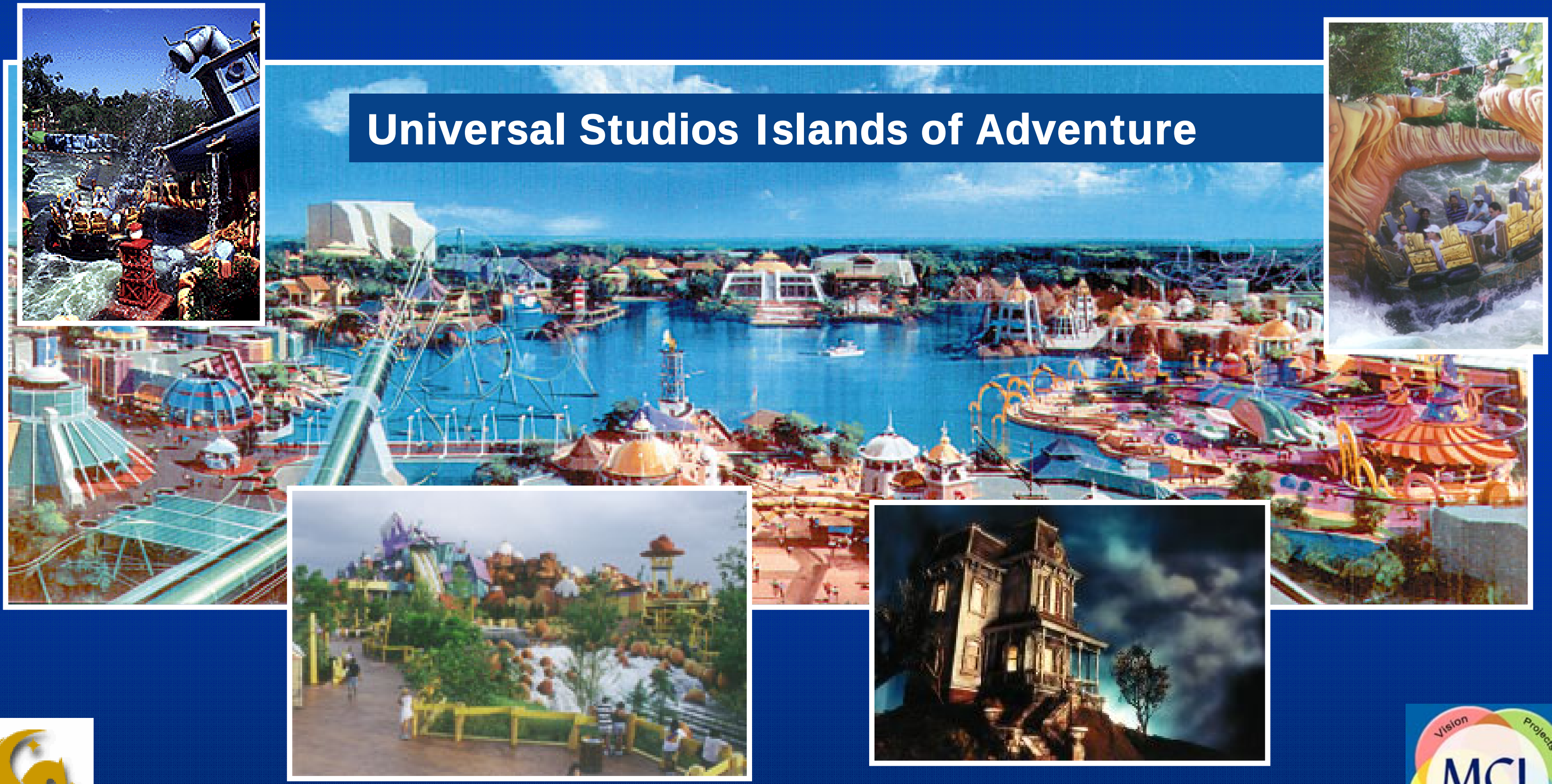
As visceral as a
Theme park

As Meaningful
as education

As interactive as
video games

As compelling as
motion pictures

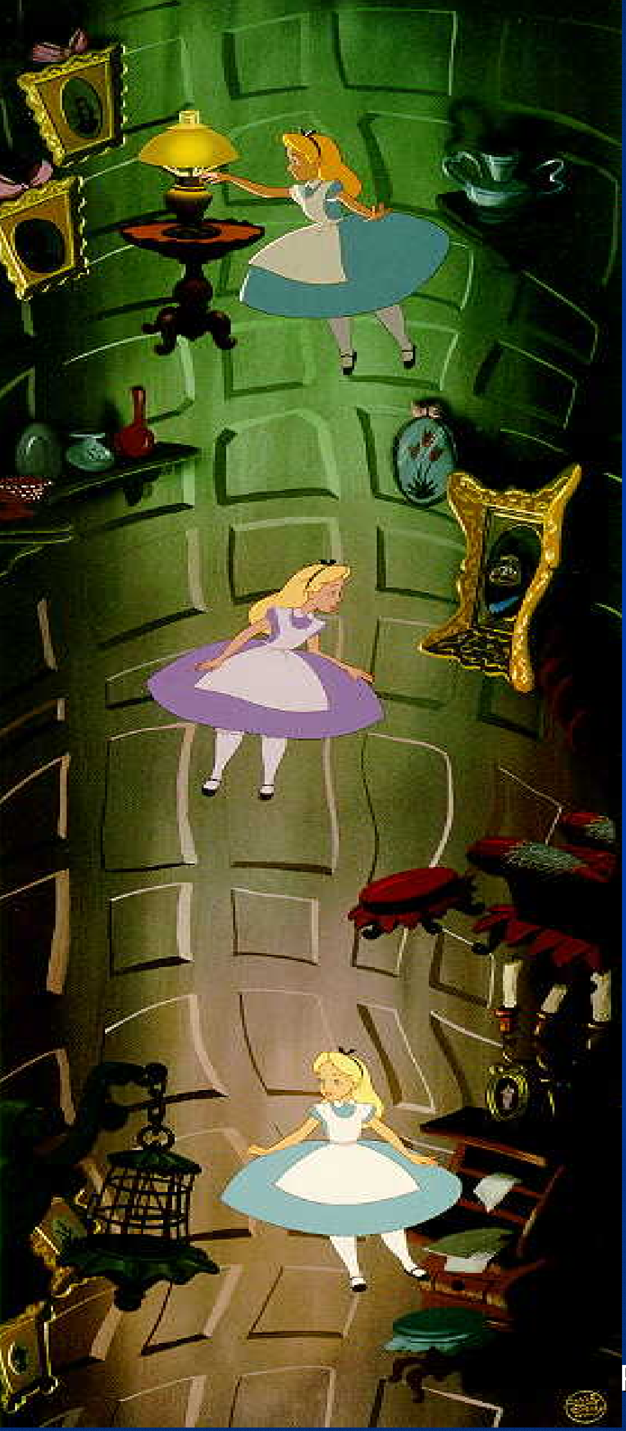
Painting with the Audience's Imagination...



Universal Studios Islands of Adventure

Universal Islands of Adventure

1. **UIOA: video of theme park screams**



Inventing the Technology of the Imagination

The Power of Entertainment

3D Video Games

Pong: Video Games

MTV:Music Video

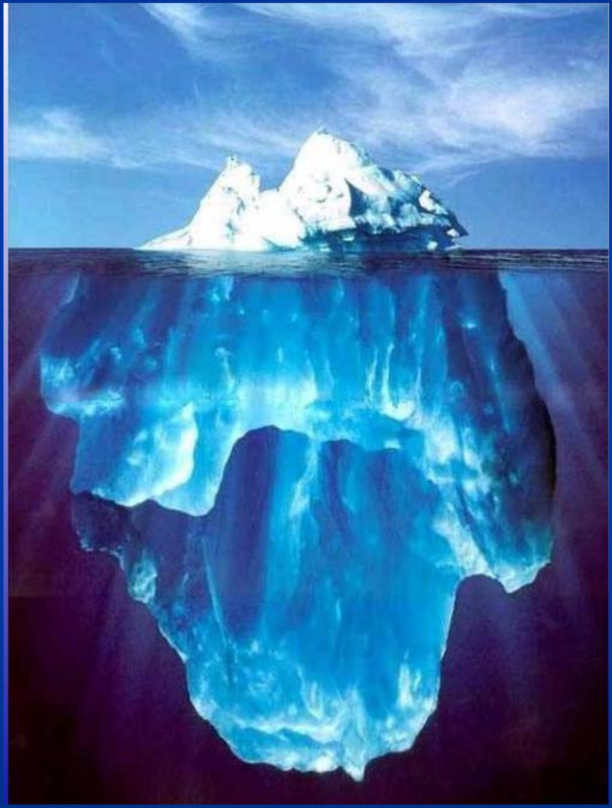
Quake: Virtual Reality

Orson Wells: Radio

D.W. Griffith: Film

Sid Caesar: Television

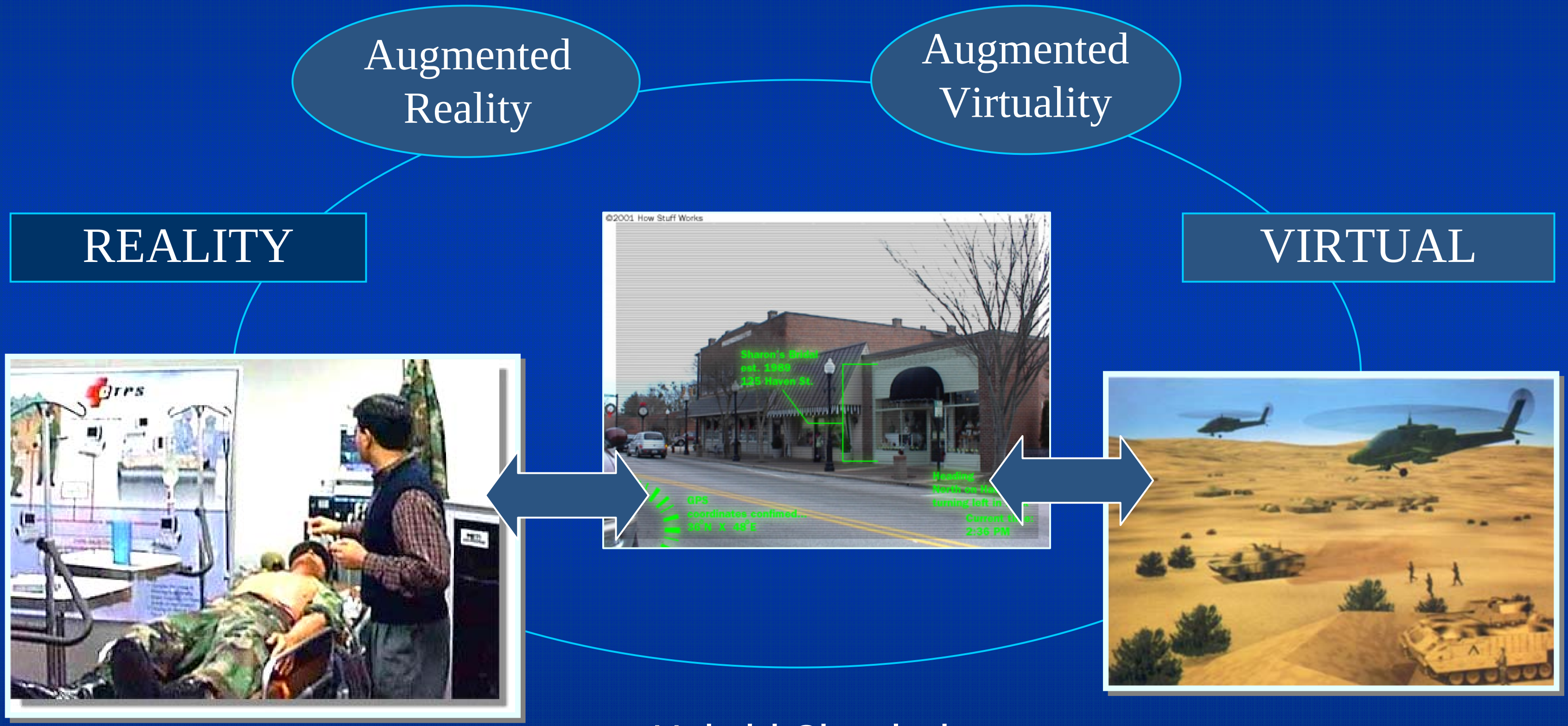
The Power of Imagination



"What is in the (text) book is only one fourth of the story. It is like an iceberg where three-quarters of the story you don't see, it is beyond the page."

Earnest Hemingway

Milgram’s Reality-Virtuality Continuum



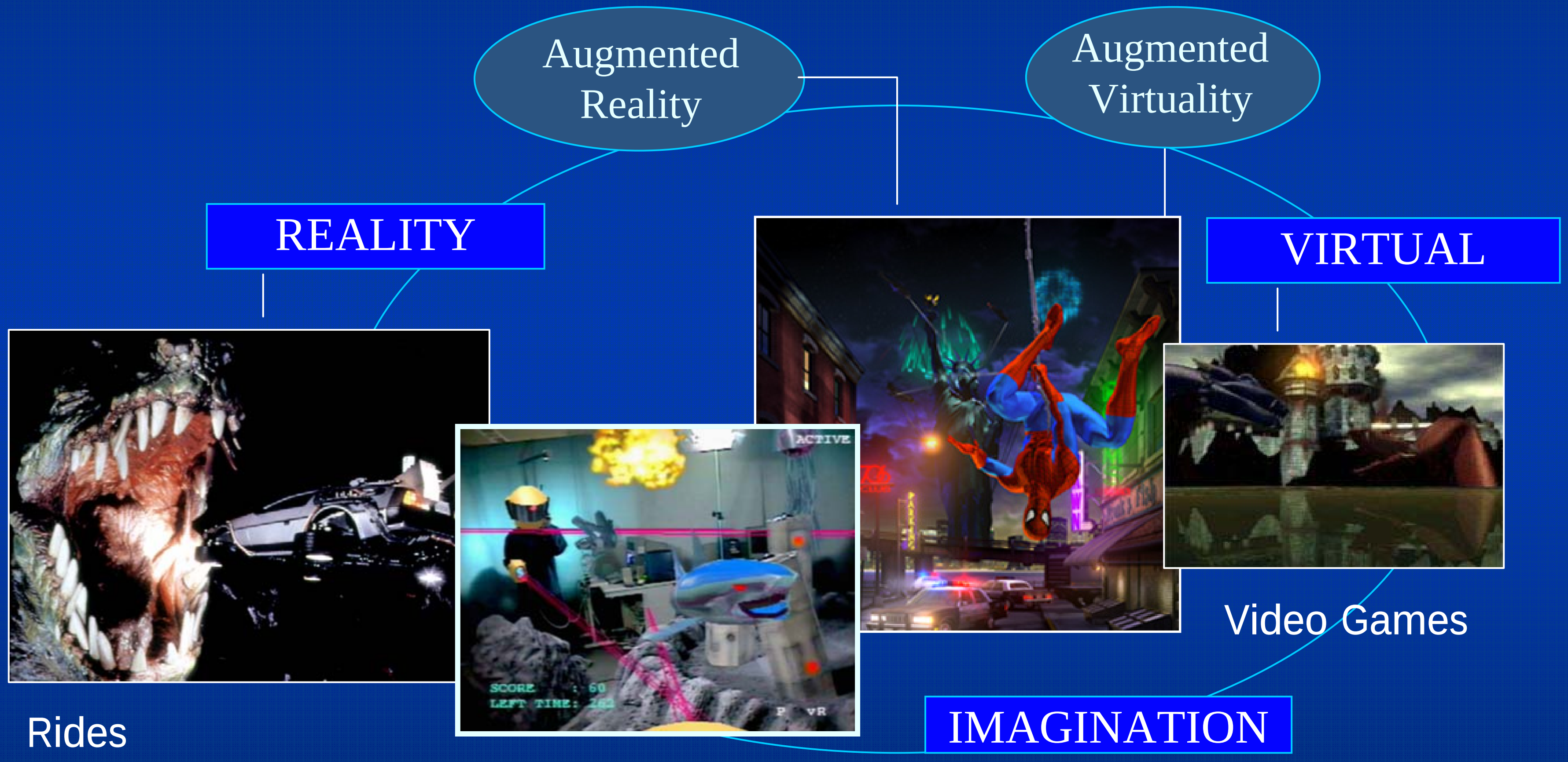
Hybrid Simulation

Live Simulation

Virtual Simulation

Redefining Mixed Reality

“Magic is behind the eyeballs”



Augmented Reality

Augmented Virtuality

REALITY

VIRTUAL

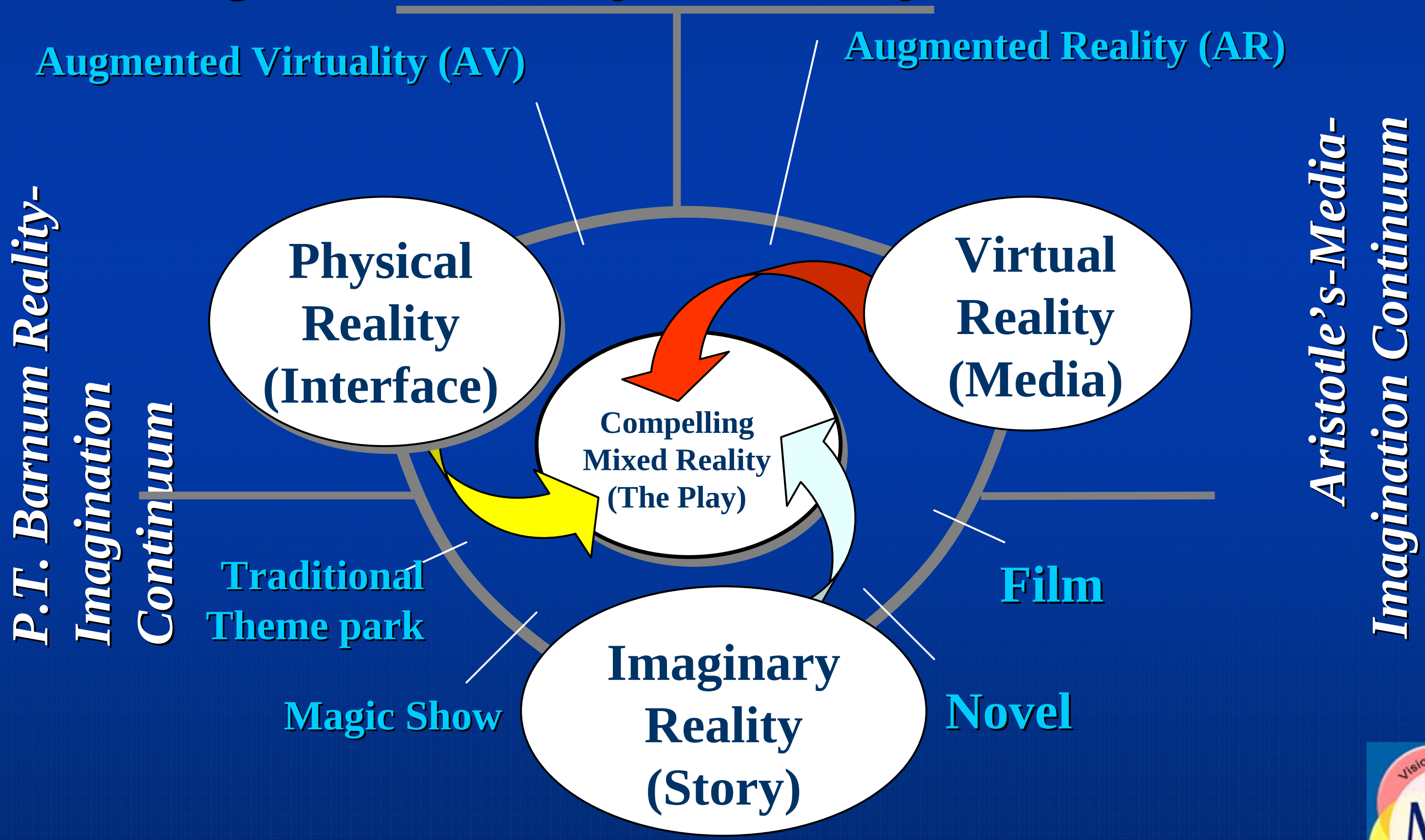
IMAGINATION

Rides

Dark Rides

Video Games

Mixed Fantasy Continuum (adding imagination)



Milgram's Reality-Virtuality Continuum

Augmented Virtuality (AV)

Augmented Reality (AR)

Physical Reality (Interface)

Virtual Reality (Media)

Compelling Mixed Reality (The Play)

Imaginary Reality (Story)

P.T. Barnum Reality-Imagination Continuum

Traditional Theme park

Magic Show

Aristotle's-Media-Imagination Continuum

Film

Novel

Making Memories for a Lifetime

Amusing

Training

Learning

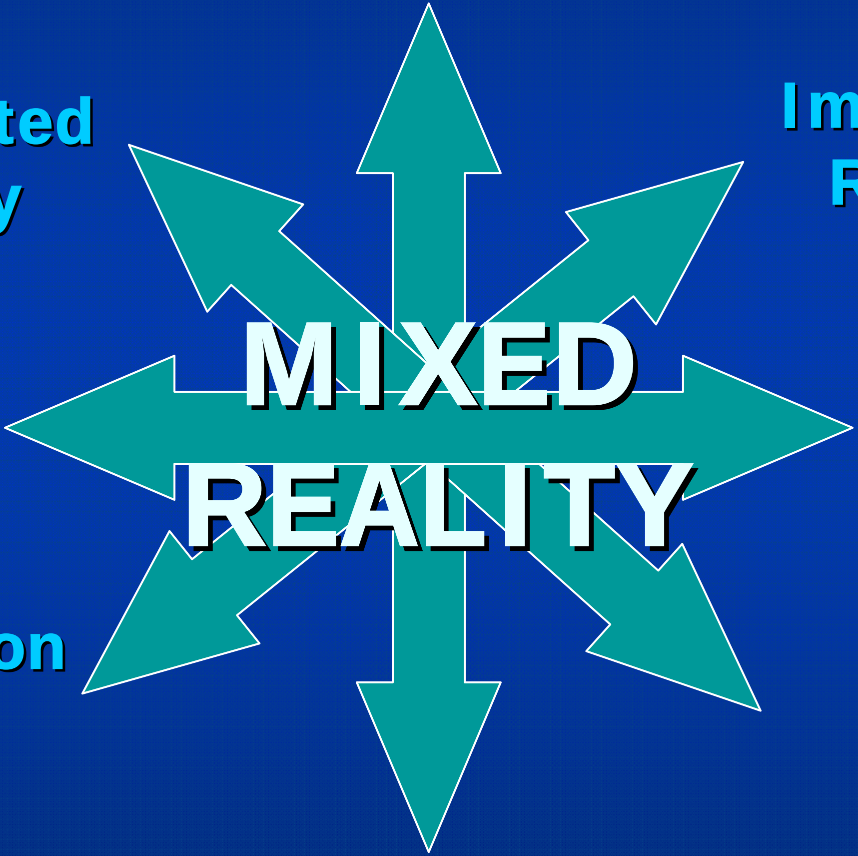
Power of Mixed Reality

Melting the Boundaries

Real-time, immersive, 3D, visceral multi-modal

Art and Science of MR

Melting the Boundaries



MIXED REALITY

Augmented Reality

Imaginary Reality

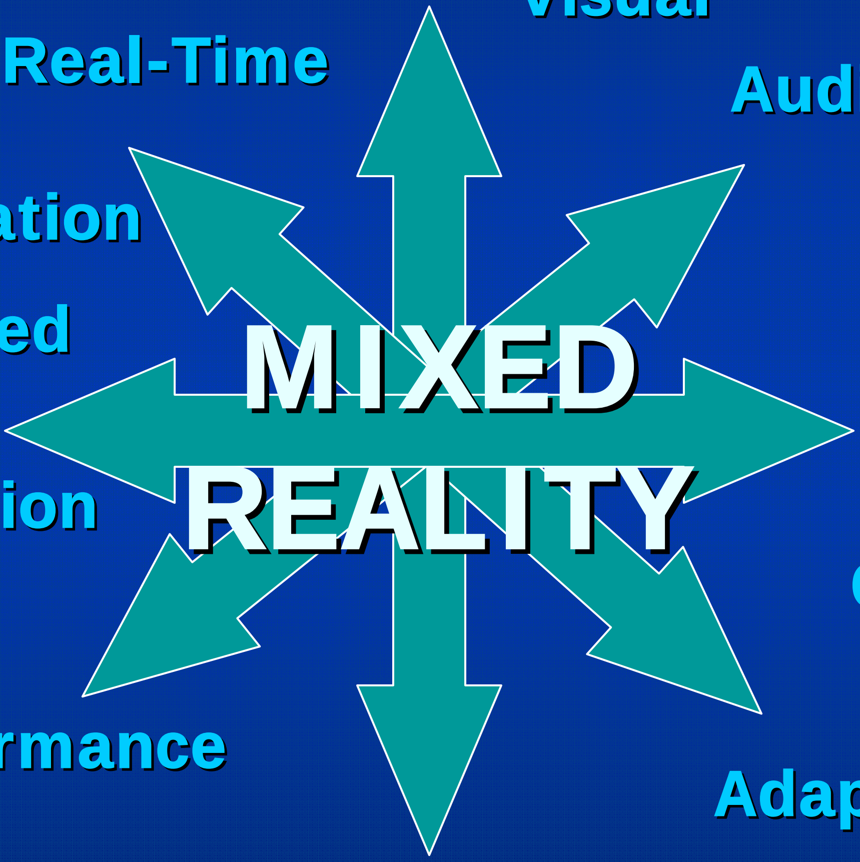
Live Simulation

Virtual Reality

Augmented Virtuality

Art and Science of MR

Filling in the Gaps



Visual

Real-Time

Audio

Integration

Haptic

Networked

MIXED REALITY

Synthetic

Perception

Captured

Performance

Adaptive

Non-Linear

Displayed

Case Study: TRAINING

Richly Layered Experiences

- All Dimensions
- All Modalities
- All Domains
- Anytime
- Any Where

Combat Reality

Blood, sweat, tears, life and death

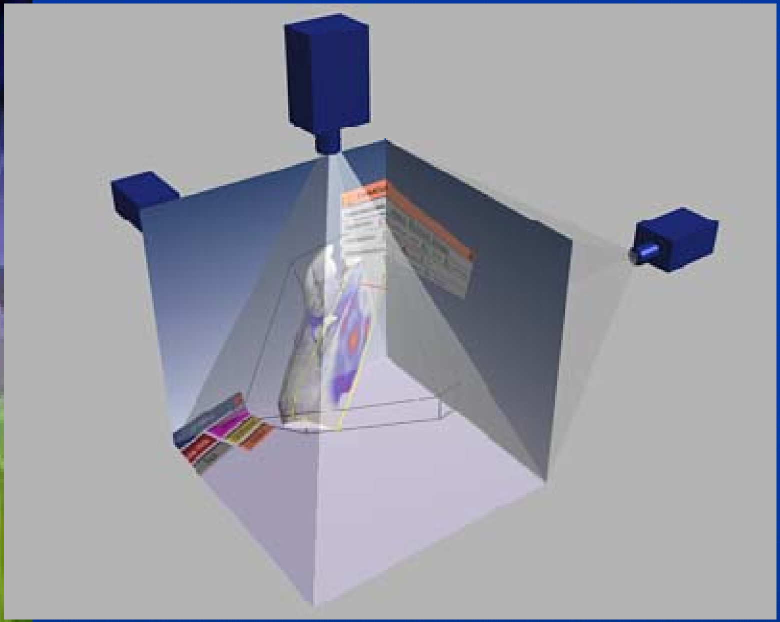
Live Simulation

Physical, immersive, multi-modal

Virtual Reality

Dynamic, flexible, on-demand

Immersion Beyond the projection screen



CAVE

Cinemagic

Imaginary Reality

Compelling, emotional, memorable

Real Training vs. Entertainment

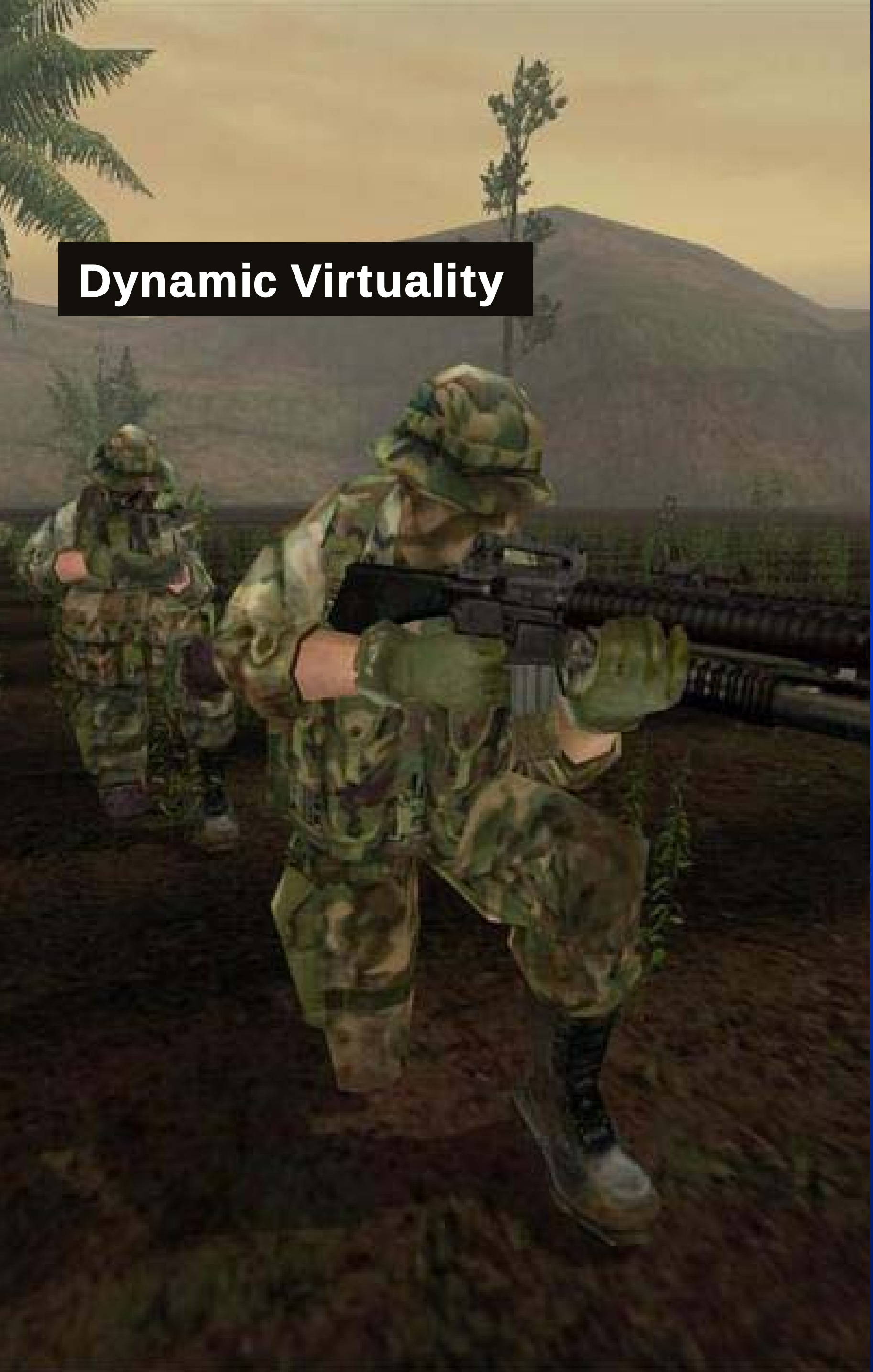
Real MOUT Training at MOUT McKenna

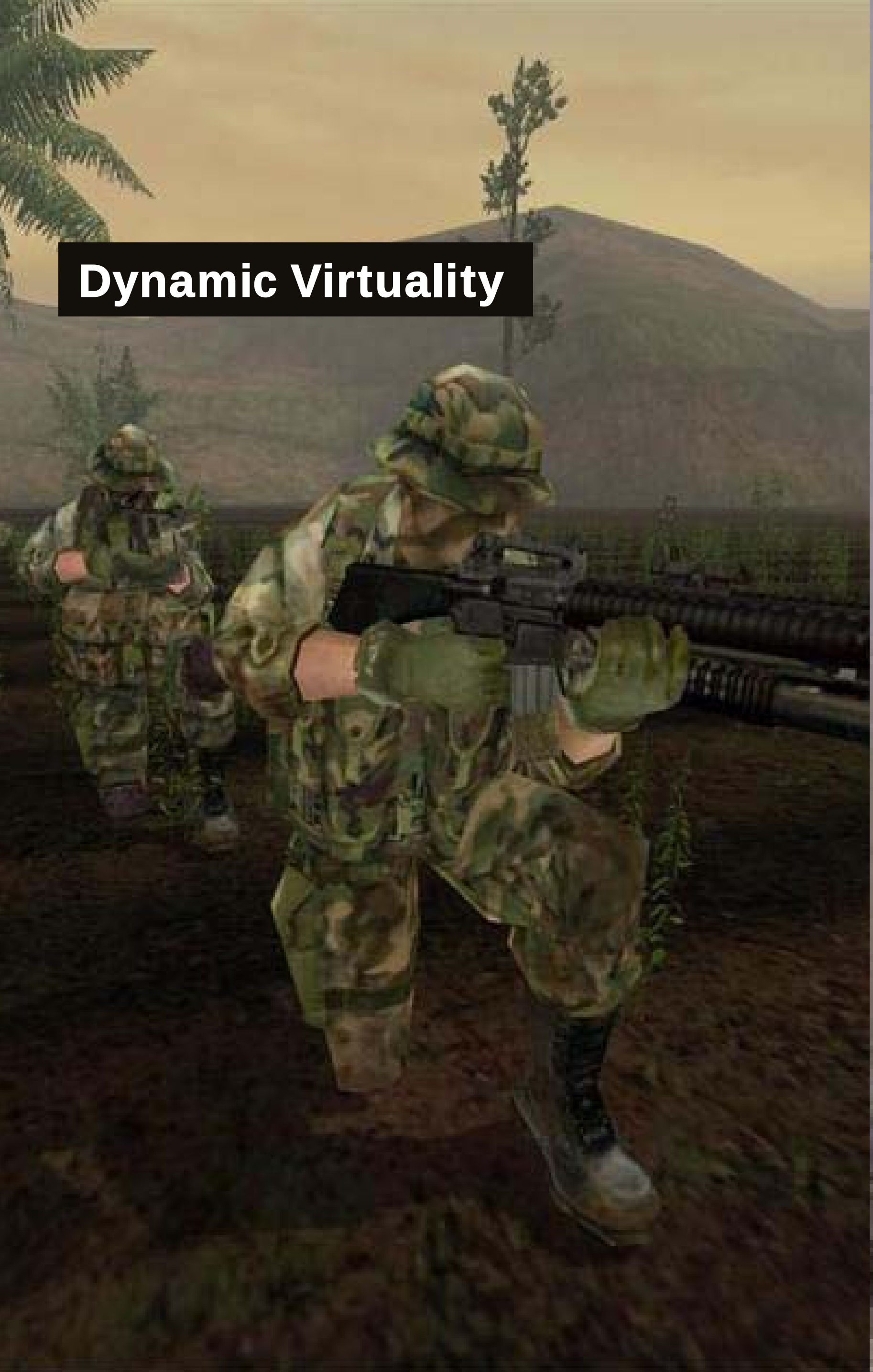
Clip from the Columbia Pictures Film - Black Hawk Down

Are these embedded?

If not, cut them.

Dynamic Virtuality



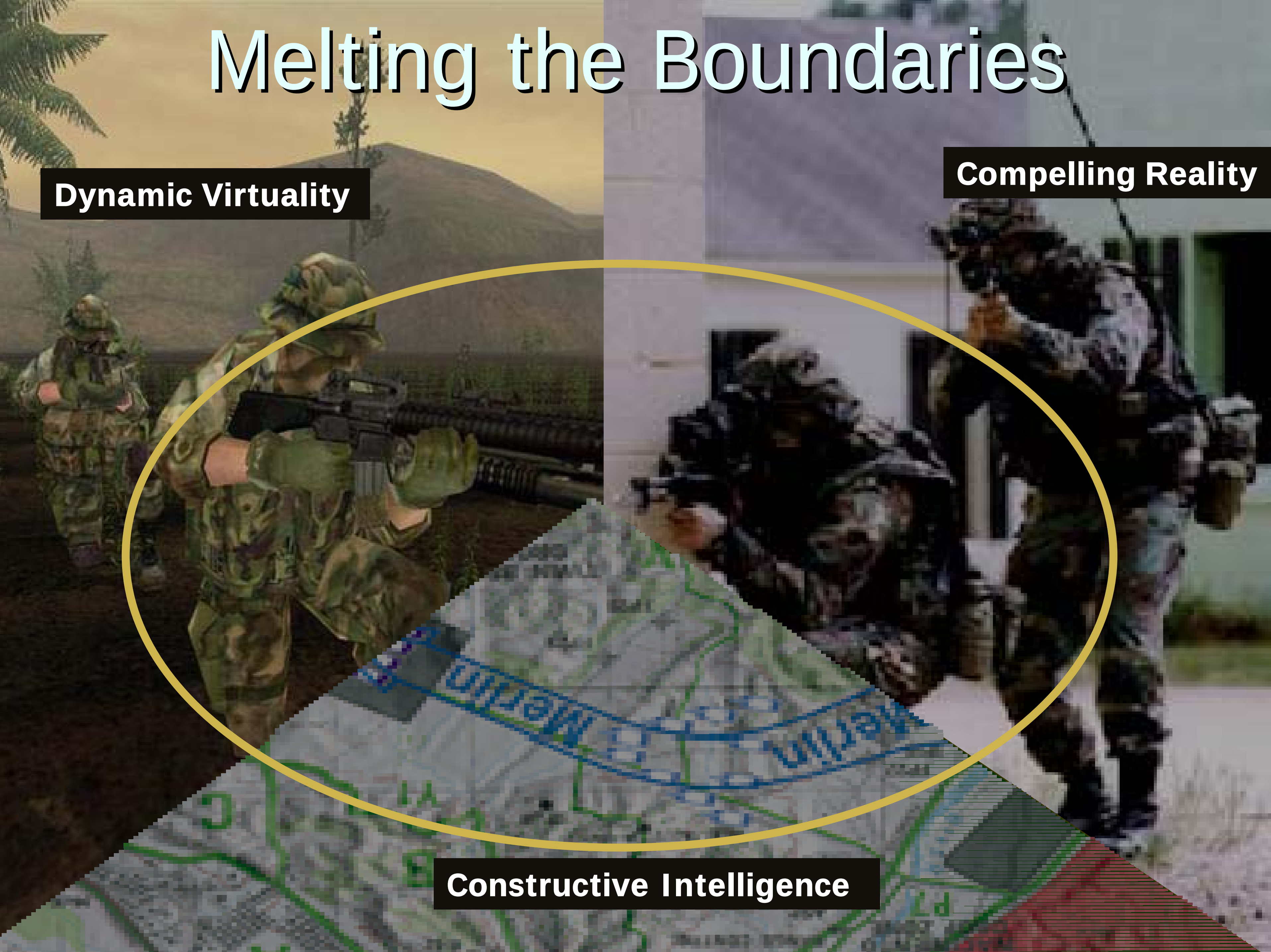


Dynamic Virtuality

Compelling Reality


Dynamic Virtuality
Compelling Reality
Constructive Intelligence

Melting the Boundaries

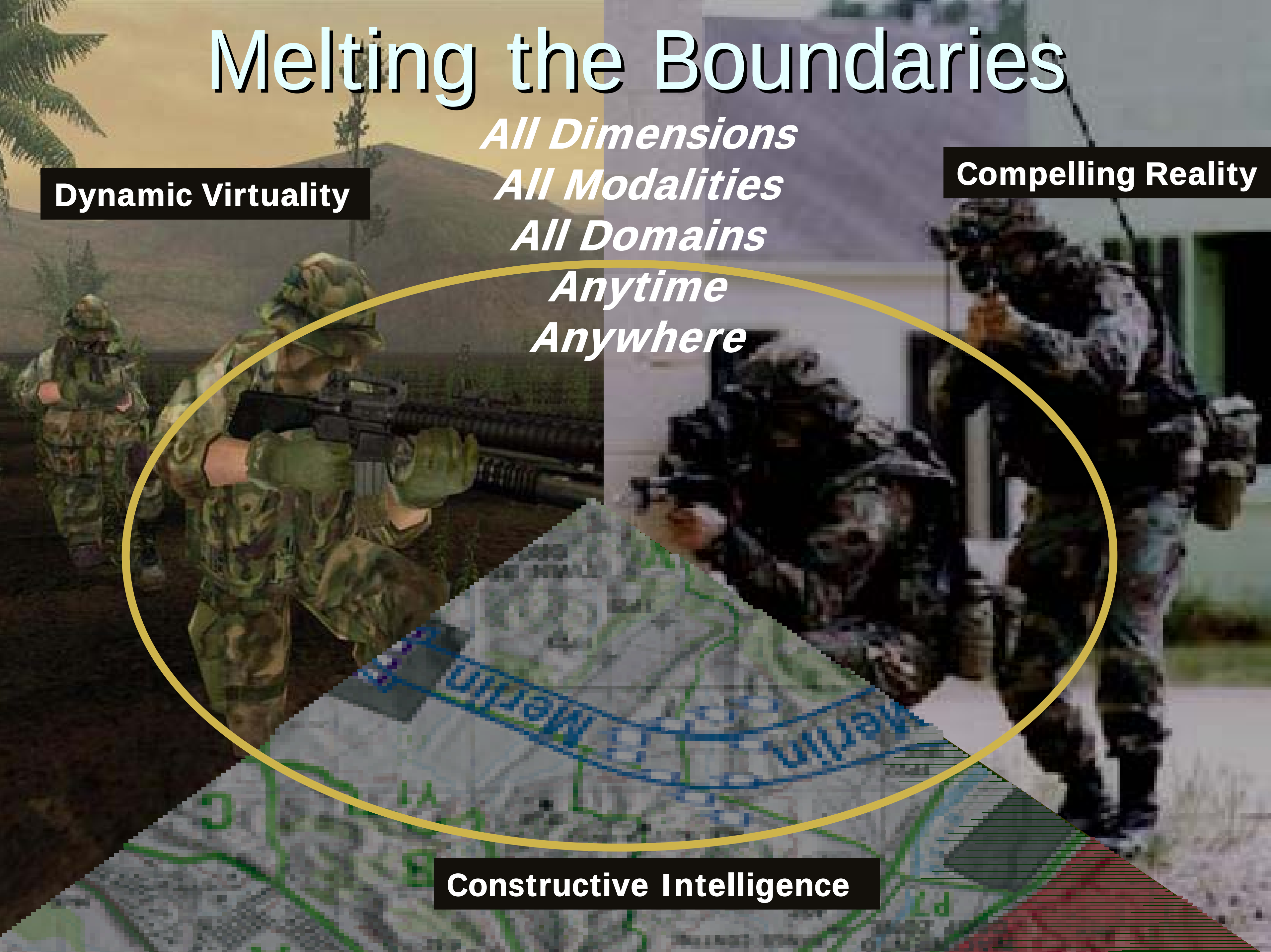


Dynamic Virtuality

Compelling Reality

Constructive Intelligence

Melting the Boundaries



All Dimensions
All Modalities
All Domains
Anytime
Anywhere

Dynamic Virtuality

Compelling Reality

Constructive Intelligence

Mixed Reality in Military Operations in Urban Terrain

Dynamic Virtuality

Compelling Reality

MR MOUT

Constructive Intelligence

U.S. ARMY

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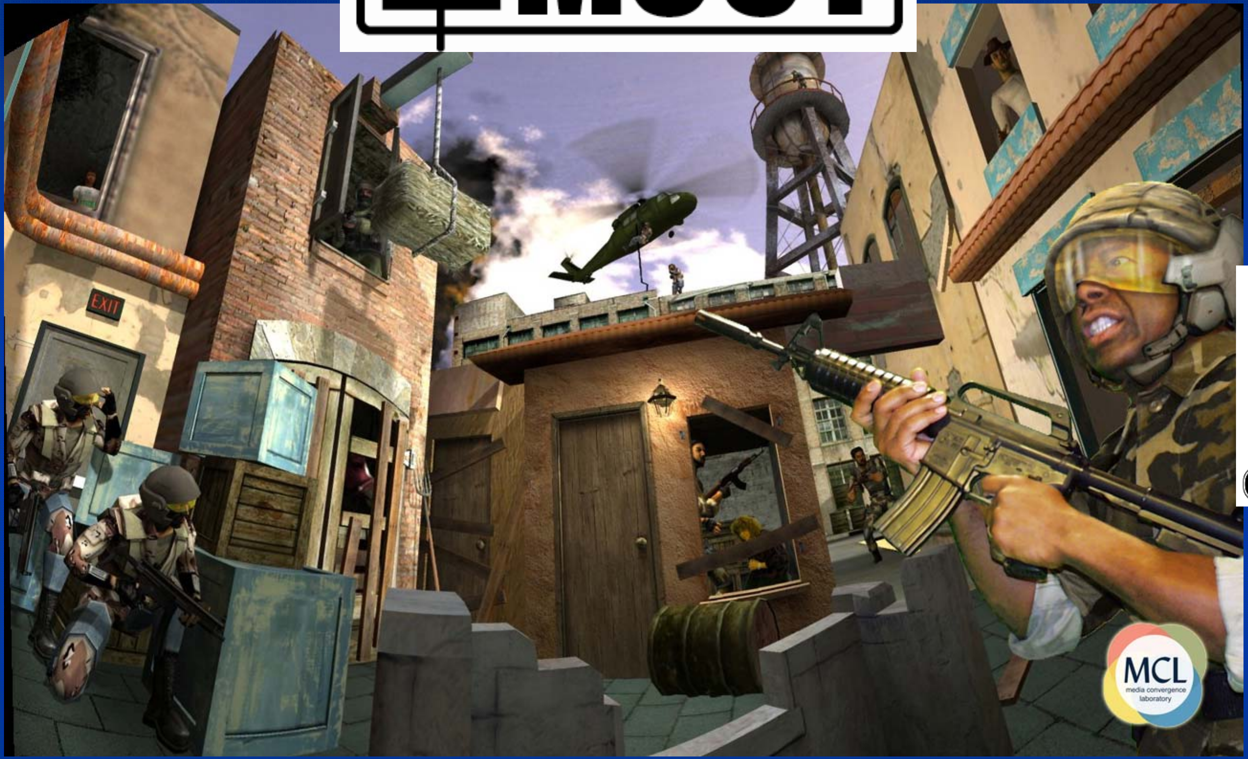
EMBEDDED TRAINING FOR DISMOUNTED SOLDIER mrMOUT

U.S.ARMY

RDECOM



ETDS

EMBEDDED TRAINING FOR DISMOUNTED SOLDIER

Mixed Reality in Military Operations in Urban Terrain

University of Central Florida www.mcl.ucf.edu Media Convergence Laboratory

MCL media convergence laboratory Vision Projects Partners Initiatives

Power of Mixed Reality

What is Mixed Reality?

2. MR MOUT 2.0 Video

MR MOUT 2.0 Scenario – Mixed Reality vs. Reality Views

Mixed Reality is the blending of the real world and the virtual world and the combination is seamless

MRMOUT 4.0

Situational Awareness to Command and Control

The Art of Mixing Reality

Artist Rendition of the MR MOUT “visor” HUD

Future: MR Backlot and Previsualization for filmmaking

Case Study: Entertainment

Experiential Movie Trailer

- Looks like a film
- Plays like a game
- Immersed like a theme park
- Embedded in Retailtainment

Eyes on the Prize

A. Previsualization

Benchmarks

B. Borrow from the best

Creating the Story Assets

C. Characters, Environments, Events

MR Mini MOUT

D. Venue Reality (Scenography)

Designing the SFX:

E. Special Effects (SFX)
(Punctuation)

Designing the Lighting

F. Illumination, Shading, Shadows Palettes (Blending the seams)

Layers of Illusion

G. Real-time Compositing

Building Each Layer

A. Video & 3D Targets

B. Physical Scenery

C. Virtual Props

D. ChromaKey Occlusion

E. Virtual Scenery

F. Virtual FX

G. Virtual Vehicles

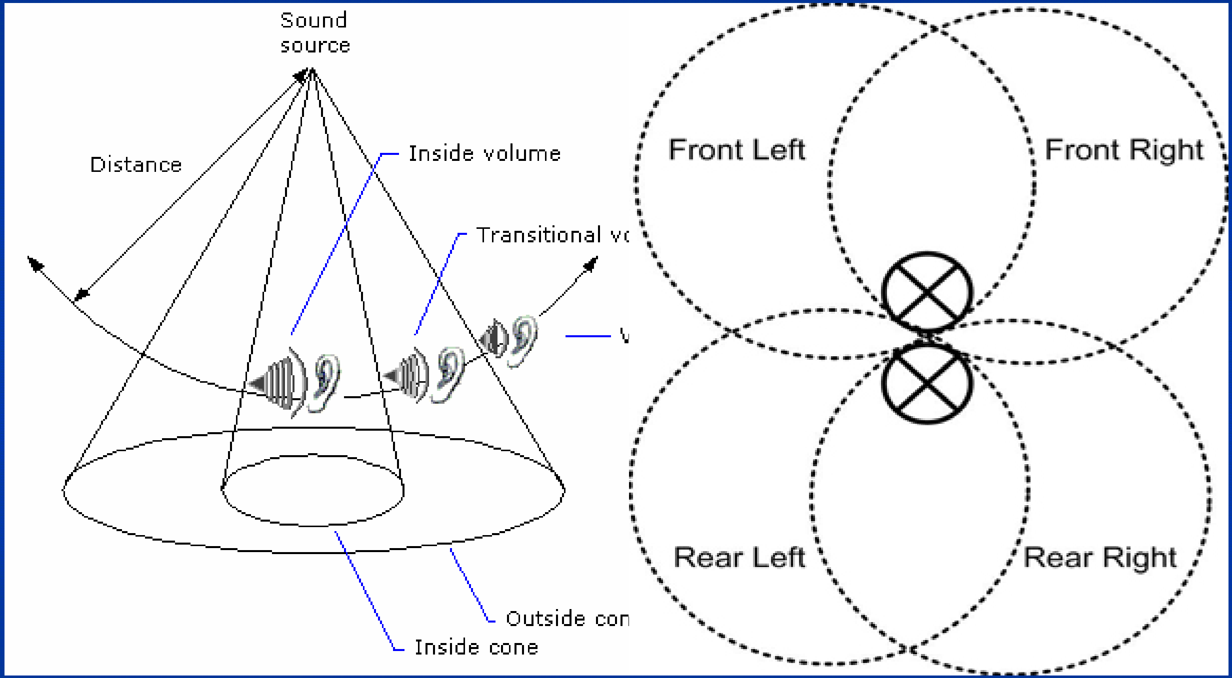
H. Haptic Device

J. 3D MR Audio

I. Physical SFX
K. Virtual Interface

L. Story

Hybrid Audio Engine

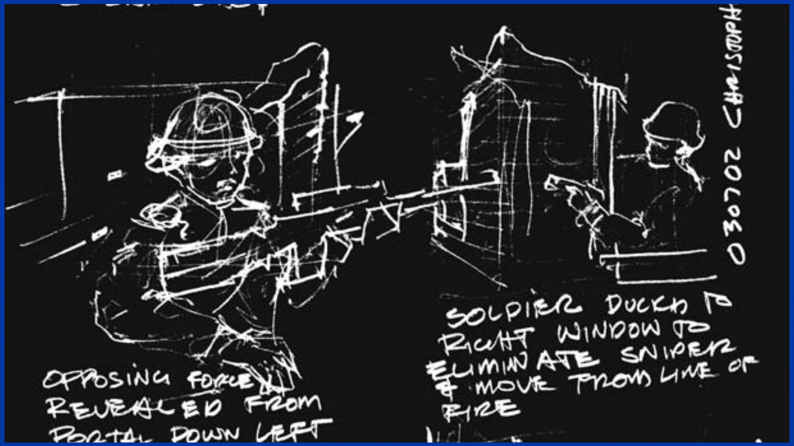


3D display

3D Capture

H. Sensory Sychronization

Animatic



Story boards

Captured Mock-up

I. Timing & Juxaposition

Virtual Test

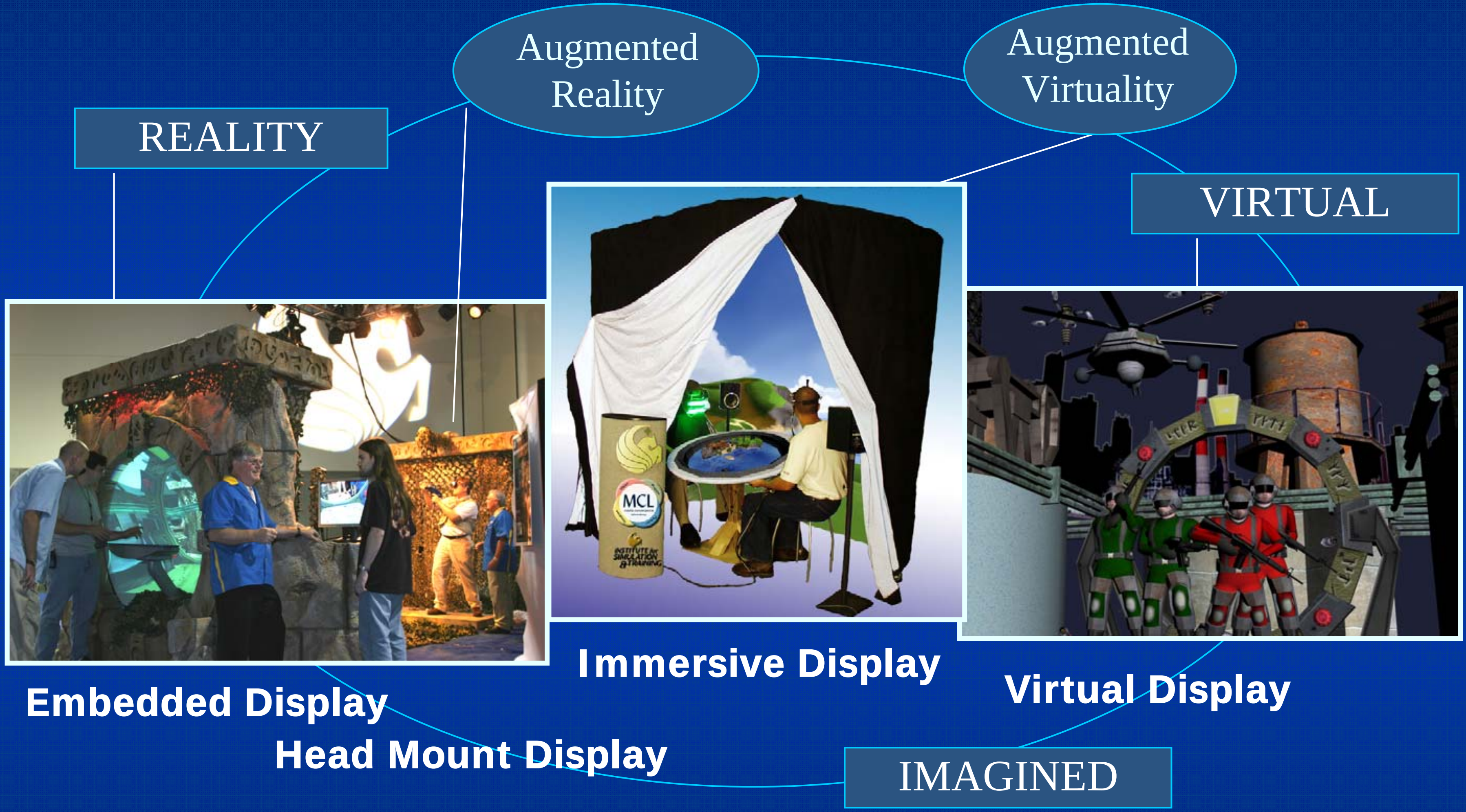
J. Interactivity and game play

Augmentation

3. Time Portal Animatic (on-line) start in middle at,

‘this is a composite video of animatic…etc.”

Points of View



REALITY

Augmented Reality

Augmented Virtuality

VIRTUAL

Embedded Display

Immersive Display

Virtual Display

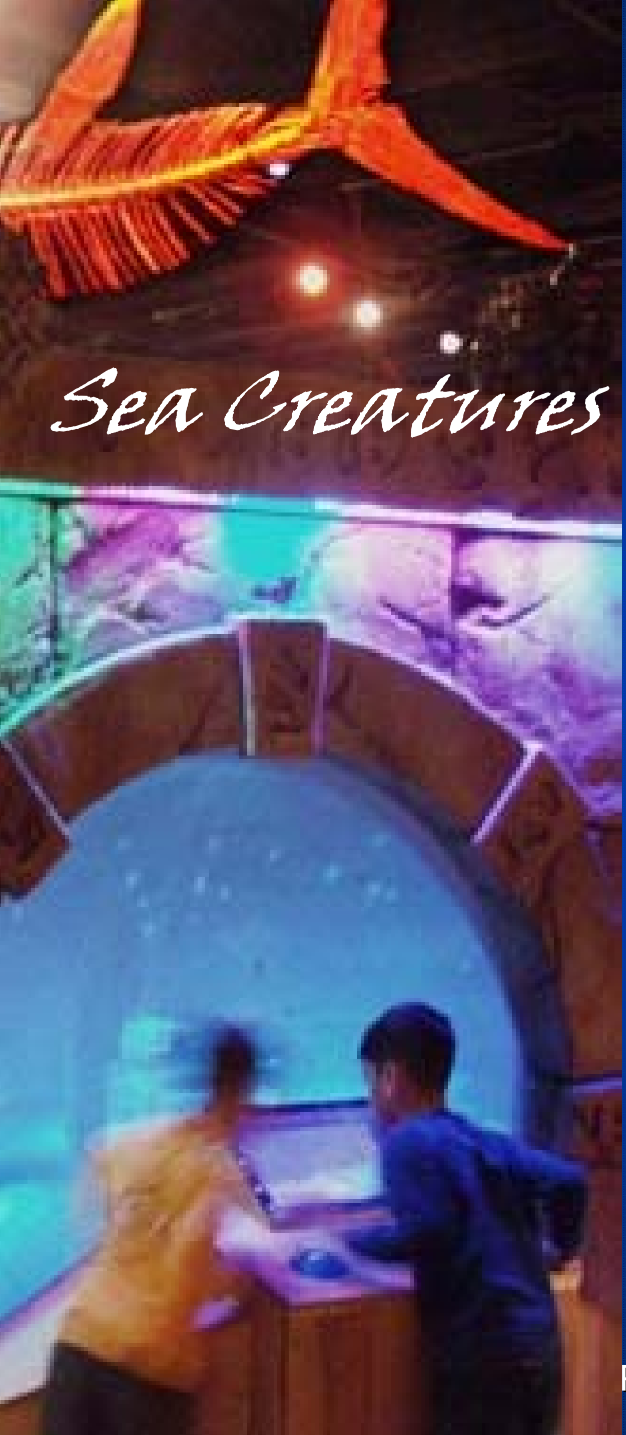
Head Mount Display

IMAGINED

L. Multi-player (Diverse Displays)

Case Study: Entertainment

Extending and Enhancing Educational Exhibits



Experiential Learning

- **Compelling Experiences**

  There is greatly increased competition for both leisure time and leisure dollars.

- **Repeatable Experiences**

  Repeat visitors demand changing experiences to keep them coming back.

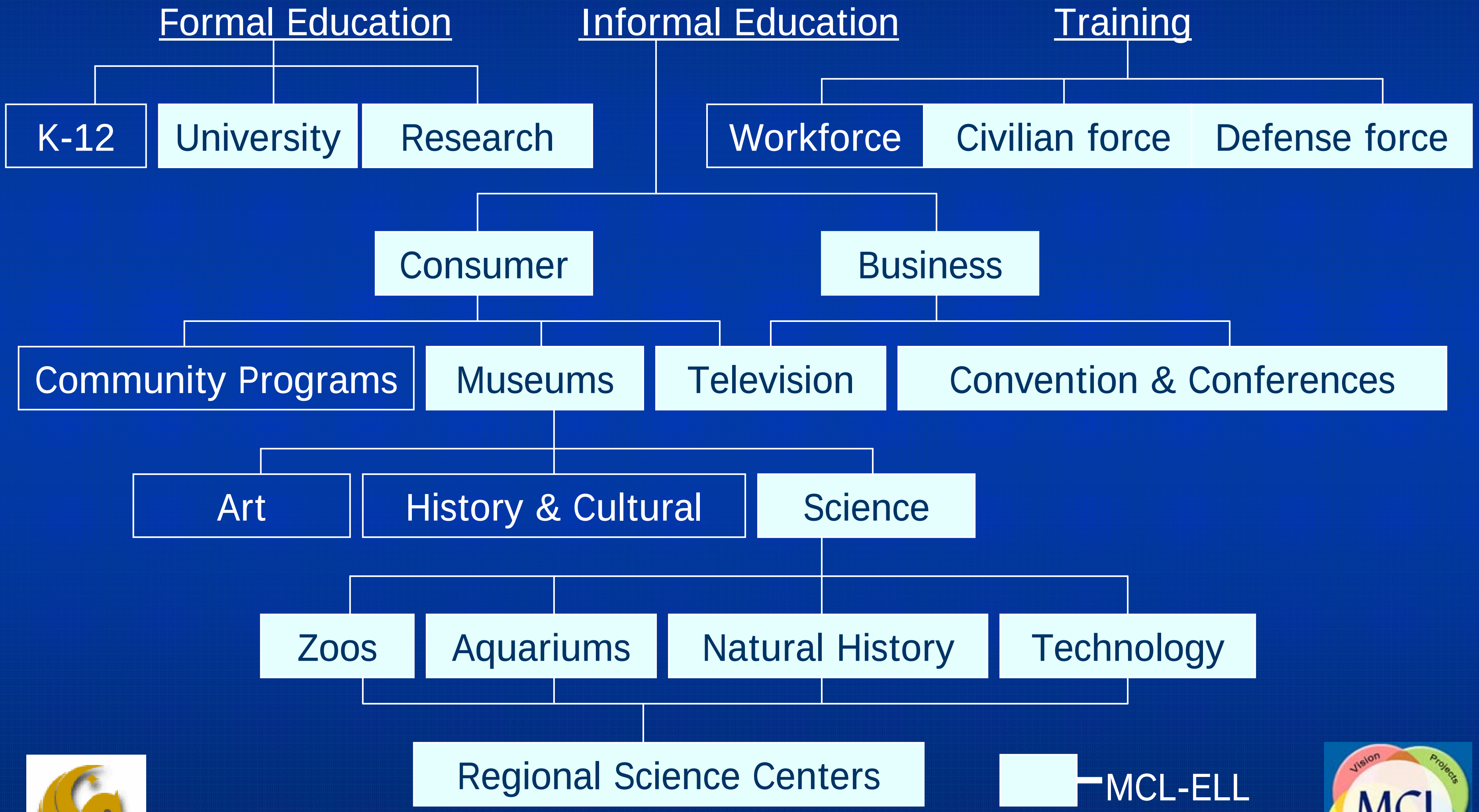
- **Throughput of Content**

  New experiences are needed for growth in membership revenue, marketing opportunities and sponsorship dollars.

- **Cross-generational Experiences**

  Museums are visited by families and others representing multiple generations, different learning styles, and varying levels of existing knowledge.

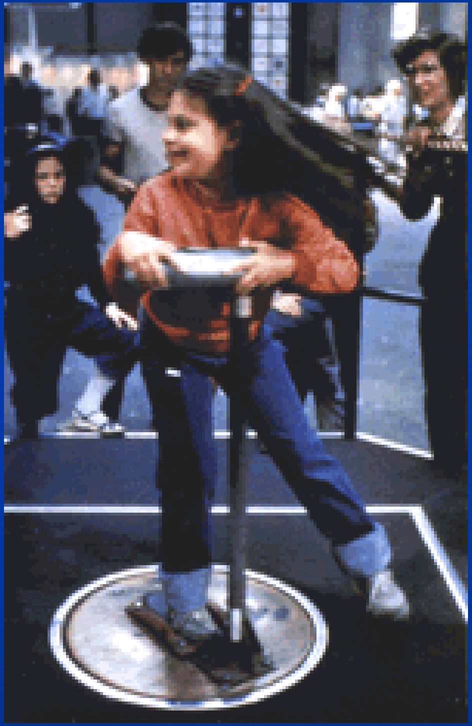
Education



- Formal Education
  - K-12
  - University
  - Research
- Informal Education
  - Consumer
    - Community Programs
    - Museums
      - Art
      - History & Cultural
      - Science
        - Zoos
        - Aquariums
        - Natural History
        - Technology
          - Regional Science Centers
    - Television
  - Business
    - Television
    - Convention & Conferences
- Training
  - Workforce
  - Civilian force
  - Defense force

⬜ MCL-ELL

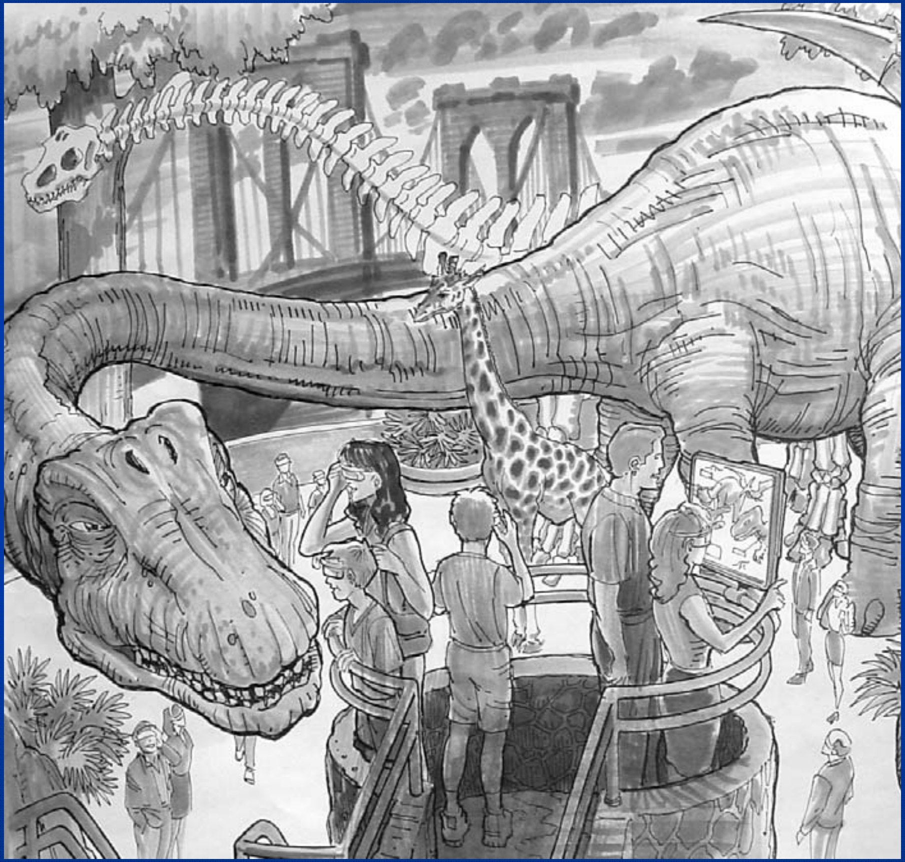
Museums



- The 16,000 American museums average approximately 865 million visits per year, or 2.3 million visits per day.
- Museums are a $16 billion dollar/year industry in America.

-1997 Census and AAM Statistics

Experiential Learning Test



A. **Does the exhibit know that I am here?**

B. **Do I Impact the Exhibit in any way?**

C. **Does the Exhibit Impact me in any way?**

Permanent Display

Limited learning, Static, Never Changing, Mostly reading, No Direct bridge to school or home.

Dino Digs Transformation

Repeat experiences (visits), Changing content, Social, Physical, Interactive, Responsive, Extended depth.

MR Sea Creature @ OSC

IMPRESS

INFORM

IMPACT

MR Sea Creature @ OSC

MR ROVER

Virtual Scientific Tools

Creatures, Environment come alive

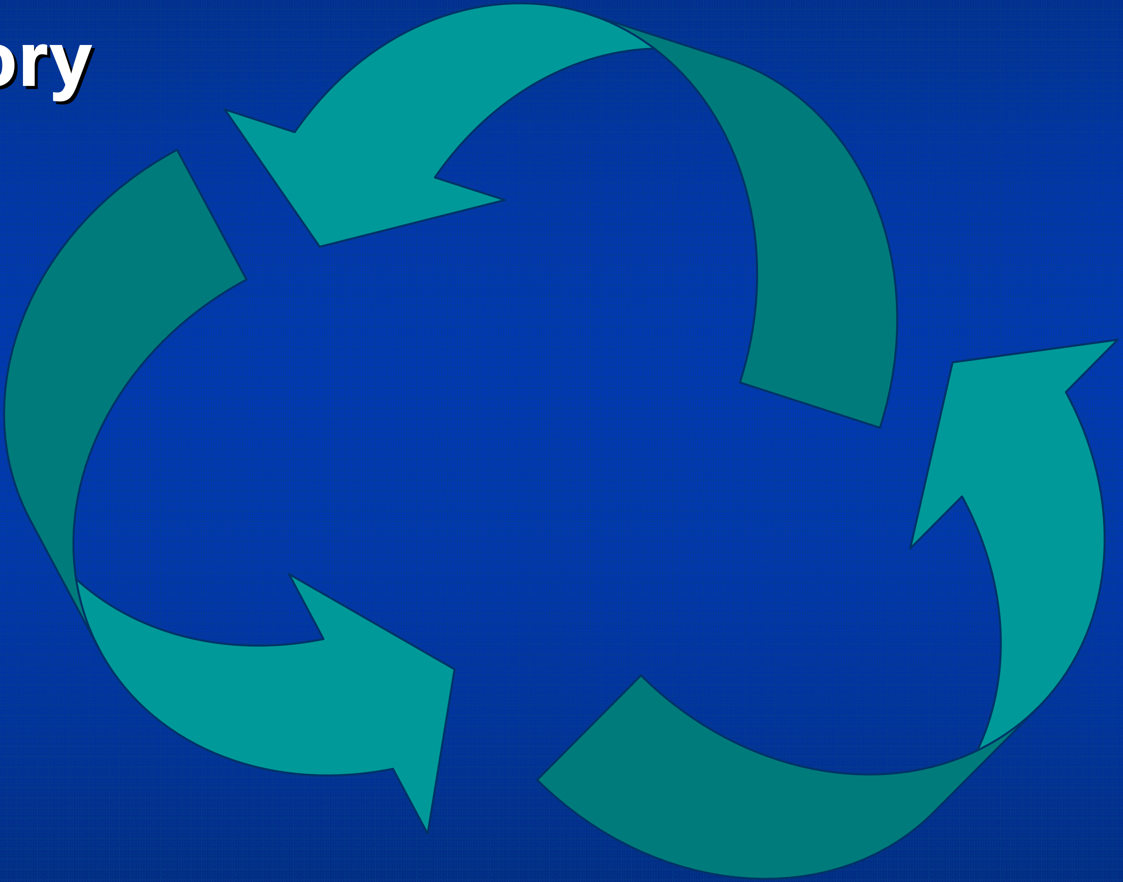
Reality triggers Virtuality, Virtuality triggers reality

Sea Creatures:
Dino Digs Transformation

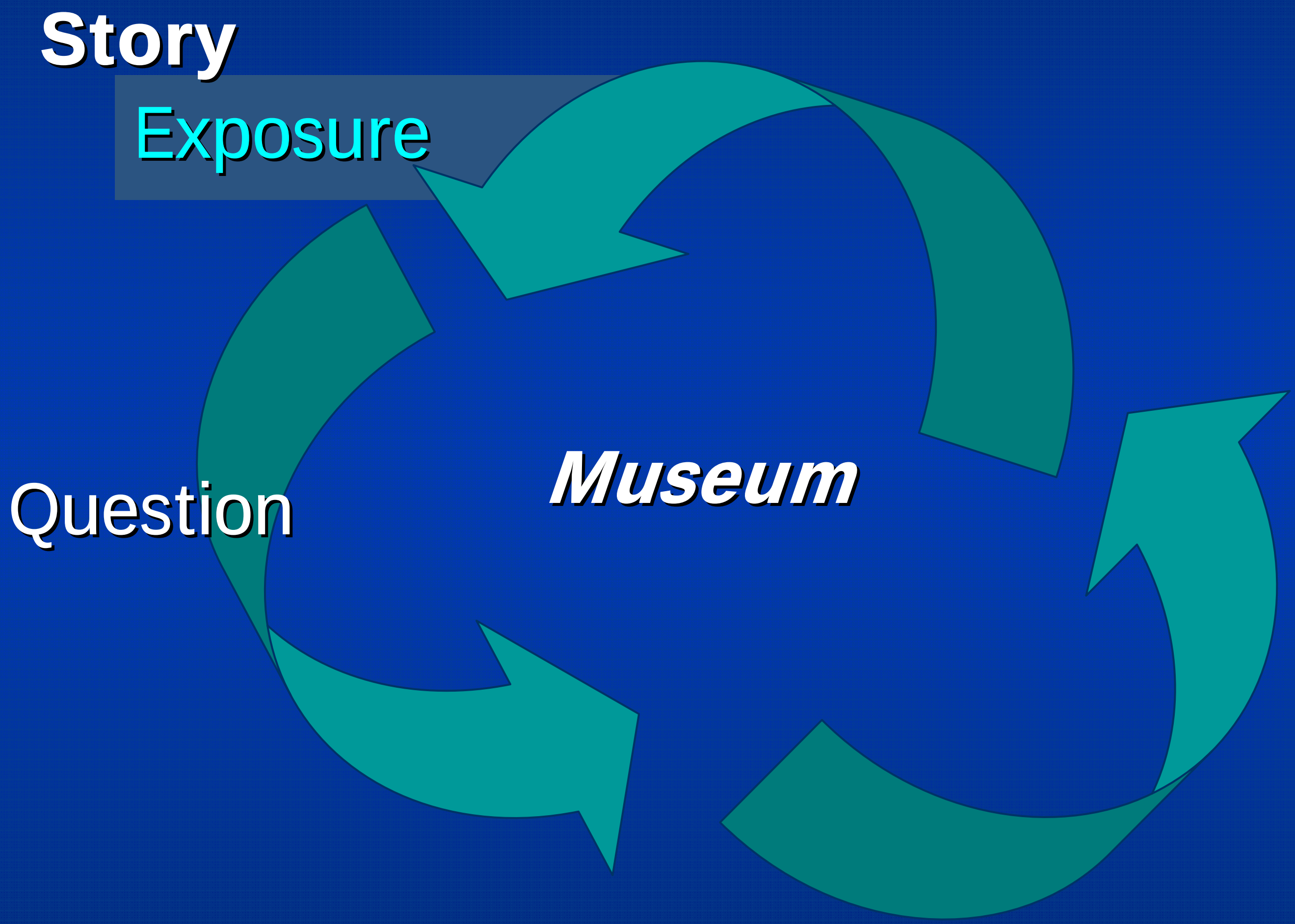
4. **Insert Sea Creature Video**

Power of Experiential Content

Story



Power of Experiential Content



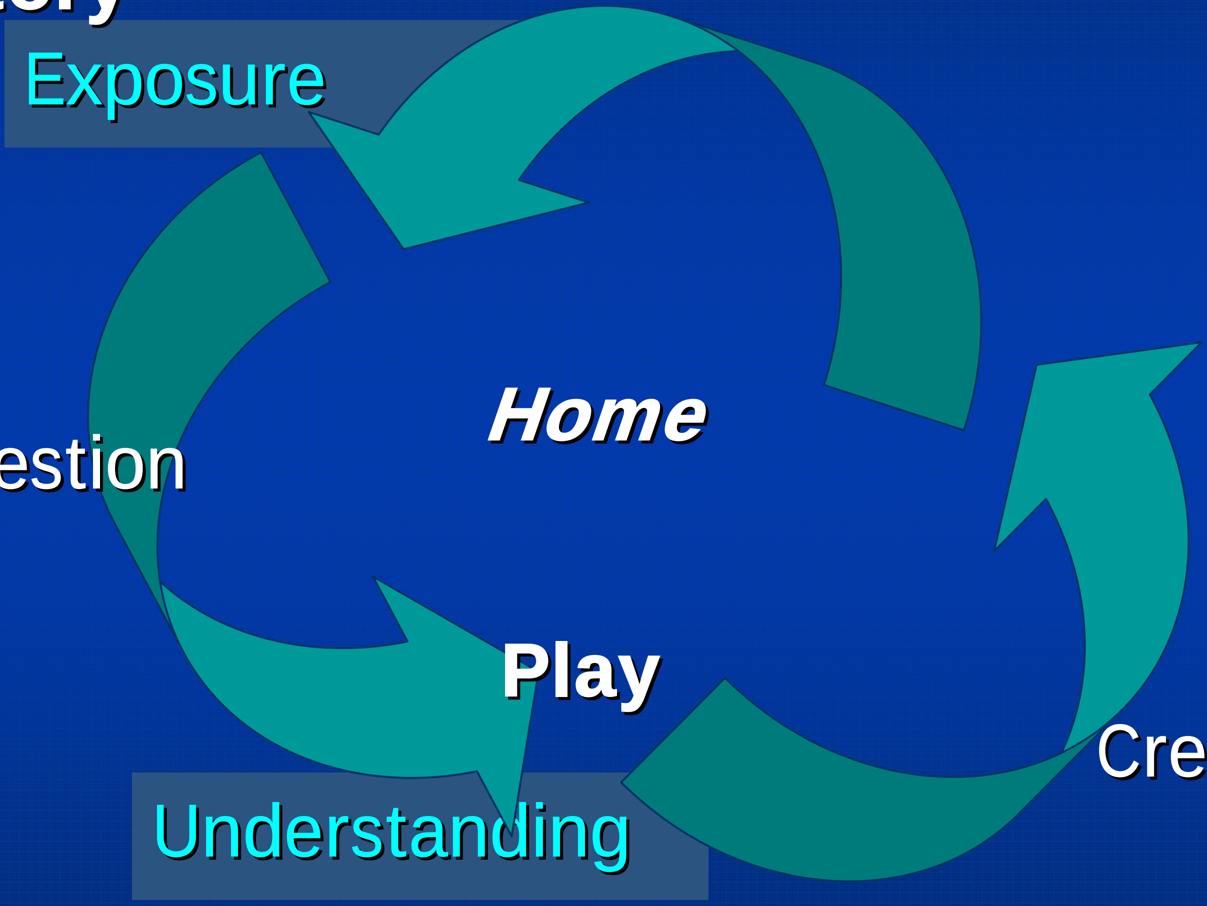
Story

Exposure

Question

Museum

Power of Experiential Content



Story

Exposure

Question

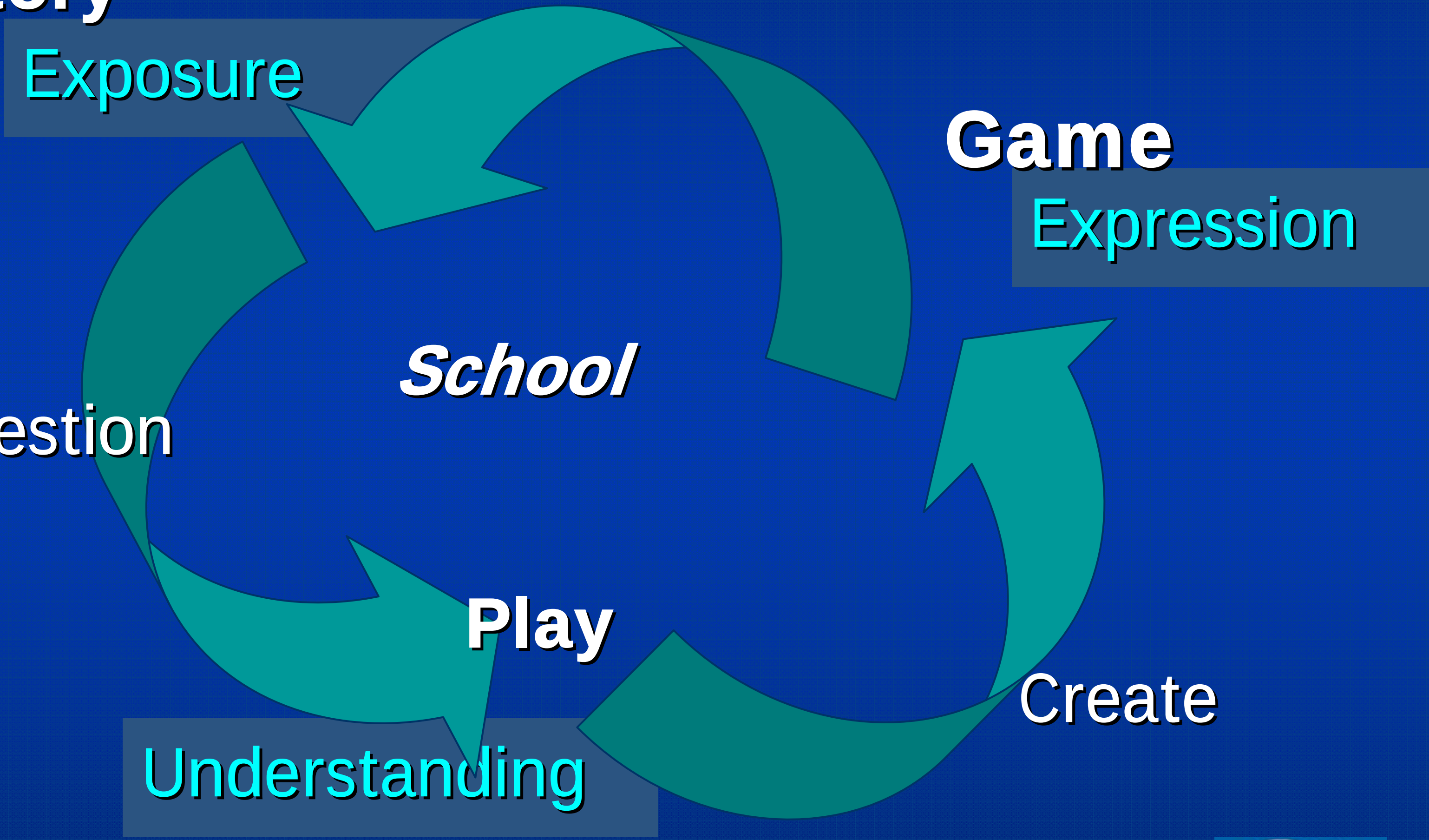
Home

Play

Create

Understanding

Power of Experiential Content



Story

Exposure

Share

Game

Expression

School

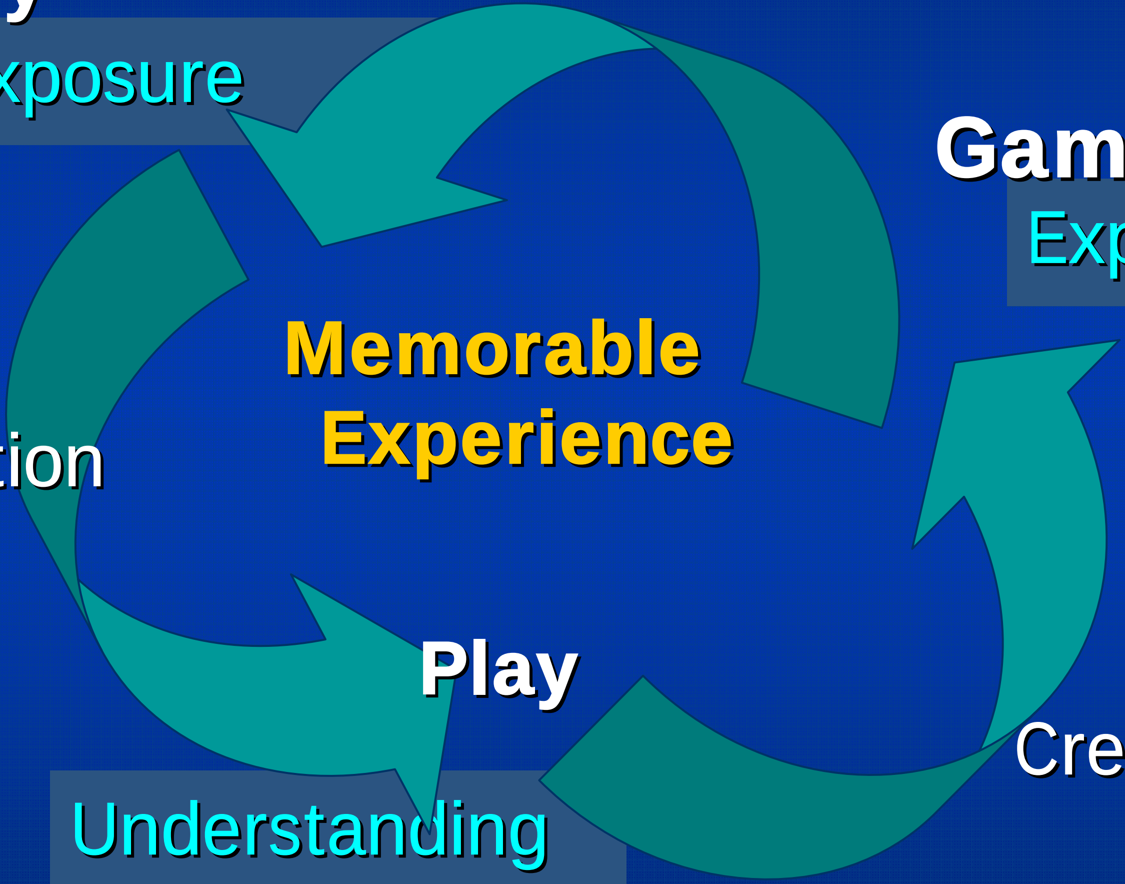
Question

Play

Create

Understanding

Power of Experiential Content



Story

Exposure

Share

Game

Expression

Memorable Experience

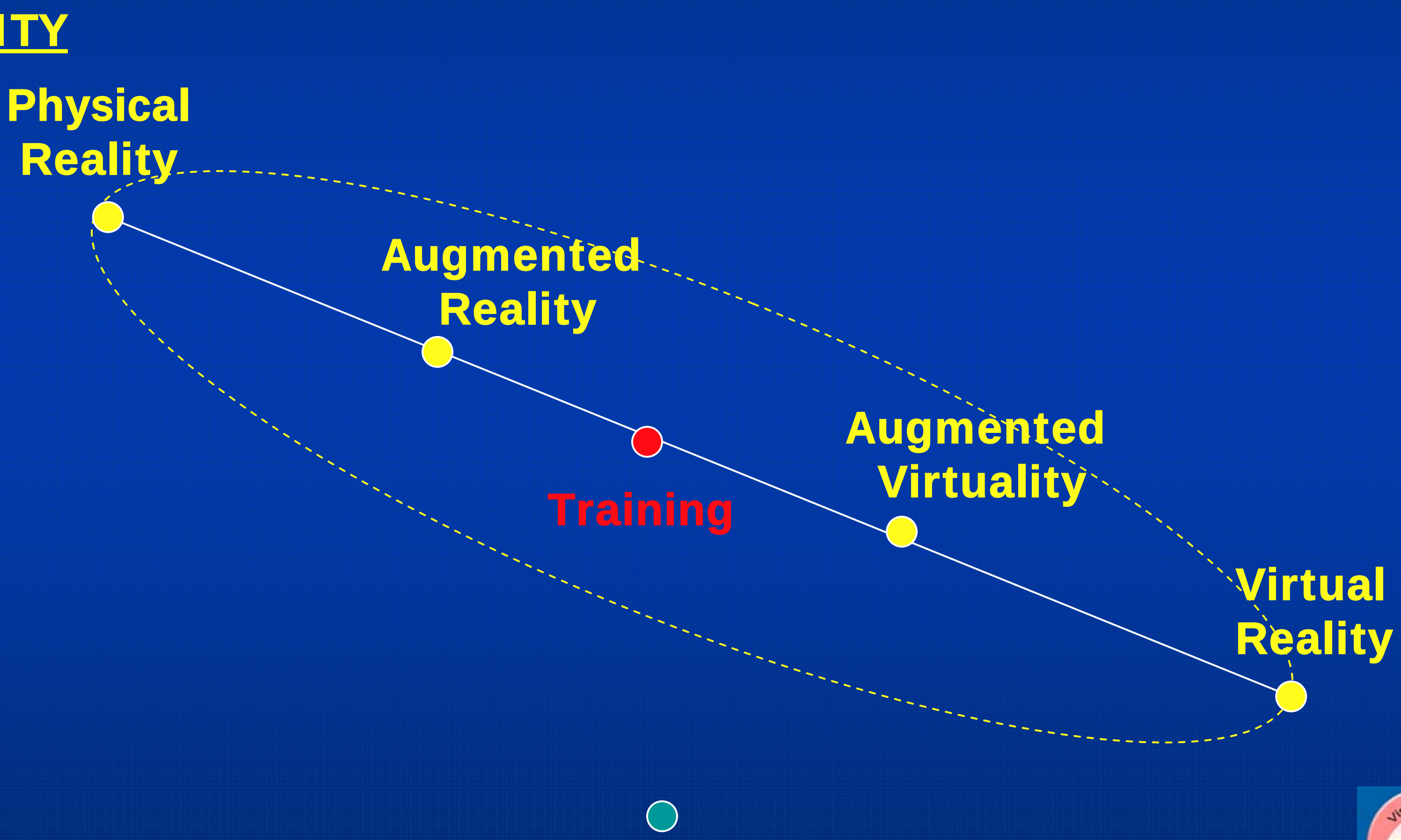
Question

Play

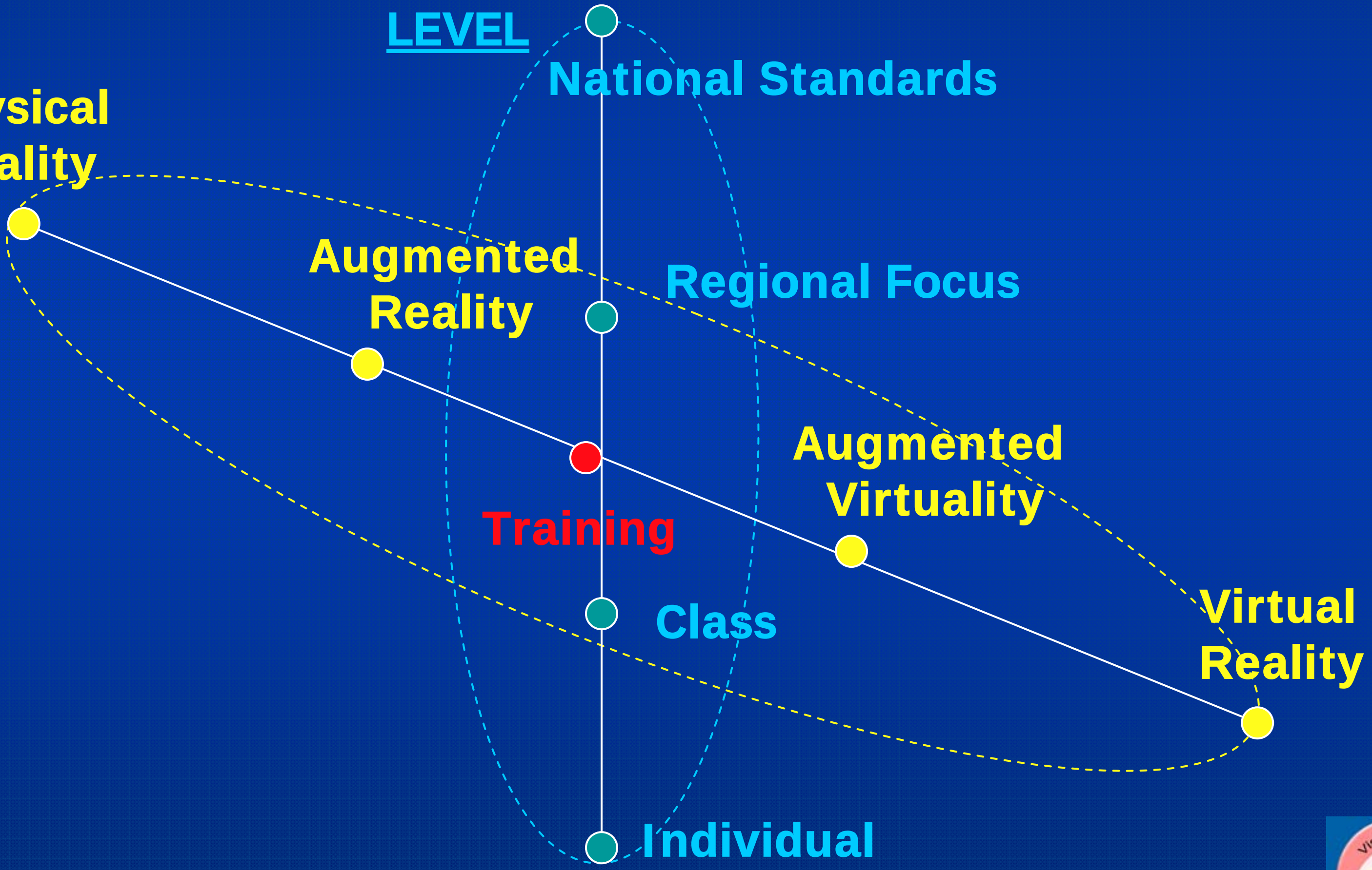
Understanding

Create

Experiential Learning Landscape



Experiential Learning Landscape



REALITY

Physical Reality

Augmented Reality

Augmented Virtuality

Virtual Reality

LEVEL

National Standards

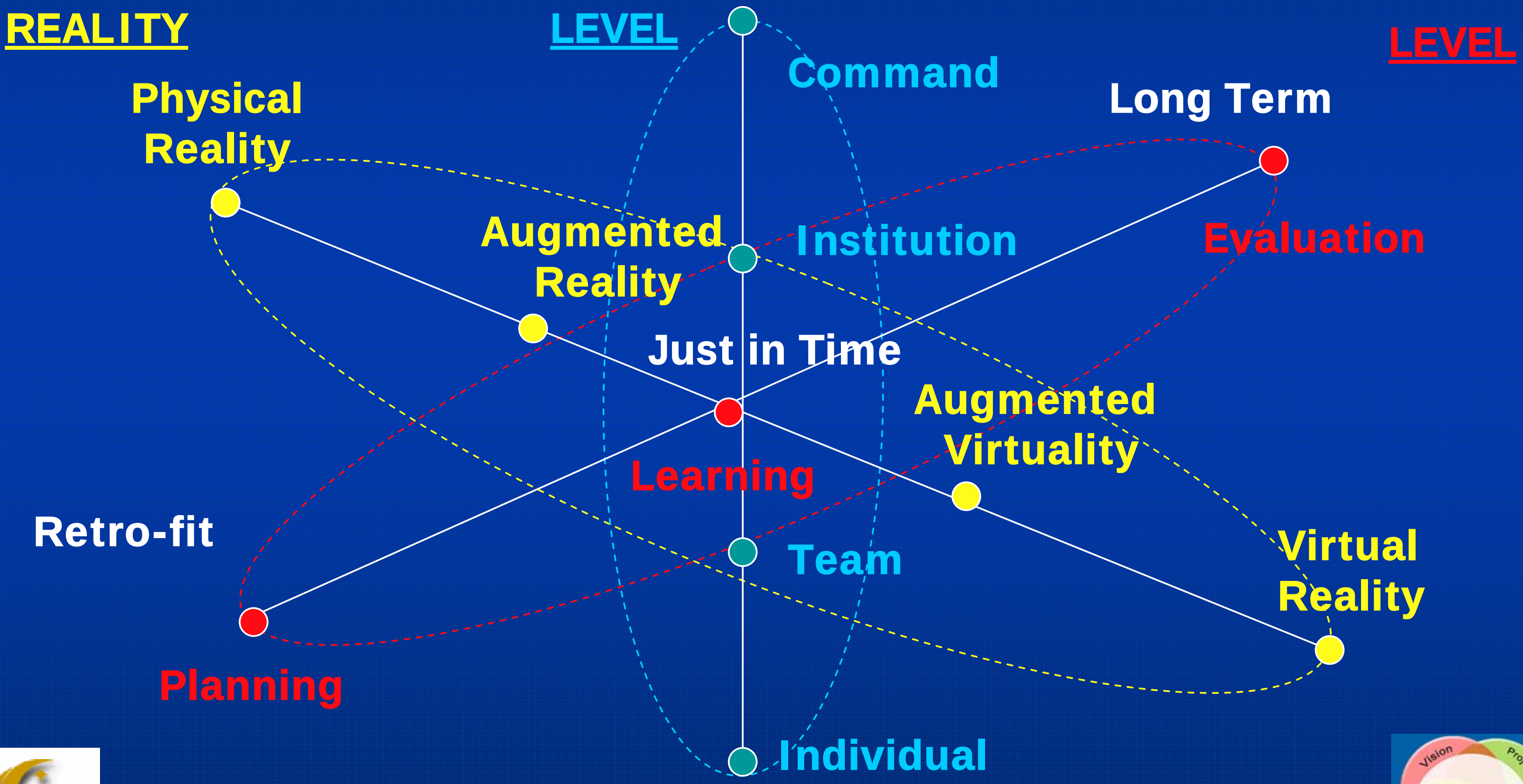
Regional Focus

Class

Individual

Training

Experiential Learning Landscape



Next Generation Challenge

- More depth and diversity
- Content validation through real-time evaluation
- MR as a critical bridge forward to formal education
- MR conduit from Scientific Virtualization to Experiential Learning Centers.

SECTION II:

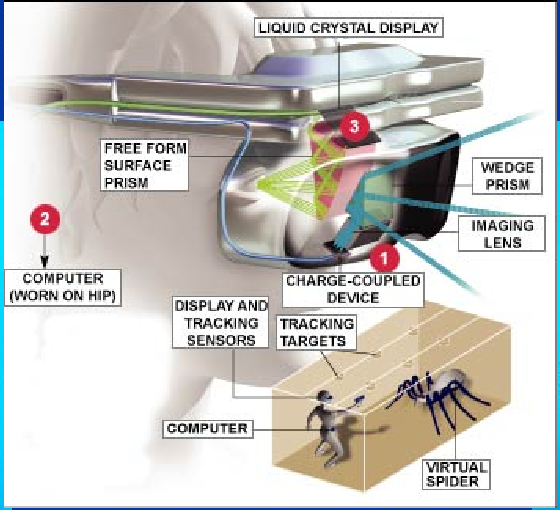
Achieving Next Generation Extreme MR

- Engine of Extreme MR
- Science & Technology of Extreme MR
- From invention to innovation
- Future Research Directions

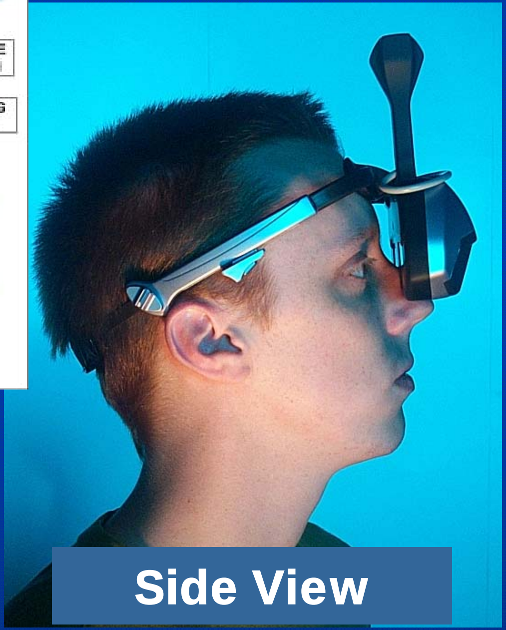
SCIENCE & TECHNOLOGY


Front View

VIDEO SEE-THROUGH DISPLAY



Canon


Side View

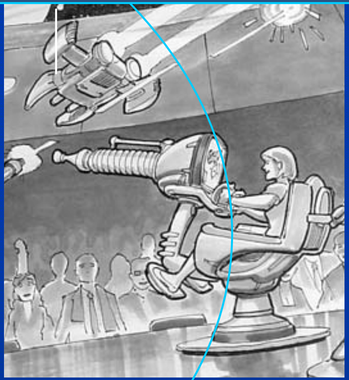
Mixed Reality Displays

REALITY

Augmented Reality

Augmented Virtuality

VIRTUAL



Video Games

Embedded Display

Immersive Display

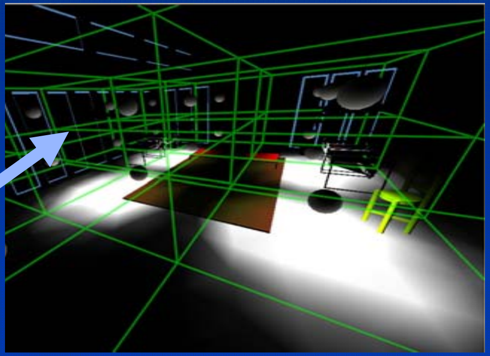
Virtual Display

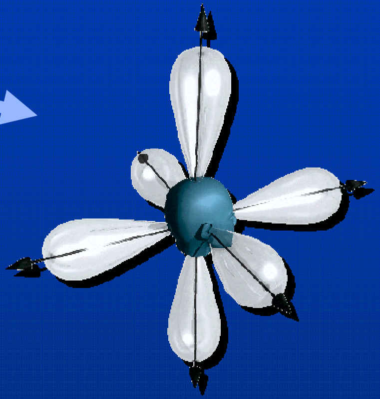
Head Mount Display

IMAGINED

The Engines

- Story
- Graphics
- Audio
- SFX / DMX





Story / Scripting / Master

- Agent architecture
- XML-based scripting
  - behaviors with guarded cases, triggers, guarded reflexes
- AI Plug-ins
- Basic physics engine
- Pluggable-interface protocol
- Procedural scripting

Graphics Engine

- OSG Open Scene Graph)
- Cal3D
- Agent peers
- Occlusion
  - Impostors
  - Matte support

Audio Engine

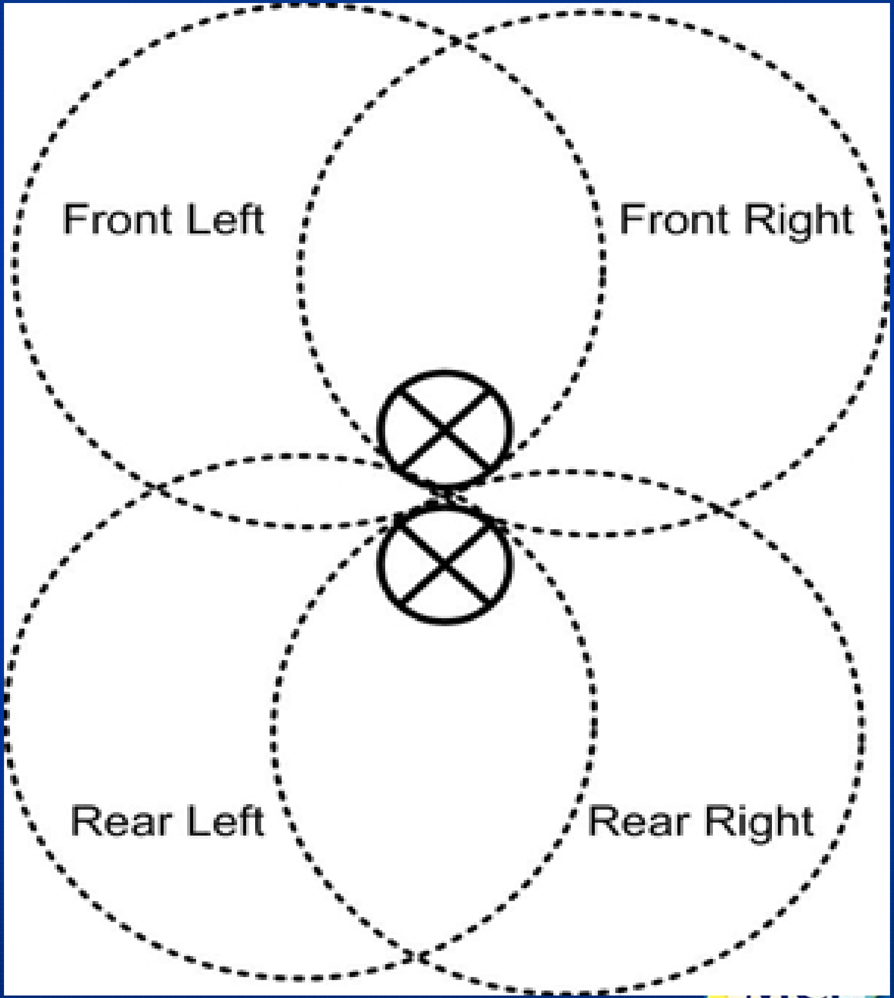
Fully 3D Peripheral Sense

- Ambient, point, dynamic (3d moving)
- Constrained based on speaker placement
- Agent peers

Audio Capture

Acoustical Situational Awareness

- Two stereo mics placed back-to-back in XY configuration with cardioids pickup patterns
- Ambience was captured in courtyard near busy road at various time during the day and evening
- Captured tracks were panned to front left, front right, rear left, and rear right within the MR Sound Engine
- Virtual ambient sounds were added in post (e.g. distant explosions, gunfire, helicopter flybys, etc.)
- Virtual sounds have an increased sense of validity when mixed with real world ambient surround capture



Hybrid Audio Display
3D audio beyond Headphones

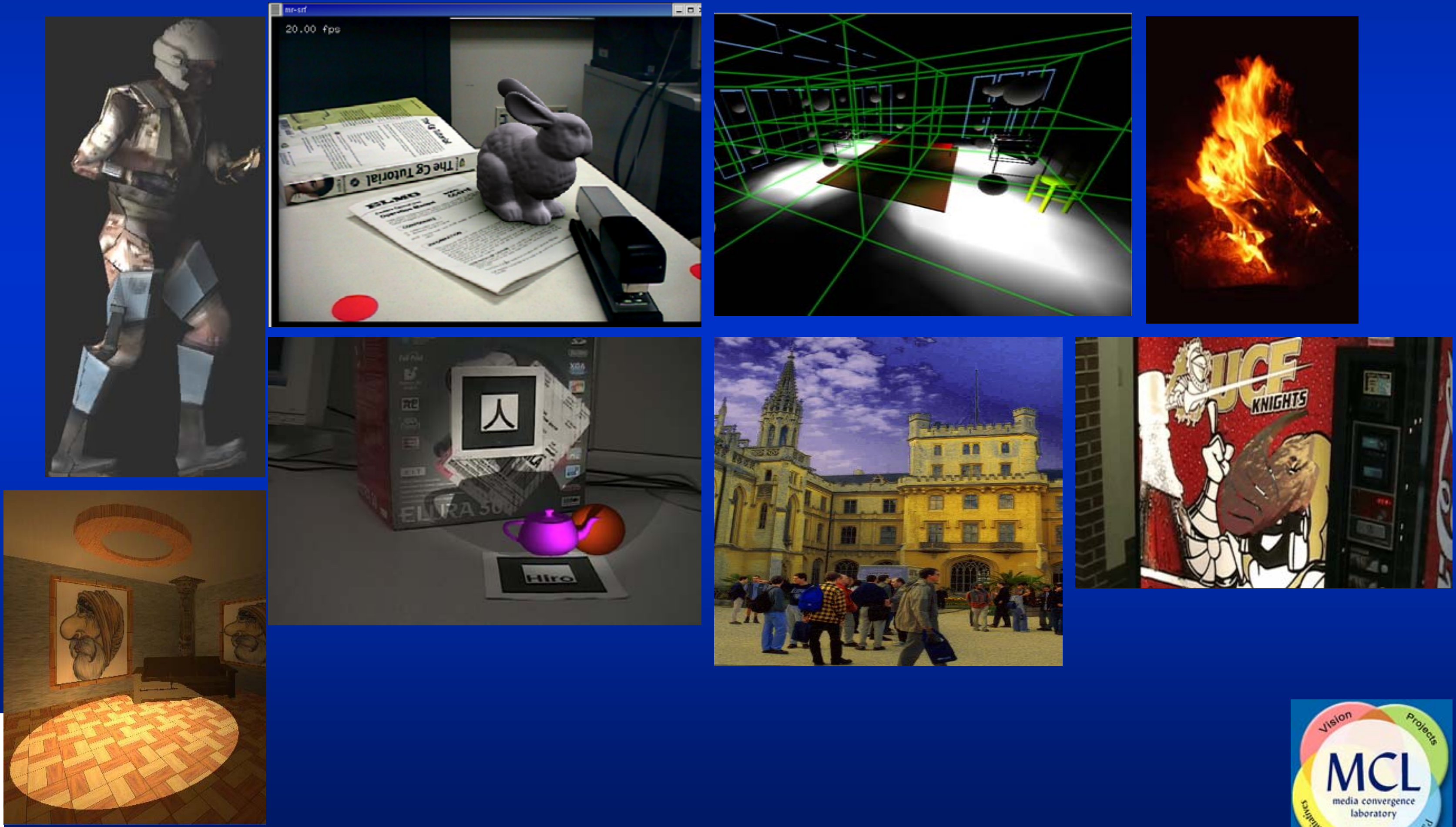
- Surround
- Embedded
- Point Source
- Environmental
- Haptic
- Hypersonic
- Asymmetrical Displays

Network Protocol

- Simple, efficient
- Command stream (show, hide, ...)
- Control stream (position, orientation, ...)
  - Can attach control stream to trackers, physics engine, other agents

Contributing Science

Melting the Boundaries in real-time



Illumination and Shadows

Sumanta Pattanaik
Erik Reinhard

Blending the Real and the Virtual

- **Use color-transfer for ambient lighting (ER)**

- **Lighting (SNP)**
  - **Virtual light on real/virtual objects**
  - **Real light on virtual objects**
- **Shadows**
  - **Cast by virtual objects on real/virtual objects**
  - **Cast by real objects**
- **Fire**
  - **Creating light and shadows on real/virtual**

Why Virtual Lighting

- How do you give a real flashlight to a virtual object?
- Certain effects, such as the overall luminance of the scene (such as changing the time of day), may be cheaper to implement virtually. Useful for dynamic simulation applications.
- In entertainment applications, sometimes physically incorrect lighting may be necessary to create the desired dramatic effect.

Shadows

Sumanta Pattaniak

Importance of Shadows

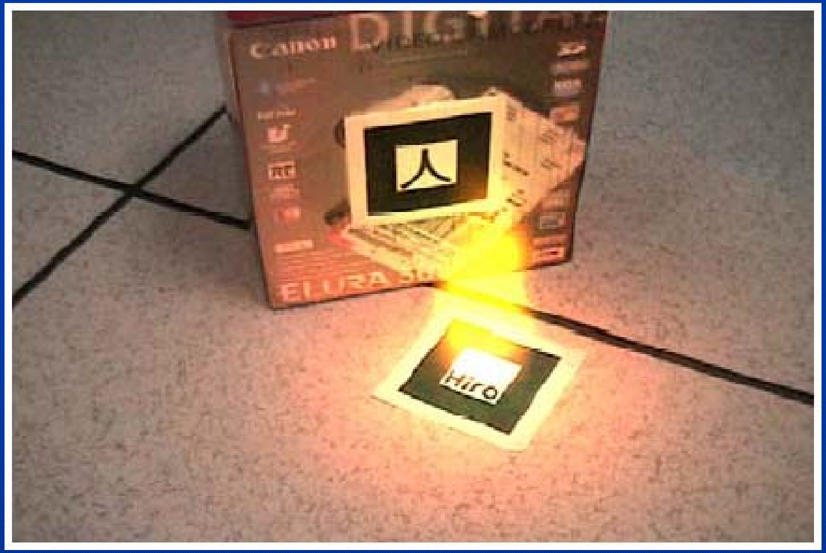
- Shadows are an important part of lighting simulation:
  - Lights should cast shadows on real objects even though the light sources are virtual.

Importance of Shadows

- Helps with suspension of disbelief.
- Helps us understand:
  - Relative virtual-to-real object position and height in space.
  - Shape of a virtual shadow receiver’s surface.
  - Position of nearby virtual objects that are occluded or outside the field of view (virtual enemy in hiding).

Our Contribution

- We demonstrate two ways to inject virtual light into a scene in the context of two practical MR applications.



Virtual Fire

Virtual Flashlight

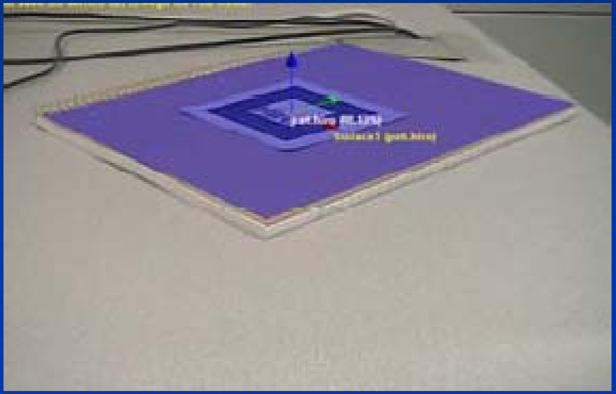
Occlusion Models

- **Our algorithms make use of the occlusion models of real objects which are common in MR applications.**
- **Occlusion models describe the geometry of all real objects in the scene. They can be pre-measured or automatically generated.**
- **Model position relative to camera is tracked.**
- **Usually used for determining which parts of virtual objects are hidden by real objects closer to the camera.**
- **Having this geometry available lets us adapt many algorithms from computer graphics.**

Occlusion Models

No occlusion model

With occlusion model



Tracking model's position

Example of the occlusion model for a notebook (approximated by a single polygon).

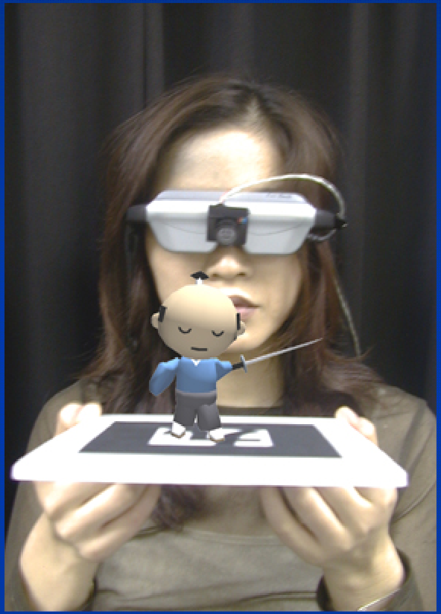
Tracked by a marker.

Tracking

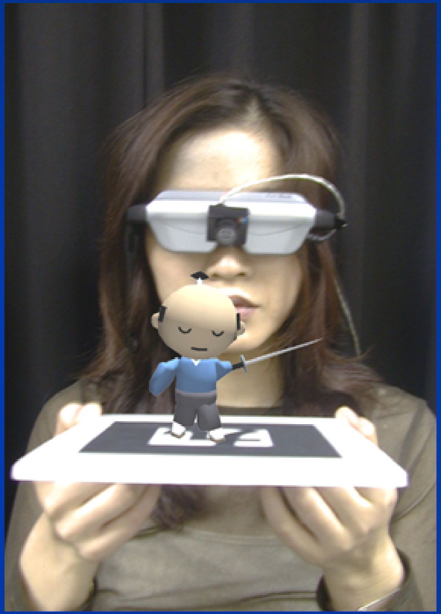
- Need to know position relative to camera of every interactive real object.
- Any object that is allowed to move independently of others must also be tracked independently.
- Several methods of tracking:
  - Sensor-based (InterSense, Polhemus, GPS)
  - Image-based (ARToolkit)

Tracking

- *ARToolkit* is an image-based tracker which derives camera position relative to a particular marker based on its location and tilt in the video frame.
- Developed by University of Washington's Human Interface Technology Lab.
- We chose *ARToolkit* for this demo for several reasons:
  - Light-weight
  - Free
  - Easy to set-up



Tracking

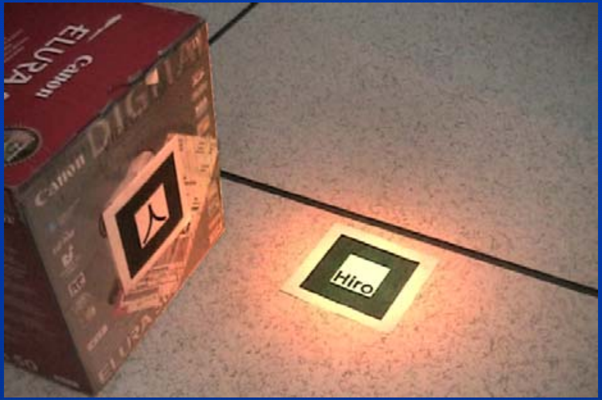


- Not necessarily great for larger projects:
  - Poor tracking quality of far-away objects.
  - Done in software = slow
  - Markers everywhere!
  - Marker must be visible in video frame
- Luckily the tracking problem can be easily isolated from the rest of the system and thus the method of implementation can be changed easily.
- ARToolkit: http://www.hitl.washington.edu/artoolkit/

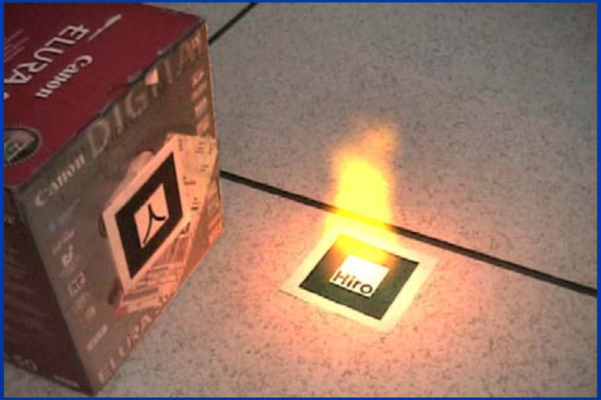
Virtual Fire

- Our virtual fire application simulates a real environment light by computer-generated fire.
- The process works by calculating how the intensity of each pixel covered by an occlusion model is increased by the virtual flames.

Unmodified frame



Virtual illumination only



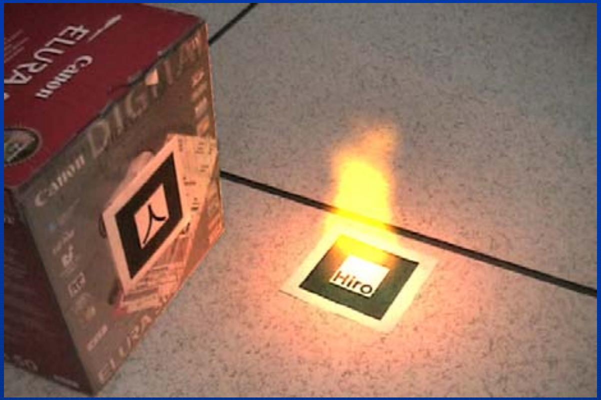
Illumination + flames

Virtual Fire

- Thanks to occlusion models, this calculation can be done with many known computer graphics lighting algorithms and can be accelerated by graphics cards. The calculation can be simple or complex depending on the requirements of the application.
- The original intensity of the pixel is scaled up based on the result of the computation. Finally, virtual flames are drawn onto the image.

Unmodified frame

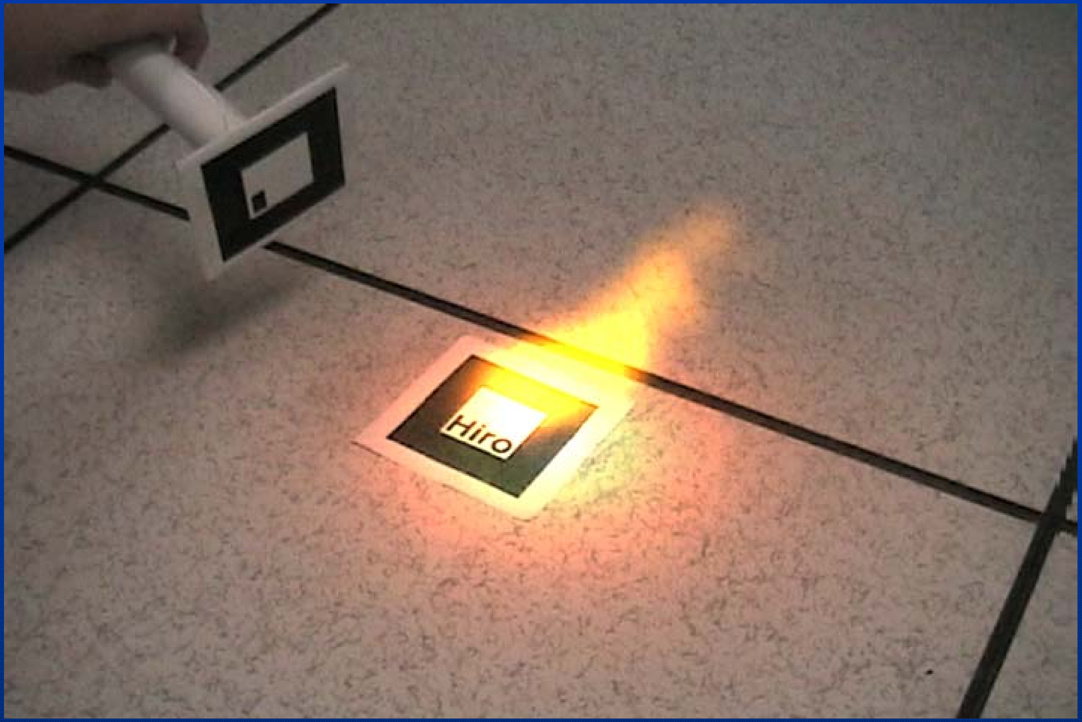
Virtual illumination only



Illumination + flames

Bonus: Virtual Wind

A separate marker tracks the position of a non-existing fan. Lighting on ground shifts with flame's position.



Virtual Flashlight

Artificially make a room darker, and restore it to its original intensity with a virtual flashlight.

Done in multiple steps.

Unmodified video frame

Final processed frame

Virtual Flashlight

Step #1: Scale down intensity of pixels that are not covered by tracked occlusion models by some constant factor.

Untracked pixels assumed to be unlit by virtual light

Partially darkened frame

Final processed frame

Virtual Flashlight

Step #2: Calculate shadows from virtual objects falling on real objects.

Using a version of the shadow volume algorithm from computer graphics adapted for MR.

Virtual shadows on real objects

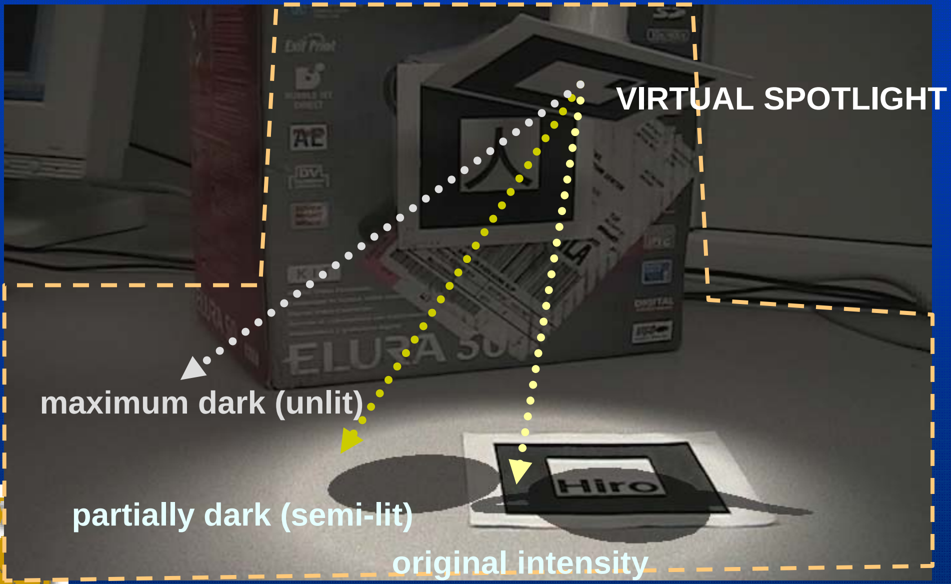
Final processed frame

Virtual Flashlight

Step #3: Artificially darken occlusion model -covered pixels, and simulate virtual light by darkening virtually “lit” pixels less.

Modified intensity is determined by the spotlight algorithm from computer graphics.

Full virtual lighting applied



Final processed frame

Virtual Flashlight

Step #4: Composite virtual objects and compute shadows from real and other virtual objects falling on them.

Use same basic algorithm as in Step #2.

Final processed frame

Video

(click image to play)

Color Transfer

Erik Reinhard

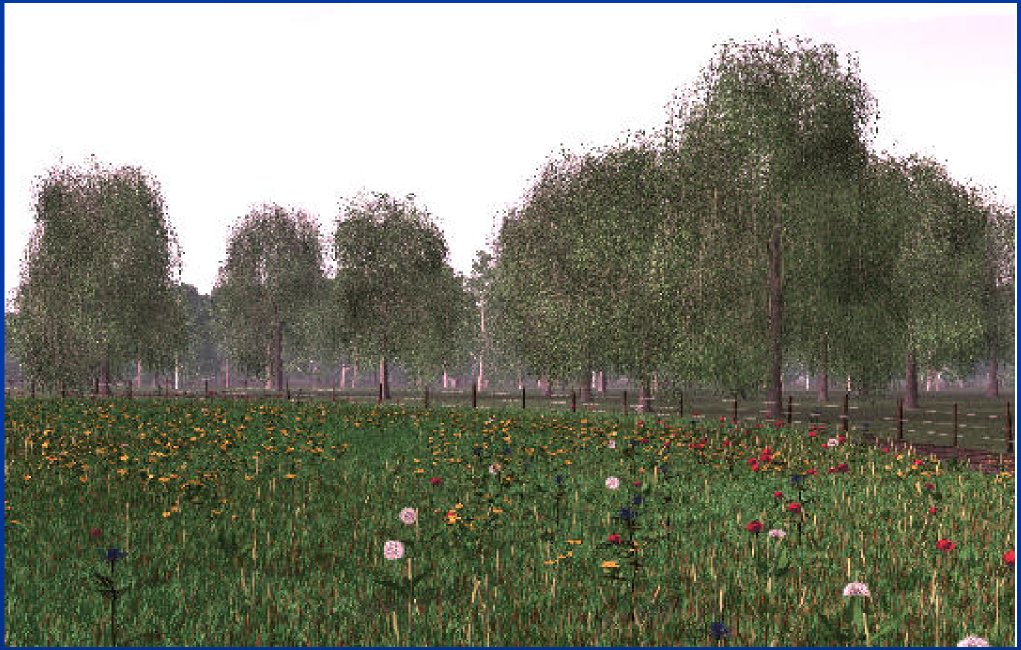
Computer generated images

Can be very realistic, but color selection is sometimes a problem

Not so with holiday snaps

Fool the human visual system

into accepting 'realistic color schemes'



Van Gogh's Holiday Photos

The Process

- Reinhard et al., 2001
  - Compute mean and variance of color attributes of pixels in source and target
  - Impose mean and variance of source on target
  - Requires source and target be similar in composition; hard to control in dynamic MR
- Chang et al., 2004
  - Name colors and maintain each pixel in its color group
  - Avoids swatches but may be hard to maintain frame rate; will try to optimize

Color Space

- RGB’s dimensions are correlated, making analysis a 3-d problem
- Can get three 1-d problems by using Lαβ space (independent in practice)

Extending to MR

- Get example from real; target is virtual
- Experimentally have found log space is not necessary; thus use CIE Lab
- Can change RGB space to LMS and then to CIE Lab in a matrix multiply; inverse is also one multiply
- Can optimize mean and variance computation by ignoring transparent parts of target; also tried optimizing by skipping mean/variance computation on every other frame and/or every other pixel

Video Samples

Pegasus uncorrected

Pegasus color corrected

Frame Rates

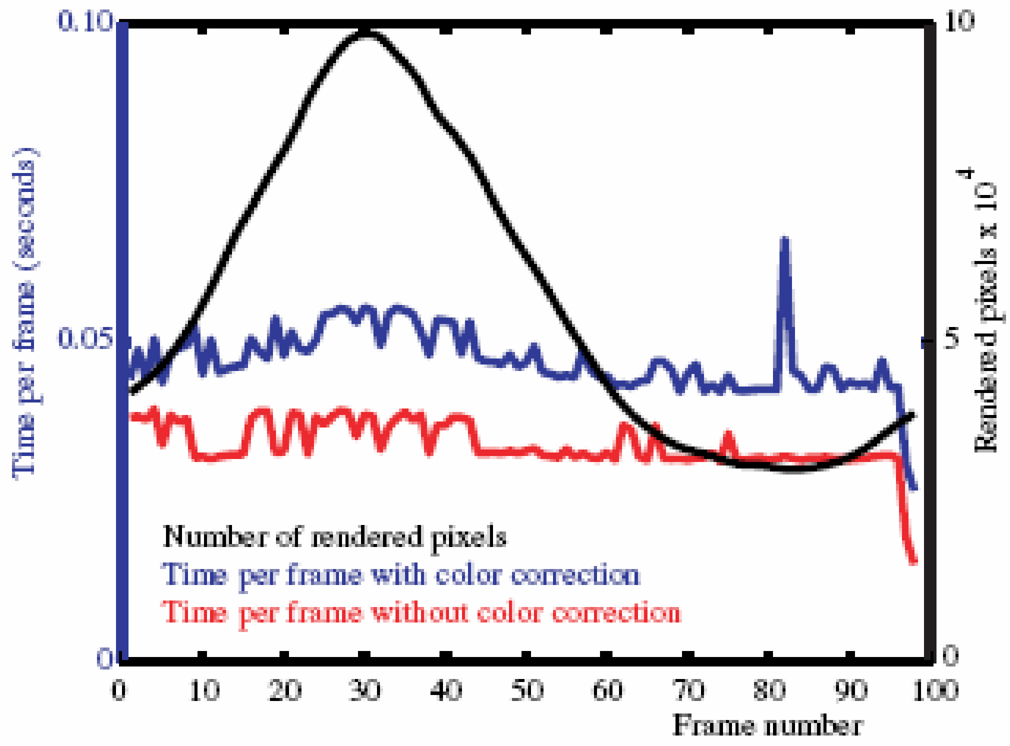


Figure 6: *Frame times and rendered pixels as function of frame-number.*

Cost of Adjustments

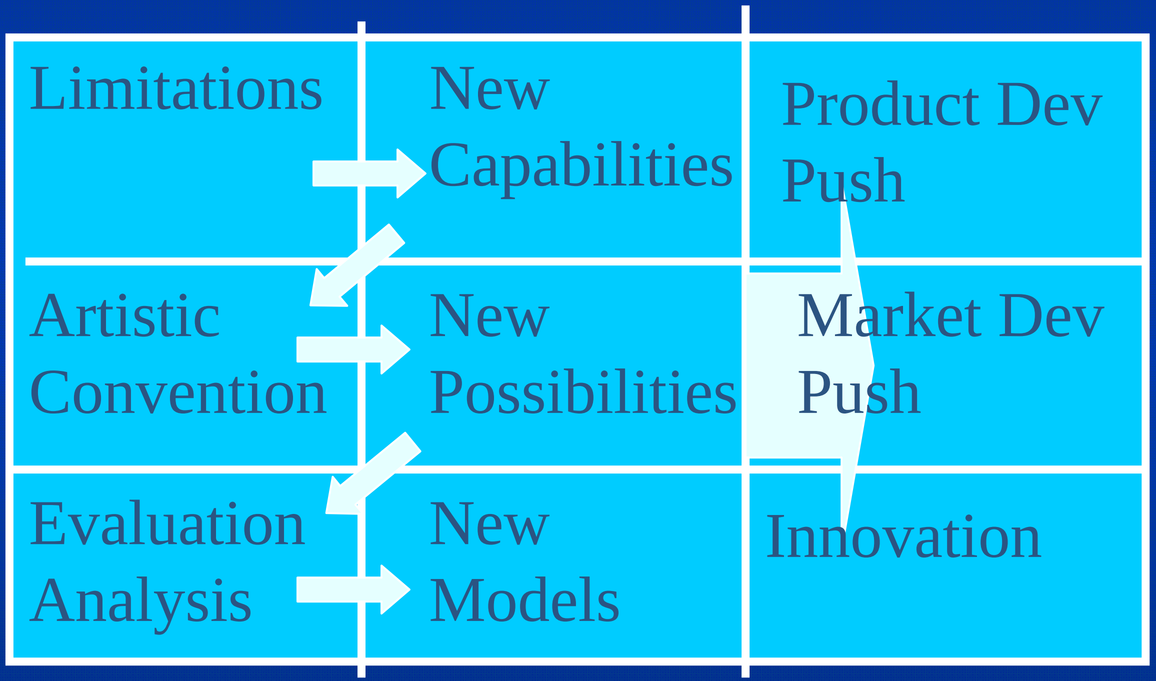
- Found no advantage in computing mean and variance every other frame or on every other pixel (actually cost 3 fps)
- Primary cost is in shifting pixels, not in computing means and variances
- Unrolling loops brought major gain
- Current cost overhead is about 23%
- There are many improvements to be made
- Experiments continue ...

Invention to Innovation

- PUSH: Technical Capabilities to Creative Possibilities
- PURPOSE: Human Impact (cognitive and Imaginative)
- PULL: Commercial Potential

Media Innovation Infrastructure

- Science & Technology
- Human Impact cognitive & imagine
- Business & Production Models



IDEA	INVENTION	INNOVATION
Limitations	New Capabilities	Product Dev Push
Artistic Convention	New Possibilities	Market Dev Push
Evaluation Analysis	New Models	Innovation
University	Laboratory	Industry

Media Innovation Infrastructure

- Science & Technology
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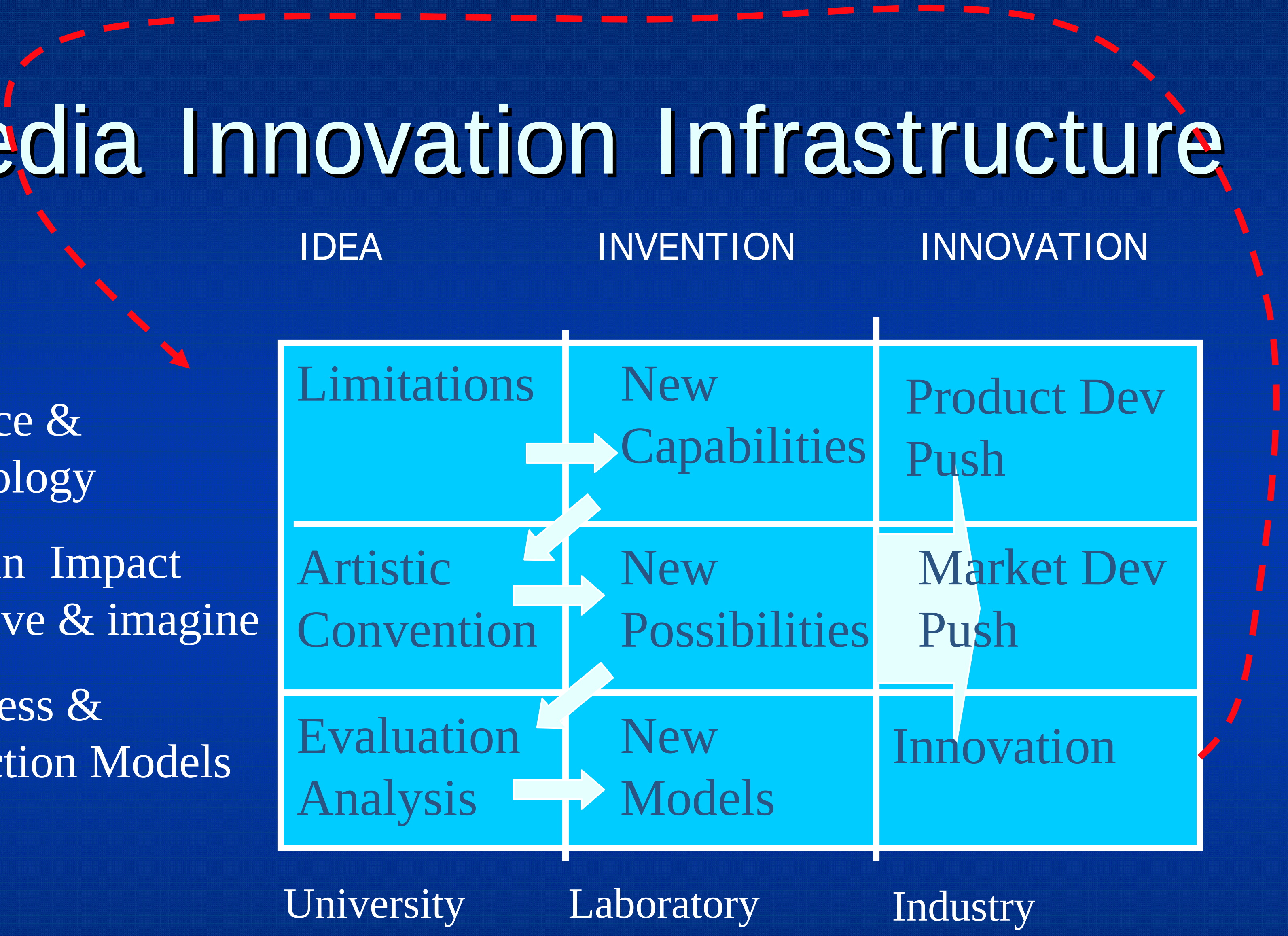


IDEA	INVENTION	INNOVATION
Limitations	New Capabilities	Product Dev Push
Artistic Convention	New Possibilities	Market Dev Push
Evaluation Analysis	New Models	Innovation
University	Laboratory	Industry

Knowledge Network

Inventing

Options in Search of Resources

Marketing

Solutions in Search of Problems

Problems in Search of Solutions

Organizing

Resources in Search of Options

Financing

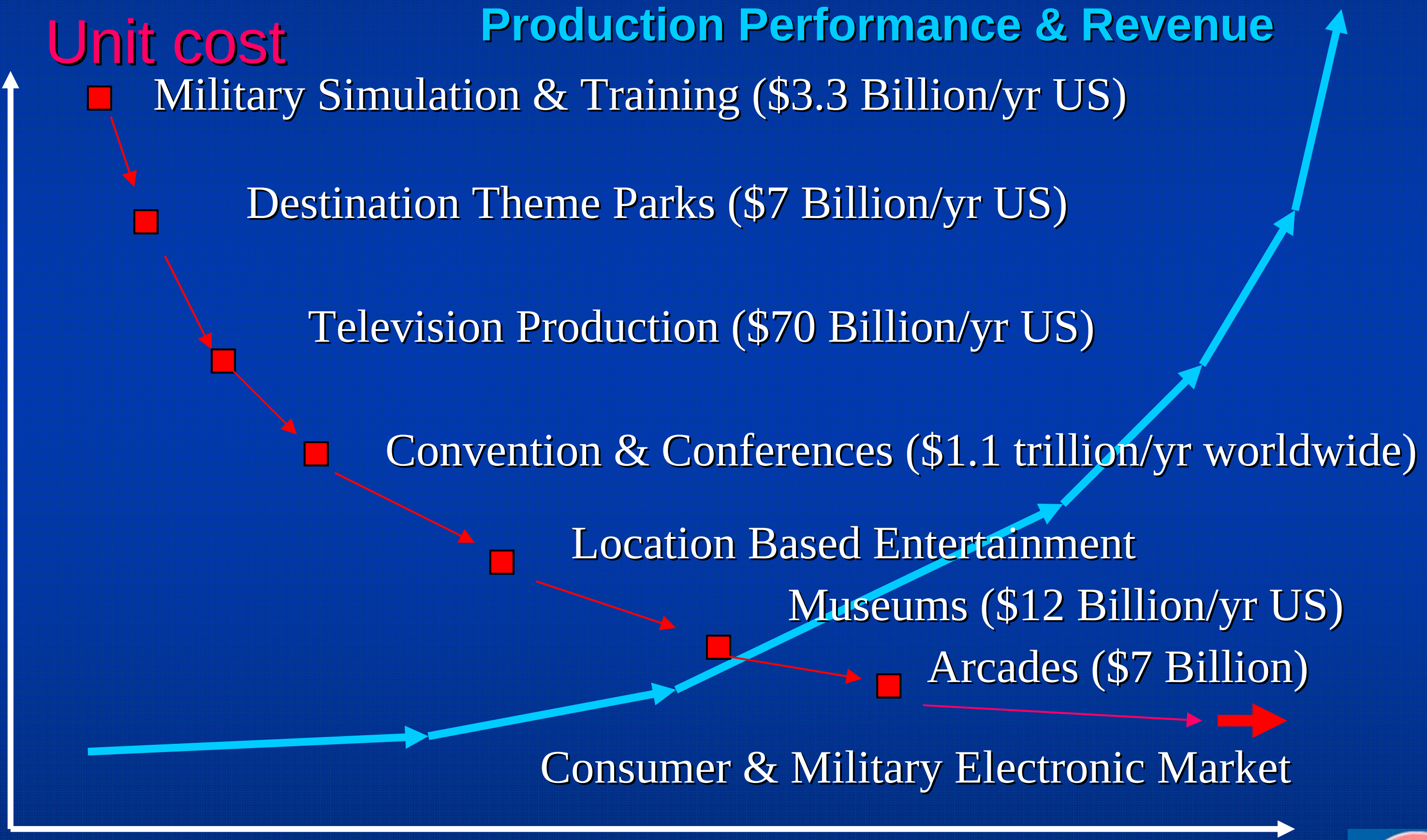
Inventing, marketing, financing, and organizing typically involve different

- *People*
- *Places*
- *Priorities*
- *Processes*

Knowledge specialization often prevents marriage of

- *Problems*
- *Solutions*
- *Options*
- *Resources*

Core Technology, Diverse Applications: *“Cross-industry value transfer”*



Unit cost

Production Performance & Revenue

Military Simulation & Training ($3.3 Billion/yr US)

Destination Theme Parks ($7 Billion/yr US)

Television Production ($70 Billion/yr US)

Convention & Conferences ($1.1 trillion/yr worldwide)

Location Based Entertainment

Museums ($12 Billion/yr US)

Arcades ($7 Billion)

Consumer & Military Electronic Market

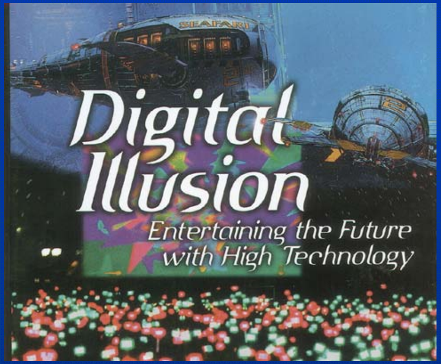
$ Millions:
Unit Cost

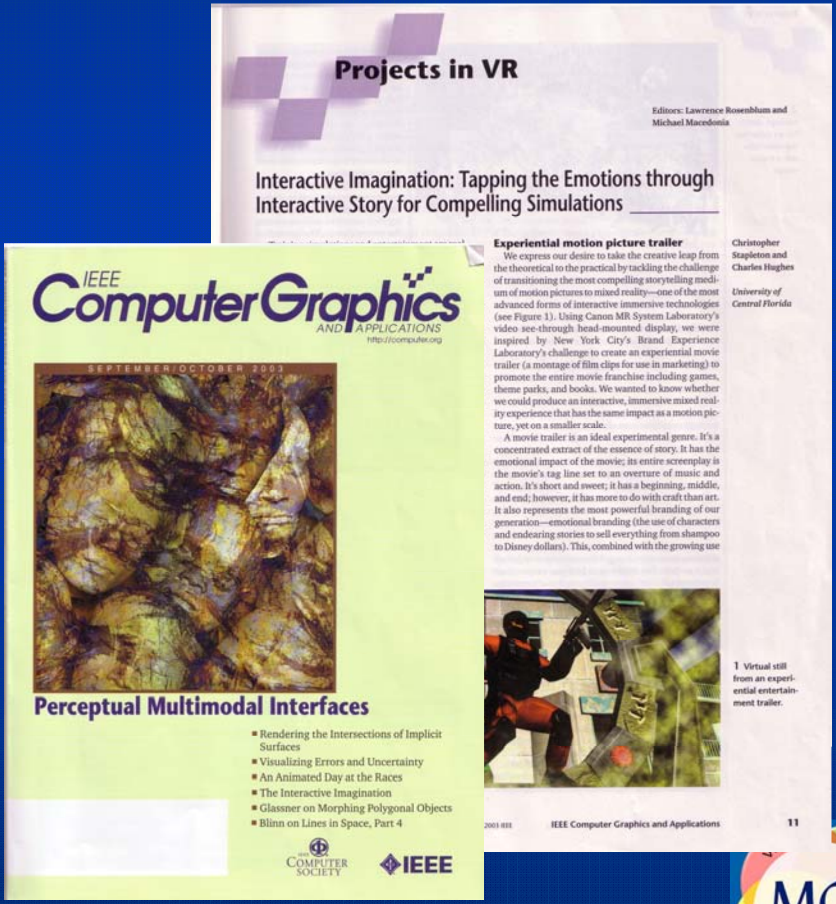
0

 # Millions: Unit Volume & increased requirements

Notable Publications:

- IEEE Computer
- Computer Graphics and Applications





IEEE Computer Graphics and Applications
http://computer.org

SEPTEMBER/OCTOBER 2003

Perceptual Multimodal Interfaces

- Rendering the Intersections of Implicit Surfaces
- Visualizing Errors and Uncertainty
- An Animated Day at the Races
- The Interactive Imagination
- Glassner on Morphing Polygonal Objects
- Blinn on Lines in Space, Part 4

Computer Society IEEE

Projects in VR

Editors: Lawrence Rosenblum and Michael Macedonia

Interactive Imagination: Tapping the Emotions through Interactive Story for Compelling Simulations

Christopher Stapleton and Charles Hughes

University of Central Florida

Experiential motion picture trailer

We express our desire to take the creative leap from the theoretical to the practical by tackling the challenge of transitioning the most compelling storytelling medium of motion pictures to mixed reality—one of the most advanced forms of interactive immersive technologies (see Figure 1). Using Canon MR System Laboratory's video see-through head-mounted display, we were inspired by New York City's Brand Experience Laboratory's challenge to create an experiential movie trailer (a montage of film clips for use in marketing) to promote the entire movie franchise including games, theme parks, and books. We wanted to know whether we could produce an interactive, immersive mixed reality experience that has the same impact as a motion picture, yet on a smaller scale.

A movie trailer is an ideal experimental genre. It's a concentrated extract of the essence of story. It has the emotional impact of the movie; its entire screenplay is the movie's tag line set to an overture of music and action. It's short and sweet; it has a beginning, middle, and end; however, it has more to do with craft than art. It also represents the most powerful branding of our generation—emotional branding (the use of characters and endearing stories to sell everything from shampoo to Disney dollars). This, combined with the growing use

1 Virtual still from an experiential entertainment trailer.

2003 IEEE IEEE Computer Graphics and Applications 11

Going Beyond Reality:
to Create Extreme Multi-Modal Mixed Reality for Entertainment

Christopher Stapleton, **MCL** Director
Dr. Charles Hughes, MCL Chief Scientist

Scott Malo, Digital Production Supervisor

Media Convergence Laboratory
University of Central Florida

A Partnership of

Institute for Simulation and Training
School of Computer Science
College of Arts and Science